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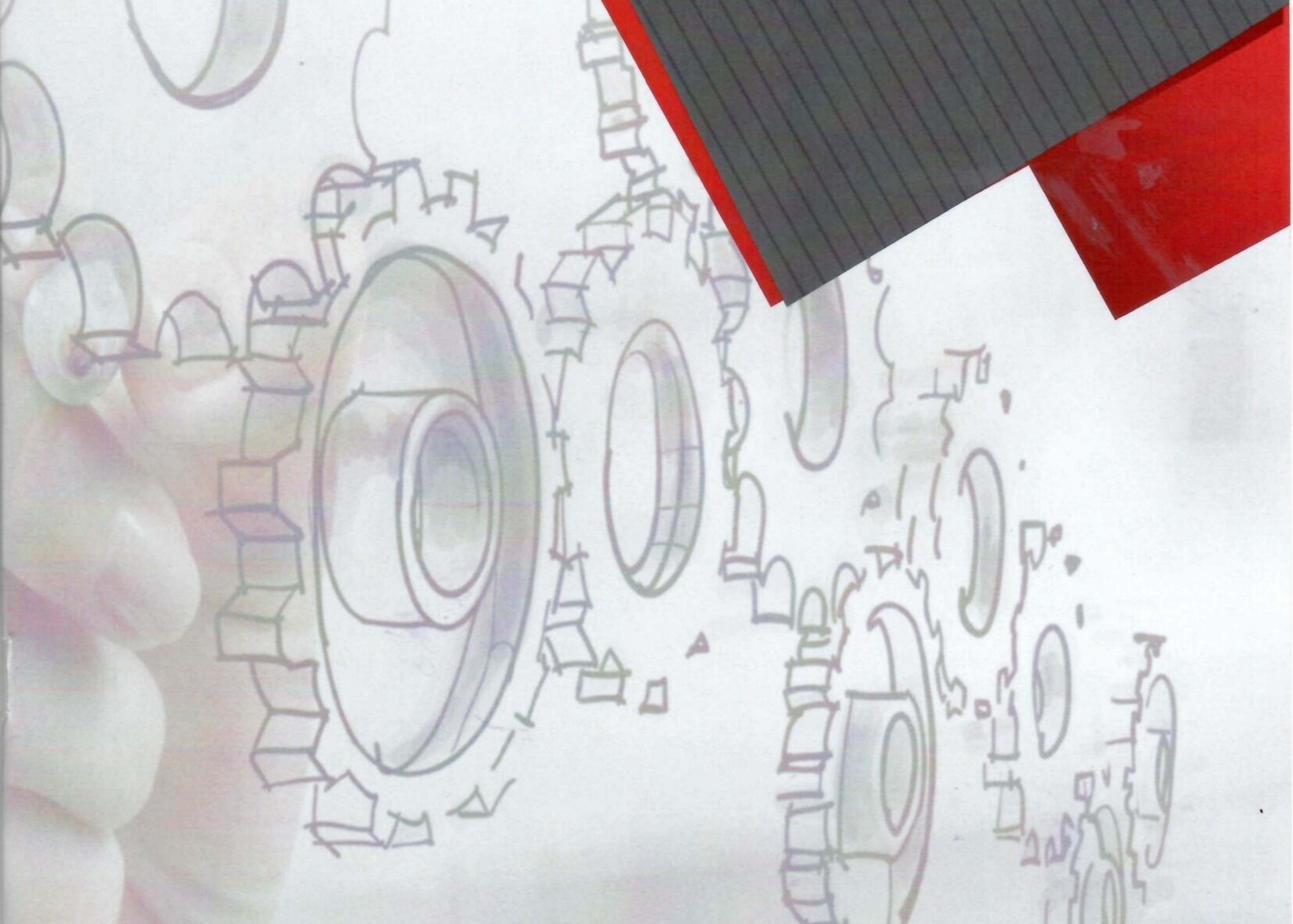
Technical Journal 2018



AIFI

ASSOCIATION OF INDIAN FORGING INDUSTRY

TECHNICAL JOURNAL 2018

ASSOCIATION OF INDIAN FORGING INDUSTRY

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Foreword

To the reader of the Journal,

Over the years, your Association has been publishing technical articles in its quarterly in-house magazine, Focus. And I am pleased to inform you that our Managing Committee decided to bring out a compiled journal of all the technical articles that have been issued since 2010.

The Technical Journal 2018 is our miniscule effort to present our members with the articles related to the technological developments under a single cover. The journal would also be available in the 'Publications' section on our official website-www.indianforging.org.

It is my sincere hope that this journal assists you in acquiring new knowledge.

Thanking you,

On behalf of Association of Indian Forging Industry

Shrabana Mukherjee
Deputy Secretary

Contents

Prediction of Metal Flow Lines in Forging

Dr. Man Soo Joun, Mr. Renganathan Sekar
MFRC (Metal Forming Research Corporation), South Korea

INTRODUCTION

In metal forming, especially in forging, metal flow lines (addressed MFL henceforth in this article) formed during rolling or drawing play a decisive role in determining the strength of product. S. Ito et al. [1] observed that an optimal distribution of metal flow lines can increase the lifespan of mechanical and automotive parts by nearly six times. These MFLs store the history of the metal formed products and they are being utilized for qualitatively evaluating product quality and durability of power transmission or load supporting parts like bearings and gears. With the help of forging simulation technology, process design engineers and researchers can predict the MFLs for their existing design and optimize it further for better strength and performance.

In this article, two prominent industrial processes (one each for 2D and 3D) are considered and the prediction of their MFLs are presented. The first process, which is a four-stage hot forging cum ring rolling process, has been shown for its generality. It should be noted that this process is sophisticated in terms of prediction of metal flow lines from a simulation perspective. The second example is representative of a wide variety of hot forging processes and the ability to visualize the metal flow lines at any time instant and at any arbitrary cross section is very helpful in quickly optimizing the process design.

HUB BEARING RACE

The process design for fabricating a first-generation hub bearing race is discussed in this section. As can be seen from Figure 1, the process consists of four stages which are hot upsetting, hot backward extrusion, hot piercing and hot ring rolling sequentially.

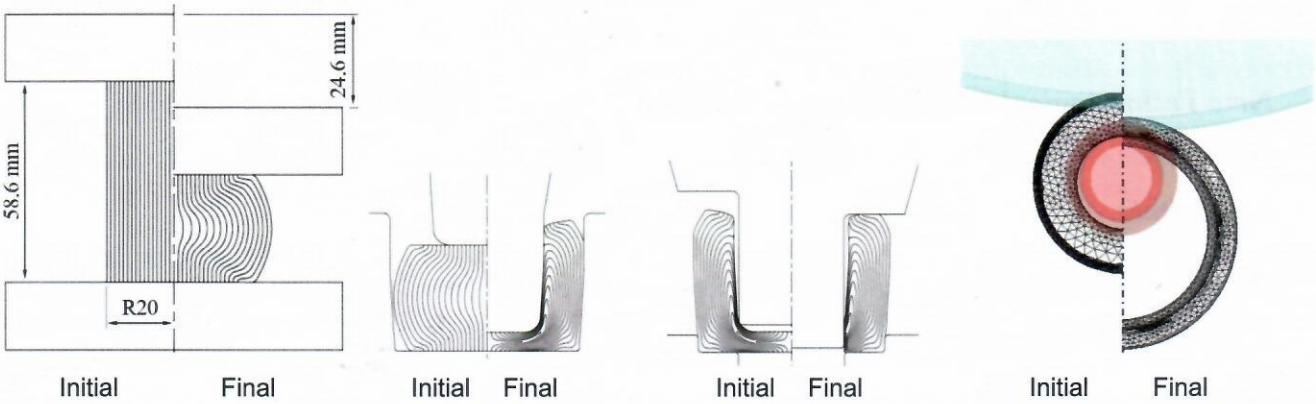

Figure 1: Process design of hub bearing race

Process conditions and simulation information are as follows: Material is STB2 [2]. An isothermal analysis was conducted with initial material temperature of 1130°C. Coefficient of Coulomb friction at the material-die interface was assumed to be 0.3 and the forming velocity to be 200mm/s [4]. The number of tetrahedral elements was controlled between 30000 (forging) and 60000 (ring rolling) for the entire solution domain.

Note that for improved MFLs the flow stress at very low strain rate was constrained not to become below a certain value, which is a kind of initial yield stress at the room temperature. Figure 2 shows predictions at some important strokes.

As can be seen in the figure, the cut MFLs generated in the piercing stage remain on inner surface of the ring rolled part where bearing balls will contact. The deep valley of MFLs formed in the backward stage became much deeper owing to the ring rolling process.

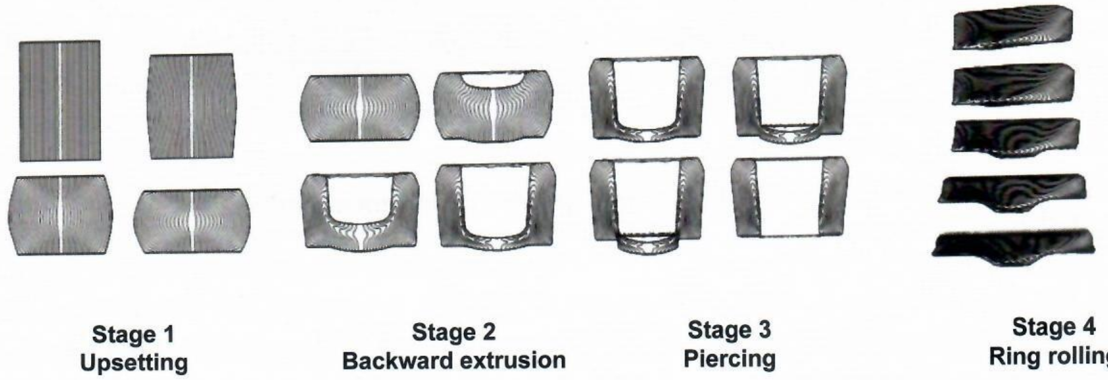

Figure 2: Visualization of metal flow lines

Consequently, the process design in Figure 1 should be much improved [1], especially for fabricating the blank for ring rolling because the MFLs cannot be improved during ring rolling. Figure 3 compares the prediction of MFLs with experiments for the final ring rolled material, revealing that they are in good agreement with each other.

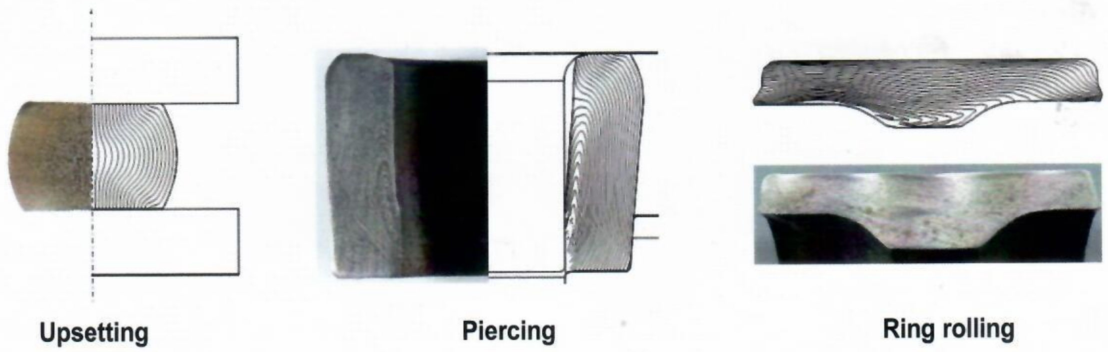

Figure 3: Comparison of predictions and experiments

The three-dimensional MFLs were traced throughout the entire process without any user intervention. This innovative approach of predicting MFLs for complicated three dimensional metal forming processes will help process engineers obtain improved process designs in metal forming.

CRANKSHAFT HOT FORGING PROCESS

In this section, metal flow lines of a forged crankshaft are visualized using a rigid thermoviscoplastic finite element method with a versatile scheme of visualizing metal flow lines formed during shape rolling from bloom to round bar. The variation of metal flow lines on various cross-sections with the stroke is shown in detail, emphasizing the importance of useful visualization capability to conduct successful process design of complicated hot forging processes.

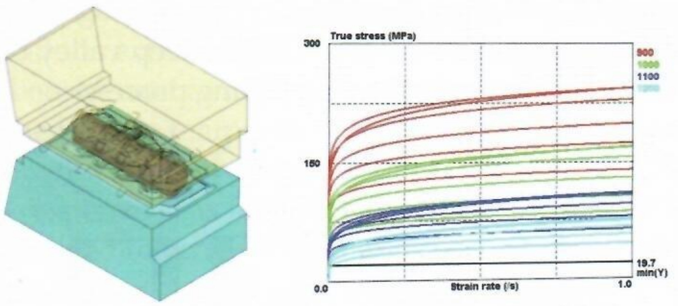

Figure 4: Process design of crankshaft and definition of flow stress

The process design and the flow stress definition of the workpiece material is presented in Figure 4. The friction at the die-workpiece interface was assumed to be following the Coulomb friction law with a coefficient of friction value being 0.2. A slider crank press with a stroke distance of 380 mm and 60 spm was used in the simulation.

Figure 5 depicts the three different cross sections where the metal flow lines are discussed in further detail here. It should be noted that the visualization of metal flow lines at any arbitrary plane directly during post-processing will be very valuable to the process design engineer.

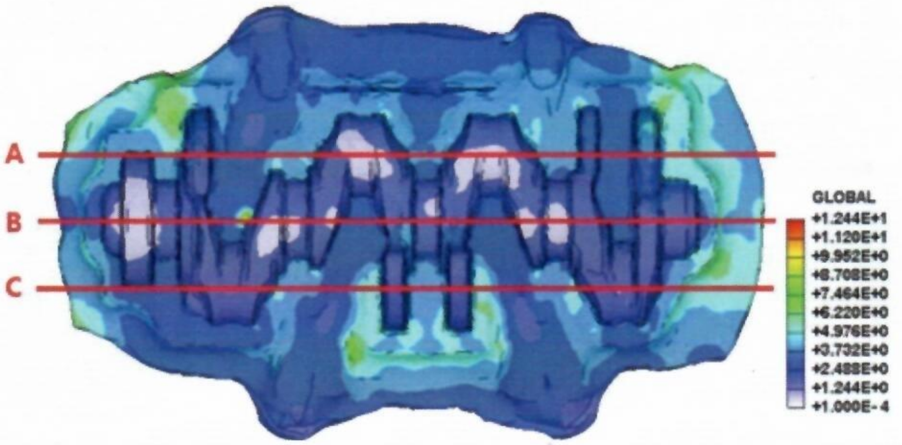

Figure 5: Cross-sections on which metal flow lines are to be visualized

Figure 6 shows the metal flow lines at different cross sections A, B and C during the three stages of the forging process and Figure 7 depicts the flow lines at cross section B in more detail.

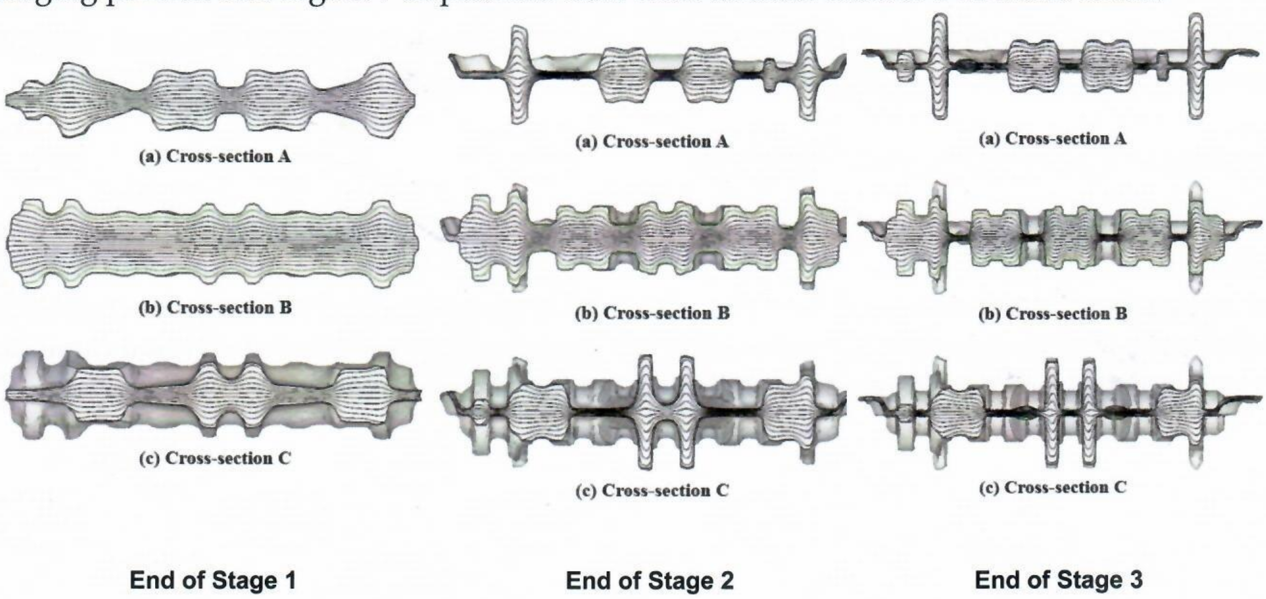

Figure 6: Metal flow lines at the end of three stages

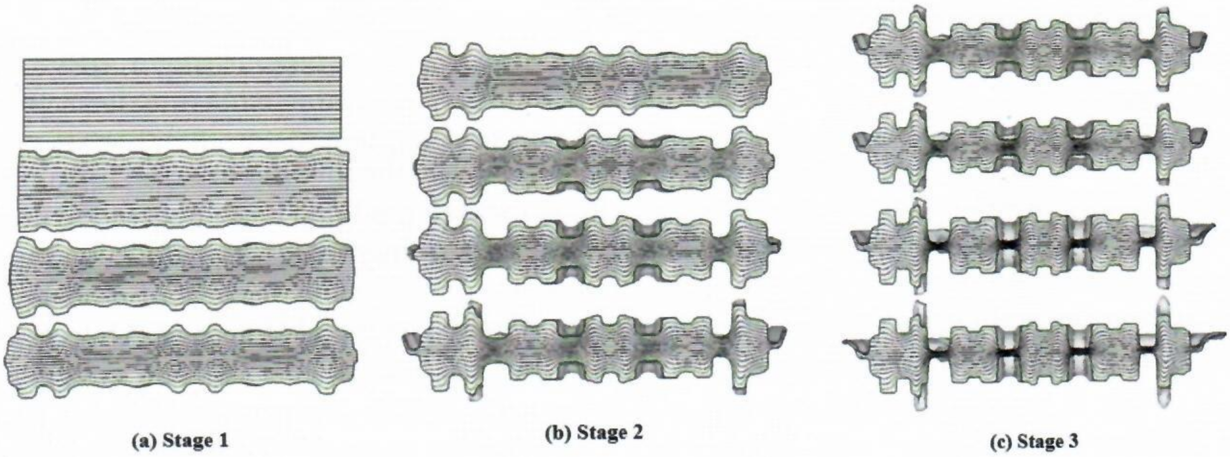

Figure 7: Detailed metal flow lines at the cross-section B

It could be observed that the distribution of metal flow lines was as expected, and this matched well with experiments too. Optimization of process design considering proper distribution of MFLs goes a long way in fabricating a component of high quality.

CONCLUSION

Metal flow lines (MFLs) are one of the major factors affecting product quality and structural rigidity. It is thus essential to test the MFLs of a forging process to evaluate its soundness in terms of metal forming because MFLs inherently contain the history of plastic deformation of metal formed product. They are thus the first barometer of structural performance, especially for bearing or gear parts which sustain extreme load conditions.

With the help of an intelligent metal forming simulator, the flow lines were predicted for two different processes and the results were compared with experiments. The ability to visualize metal flow lines at any arbitrary cross-section directly during post-processing is very important and this helps the process engineers in visualization, obtaining valuable information thereby resulting in optimized process design.

As the quality of metal flow lines have a noteworthy influence of the life span of the part, the optimization of process design should be carried out based on the high quality of metal flow lines rather than just the forming load. With fierce competition around the globe, such practical insights are valuable for forging companies to stay ahead and be creative.

For other similar and interesting examples, the reader is advised to visit www.afdex.com

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ABOUT MFRC:

MFRC has developed and successfully commercialized AFDEX, the intelligent metal forming simulator. AFDEX provides the state-of-art prediction (Japanese patented) technology of metal flow lines which can be directly applied to a versatile range of metal forming processes. MFRC also supports and consults our customers in numerous ways of both online and offline education, sharing application experiences and useful findings from annual conference on metal forming CAE technologies which covers special short term or long-term lectures and publication of books and papers as well. MFRC's policy is to organize and network full-time professionals and specialists from academic side in fulfilling our customers with engineering achievements and satisfaction. MFRC consistently pursues genuine integrity to become loyal friends of metal forming engineers and researchers full of passion and enthusiasm.

Out of The Box Solutions for Forging Component Industry

Dr. Vasant Khisty, Sammy Consulting, India

Forging technology is one of the oldest technology in the evolution of human being and technology to make a human life more convenient. I have been associated with Forging for last 35 years and I have seen it evolving slowly especially in India. Technology like Press Hammer Upsetter have been predominant and use of two dies has been the basic method of forming the shapes. Forging in India has been directed by technologies developed in west and I don't see any quantum leap except yield improvements, die life improvements and limited automation. I don't see out of the box thinking of what could be done further to make optimum use of the technology.

I have the privilege to use a very high end accurate simulation software developed by German researchers and it is called Simufact. Though I don't have forging equipment at my disposal I use this software to crank my head and come out of some out of the box thought processes.

I feel one of the major areas we need to work between OEM and supplier is to co design components which are designed historically such that the ultimate yield after machining is very high. Designing of components for ease of manufacturing will save tons of material and machining allowances if the OEM engineering and forger co design a component.

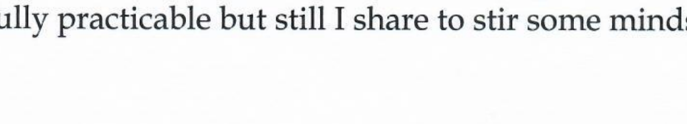
Through this paper I am throwing some ideas to be taken over by people who have the resources to commercialise these ideas. I don't have physical evidences except some simulation results and my imagination may not be fully practicable but still I share to stir some minds.

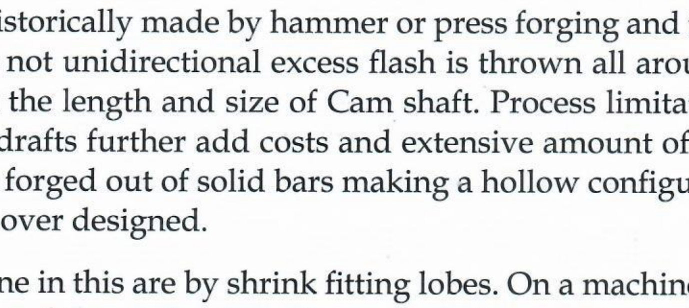
CAM SHAFT

Cam shafts have been historically made by hammer or press forging and then machining. Since the profile of cam lobes are not unidirectional excess flash is thrown all around which can be around 30%-40% depending on the length and size of Cam shaft. Process limitation like bend, mismatch, machining allowances, drafts further add costs and extensive amount of machining has to be carried out. Since these are forged out of solid bars making a hollow configuration is not possible and thus the Cam shaft gets over designed.

Some work has been done in this are by shrink fitting lobes. On a machined bar but I am not aware of 100% implementation of this technology. I wonder why an extruded pipe can't be machined and round cylinders are shrink fitted on the pipe at designated locations and then the lobes are machined. The other way would be to machine the lobes carry out induction hardening and shrink fitting them or press fitting them. Methods can be adopted to prevent lobes from rotating.

The Cam shaft thus can be lighter in weight and cost effective in terms of over machining cost.

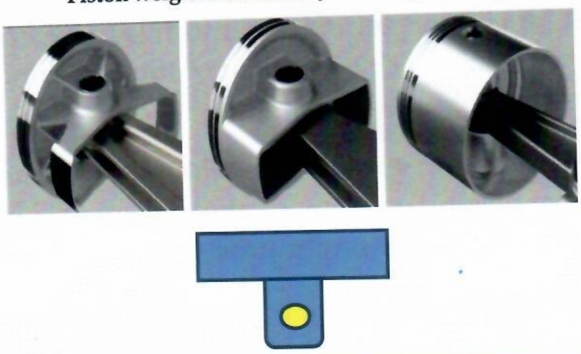


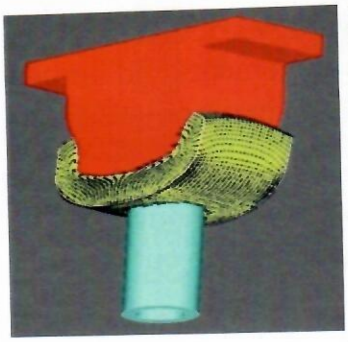


PISTON

New fuel efficiency norms are shifting pistons from aluminium to steel which gives 2% saving on emissions. The functional part are head of piston, the piston ring and piston pin hole. Historically we see a long skirt below the piston which has no functional role. The complete sliding load is taken by the rings and the piston head with two lobes is sufficient to hold the connecting rod with a pin. This will reduce the material cost at least by 20% and make the piston lighter in weight.

Piston weight reduction by reducing the skirt





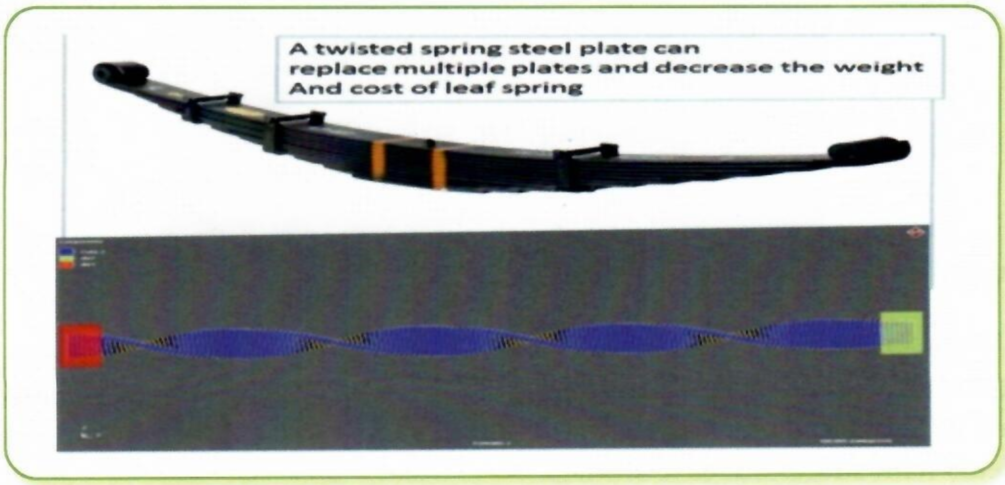
Wrap forging and Bi metal forging for making flashless forks, yoke shafts etc

Steering yokes or propeller shaft yokes are made very complex in design. In order to manufacture them in forging they have to be forged horizontally in dies thus throwing a lot of flash all around. Yokes can be made flashless by forging them vertically and another option here is concept of wrap forging can be implemented here. Different mechanical properties are required at different location. Some where carburising , some where induction hardening would be suitable in the same component. Concept of wrapping a hot forging around a cold part can help reduce wastage and material properties can be optimised. The forging can be made lighter by using hollow configuration which tradiotionally cannot be done due to process limitations.

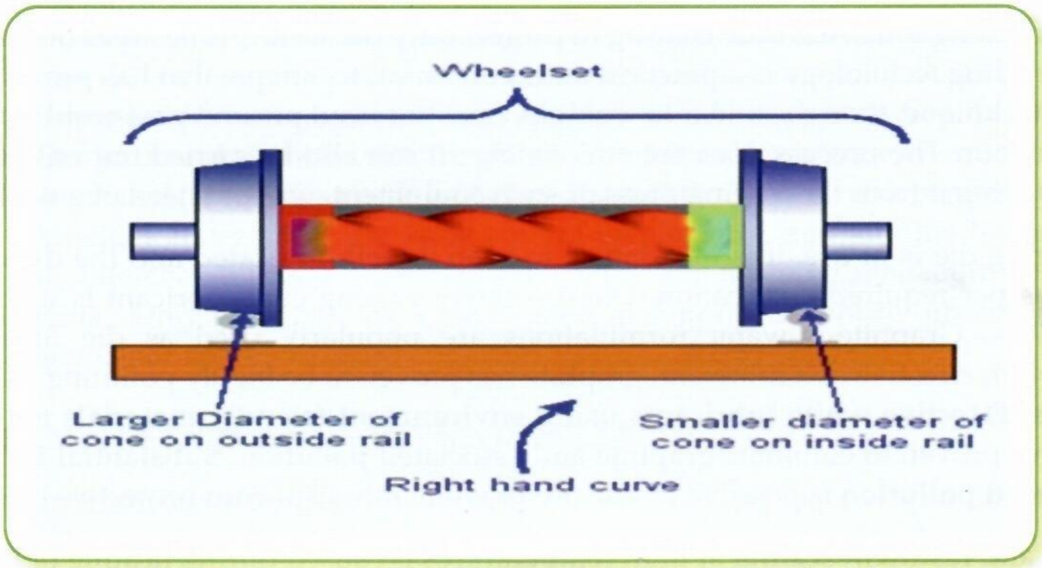
TWISTED FORGINGS

Bars have been used by twisting for ornamental purpose as step railings or gates etc. Even cycle carriers have twisted plates. Twisted bars have twisted grain flows and hence better mechanical properties. Experiment shows that the strength of twisted plate or bar increases three fold. The principle is like using a twisted wire rope where each wire strand is like a grain flow. Crank shafts have been twisted in order to create orientation among the crank pins. There are several applications where twisted technology can be used like axle shafts, engine valves, railway axles, leaf springs etc. This needs to be validated by field tests before implementing and remains just as a logic as to why cannot this be implemented in automobiles to reduce the mass of material. Some pictures below explain the applications.

Example of leaf spring to be replaced by twisted leaf springs



Example of a twisted railway axle to reduce the weight of axle for the same strength.



CONCLUSION:

Historically the designers of OEM products designed their products with application in their mind and not with the objective of manufacturing by most economical method. Many complicated configurations were added which resulted in component weight reduction but increased the raw material consumption. Going forward nothing much has been left in forgings to be squeezed out by reducing the conversion costs. Now costs have to be looked into totality including machining and assembly and not just forging cost. Engineers of OEM need to sit down with manufacturers and make changes to eventually make components which have higher value to cost.

AUTHOR:

*Dr Vasant Khisty has more than 35 years' experience in Auto component business. He has done his research on global competitiveness of auto industry. He has a consulting business named Sammy Consulting which carries out consulting training and research in order to make Indian Forging globally competitive. He can be contacted at sammyconsulting@gmail.com.

Increasing Forging Die Life and Reducing Rejections Using Protective Coatings

Mr. S. P. Shenoy, Mr. Srikar Shenoy,
Steel Plant Specialities LLP, India

ABSTRACT AND INTRODUCTION:

Protective coatings continue to play a major role in increasing productivity and reducing costs in metal forming and heat treatment processes. With the recent advancements, nanotechnology has been introduced in the manufacturing of protective coatings for the metal forming processes. This presentation deals with successful case studies.

1. Die, mould and tool wear are major reasons for production downtime and increased costs in most industries. Apart from using suitable alloy steels for making dies, a few effective treatments like nitriding, PVD & CVD can be administered to increase die life. Such treatments are not feasible for all metal forming units. **Carbide coating to protect only the wear-prone areas** of dies using Japanese cold-welding technology is a practical and economical technique that has proven to increase die life. This technique, though similar to welding, does not need pre and post-weld heat treatment and skilled labour. The process does not emit smoke. It can also be carried out on the die or tool without unloading it from the forging press or such equipment, without need of a weld shop.

2. When forging die is in use, it is mandatory to keep it well lubricated and the die temperature maintained as per required application. Die protective coating cum lubricant is used to achieve these objectives. Graphite-in-water formulations are popularly used as die lubricants until recently. Though effective as a lubricant, graphite has proven to be highly polluting and dirties the surroundings. **Effective white lubricants using environment friendly materials** are now developed that have proven to eliminate graphite and associated pollution. **Substantial increase in die life and reduced pollution** is possible by the use of white lubricant cum protective die coating.

3. Oxidation and resultant scaling at high temperatures is caused during heating of billets, ingots for forging and during heat treatment of formed components. Scaling leads to enormous losses by way of rejections of produce, reduced yield and increase in non-value adding operations like shot-blasting, grinding, pickling, etc. These parameters are becoming increasingly sensitive in open and closed die forging, especially of expensive grades of steel like stainless steel, nickel-bearing steels and aerospace forgings. **Anti-scale protective coatings** can be used to prevent or substantially reduce high-temperature oxidation and scaling. Nano-material based protective coating have **proven to reduce rejections, reduce quench cracks, improve surface finish** of parts, reduce shot blasting and increase yield. This technique is also proven useful in protecting dies and tools during heat treatment.

These techniques can be easily adopted by all metal forming units, big and small.

SUBJECT 1: INCREASING FORGING DIE LIFE BY THE USE OF JAPANESE COLD-WELDING TECHNIQUE.

Problem: Die, mould and tool wear are major reasons for production downtime and increased costs in most industries. Apart from using the most appropriate die steel, a few effective treatments can be administered to dies to increase their service life. Even if possible, such treatments are not feasible for all forging units. For example, installing and maintaining an in-house nitriding facility is not feasible in many forging units.

Observation: Most of the forging dies wear out only in certain areas. The complete die impression does not wear out at once. Only sensitive portions of the die, like edges, profiles that take majority forging load, etc. wear out much faster than the rest of the die profile. Some examples are shown below:

Technology: Japanese cold-welding technique enables appropriate surface hardening of dies, moulds and tools to increase their service life. The technique involves coating of tungsten carbide on selective wear-prone areas of dies/ moulds / tools through the special electronic Japanese Cold Welding Technique.

Cold welding is carried out as a 'Preventive Maintenance' technique on new dies. It is a surface hardening technique, similar to nitriding and PVD, but is administered manually using the Japanese cold-welding equipment. Hardness of tungsten carbide layer deposited by cold-welding on dies can surpass nitriding to reach hardness of more than 70 HRC.

BENEFITS OF JAPANESE COLD WELDING TECHNOLOGY:

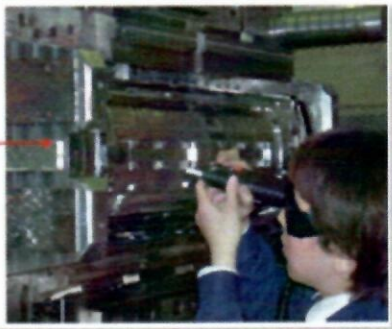
1. Skilled welders not required. Can be carried out by anyone
2. Open space / ducting not required. No fumes are generated during cold welding
3. Time saving process as dies need not be removed from forging equipment
4. Pre and post welding heat treatment not necessary. No stresses are generated during cold welding as it is a cold process.

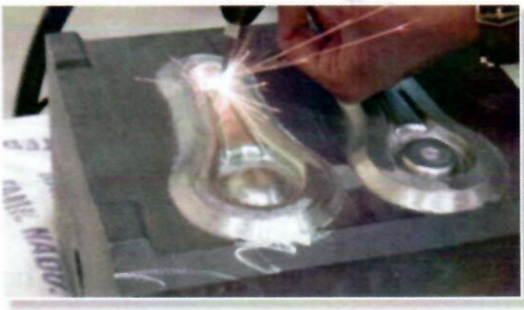
ADDITIONAL BENEFITS OF JAPANESE COLD WELDING TECHNOLOGY:

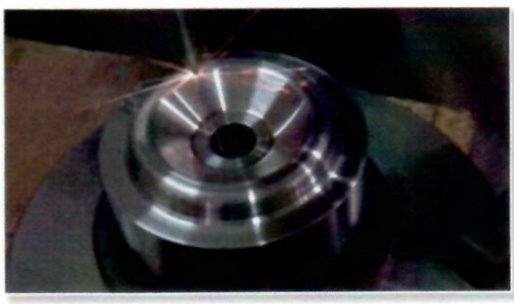
1. Nitriding of dies not required. Hardness of tungsten carbide coating is more than 70 HRC, which is higher than hardness obtained by nitriding process (62-64 HRC).
2. Increased die life due to high wear resistance.
3. Substantially reduced maintenance downtime of dies and tools.
4. Ability to coat selective areas of dies that are prone to wear. Process does not require the complete die to be treated/ protected.

COMPACT COLD WELDING EQUIPMENT AND APPLICATORS

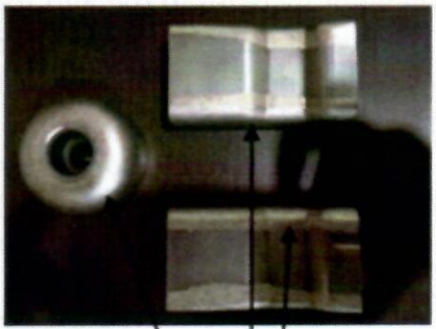
CAN BE USED BY ANYONE, ANYWHERE







Carbide coating is seen as silvery, coarse coating on wear-prone areas of dies:



Scratch and serrations-prone inner diameter of a forging die that was coated. Carbide coating is seen as silvery coarse layer.

Sheet metal pressing and punching tools set carbide coated on edges and wear-prone areas.

Sensitive areas of the die were protected with carbide coating. It is seen as silvery layer on edges of die profile.

Substantial increase in die life after cold-welding:

S.No.	Description of die / tool	Metal Forming Equipment	Not coated die life (No of parts formed)	Japanese cold-welded die life (No of parts formed)	Percentage of increase in die life
1.	Punching tool	220 ton hot forging press	13000	17000	23.5%
2.	Sheet metal pressing die & tool set	Sheet metal press (cold pressing)	18500	25900	40%
3.	Hot forging die	1000 ton hot forging press	4000	5400	35%
4.	Hot forging die	1000 ton hot forging press	8000	12000	58%
5.	Hot forging die	1600 ton hot forging press	10000	15900	62%
6.	Hot forging die	1600 ton hot forging press	10000	22000	120%

Observation after implementing Japanese cold-welding technique: Till date, all the demonstrations of this technique have shown encouraging results. Hence, there is no risk in terms of die/ tool breakage or reduced life. The percentage of increase in die and tool life has varied from as low as 35% in initial trials to as high as 120% in recent trials. Various parameters that contribute to success of this technique are well documented, leading to refinement of the technique. This has assured better results on subsequent demonstrations on hot forging dies.

SUBJECT 2: INCREASING DIE LIFE USING CUSTOMISED DIE LUBRICATING EQUIPMENT AND ENVIRONMENT FRIENDLY DIE LUBRICANTS.

Die lubricants play an important role in achieving optimum die life.

Problem: Use of cheap oils when used as die lubricant leads to very low die life and pollutes the forge shop. Water miscible graphite based lubricant is better than oils. However, graphite spreads around and makes the forge shop dirty. Being good conductor of electricity, graphite damages the electrical equipment of modern forging presses.

Observation: Many times, switching over from oil to water-based graphite or to synthetic lubricants is daunting. This is due to improper spray techniques, leading to low die life or die breakage as depicted.

Technology: New generation synthetic die lubricants that are effective and clean are now available. Synthetic die lubricants have often proven better compared with graphite. This is possible only when synthetic lubricants are used with correct method of spraying. Customised spraying systems and sprayguns, depending on the specific forging profile need to be used.

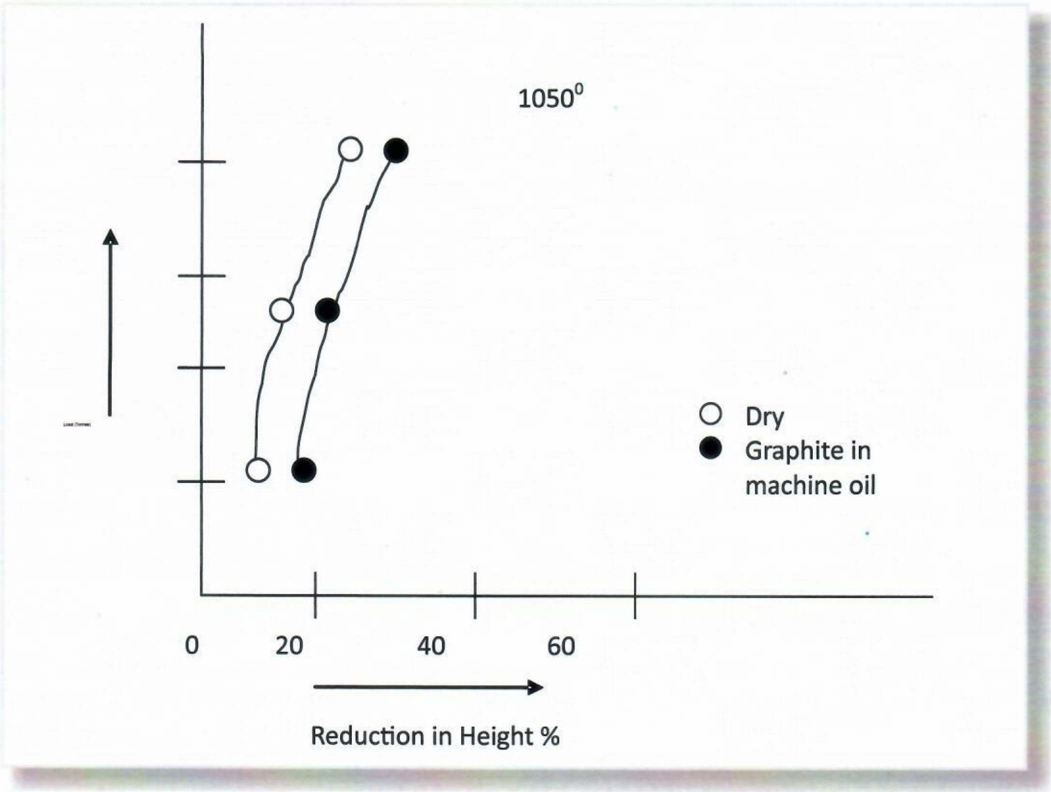


Fig 1: Reduced forging load by using lubricant.
Ref.: Dr. A. S. Deshpande, IIT, Mumbai, India.

Case StudyI: Productivity Improvement due to reduced die grinding time by switching over to graphiteless, water soluble lubricant.

Sr.No.	Particulars	Graphite Based Die Lubricant	Graphiteless Die Lubricant
1.	Forging Equipment	1000 Ton Press	
2.	Product	Forging Sleeve 	
3.	Dilution Ratio	1 : 10	1 : 10
4.	Time Loss Due to Die Grinding at Each Shift	1.5 hours	NIL
5.	Production in 3 shifts	7000	9000
6.	Productivity Improvement	---	22%

Case Study II : Cost Saving due to graphiteless, water soluble forging lubricant.

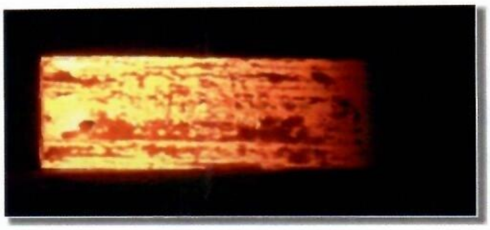
Sr.No.	Particulars	Graphite Based Imported Lubricant	Graphiteless Indian Lubricant ESPON
1.	Forging Equipment	1000 T Press	
2.	Product	Two Wheeler Crank Shaft 	
3.	Total Production	100 Tons	
4.	Consumption of lubricant per 100 tons	400 kgs.	
5.	Cost per kg.	Rs. 180/-	Rs. 117/-
6.	Total cost of lubricant per 100 tons (cost per kg. x 400 kgs.)	Rs. 72,000/-	Rs. 46,800/-
7.	Saving per 100 tons	--	Rs. 25,200/-

Observation after implementing new generation synthetic die lubricants: Substantial increase in die life is possible by the use of environment friendly die lubricants when correct spraying equipment and spraying techniques are implemented.

Subject 3: Reducing rejections and increasing yield using anti-scale protective coatings.

Problem: Oxidation and resultant scaling leads to pit-marks and rejections. Non-value adding operations like shot blasting, grinding, etc. are costly and time consuming.

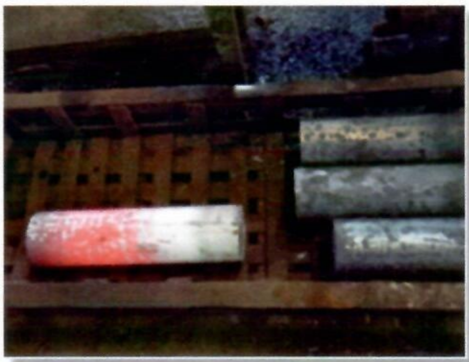
Observation: Oxidation and scaling are a function of time, temperature and the thermodynamic affinity between oxygen and metal. Recent developments in highly oxidation-prone grades like nickel bearing steels, high speed steels and stringent customer demands do not allow for scale pits, uncontrolled decarburisation and bad surface finish.

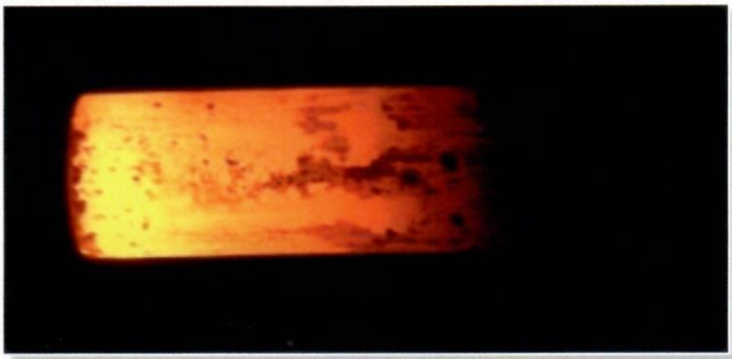


Excessive scaling on billets (above) cause pit marks and rejection on forgings as shown in adjacent image.

Technology:Anti-scale protective coating is applied on billets or components to be heated before charging them into furnace. This anti-scale coating acts as a barrier between oxygen and metal. Care is taken to apply a uniform, impervious layer of coating by brushing, spraying or dipping.

Use of anti-scale protective coatings on billets during heating for forging and again on forgings during heat treatment have proven to substantially reduce scaling, control decarburisation, improve surface finish and increase yield. Photos below show substantially reduced scaling on billets. As a result, forged parts do not have scale-pits and have acceptable surface finish.





Observation after implementing anti-scale protective coatings: Benefits proven by the use of anti-scale protective coatings are:

- *Substantially reduced scaling. Reduced rejections due to scale pits.*
- *Shot blasting / acid pickling time is either reduced to a great extent or eliminated.*
- *Consistently controlled decarburisation.*
- *Increased yield.*

CONCLUSION

Forge shops are assured of increased productivity and substantially reduced costs in hot forging and heat treatment processes by the use of protective coatings like:

Japanese cold-welding on dies,
Synthetic lubrication of dies and
Anti-scale protective coatings of billets and forged parts

A number of esteemed forge shops in India and abroad have adopted these techniques to increase die and tool life, eliminate pollution and substantially reduce costs.

About the Authors-Mr. S. P. Shenoy, M.Tech in metallurgical engineering from the Indian Institute of Technology-Mumbai, established STEEL PLANT SPECIALITIES (SPS) in the year 1985. Products developed by him enable to reduce losses due to scaling and decarburization during hot rolling, hot forging and heat treatment.

Mr. Srikar Shenoy completed his management studies from Welingkar's Institute, Mumbai, and joined team SPS in year 2003. He is involved with esteemed forge shops in projects for increasing productivity and reducing costs through products manufactured by SPS.

Elimination of Lap Using Forging Simulation Technique

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CAE, ARAI - Forging Industry Division, Pune, India

INTRODUCTION

Forging is defined as the process in which a metal billet or blank is shaped under tools / dies with application of temperature and pressure. In forging process many parameters influence the process viz. temperature, force, lubrication, location, design etc. Tight control is required to achieve good quality of forging. If parameters are not controlled then number of trials will increase, which results into increase in cost, time and energy requirement. With computer simulation, the forging process can be optimized and also reduces no. of trials, ultimately saves time, energy and also helps in achieving the first time right component.

Presented in this article, is a case study where, a hot, closed die, existing forging process was simulated to establish a correlation in terms of defects produced with physical sample. The methodology was extended to modify the process for removal of defects and further optimization. To optimize the process, different die configurations and billet shapes were simulated in order to produce the best configuration. The modified process resulted in elimination of lap. Thus helped to produce components without defect. Effective use of simulation software helps to optimize the forging process, minimize material scrap or improve yield, reduce forging stages and hence reduce the overall cost of manufacturing.

PRODUCT DEVELOPMENT CYCLE

Figure 1, shows forging process development cycle comparison between industries that use or do not use with simulation software. The cycle shown on left is generally followed for all new part development in the industry. Process design is carried out once machining drawing is received. CAD modeling of different forging stages was prepared which was further considered for CAM program generation. Manufactured dies are used to produce forging samples which later undergo various checking parameters such as quality checking, defects checking, etc. If samples don't meet quality criteria, above mentioned cycle is repeated until it meets these requirements.

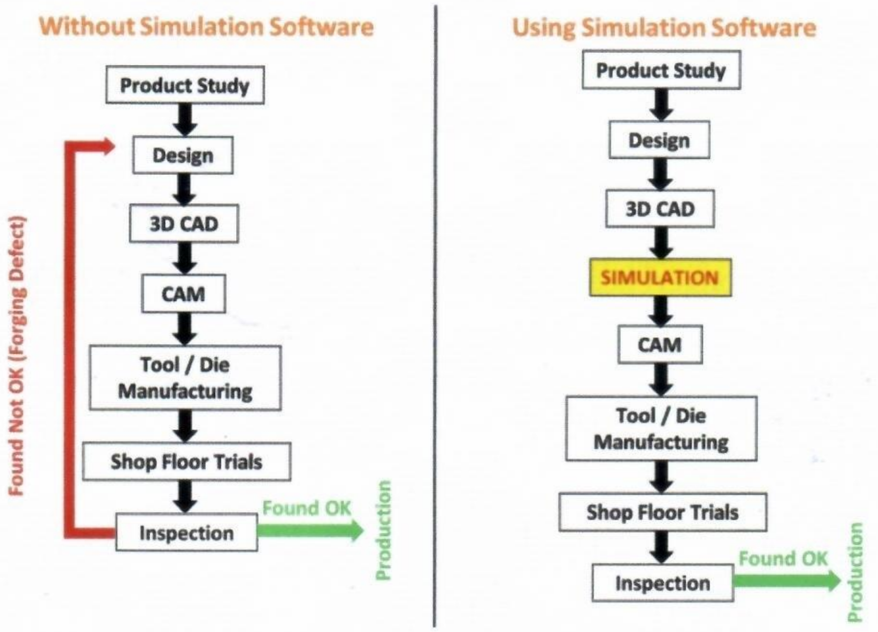


Figure 1- Forging Process Design Development Cycle

This iterative process can be eliminated by use of simulation as a tool as shown in the cycle on the right side in Figure 1. Number of iterations can be tried out using simulation until defect free component is produced. Once process is established in simulation without any defect then CAM program can be released for further processing.

EXISTING FORGING PROCESS

In the case study presented, forging a valve body of approx. 310 Kg on 16 T hammer was very challenging. In the conventional forging process, this valve body was forged in two stages viz. heating, pre-form, finisher using hammer followed by trimming operation. During finisher process, a big lap formation was taking place as shown in figure 2. It was very difficult to visualize during the actual forging process how metal was flowing and how lap was getting formed. The use of computer simulation helped in understanding the metal flow inside the cavity. Input parameters used for simulation were thermal details, die geometry, lubrication details, forging material, equipment kinematics etc. The simulation findings and root cause analysis method helped to eliminate the lap formation, which is discussed in subsequent sections of this paper.

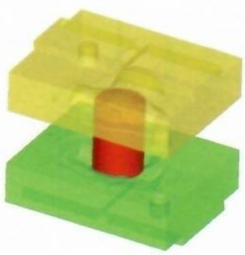
Figure 2 - Actual Lap

Assumptions and input parameters considered for simulation of existing forging process are as follows:

- Billet temperature was 1230°C and die temperature was 200°C.
- Billet material is SAE 4130 (Alloy steel), Die material is DB6. Input Billet weight - 385 Kg.
- Lubrication used - Oil
- Forging Equipment - 16 T Hammer.
- CAD for die geometries and billet were created.

Preform stage is used to convert heated Round Corner Square (RCS) billet into cylinder shape

This pre-form shape was then transferred to finisher stage. Fig. 3 shows, preform shape billet placed between top and bottom die and lap formation inside the component after finisher stage.



Finisher process setup

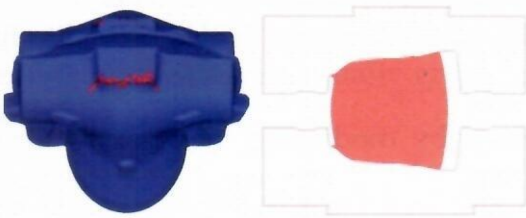


Figure 3 - Lap Formation

As shown in figure 3, at pad area, lapping formation takes place. Various result parameters viz. temperature, force/energy prediction, die wear/stresses, grain flow etc. were analyzed. Simulation and actual results shows very good co-relation which is evident from comparing figure 2 and 3. A detailed study was conducted to understand the possible reason for lap formation. Various design parameters were cross verified, which includes flash thickness and land width calculation, parting line radius, stock size calculation and complexity factor.

MODIFIED FORGING PROCESS

The simulation methodology thus is developed to eliminate the defects, and further optimize the process. Taking into consideration the forging process and analysis of simulation results, changes were carried out in preform shape and in finisher dies. With these modifications, improvement was observed. Figure 4 shows upset operation and initial setup of finisher operation. The modified process results into eliminating forging defect, additionally number of blows reduced and hold up of component was minimized.

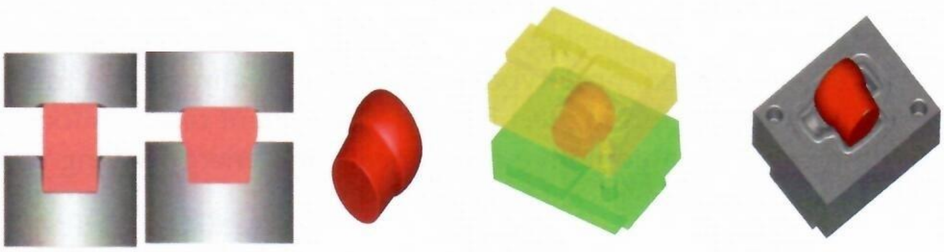


Figure 4 - Upset forging and initial setup of finisher forging

Physical trial was carried out with modified designed process. A batch of 50 components was forged. All the samples were found to be satisfactory without any forging defect; this establishes good correlation with predicted results. Figure 5 shows final shape of forged component from simulation and physical trial.

Figure 5 - Simulation and actual result correlation

CONCLUSIONS

- Computer simulation was able to capture the defects occurred in existing forging process and gave insight about the forging process. It also helped to find the possible reasons for the defects.
- Optimum solution achieved by modifying the process through iterative forging process simulation.
- All the forging defects (i.e. folds, laps, etc) were removed by using appropriate modification in forging process.
- Modified forging simulation process helped in reducing number of blows as well as hold up of component, which helps in less machining.
- Results of the simulation were validated by shop-floor trials and excellent correlations in the results were established.
- The benefits of this exercise are reduction in cost, increase in productivity without any forging defects.

About Forging Process Simulation Service of ARAI-FID: ARAI-FID has been offering this service for more than a decade and has served variety of forging industries from small to large scale covering variety of forging materials like steels, aluminium, copper and titanium alloys that has resulted in forging defect elimination, input weight optimization, reduction in forging load, improved productivity, reduction in energy consumption etc. Input weight reduction of as high as 40%; reduction in % rejection from more than 10% to less than 2%; and productivity improvement by factor of two are some of the feedbacks received against the solutions provided to the forging industry.

About ARAI-Forging Industry Division (ARAI-FID): ARAI-FID offers services of mechanical & metallurgical testing, fatigue testing, 3-D scanning, benchmarking, forging component design, forging die design, forging process simulation, prototype forging, heat treatment and training. It also carries out research in various areas of forging technology. The current research focus is on developing lightweight forging process for automotive components and energy saving by heat treatment optimization. ARAI-FID works in close association with AIFI.

Increase in Die and Tool Life-using Japanese Cold-Welding Technique

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Steel Plant Specialities LLP, India

ABSTRACT

Japanese cold welding technique of electronically overlaying protective carbide layer on metal-forming dies and tools holds promises of increased die & tool life, reduced maintenance downtime, convenience of operation and better productivity.

Die, mould and tool wear are major reasons for production downtime and increased costs in most industries. Apart from using strong base metals for making dies, a few effective treatments can be administered to dies to increase their service life. Conventional methods to increase the life of die or repair forging dies include nitriding, PVD (Physical Vapour Deposition) & CVD (Chemical Vapour Deposition), and welding. Usually, conventional welding is a 'Repair-oriented' technique carried out after the dies are damaged or worn out.

JAPANESE COLD-WELDING TECHNIQUE

Now a new Japanese cold-welding technique is available that enables appropriate surface-hardening of dies, moulds and tools to increase their service life. The technique involves electronic coating of tungsten carbide on selective wear-prone areas of dies/ moulds / tools through the special Japanese cold welding technique.

Cold welding is carried out as a 'Preventive Maintenance' technique on new dies. It is a surface hardening technique, similar to nitriding and PVD, but is administered using a completely different methodology. Hardness of tungsten carbide layer deposited by cold-welding on dies can surpass nitriding to reach hardness of more than 70 HRC.

Pre-requisites of using this technique are:

1. Accurate history of die life to monitor the increased die life.
2. Correct understanding of wear pattern of dies.

Especially in the case of small to medium automotive forgings, selective areas of dies wear out faster compared with rest of the die. If these areas are protected with carbide coating using Japanese cold-welding technique, the die wear will be delayed, thereby increasing service life of die.

Die wear begins from small, critical areas. Due to wearing out of such small areas, processes like repair welding, grinding or die sinking need to be carried out. These processes require the die to be unloaded from forging press leading to loss of production. If these small, critical areas are protected with carbide coating using Japanese cold-welding technology, die wear can be delayed and its life increased substantially.

CHARACTERISTICS OF CARBIDE COATING

1. Wear resistant: Due to inherent strength of tungsten carbide, the wear resistance is high. If the die is hard and heat treated well, a good forging die life can be expected after carbide protective coating.

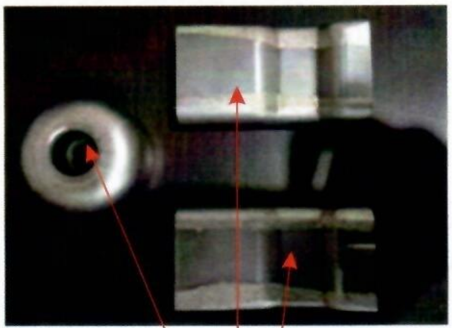
2. Heat resistant: The coating is heat resistant and will not cause heat checks. Excessive heat leading to die wear will be prevented in protected areas.
3. Scuffing resistant: Scuffing and bruising is the initial stage of having serrations on die. This scuffing will be prevented or substantially delayed.
4. Lubricity: Many times, due to very smooth finish of new dies, the forging / casting die lubricant does not adhere to the die. This problem is not faced in the case of carbide coated dies. It is observed that die can be lubricated better than before.

ACTUAL USE OF THE TECHNIQUE

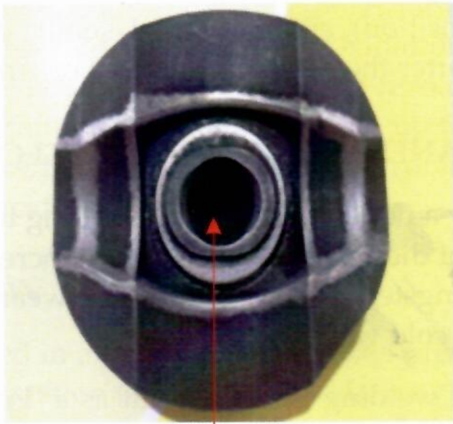
The use of the Japanese Cold Welding technique has been studied in a number of Indian Metal forming companies which have tried out carbide coating on wear-prone areas of the dies and tools.

SHOWN BELOW ARE SOME PHOTOGRAPHS OF CARBIDE-COATED DIES.

Scratch and serrations-prone inner diameter of forging die that was coated. Carbide coating is seen as silvery coarse layer.



Sheet metal pressing and punching tools set carbide coated on edges and wear-prone areas.



Wear-prone edges of the die were protected with carbide coating. It is seen as silvery layer on edges of die profile.

Lug gear die carbide coated on wear-prone areas.

Punching tool carbide coated on wear-prone areas.

The table below indicates that there has been substantial increase in die-life after cold-welding:

S. No.	Description of die / tool	Metal Forming Equipment	Not coated die life (No of parts formed)	Japanese cold-welded die life (No of parts formed)	Percentage of increase in die life
1.	Punching tool	220 ton hot forging press	13000	17000	23.5%
2.	Sheet metal pressing die & tool set	Sheet metal press (cold pressing)	18500	25900	40%
3.	Hot forging die	1000 ton hot forging press	4000	5400	35%
4.	Hot forging die	1000 ton hot forging press	8000	12000	58%
5.	Hot forging die	1600 ton hot forging press	10000	15900	62%
6.	Hot forging die	1600 ton hot forging press	10000	22000	120%

Till date, no negative result is observed in any of the trials of this technique carried out in various metal forming operations. Hence, there is absolutely no risk in terms of die/ tool breakage or reduced life. The increase in die and tool life has varied from as low as 14% in initial trials to as high as 120% in the latest trials.

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Defects Elimination by Using Forging Simulation for Valve Body

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Automotive Research Association of India (ARAI) - Forging Industry Division, Pune, India

PROBLEM DEFINITION

Forging valve body of approx. 400 kg is very challenging. In conventional forging process, valve body was forged in two stages, viz., heating, pre-form, heating, finisher using hammer followed by trimming operation. During finisher process, a big lap (Crack) formation was observed as shown in Figure 1. In conventional process, initial 2-3 blows were required to blow off the scale. From 4th blow actual metal flow starts. Forging operation takes only few seconds and it was difficult to visualize how metal flows and how lap was formed. Thus it was difficult to produce defect free component on time to meet customer requirements. The confidence in "First Time Right" was becoming challenging for this new part development.

The use of computer simulation helps in understanding the metal flow inside the cavity. The simulation findings and method of tracking lap formation is discussed in subsequent sections of this article.

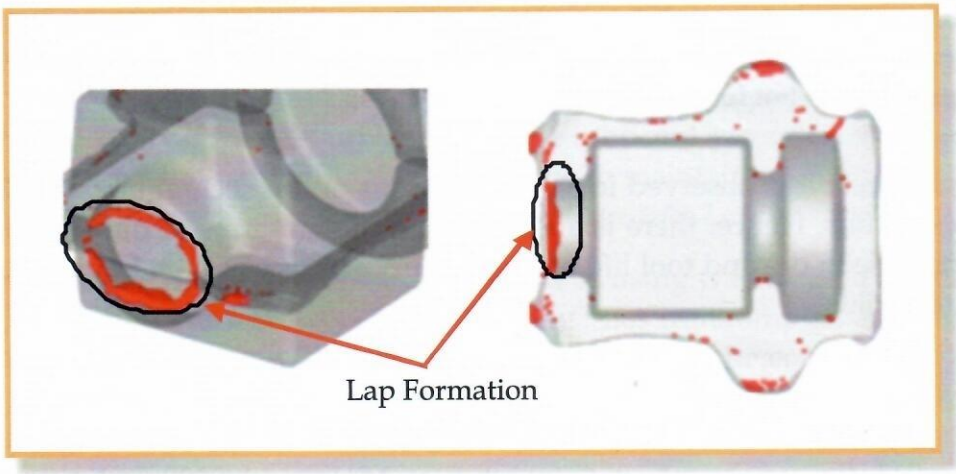


Figure 1 - Cracked area marked in circle shown by red color

SIMULATION METHODOLOGY

Assumptions & input parameters, considered for simulation of existing forging process, are as follows:

- Actual furnace temperature was considered higher than specified temperature by considering transfer time of 60s, the specified temperature of billet was 1230°C on hammer.
- Dies temperature was 200°C.
- Material of Billet is SAE 4130 (Alloy steel), Die material is DB6.
- Lubrication used - Oil
- Press Capacity - 16 T Hammer, striking height of 1500mm, top Mass of 2570 kg and
- Maximum Energy of 392 kJ.
- Die geometries and billet 3D model were created with the help of drawings.
- Only Finisher process was simulated.

The existing forging sequence was as shown in figure 2. In pre form stage, heated Round Corner Square (RCS) billet was used to prepare a preformed shape as shown in fig. 3. The pre-form shape was then heated and transferred to finisher stage. Finally finisher process was carried out. Out of this, only finisher process was simulated. Fig. 3 shows, preformed shape billet placed between top and bottom die.

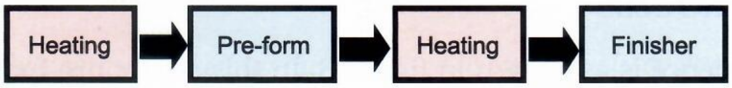
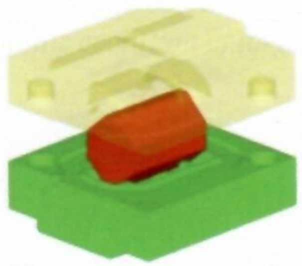
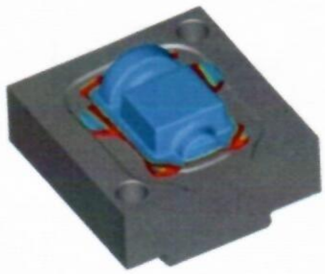


Figure 2 - Existing forging sequence





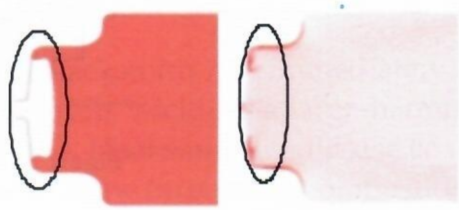


Figure 3–Finisher process setup **Figure 4–Forged Component** **Figure 5– Cracked area**

As shown in Figure 4, at the end of small flange, lapping formation takes place. Various result parameters viz. temperature, force/energy prediction, die wear/stresses, grain flow etc. were analyzed. Figure 5 shows sectional view of area of cracked zone and grain flow image, which clearly shows that grains are gathered and crossed each other.

A detailed study was conducted to understand the possible reason for lap formation. Various design parameters were cross verified, which include flash thickness and land width calculation, parting line radius, stock size calculation and complexity factor [2], [3], [4]. Lap formation was analyzed by using various modules like reverse analysis module, grain flow prediction module, point tracking module etc. Of all the available modules, reverse point tracking module was utilized to identify the root cause of the defect. Figure 6 shows points considered for reverse tracking. The conclusion from reverse point tracking shows that, the defect was generated from front face of the billet. (Fig 7)

Thus, the results from simulation were validated with physical test results. The simulation methodology thus developed is available for further modification process to eliminate the defects and optimize the process.

Figure 6- Point Tracking at lap formation **Figure 7 - Point tracking reverse analysis.**

Taking into consideration forging process and analysis of simulation results, changes were carried out in initial billet location in finisher operation. With these modifications, some improvement was observed, but still problem of lap formation was not totally eliminated. So, it can be inferred that, only changing billet locations was not sufficient. Modifications in terms of different billet shapes and locations were tried. Out of these modifications, best one was selected.

MODIFIED FORGING PROCESS

The modified forging sequence is as shown in figure 8. In this setup, pre-forming stage was eliminated. Modified billet geometry of RCS billet of dimensions 330 was used. In addition to billet section modification, billet placement location in the dies was also changed as shown in fig.9 same input parameters and assumptions, as used during existing forging simulation, were used for simulating the modified forging process.

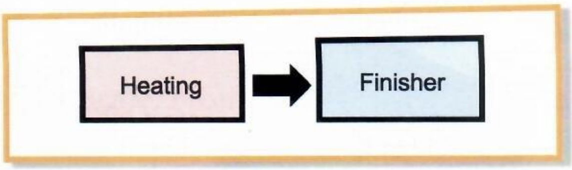


Figure 8 - Modified sequence of forging

In simulation it took 45 numbers of blows to complete the process. Fig. 10 shows, final forged component with flash. The modification resulted in no lap/crack generation inside the impression. In addition, the component was checked by analyzing grain flow and fold analysis to confirm that the component is defect free. Fig.11 shows component produced by modified process with grain flow lines parallel to each other indicating defect free component. Thus, using modified process, defect free component was produced by eliminating one heating and pre-forming operation. These modifications in turn improved productivity, saves significant energy and time. Table 1 compares existing process and modified process in terms of stages required, no. of heating, no. of blows required etc.

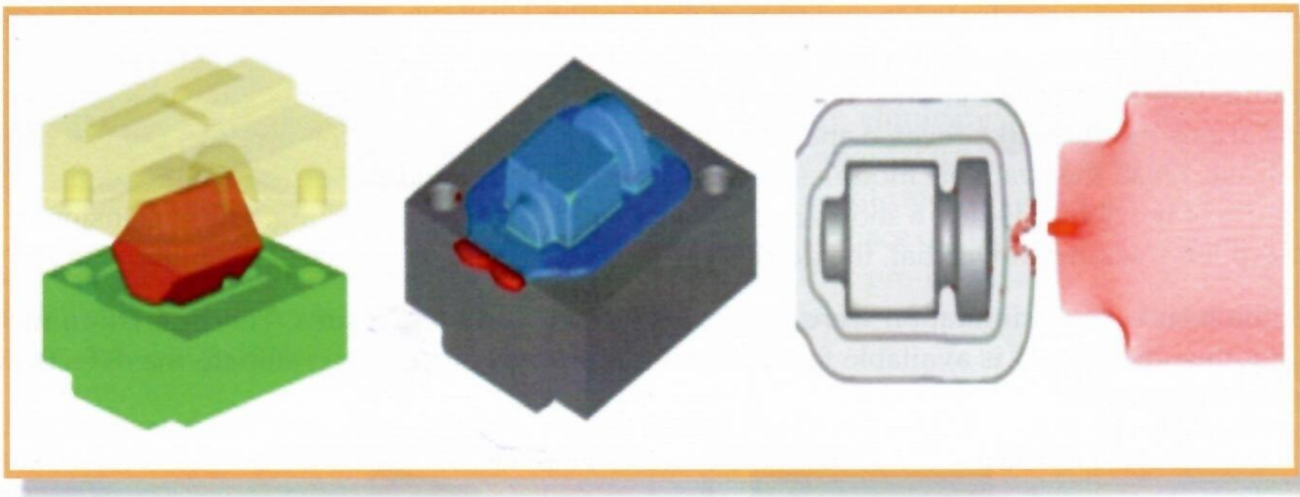


Figure 9- Modified setup with direct RCS billet

Figure 10 - Fill up analysis Component fully filled

Figure 11- Crack free component : Grain Flow

Parameters	Existing Process	Modified Process
Initial Billet	RCS 330	RCS 330
No. of heats	2	1
Stages	Pre-form + Finisher	Finisher
No. of Blows	10 + 30	45
Defects	Lap, non-uniform flash	No lap, uniform flash
Cut weight	484 kg	484 kg

Table 1: - Comparison between Existing Process vs. Modified Process

PHYSICAL TRIAL

Actual forging of the component was carried out with modified process. Inputs such as position of billet, number of blows, lubrication, energy per blow etc. was taken from simulation. A batch of 50 components was forged. All the samples were found to be satisfactory without any forging defect, this established good correlation with predicted results. Fig. 12 shows final shape of forged component from simulation and physical trial. Table 2 compares simulation data and actual data in terms of billet weight, stages required, no. of blows required, defects etc.

Parameters	Simulation Data	Actual Data
Billet Size and Weight	RCS330 x 570 L 484 KG	RCS330 x 570 L 484 KG
No. of Stages	Direct Finisher	Direct Finisher
Defects	No Lap, Uniform Flash	No Lap, Uniform Flash
No. of Blows	45	45-48
Image	As shown in fig. no. 12	As shown in fig. no. 12

Table 2: - Comparison between Simulation Data Vs Actual Data

The modified process resulted in reduction in energy consumption & time required to produce components and ultimately increased productivity. Also due to elimination of one heat there will be less scale loss, which results into less input weight. Considering the range of cost of heating from Rs 3 to 5 per kg, the saving in heating cost due to elimination of one heat cycle is in the range of Rs. 1450 to 2400 for the given input weight of 484 Kg. And considering 50 to 200 pieces per month for one year, approximate saved cost will be in the range of Rs. 8 Lakhs to 50 lakhs.

Thus the entire exercise of computer simulation helped to arrive at optimum forging process with no forging defects with added benefit of reduction in time, cost, energy consumption, material wastage and improved product quality.

Figure 12 - Comparison of simulated component and actual forged component

CONCLUSIONS

- Computer simulation was able to capture the defects occurred in existing forging process.
- Simulation results gave insight about the forging process and it helped to find the possible reasons for the defects.
- All the forging defects (i.e. folds, cracks, etc.) were eliminated by using proper modification in forging process.
- Modified forging simulation process helped in eliminating two operations in forging cycle viz. heating and preforming. The benefits of this exercise are reduction in cost, increase in productivity without any forging defects.
- Results of the simulation were validated by shop-floor trials and excellent correlations in the results were established.

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Energy Consumption and Conservation in Forging Industry

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Forging industry is principally known for their ability to make superior precision auto components and non-auto components, which are supplied to a wide range of vehicle production industries, machinery, engineering and electrical equipment production industries and others. Energy being a major contributor to production cost shows that the forging industry is energy intensive. The most of the energy intensity is in the process of heating in the furnaces. The furnaces are operated by either use of oil or gaseous fuel or electricity depending on the availability and cost of fuel in that particular location. The input energy cost in many of these industries is high hence industries are seeking to use energy efficiently by using efficient combustion management techniques and energy efficient equipment's. Also motors in hammers, presses, air compressors, cooling tower, trimming machines etc., consume high energy.

The forging units that are using furnace oilfired forging furnaces consuming between 100–200 litre/tonne of heated job for forging. For units using natural gas fired furnaces for forging, the gas consumption varies between 100–180 SCM/tonne of heated job for forging. The energy consumption of electrical furnaces typically ranges between 400–450 kWh/tonne of heated job for forging. This variation shows the way forward for energy costs savings through various energy conservation measures.

Also the utilization of forging plant loads like transformers, process machinery mainly heating through furnaces, forging through hammer/presses/up-setter, air compressors, cooling towers and lighting is a function of production, planning, reliability and particularly loading of various jobs. Many of the controllable factors such as loading, losses, and breakdowns, technology used can be managed to improve energy utilization. These factors can collectively result in a variation in energy demand pattern and specific energy consumption, which provides basis for energy conservation.

Some of the major energy-saving opportunities in the Forging units are discussed below:

1. Technology replacement oil fired to induction billet heater

Induction billet heater in forging is a new age technology provides potential of 20-40% energy savings in terms of tons of oil equivalent and monetary savings as compared to oil fired heating for forging range from 10% to 15% based on the existing rate of electricity say about Rs. 7 per kWh and FO rate of say about Rs. 22 per litre. Induction technology is flexible in operation with reduction in scale losses, which leads to material savings. It also avoids other hassles of storage of oil, piping arrangements etc. Also surrounding temperature near induction furnace is very less which creates better working conditions for the labour. Specific energy consumption for FO fired furnace can be brought down from 120-150 litres/tonne to 400 kWh/tonne using induction billet heater. **But this calls for a specific (customized) study for technical and financial feasibility of change of technology and change of fuel source along with considering the type and size of jobs being heated.**

2. Reheating furnaces optimization

Furnace oil fired or PNG (piped natural gas) fired box type furnaces are mainly used for heating the forging job. Cut billets once heated in these furnaces transferred through gravity tray channel to hammer for forging operation. These furnaces are prone to surface heat loss and heat loss through flue gasses. Normally furnace oil fired box type forging furnaces and heat treatment process furnaces are used however electrical heat treatment furnaces also being operated.

Recuperator for waste heat recovery from hot flue gasses of furnace

The exit flue gas temperatures of furnace oil fired furnaces used may be in the range of 450-900°c. Such furnaces may not be equipped with any heat recovery systems. The waste heat available with high temperature flue gases can be recovered in a metallic recuperator system to preheat combustion air that can result in significant improvement in furnace efficiency (over 10%) substantial reduction in fuel consumption. Energy savings of 8% to 15% can be achieved depending on the type of process, process cycle time and flue gas temperature

INSULATION FOR FURNACE

Forging and heat treatment furnaces are mostly built with a refractory brick lining which are prone to heat losses after a continuous usage over the period and results in fuel loss. There is a huge potential in using ceramic insulations in the box type furnaces, which enables less fuel consumption in cold start in the furnace along with less heat up time. Energy savings 4% to 6% can be achieved by improving insulation of the furnace depending on the previous surface heat loss and type of refractory used and size of the furnace.

THYRISTOR CONTROL FOR ELECTRICAL HEAT TREATMENT FURNACES

Electrical heat treatment furnaces used are of resistance heating type. Normally on-off control is used for controlling the heating cycle and due to continuous switching, life of heating coil reduces due to thermal shocks and frequent failure occurs. Thyristor control can be used instead of on-off control, which can give around 7-15% energy savings and can increase coil

life due to smooth switching with the precise temperature. **These measures also calls for a specific (customized) study for technical and financial feasibility to check the efficiency improvement and losses reduction w.r.t specific energy consumption considering the type and size of jobs being heated.**

3. Application of Variable Speed Drives (VSD) Mainly in Pumps of Cooling Tower

Motor-driven systems often are oversized and inefficiently controlled. VSDs can provide a more cost-effective method for reducing flow or pressure at the source by varying the speed of the connected load to match the process requirements. Energy savings in VSD applications usually range from 8% - 20 %. Some of the potential applications of VSDs in forging industry are mentioned below. Press motors, Mechanical and hydraulic presses are generally used in forging industries. Mechanical presses go under variable load depending on job size and operation to be performed. Jerk load operations are frequent in presses and this can be improved by using VSDs. VSD can reduce overall power consumption along with soft starting of the motors which will improve life of motors. This calls for a trial of VSD for a particular period to establish the technical feasibility.

4. Optimization of compressed air system

Energy savings of up to 40 percent is possible through improvement in the supply and reduction in demand in compressed air systems. The supply side opportunity for energy savings is installation of new or optimization of existing equipment through reducing the system pressure settings. Demand can be reduced through improvement in the end uses and repairing leaks. Blow-off nozzles can be upgraded to high-efficiency engineered nozzles or replaced with a low-pressure electric blower. Some of the potential areas of compressor system with specific option are mentioned below.

Replacement of air compressor with variable frequency drive air compressor

During normal operation, screw air compressor operated on unloading position for almost half of the operational time. Installation of new variable frequency drive (VFD) air compressor instead of load unload control air compressors will minimize the unload power consumption resulting in energy savings of 20% to 35%.

Reduction of the compressed air leakages

Compressed air is an expensive utility in a plant.However, in most cases, air leakages in piping system are quite high (more than 20%) and go unnoticed. The compressed air leakage can be reduced to about 5% with better operating practices. Plant can reduce significant energy consumption by controlling compressed air leakages with no or minimum investment.

Reduction in pressure setting of air compressor

The pressure settings of air compressors are often much higher than the actual air pressure requirement at the point of use in the plant. The typical unload and load pressure settings are 8.5 and 7.5 bar respectively. Reducing the compressed air pressure as per end-use requirements will result in high-energy savings. Reduction of generation pressure by one bar can lead to energy saving of 6%.

5 Replacement of rewound motors with energy efficient motors

Rewinding of motors result in a drop in efficiency by 3-5%. It is better to replace all old motors, which have undergone rewinding two times or more. The old rewound motors may be replaced with EE motors (IE3 efficiency class).

6 Lighting

In many forging units mercury vapor lamps (MVL), halogen lamps of 150W, 250W and 400 W and/or CFLs are generally used on shop floor. This lighting system has low lux levels with less life. Magnetic induction lamps of 100W, 150W and 200W can be installed in place of MVLs, which will give better illumination along with bright light with up to 1 lakh burning hours life. T-12 tube lights (of 52W including choke) and halogen lamps (150W and 250W) are generally used by Forging units in the cluster. These inefficient lightings can be replaced with energy efficient LED lighting (LED tube lights of 10W and 20W) and flood lamps and high bay lamps (20W, 40W and 80 W) which would provide better illumination and energy savings. Since a large number of lamps are used in the units, the existing lighting may be replaced with EE lighting in a phased manner.

Quenching Dilatometer for Material Phase Transformation Study

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INTRODUCTION

Automotive Industry is not only one of the biggest sectors in India but also a fast growing one. As per the recent announcement from the MoRTH, BS VI standards will be implemented in India soon. This calls for exponential increase in pace of innovation in component manufacturers and OEMs to meet the requirements and also to remain competitive by maintaining the cost of vehicle production.

One of the major areas to reduce the cost of the vehicle is to reduce component production costs and this can be achieved if significant energy is saved during the manufacturing process. There is a huge potential in developing cost effective production technologies in India without compromising the technical requirements. In parallel such technologies need to be made wide-spread in the Indian context to change the 'ground reality'. ARAI FID is equipped with state of the art quenching dilatometer and the article explains the dilatometry technique.

QUENCHING DILATOMETER

Dilatometry technique is used for the study of phase transitions in a material by measuring its linear strain. Strain occurring because of microstructural changes is one of the important parameter used in studying the phase transformation. This technique is aimed at establishing direct link between discrete values of strain and specific microstructure constituents in materials. The experiments can be performed in controlled atmosphere i.e. Noble gases. Continuous Cooling Transformation (CCT) and Time Temperature Transformation (TTT) curves are obtained as the output. A1033 gives the standard practice for quantitative measurement and reports on hypo eutectoid carbon and low alloy steel phase transformations.

WORKING PRINCIPLE:

- The sample is heated by induction principle.
- Cooling is achieved by a combination of controlled reduction in the heating current and the injection of helium gas onto the sample.

Dimensional change is measured along the longitudinal axis of the sample and Temperature change is measured by means of thermocouple welded to the surface of the sample midway along its length.

- Depending on the output required the sample is subjected to thermal cycling whose duration can vary from seconds to hours. Refer Fig 1 for a typical sample and quenching dilatometer available at ARAI-Forging Industry Division.

Fig 1: RITA Quenching Dilatometer, Make: - Linseis GmBH, Germany Applications:

1. HEAT TREATMENT:

Provides transformation diagrams that depict the microstructures developed during the thermal processing of steels as functions of time and temperature. Such diagrams provide a qualitative assessment of the effects of changes in thermal cycle on steel microstructure.

2. SELECTING STEEL GRADES:

Dilatometry technique is useful in providing data for the prediction of microstructures and properties to assist in steel alloy selection for end-use applications.

3. INPUT IN FEA MODEL:

This technique provides data for computer models used in the control of steel manufacturing, forging, casting, heat-treating, and welding processes.

4. PHASE TRANSFORMATION DATA:

Dilatometry technique is used to provide steel phase transformation data required for use in numerical models for the prediction of microstructures, properties, and distortion during steel manufacturing, forging, casting, heat treatment, and welding.

DETERMINATION OF CRITICAL TEMPERATURES:

Critical temperatures are those temperature at which austenite begins to form on heating i.e. Ac1 and the temperature at which the transformation from ferrite to austenite is completed, i.e. Ac3. The critical temperatures can be determined from changes in the slope of a strain versus temperature plot. Strain increases with temperature until Ac1 is reached and will begin to decrease with increasing temperature and after reaching Ac3 will again begin to increase with increasing temperature.

CRITICAL TEMPERATURE FOR 40CR4:

The following graph (Fig. 2) shows the plot of Strain vs. Temperature with Delta- L on y-axis and Temperature on x-axis for determination of Ac1 and Ac3 temperature for 40Cr4. The enlarged portion shows the start and end of the phase transformation from ferrite to austenite. It can be observed that at 749.5°C the austenite begins to form and at 796.8°C all 100% austenite is achieved. Hence the critical temperatures for 40Cr4 are identified.

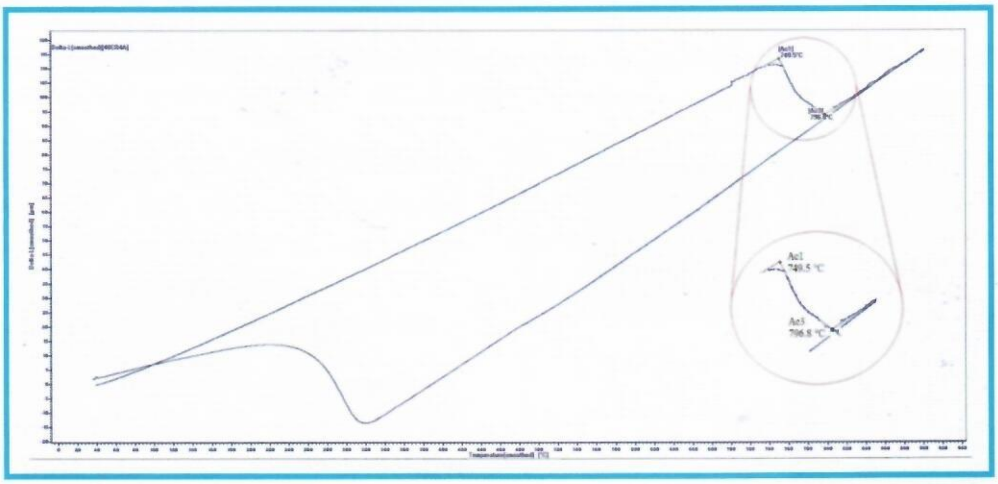

Fig 2 Critical Temperatures for 40Cr4 Time Temperature Transformation (TTT) Curve:

TIME TEMPERATURE TRANSFORMATION (TTT) CURVE:

Time Temperature Transformation (TTT) diagrams or Isothermal transformation diagrams are plots of temperature versus time. They are used to represent transformation kinetics for steels, but also can be used to describe the kinetics of crystallization in other materials. They are generated from percentage transformation vs. logarithm of time measurements, and are useful for understanding the transformations of alloy steel that is cooled isothermally.

CONTINUOUS COOLING TRANSFORMATION (CCT) CURVE:

Continuous Cooling Transformation (CCT) diagram is used to represent which type of phase changes will occur in a material when it is cooled at different cooling rates. CCT phase diagram is often used when heat treating of steel. For continuous cooling, the time required for a reaction to begin and end is delayed. Control can be maintained over the rate of temperature change depending on the cooling environment. Depending on the cooling rate i.e. fast or slow the required microstructure changes can be obtained.

Automation of Large Forging Lines by the Use of Robots

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TOPIC AND ABSTRACT:

'Automation of big Forging Lines by the use of Robots' The focus of this presentation is to describe the possibilities of automation on big Forging lines for automotive products. This includes an introduction of the SMS Meer Company, a short view into the history of automation concepts and equipment and a view to the actual technology of SMS Meer GmbH, especially of the Eumuco Hasenclever Closed Die Forging division.

Taking the example of a fully automated forging line for crank shafts and front axles for trucks the presentation shows the process from development to realization of an automation concept.

As one of the leading companies offering complete equipment for forging plants, the product program of SMS Meer includes stroke, force and energy-bound presses in all sizes as well as the required pre-forming and finishforging equipment. Our own developments in the areas of transfer technology, spraying technology as well as plant control and visualization, permit plant concepts with all the machine elements working in harmony with each other.

SMS MEER GmbH

SMS GmbH is the holding company of a group of internationally operating companies in the plant and equipment-building business for the processing and shaping of steel and NF metals. One part of the group referred to as SMS metallurgy comprises SMS Siemag and SMS Meer. In 2010, around 9,000 employees all over the world generated sales of approx. 2.9 billion.

In the field of tube, long product and forging technology, SMS Meer ranks among the world's leading machine designers and constructors.

Beginning 2007 the various forging activities of the SMS group merged under the roof of SMS Meer GmbH. Within SMS Meer GmbH you will find the well known companies of the former SMS Eumuco GmbH like Eumuco, Hasenclever, Berrenberg, Banning, Thyssen Wagner, Schloemann etc. and this is in addition to our Hydraulic Open die forging press manufacturing.

The competence SMS Meer has in the layout of technologies and processes is an important prerequisite for the drafting and successful realization of turn-key plant concepts.

Beside megatrends such as geopolitical change, sustainability and evolution of mobility, it's not only stricter ecological requirements, but also increasing international competition and global cost pressure caused by increasing material prices that present a constant challenge to the forging industry.

Identifiable ecological trends in the forging industry include:

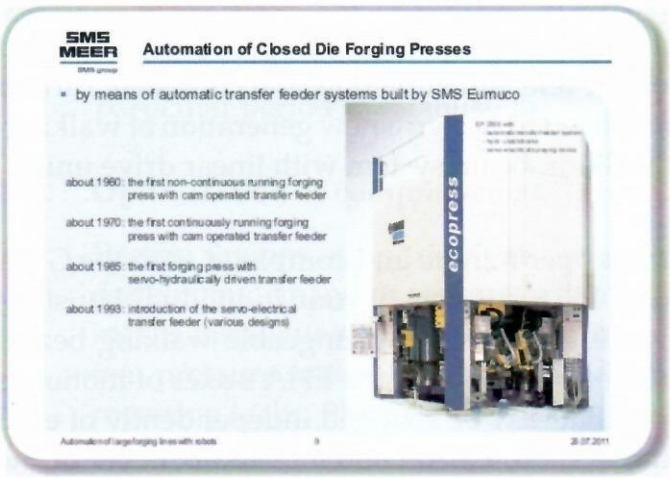
- Reduction of process chains through
- New developments
- Increase in efficiency
- Reduced energy input
- Reduced spraying fluids
- Reduced material input
- Use of new materials
- Increased flexibility

Especially with today's high cost, but also due to technological developments, rising demand and stricter environmental legislation, flexibility is a must for every future-oriented company.

For customers around the world in the Automotive and Non-Automotive Industry it is a big challenge to deal with this situation.

In this colloquium it is our target to show that traditional processes like massive forming are still highly innovative.

Development of Automation Technology



Eumuco Hasenclever has concentrated on automatic forging from very early on.

For press sizes of up to 6.300 ton forging capacity, automatic walking beam transfer systems have been developed.

The consistent ongoing development resulted in an innovative automation system with a high degree of flexibility. A great many development steps were made fromthe continuous-type, cam-controlled automatic walking beam system to today's electrically powered units.

The continuous type cam-controlled automatic walking beam system was developed in the 1970's.

The functional principle of this automatic workpiece conveying system was based on direct coupling to the press drive unit.

The automatic walking-beam system was directly driven by the eccentric shaft of the press via a cardan shaft. The rotary motion was distributed to the cam-controlled stroke and step-by-step motion linkage.

The continuous type cam-controlled automatic walking beam system was subsequently replaced by the camcontrolled automatic walking-beam system that operates separately from the press drive unit.
The three-dimensional conveying motions, i.e.

- Conveying step
- Lifting/lowering
- Opening/closing

are generated by a cam plate drive unit. This cam plate drive unit is equipped with an electric motor. The press could thus be switched on at maximum speed for each stroke so as to ensure short pressure contact times. In the process, the automatic walking-beam system was circulating continuously.

In 1985, customer requirements for making automatic systems more flexible led to the development of the servo-hydraulically controlled automatic walking-beam system type GHA. In this system the three-dimensional movement of the walking beams is powered by electro-hydraulic linear amplifiers. The stroke, speed, acceleration or deceleration are all set via stepper motors. The system's cycle time can be preselected via the control unit.

As a function of the occupation of the forming stages in the press, the automatic walking-beam system operates on full or half steps, with a pause for spraying between two dies. When fully utilising the performance potential of the servo-hydraulic axis drive units, this system achieves a number of strokes of 30 per minute.

The power of the hydraulic drive units has in the meantime also now been achieved or even surpassed by new, more powerful electric servo drives. Based on the relevant knowhow and consistent further development, at the end of the 1990's SMS Eumuco managed to design a new generation of walking-beam systems, viz. the EHA electric type automatic walking-beam system with linear drive units.

The EHA is rated for a working speed of up to 30 strokes per minute and compared with the GHA includes a number of additional special features. The EHA consists of four individual housings with drive units which are fastened to the press frame. It has two exchangeable walking beams with their own drive units which are independent of the press. Each of the EHA's axes of motion is separately driven by a total of 10 electric servo motors that may be changed independently of each other. The latest-generation automatic walking-beam system, GEA, combines the benefits of the two systems described. The high degree of flexibililty of the EHA's servo-electrical system with the GHA's rocker arm unit.

Here again each axis is individually driven by servo motors. The two separately operated walking-beams at the front and rear are electronically coupled to each other. The GEA's stroke axis is arranged completely in an airpressurized, enclosed housing. All openings are sealed by covers and additional labyrinths. The rotary guides of the other axes of movement are equipped with seals and labyrinths to avoid the ingress of dirt.

As compared to the previous drive units, the maintenance effort required is reduced.

The rotary transmission elements are arranged outside the lifting-axis box. Further benefits of this type of automatic system include:

- Major reduction of protective hoods, covers, hoselines and rotary screw joints
- More freedom in designing the walking beams due to the absence of linear guides and no more protecting hoods in the press area

- Removal of additional balancing joints, since potential axis errors in the drive units are directly balanced by the joints
- All components now essentially contained within the press frame. This provides an optimal infeed and withdrawal of the forgings as well as improved access to the press side as well as freedom in the layout design.

The resulting reduction of the masses moved and thus the necessarily shorter, more torsion-resistant walking beams eventually lead to a rise in the maximum number of strokes and hence to an improved performance.

The GEA has its own control system with the variety of functions of a Sinamics Motion Control. From the parameters input for the individual axes, this control establishes the total cycle time as well as the resulting number of press strokes.

The individual housings with drive unit can be adapted to every press size. Different opening strokes can be performed and in addition the elevation of the beams relative to each other may be varied.

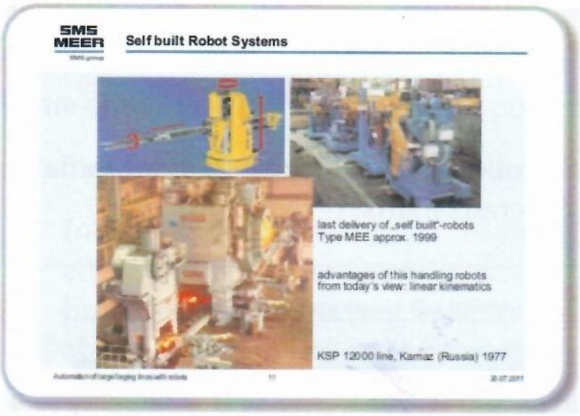
The central parts of the walking beam are equipped with a tried-and-tested quick-clamp mechanism and can be changed with the help of a changing arm or alternatively together with the tool holders.

The workpiece grippers of the automatic walking-beam systems are monitored by sensors. In the event of a workpiece misplacement the press is immediately shut down.

If a workpiece is to be turned through 90° or even 180° between two forming stages, rotatable grippers are used.

The system may also be designed as a one-sided walking beam with controlled grippers.

The servo-electric drive units are designed to allow retrofitting on existing hydraulically powered automatic GHA systems.



Consequently in this manner since 1990, more than forty presses have been equipped with such types of automatic transfer feeder systems.

For a long time Eumuco and Hasenclever have been automating big forging lines with the help of robots.

The picture on the left shows a choice of our "Self Made" robots which were developed including the controls in our own company because at the time suitable industrial robots with acceptable payloads were not available. The manipulators were e.g. used for automation of 12.000 t wedge press lines, and a 14.000 t eccentric press line. The robot systems in different sizes were capable of handling workpieces weighing from 5 to 300 kg under the extremely hard conditions of hot forming.

Movement Options: (maximum 6 axis)

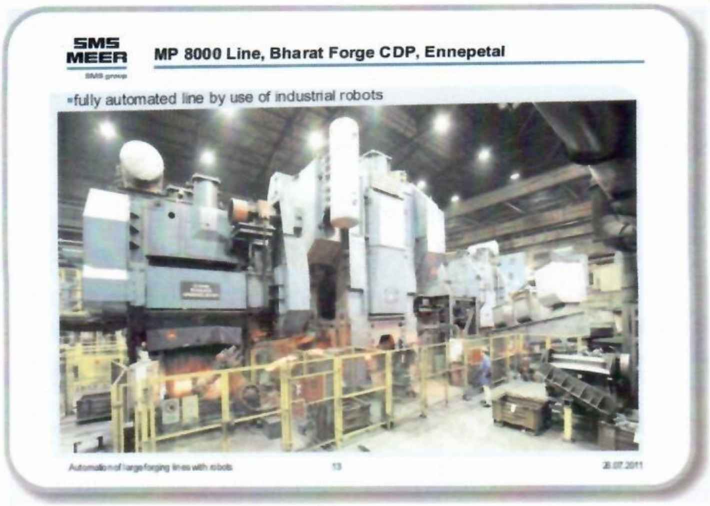
- x-axis Horizontal advance and retract of the tong arm
- y-axis Rotating of tong arm
- z-axis Raising and lowering of tong arm
- c-axis Transverse movement of the robot
- a-axis Horizontal rotation of grippers through 360°
- b-axis Upward and downward pivoting of grippers from + 30° to - 95°

A big advantage - still valid today - of this type of manipulator was the linear kinematics which is optimum for workpiece handling in the tool area.

As shown on the picture, the last "Self Made" robots were delivered in 1999 due to the fact, that meanwhile industrial robots with acceptable payloads and the necessary number in degrees of freedom were available in the market to cover almost all requirement profiles.

PRESENTATION OF IMPLEMENTED PROJECTS

Accordingly, our first line based on using industrial robots was realized at CDP Bharat Forge, Ennepetal.



The Project was realised by SMS Eumuco as general contractor.

Line engineering incl. automation concept and process development were executed by SMS Eumuco.

The main unit in this line is an eccentric press size MP 8.000.

The whole line consists of:

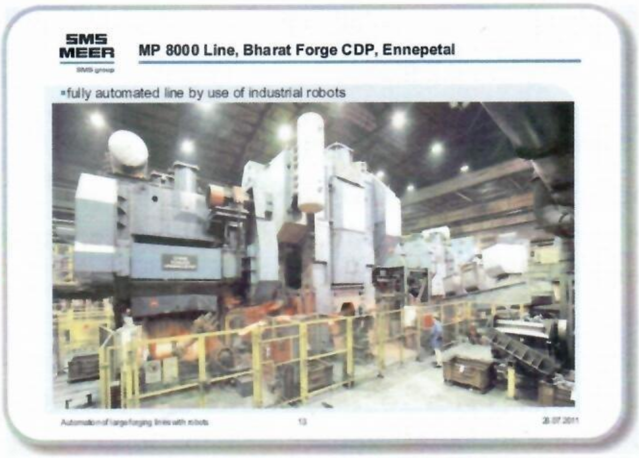
- INDUCTION HEATING SYSTEM
- HOT SHEAR
- PRE- FORMING PRESS
- MAIN PRESS MP 8000
- TRIMMING PRESS
- CALIBRATING PRESS

For the automation, we used 8 robots made by Kuka.

As part of a move of equipment from Germany to the U.S., robot automation by ABB Automation was implemented to a 12.500 t. SMS Eumuco forging line for crankshafts.

The whole line exists of:

- INDUCTION HEATING SYSTEM
- FORGING ROLL
- PRE- FORMING PRESS
- MAIN PRESS KP 12.500
- TRIMMING PRESS
- TWISTER
- CALIBRATING PRESS



So not only new lines but also existing equipment can be upgraded by integration of robots into the process.

PRESENTATION OF ACTUAL PROJECT

When looking to the potential of forging processes on big forging lines one big aspect is the automation by use of robot systems.

SMS Meer GmbH, with their product area Closed Die Forging, has carried out numerous automation projects in connection with forging machines built new, as well as with overhaul and modernisation projects. Many previously manually executed processes have now been automated.

The basic aim of the automation is on one hand to lower the production costs and on the other hand to raise the process quality.

The degree of the automation is an important factor. Complicated automation does not necessarily fit to the specific demands especially when dealing with varying or very diversified product ranges.

Generally automation can be used in the process chain in all areas, beginning with the material supply, the cutting, heating up, pre-forming, finish-forging up to the final manufacturing.

A team of project engineers develops, on this occasion, with the help of the given parameters the first layout as a base of the discussion with the customer.

Under consideration of the planned forgings and in connection with the planned cycle time, in the next step selections of the necessary machines, robots, gripper systems and peripheral facilities are made.

After final discussion and arrangement with the customer final investigations occur.

A collision investigation, a cycle time analysis and optimization with dynamic load, the definition of a regular sequence as a template for the line control with integration of the signal exchange with other system components, serve as baseline data for the robot programming.

Only after all of these have been done do we get to the final implementation of the project.

The automation of forging lines is a possibility to further improve already cost-effective processes. Our project shows this example of the fully automated production of crankshafts and truck axles, with a concatenation of forged preforms to finished forging products that was put into a line.

The crankshafts and axles to be produced belong to the group of forgings, which place high demands on the forming technology. This makes the task of automating such a forming process more difficult, but still possible.

There are extreme workpiece geometries in left-and righthand direction to be taken into account that often overwhelms the space in the tool area of the forging press. Thus a line concept for manufacturing this type of forgings is obvious, where preforming and finish forming is shifted to auxiliary equipment.

A multiple occupancy of the forming stations in the main press, as is usual with an automatic workpiece transfer, is generally not realizable due to the sum of high forging forces.

Hence, forging robots with up to five degrees of freedom and self made individually adaptable gripper systems are the suitable solution in general.

Thus the following forging sequences were determined for manufacturing crankshafts and truck axes:

Crankshafts

- roll forging I
- roll forging II
- preforming
- finish forming
- trimming

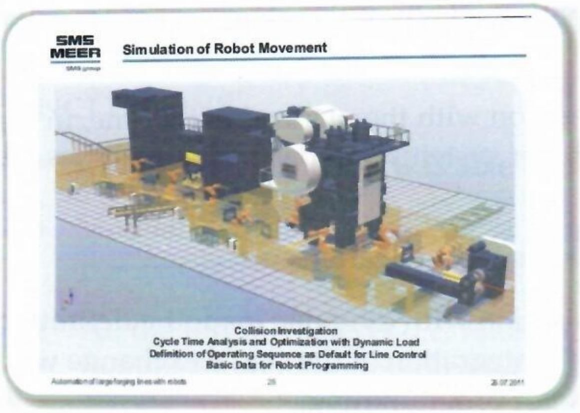
Truck Axles

- roll forging I
- roll forging II
- bending
- preforming
- finish forming

- twisting
- calibrating
- trimming
- calibrating

The forging line designed for this purpose consists of five individual units and is linked with appropriate intermediate transport:

- Forging Roll Size Rww3
- Wedge Type Press Kp 125 Mn
- Trimming Press
- Twister
- Calibrating Press



A total of eight robots most with individual configurations, as well as individually adapted gripper systems designed by SMS Meer, guarantee the fully automatic operation of the whole forging line.

To be able to respond flexibly to new trends, in-depth market studies are an absolute must for success. of course, this is also true for machine designers and constructors. Experience gained during the last few years has shown that technological developments never stop. The name SMS Meer continues to stand for innovative, customer oriented solutions.

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Evolution of Forge Shops - From Blacksmithy To Whitesmithy

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Director, Steel Plant Specialities LLP, India

ABSTRACT

Indian forging industry has actively taken up the challenge to consciously evolve from Blacksmithy to Whitesmithy. Many industry leaders have either already made the shift or are in the process of establishing themselves as Whitesmiths.

Use of cleaner fuels for furnaces and anti-scale protective coatings to reduce scale, use of customised, environment-friendly products like graphiteless water-soluble die lubricants, EP00 grease for centralised press lubrication and water-based oil-cleaning chemicals have not only been economically lucrative but have greatly accelerated the evolution of forge shops from Blacksmithy to Whitesmithy.

When we hear the term 'Blacksmith', we immediately imagine a burly man in filthy overalls wielding a large hammer, covered head to toe in soot. A blacksmith would use coal as fuel for furnace. Blowing air into the furnace for combustion would make the coal dust fly all over the shop and on the blacksmith too. The metal itself was lacking in lustre, and black.

Manual hammering has been replaced by modern production and finishing equipment. However, not many forge shops are able to successfully transform into 'Whitesmithy'.

BLACKSMITHY PERSONIFIED

Forging has been considered to be a polluting industry, and truly so until a few years ago. A number of factors have contributed to this notion. Prime reasons for forge shops being 'black' are:

1. Furnace oil: Many forge shops use furnace oil as fuel for billet heating furnaces and heat treatment furnaces as it is economical. This furnace oil, when spilled around the mother tank and day tank, dirties the shop floor and makes it black. Oil and impurities are sometimes spewed out from burner area. Black carbon deposits on burner blocks need to be removed frequently. Dense smoke is generated during combustion of furnace oil due to impurities in furnace oil and if the air-fuel ratio is not controlled.

2. Die lubricant: Before each blow of a forging hammer or press, the die must be well lubricated to aid metal flow and prevent sticking of forging. Furnace oil, oil-in-graphite and water-based-graphite are popular choice for die lubricants. Oil leads to blackening of the die, forging equipment and forge shop floor too. It also emits dense dark smoke, which is highly polluting in nature. Oil, graphite and smoke contribute heavily to blackening the forge shop. Graphite-in-water die lubricants contain graphite particles as minute as 2 microns. These particles fly around the forge shop and eventually lead to layers of black graphite dust settling throughout the forge shop. Graphite particles also find their way into workmen's toilets, canteens and often into offices that are juxtaposed to forge shop, through footwear of staff.

3. Centralised lubrication of forging presses: Ambient temperature near a forging press is higher than most other metal forming operations. Most greases that are used in centralised lubrication system of forging presses tend to lose their viscosity at temperatures above 100-150 degrees and begin to flow freely, sometimes flowing out of the press lubrication system. Due to overflow or leakages in centralised lubrication of presses, the chequered plates and surrounding areas around the forging press are constantly dirty due to oil overflow and spills. Many times, tramp oil and die lubricant together get accumulated at the bottom/ foundation of the forging press. Apart from oil wastage, it takes special efforts to pump out this dirty black oil from below the forging press.

4. Use of oil as quenchant: Due to specific end requirements, many forgings require that oil be used as quenching medium. In such cases, large volumes of quenching oil are stored in tanks. During handling of such large volumes of oil, it is normal to have spillages. Forgings too, drip of oil once they are removed from the quenching tank, thus making quite a mess on the shop floor.

5. Scale: From 0.5% up to 3% of metal is lost due to burning loss or scaling. Removing the scale from forged components and cleaning the scale from forge shop floor are tasks that add costs but no value. Apart from the material loss, loose black scale falls around the forging press and dirties the area, as shown in adjacent image.

FROM BLACKSMITHY TO WHITESMITHY:

In view of the mentioned aspects, transition from Blacksmithy to Whitesmithy seems to be an up-hill task. However, let us examine the possibility of effectively eliminating each cause of 'black' in forge shops:

1. Furnace oil as fuel for furnaces: Exploring alternatives, enabling better combustion.

Alternatives to polluting furnace oil as fuel are gas and induction heaters. They can successfully eliminate blackness from the forge shop. The choice of these alternative fuels largely depends on availability of the resource, consistent calorific value and price per unit. Techniques like pre-heating furnace oil, maintaining optimal air-fuel ratio using flawless instrumentation, use of recuperators that pre-heat air up to 600 deg. C., and emulsification of water in furnace oil ensure better combustion of fuel, thereby eliminating black smoke and also reducing fuel consumption.

2. Die lubricant – oil based or graphite based: Switching over to synthetic white lubricants.

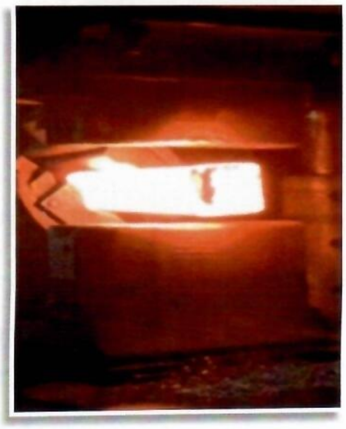
World-over, graphite-in-water based die lubricant is used in almost 65% of forgings and oil-based lubricants are used in almost 20% of forgings in hammers and presses. Synthetic white lubricants have had limited success till date. Most forging companies find the first step in correct die-lubrication to be most difficult: Switching over from oil-based lubricant by manual swabbing to using water-based lubricant by manual spraying. The reason being, oil and water-based lubricants are both very different in nature and need to be used by very different techniques. A water-based lubricant will have limited success if it is used in the same manner as oil-based lubricant by manual swabbing. Hence, it is best to train the entire forging production team in the correct method of die-lubricant spray through die-lubrication experts. Reputed suppliers of die lubricants offer such hands-on dedicated training service. It helps to involve the die lubricant suppliers deeply as lubricants and spray techniques can be customised to suit each type of forging. This in-turn enables increased die life and reduces excess consumption of die lubricant. At the same time, manufacturers of die lubricants who are adept at customising die-lubricant formulations will be able to work towards the target of eliminating black oil and graphite from forge shops. In recent times, white lubricants are in the nascent stage of replacing graphite. This is proven in the fact that white lubricants are now successfully used in complex forgings like two-wheeler crank shafts and four-wheeler crank shafts. Efficacy of white die-lubricant on each forging may vary. Equal involvement by forge-shops and die-lubricant manufacturers can only help in nailing the correct formulation and technique of die-lubrication on each forging.

3. Centralised press lubrication: Avoiding oil overflow and spills by the use of appropriate grease.

Greases that have good viscosity at ambient temperatures are used in the centralised lubrication of forging presses. However, it is important to check the efficacy of these greases at operational temperatures which may be over 100-150 deg. C near forging presses. Overflow, leakage and spillage of oil can be experienced due to quick melting of grease at high temperature, such that it loses viscosity and turns into free-flowing oil. A solution to this problem is found in the use of effective EP00 grade lithium grease that maintains its viscosity at high operating temperatures as observed in forging presses. The grease is neither too free-flowing nor too viscous. This also ensures optimum lubrication, reduced consumption of grease and prevents wastage. Recently, greases are being customised to suit the specific requirements of centralised lubrication system nozzles and pumps of forging presses. This has given good all-round results, including reduced wastage and blackening of forge shops.

4. Oil spills on shop floor - furnace oil, die lubricant, centralised press lubricant, oil-quenchants: Cleaned with water-based oil-cleaning liquids.

Using mentioned techniques, it is possible to substantially reduce black smoke, reduce blackening due to die lubrication and reduce oil spills from centralised press lubrication overflow. However, despite precautions, some graphite and/or oils may still find their way in forge shops and dirty them. These can be cleaned by using water-based, environment friendly oil-cleaning liquids that are specially manufactured keeping in mind the requirements of the forging industry. These water based oil-cleaning liquids are to be simply poured over the oil spill on shop floor, allowed some time for completely dissolving the oil and cleaned off with water. Use of acids, kerosene or sawdust is not required. Cleaning of dies, degreasing of machine parts during maintenance of forging press, de-greasing of forgings after quenching in oil can all be carried out safely and very easily by use of water-based oil-cleaning liquids.



5. Loose scale on shop floor: Reduced by better heating methods and anti-scale protective coatings

Use of induction billet heater against open-atmosphere fuel-fired furnace has been the most effective method of reducing scale till date. Excessive scaling can be slightly reduced by maintaining optimal air-fuel ratio with flawless instrumentation in furnace burner systems. Use of anti-scale protective coatings makes it possible to reduce scaling on ingots, billets during heating for forging and preventing scaling during heat treatment of forgings and dies. Though all these methods may not be practical in each forge shop, some of them can certainly be implemented. Adjacent image shows minimal scaling on ingot that was protected with anti-scale coating prior to heating.

WHITESMITHY - HOW INDUSTRY LEADERS IMPLEMENTED IT

(Updates from owners, senior management and production-heads of esteemed Indian forge shops)

"We have tried out various types of die lubricants ranging from the conventional furnace oil as die lubricant, salt water and even imported graphite die lubricant. Due to various problems like dirty environment and smoke due to furnace oil, corrosion of forging equipment due to salt water, deposition of graphite throughout forge shop floor and forging press foundation, I have taken a decision of banning furnace oil, salt water and graphite lubricants in my forge shop. We are able to do so by using effective graphiteless, water soluble forging die lubricant specially developed for us by M/s. Steel Plant Specialities, Mumbai (SPS). This enables us to maintain our forge shops neat and clean, free from graphite." *Mr. Umesh Munjal, MD, Highway Industries Ltd., Ludhiana*

"Forge shop owners like me have known the benefits of using water-based die lubricants over use of furnace oil as die lubricant. However, the challenge lies in its implementation, especially with conventional-thinking workmen who take time in appreciating the concept and usage techniques. In such cases, dedicated training through technicians trained for this purpose helps. SPS has been able to successfully carry out such trainings in forge shops throughout India, including mine, and have made a positive impact in this field. Knowledge of correct spraying equipment, spray nozzles, timing of dispensing the lubricant and amount of lubricant are all important factors in achieving optimum die life." *–Mr. Asheet Pasricha, Jt. MD, Trinity Engineers Pvt. Ltd., Chinchwad*

"Like most forge shops with belt drop and pneumatic hammers, we were using furnace oil as die lubricant as it was easily available, apparently cheap and functional too. However, I felt that we must stop using furnace oil as die lubricant due to hygiene and environmental issues. Initially, there was some apprehension from my workmen. However, with appropriate training from team SPS regarding correct die-lubrication spray techniques, my workmen started using and liking water-based die lubricant. More importantly, after switching over to water-based die lubricant manufactured by SPS, there has been lucrative increase in die life. Overall hygiene in my forge shop has improved. We are now using water-based die lubricant for approximately 80% of our forgings." *–Mr. Mrinal Aggarwal, Director, Him Tekno Forge Ltd., Baddi*

"Oil was conventionally used as die lubricant in my forge shop for many years. Besides the workmen, I too had apprehensions using water based die lubricants. However, since the past 6-7 years, we have shifted from oil to water-based die lubricants for majority of our forgings. The results have been satisfactory in terms of die life, and maintaining my forge shop clean and smoke-free." *–Mr. D. R. Subramanya, MD, Fitwel Tools & Forgings Pvt. Ltd., Tumkur*

"IMS audit laid down stringent conditions on hygiene and smoke emission in my forge shop. We in-turn, asked SPS to take up the challenge of eliminating smoke from our forge shop. They customised for us a graphiteless die lubricant for small to medium forgings and developed water-based oil cleaning chemicals. These have worked well in keeping my Plant clean, free from graphite, and my machinery and shop floor free from oil. Since over three years now, we are regularly using SPS make water-based die lubricant on our non-complex forgings on presses and hammers. For very heavy, complex forgings, we have tried out their low-smoke oil-based lubricant. As my overseas customers visit my Plant often, cleanliness and hygiene in the forge shop play an important part in winning customers' confidence. I would hate to see my important customer slip on the forge shop floor due to oil spill and am now assured that such instance is prevented."*–Mr. Pradeep Goyal, MD, Pradeep Metals Ltd., Navi Mumbai.*

"We were advised by our customers that water-based die lubricants are used internationally. When we installed our forging press, I made it a point to start using water-based die lubricant from day one. This has given us satisfactory results. My customers who visit my Plant appreciate the cleanliness of my forge shop."*–Mr. Harshdeep Singh Anand, MD, Golden Temple Forgings Pvt. Ltd., Ludhiana.*

"Owing to the complexity of our heavy forgings, we have been using graphite-in-water and graphite-in-oil lubricants in most of our forgings. Synthetic lubricants are used on some of our forgings. However, we are in the process of working with suppliers like SPS to develop customised graphite-less white lubricant for our specific requirements."*-Mr. Mukund Mavalankar, Technical Director, Bharat Forge Ltd., Pune.*

"When I was heading production at Ahmednagar Forgings Ltd. Kuruli, in year 2010, we were using graphite lubricant on large presses and furnace oil as lubricant on all the smaller forging presses. I set a target for SPS: There should be no smoke in my small forge shop. With dedicated efforts every day for almost two months by SPS technicians, and lot of motivation to my workmen by me, we achieved the target. Synthetic white lubricant was successfully used in lot of forgings in small forge shop. However, due to complexity of many of our forgings, we couldn't use white lubricant on all forgings. For the sake of ease of procurement and uniformity of lubricant, we then switched over to water-based-graphite die lubricant. To control costs and blackening of forge shop due to excess graphite lubricant, we worked out techniques like increasing the dilution ratio of graphite in water to maximum (1:25 on many forgings) and foot-pedal operated die-lubricant spray-control system developed by SPS. The forge shop is now using water-based-graphite die lubricant on 100% of forgings. Polluting oils are no longer used as die lubricant. Using the water-based lubricant with special foot-operated spray technique, we were able to reduce activity (and cost) of shop floor cleaning daily to once in 3 days as shop-floor blackening was minimal."*-Mr. Annasaheb Shinde, Ex-Production Manager, Ahmednagar Forgings Ltd., Kuruli*

"Working on different profile forgings and numerous hammers of various capacities has its own challenges. We had great difficulty in establishing water-based lubricant in hammer shop. However, when our new press was installed, I made it a point to use water based die lubricant from the start. Success of water based die lubricant in press made it easier for me to show its benefits to hammer-shop workmen. This led to wider acceptability of water-based die lubricant on our shop floor. I can confidently say that any forge shop with belt-drop and pneumatic hammers willing to take the efforts can be trained to use water-based lubricants on their forgings." *-Mr. R. S. Sharma, Plant Head, M/s. Varsha Forgings Ltd., Aurangabad*

For many years, we were using furnace oil and even used oil as die lubricant for small forgings. Our production was running continuously and we were not too concerned about the die life. After use of graphite-less water soluble die lubricants from SPS, our die life has increased substantially. We have been able to successfully eliminate black from our small forge shop. My workmen too, feel much better working in a smoke-free environment.*-Mr. Sanjeev Dixit, Div. Manager (Prodn.), Microtek Forging(Bajaj Motors Ltd.), Bawal*

How to Increase Yield and Save Costs in Stainless Steel Open Die Hot Forging and Hot Rolling

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ABSTRACT

This article introduces a practical technique pioneered by a metallurgist from Indian Institute of Technology. The technique enables reduction of burning loss and increasing yield in most kinds of steels. The technique is most successfully adopted in stainless steel open die hot forging, hot rolling and expensive alloy steels.

INTRODUCTION

In open die forging and hot rolling and even closed die forging of Stainless Steels, the major factor accounting for reduced yield is 'burning loss' or 'scale loss' caused due to Oxidation. Oxidation and decarburization of steel take place when billets or ingots are heated in a billet re-heating furnace, in the presence of air or products of combustion. Apart from burning loss of between 1.5% up to 4%, oxidation leads to numerous other problems like scale pit marks, bad quality surface finish of metal, rejections, and increased expensive operations like grinding, acid pickling, etc.

UNDERSTANDING BURNING LOSS DUE TO OXIDATION

For the purpose of hot rolling, when billets or ingots are heated in an open furnace in the presence of air or products of combustion, the surface phenomena of oxidation takes place. Oxidation causes immediate corrosion of steel at high temperature and creates a layer of metal-oxide, or scale, on the surface of the billets or ingots. Decarburisation is a simultaneous reaction that takes place along with oxidation. However, this decarburization is limited to certain grades of steel only.

OXIDATION

Oxidation of steel is caused by oxygen, carbon dioxide and/or water-vapour. The general reactions are given below :

$$O_2 + 2\,Fe \rightleftharpoons 2\,FeO$$

$$O_2 + 4\,FeO \rightleftharpoons 2\,Fe_2O_3$$

$$CO_2 + Fe \rightleftharpoons CO + FeO$$

$$CO_2 + 3\,FeO \rightleftharpoons Fe_3O_4 + CO$$

Oxidation of steel may range from a tight, adherent straw-coloured film that forms at a temperature of about 180^{0}C to a loose, blue-black oxide scale that forms at temperature above about 450^{0}C with resultant loss of metal or reduced yield.

HARMFUL EFFECTS OF OXIDATION

Oxidation leads to loss of dimensions and material as extra material allowance needs to be kept for scaling. Often, surface quality is deteriorated due to scale-pitting. This is especially true in the case of Nickel bearing grades of steel.

Throughout the industry, this burning loss or scale loss is simply treated as wastage and not many practical solutions are available to stop or reduce this wastage. Problems like thick adherent scaling or scale pit marks or decarburization are dealt by manually grinding off the scale or decarburized layer after the hot forging or hot rolling process.

PREVENTING OR REDUCING BURNING LOSS DUE TO OXIDATION

Prevention or substantial reduction of oxidation is not only better than cure, it is profitable too. However, most of the available solutions pose a number of practical difficulties. Capital-intensive special furnaces and availability of human resource for using these high-end furnaces is a major issue. Many small hot rolling Organisations cannot afford these solutions. Yet they are under mounting pressure to increase yield and reduce costs. **Use of protective anti-scale coating has proven to be a logical solution to the problem of scaling and decarburization.**

CHARACTERISTICS OF PROTECTIVE COATING AND ITS USE:

Use of protective coating has been found beneficial and cost-effective. An anti-scale coating is applied on billets / ingots to be heated, before charging them into furnace. This anti-scale protective coating acts as a barrier between oxygen and metal. Care is taken to apply a uniform, impervious layer of coating on the billet to be heated. Coating ensures substantial reduction of oxidation, and thereby reduction in burning loss and scaling. Anti-scale coating also reduces decarburization on billets during hot rolling operations. Heat transfer from heating media to metal is not affected due to anti-scale coating.

No reaction with steel surface, no release of toxic fumes during use or hot forging or storage, non-hazardous and economical implementation are other required characteristics of the coating.

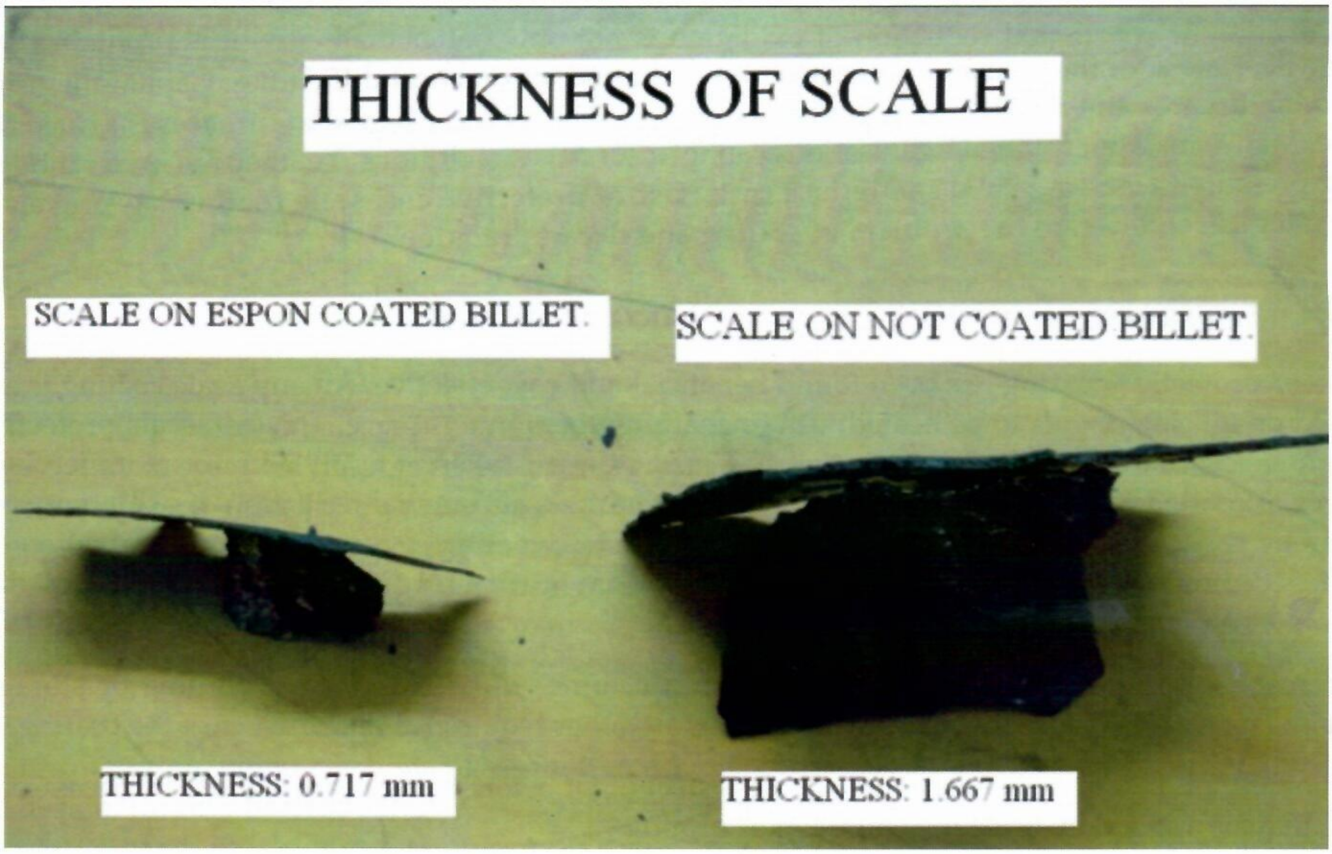
Adjoining photograph shows coated stainless steel ingot before being charging into furnace. Coating may be applied by brushing, spraying or dipping.

INCREASING YIELD BY THE USE OF PROTECTIVE ANTI-SCALE COATING; INDUSTRIAL CASE STUDIES AND SUCCESS STORIES.

Due to reduction in oxidation by the use of protective anti-scale coating during hot forging and hot rolling, the scale thickness is considerably reduced. Adjoining photographs are of scale that were generated on billets during re-heating with and without using protective anti-scale coating:

Thin, loose scale is observed on billets when protective coating is used.
White layer of coating residue is observed on scale.
This indicates efficacy of coating.

Thick adherent scale is observed on billets when coating is not used.



Thickness of scale is measured using digital vernier calliper. As shown in image, scale of much lower thickness of 0.717 mm is generated on billets that were protected using anti-scale coating. In comparison, billets that were not protected and were charged in the same batch of heating have shown thicker and more adherent scale of 1.667 mm.

Total reduction in scale: **0.95 mm.**

Percentage reduction in scale loss due to use of protective anti-scale coating: **56.98%**

On an average, approximately 70% reduction in scale is usually achieved by the use of anti-scale protective coating in open die hot forging and hot rolling of stainless steel. This amounts to lucrative savings and increased yield.

Another report of a number of mild-steel billets hot rolled without coating in comparison with hot rolling similar billets with single coating and double coating of anti-scale protection is provided below:

Sr No	Billet wt before coating in kg	Billet wt After Heating in Kg	Scale Difference in Kg	3 billet wt before coating in Kg	3 billet wt after heating in Kg	Coating Type
1	47.720	47.330	0.390			With Coating
2	47.010	46.660	0.350			With Coating
3	46.510	46.110	0.400	141.240 (Sr No 1,2, 3)	140.100 (Sr No 1,2,3)	With Coating
4	47.720	46.900	0.820			Without Coating
5	46.930	46.260	0.670			Without Coating
6	46.450	45.800	0.650	141.100	138.960 (Sr. No 4,5,6)	Without Coating

Scale loss of 2.140 kgs. was observed on billets without coating.

Scale loss of 1.140 kgs. was observed on billets with double layer of protective anti-scale coating.

Percentage reduction in scale loss due to use of protective anti-scale coating: 47.00%

OTHER BENEFITS OF USING PROTECTIVE ANTI-SCALE COATING IN STAINLESS STEEL HOT ROLLING AND OPEN DIE FORGING:

1. **Reduction in grinding, acid pickling time of hot rolled products:**

   Operations like grinding, acid pickling, etc. do not add value, are expensive and time consuming procedures. These operations are necessary to remove adherent scaling from the hot rolled billets. Time required for operations like shot blasting, grinding, acid pickling, etc. can be substantially reduced if protective anti scale coating is applied on components before heat treatment. Aesthetic appeal of components is automatically enhanced without much effort as scaling is either prevented or reduced by the use of anti-oxidation protective coating.

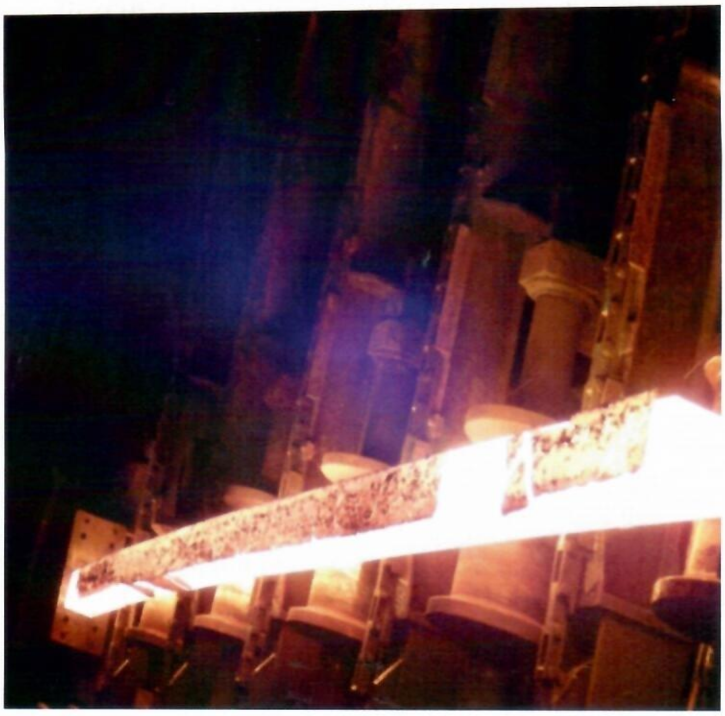
2. **Reduced decarburization during hot rolling & hot forging:**

   Certain grades like spring steels, ball bearing steel and rail steel are susceptible to decarburisation. During hot rolling of these special grades, decarburization needs to be consistently maintained to the required specification. However, due to unforeseen conditions like mill breakdown and unplanned downtime, billets remain in the furnace for longer time than usual. Also, when the plant is closed for weekly holiday, furnace is shut off abruptly, subjecting the billets to prolonged heating inside the furnace. If billets are not coated, it becomes difficult to guarantee the consistency in the decarburization level. Use of protective coatings on billets before charging them into the re-heating furnace enables to maintain the decarburization level consistently. This enables the hot rolling mill to guarantee their customers that decarburization level will always be less than the upper control limit.

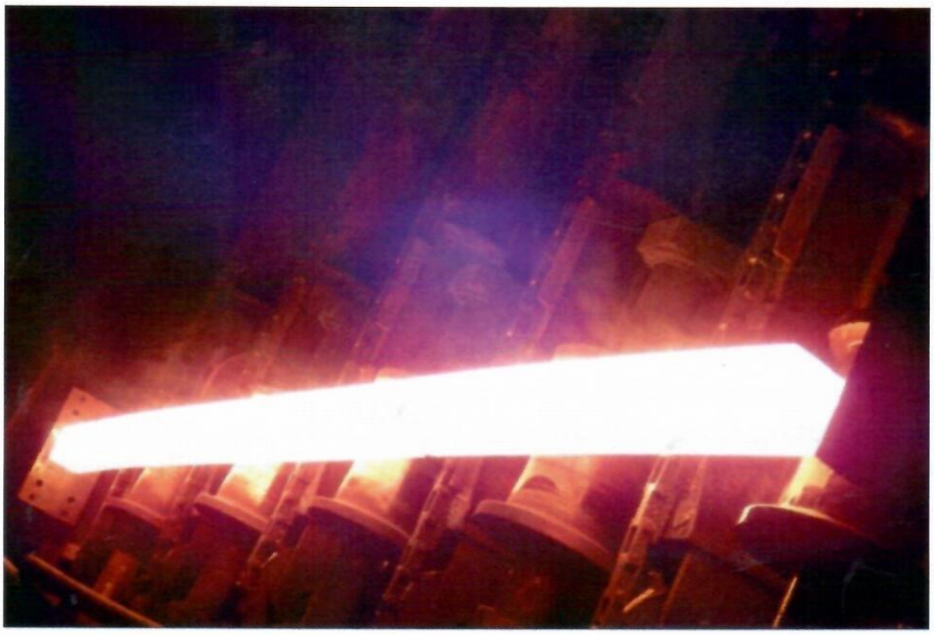
   Reduced decarburization on automobile leaf springs leads to increased fatigue strength of the leaf springs and greater reliability. Leaf springs heated after applying protective coating show substantially reduced decarburization and scaling.

3. **Improving surface finish of hot rolled components and preventing welding of billets during heating:**

During hot rolling of special grades of steel like Nickel (Ni) and 416 Stainless Steel containing high sulphur content, mill scale is greatly increased. Surface finish of hot rolled product may be compromised due to scale pits and rolled-in scale. Occasionally, due to heavy adherent scale, problem of roll skid is also encountered. Subsequent grinding operations are increased due to excessive mill scale. Applying anti-scale coating on billets before charging them into the re-heating furnace ensures reduced oxidation and mill scale. Coating the billets before charging them into the reheating furnace enables to achieve good surface finish of the hot rolled products free from scale pits and rolled-in scale.



Photograph shows not coated billet on conveyor, discharged from furnace and passed through water de-scaler. As thick, adherent scale was formed, water de-scaling has not been effective. Adherent scale is observed on the top surface and some adherent scale on the left side surface.



Photograph shows anti-scale coated billet on conveyor, discharged from furnace and passed through water de-scaler. As thin, loose scale was formed, complete scale has fallen off during water de-scaling.

This proves that scale loss is reduced. Ease of rolling operation and reduced scale deposits on the rolling mill machinery are ensured.

During re-heating of billets for hot rolling and also during induction heating of billets for hot forging, sometimes, billets are welded together. This leads to unproductive process of separating the welded billets and downtime. Welding of billets during hot rolling and hot forging can be prevented by applying protective coating on billets before charging them into the furnace.

4. **Improving surface finish of seamless pipes:**

   In the manufacture of seamless pipes, machined hollow ingots are used in many places, especially in Poland. It becomes a necessity to protect the surface by protective coating when the ingot is reheated. This ensures better surface finish of the seamless pipe. This is achieved by the use of anti-scale protective coatings.

SUMMARY

1. 70% average reduction in burning loss or scale loss and increased yield in stainless steel open die forging and hot rolling is possible by the use of protective anti-scale coating.
2. Use of protective coating on billets ensures a number of additional benefits like elimination or reduction of operations like grinding, acid pickling, etc., reduced decarburization, prevention of billet welding in furnace and improved surface finish.

Die Life Optimisation by Numerical Modelling with Simufact Forming

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INTRODUCTION

Die life is a major concern when for the forging industry. Fig. 1 shows the major failure mechanisms of forging dies of which cracking is the most dominating failure mechanism followed by wear.

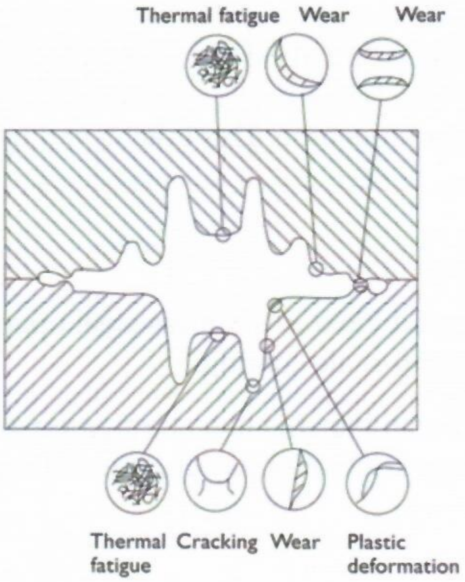


Fig. 1: Overview of forging die failure mechanisms [1]

Improving die life by premature die failure due to crack is a one of the dominating challenges most of the die and forging process engineers are facing. During the die design seminars which were jointly conducted by AIFI, Simufact India Pvt. Ltd. and Kadkraft Systems Pvt. Ltd. in February in four Indian cities, one third of the participants mentioned it as a major challenge in their company. This is not a representative result, but motivated us to write this technical article, in which we would like to demonstrate how the numerical process simulation tool Simufact.forming can be used to significantly increase die life by optimising the forging process by optimising the pre-shape produced in the blocker stage. This is achieved by removing excess material. This has three major positive effects significantly reducing manufacturing costs:

1. increased die-life
2. material saving
3. enhanced productivity due to lower die-change.

The optimisation can be done for components in production and for new products by introducing die-life studies during the forging die design phase.

BACKGROUND

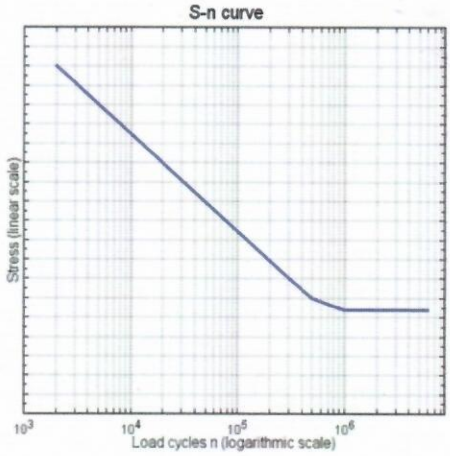


Fig. 2: S-N curve (schematic)

Complete die cavity filling too early before the final stroke of any forging press is reached results in high (hydrostatic) stresses in the forged workpiece, since the material can flow only into the flash area. This results in high (tensile) stresses in the forging dies. These stresses are so high, that after a limited number of forgings the dies will dies will fail at the point which experiences such high stresses resulting in a visible crack.

The life span of steels under high cyclic loading is described by S-N curves. This is a graph of the magnitude of a cyclic stress (S) against the logarithmic scale of cycles to failure (n) as shown in Fig. 2. It shows the expected number of loadings (number of parts that a blocker or finisher die can produce) depending on the stress (max. tensile stress) loads on the die for a particular die material.

These curves give approximate indications how many load cycles a certain material can withstand. Since these curves are determined in laboratory conditions (uni-axial stresses, uniform peak stresses, sinusoidal loading, constant temperature) the load cycle numbers given in the S-N diagram cannot predict the exact number of components a die can produce. Nonetheless, the principle behaviour is correct described and reveals the key to improve die- life.

At low stress values a certain value the material can withstand an infinite number of loads, which is called fatigue limit and equals about one million load cycles (106). Forging are subject to much higher loads and their life span is much shorter - a few hundred to approx. 40,000 load cycles (forgings) and their behaviour is determined by the low-cycle fatigue characteristics where slight changes of the stress can have a large impact on the life span. Hence, an even slight reduction of the stress by 20% of has a large impact on the die-life.

This means: If die-life is to be increased, the primary goal is to reduce the tensile peak stresses in the dies! For this task the precise information of the S-N curve is not even required.

The stresses in the dies reach their maximum when complete die filling is reached. Thereafter excess material can only leave the cavity through the flash which requires very high pressure (hydrostatic stresses) within the workpiece. These cause high contact stresses on the tools and finally high tensile stresses in the edges of the tool cavity.

This mechanism applies not only to complete die filling of the entire but also to locally premature die filling which can significantly increase the die stresses in a local region. An adjusted material distribution or pre-form is the key to reduce the excessive die stresses to significantly improve die life. Let's study this on an real life example.

ANALYSIS OF ORIGINAL PROCESS

Fig. 3 shows the workpiece geometries of the forging process analysed with Simufact.forming.

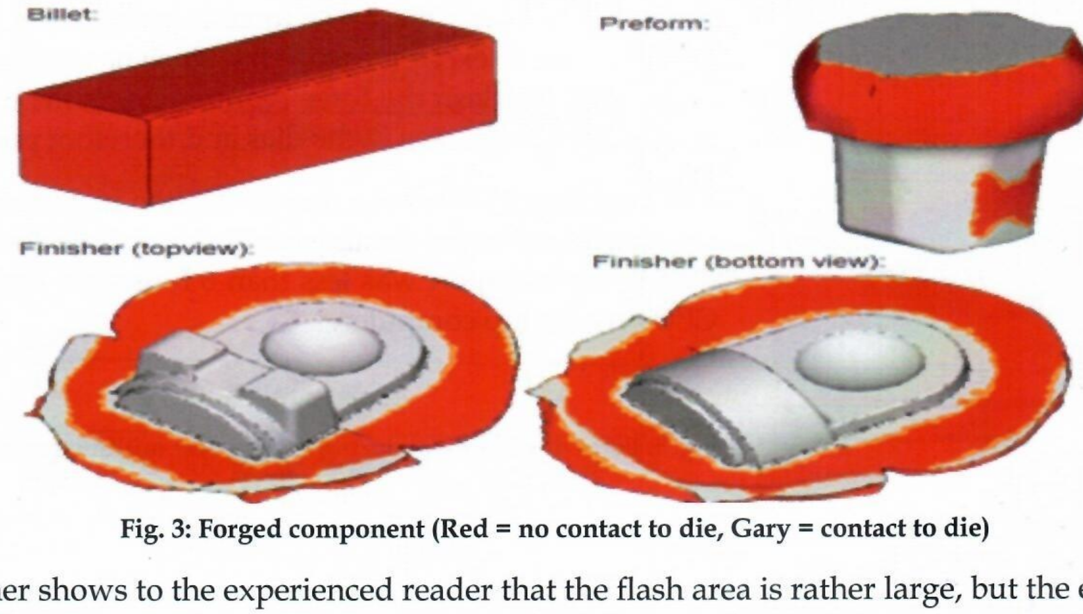


Fig. 3: Forged component (Red = no contact to die, Gary = contact to die)

The finisher shows to the experienced reader that the flash area is rather large, but the experienced reader will also agree, that this is a common sight in forging shops.

Now let's have a look on the development of the die filling during the finisher stage in Fig. 4.

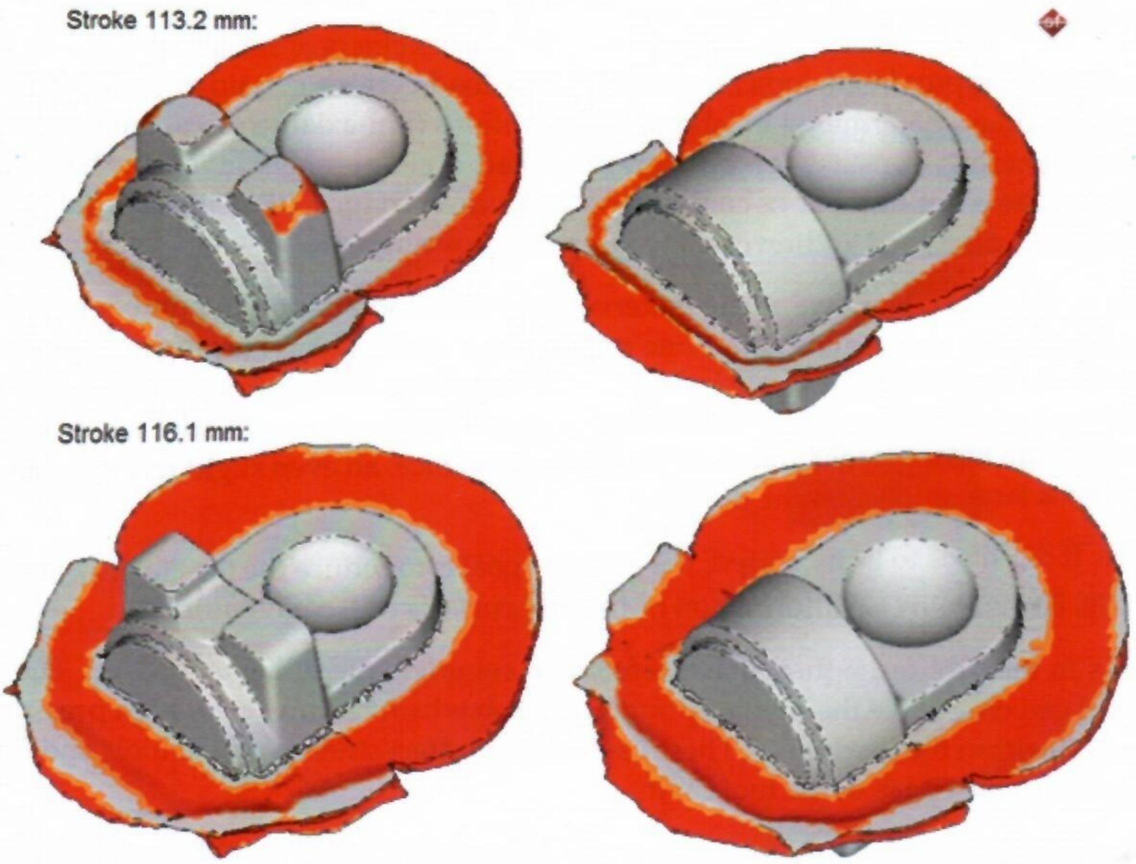
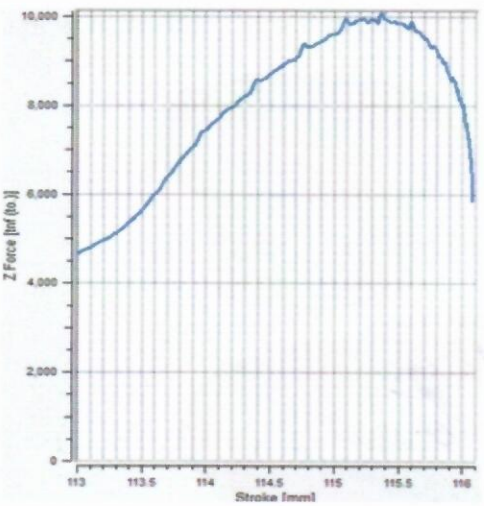


Fig. 4: Die filling finisher die (Red = no contact to die, Gray = contact to die)

These simulation results reveal that complete die filling occurs 2.9 mm before the final stroke is reached in this forging process. This is too early and indicates excessive flash which is wasted material.



But this is not the only negative effect. Fig. 5. shows the force development as a function of stroke for the last 3 millimetres of stroke in which the press force is rising from 5,000 T to 10,000 T. Due to excessive material which has to flow from the cavity into the flash the force requirement is very high. This results in high stresses in the dies and therefore poor die life.

The total time to carry out this simulation including all forming stages, the initial heating and intermediate cooling times during the transport was less than 6 h using a single Intel i7 CPU on a laptop computer.

Fig. 5. Force development during the last few millimetres of the stroke

1. MODIFICATION: BILLET LENGTH

The top view of the finisher (Fig. 6) shows that the largest flash extension is in the lower halve of the component. This flash pattern is used to calculate the excessive material which volume can be approximately calculated as follows:

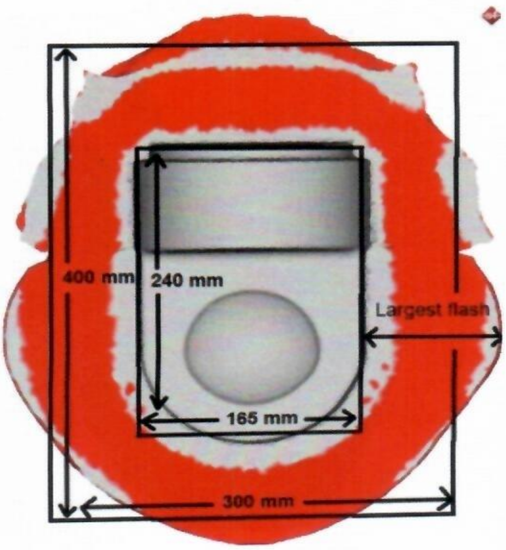
Area of flash = Area of outer box (300mm x 400mm) - Area of inner box (165 mm x 240 mm)

Area of flash = 80,400 mm^3

Given a flash thickness of 3 mm the flash volume is 2,41,200 mm³

Since we cannot remove the flash entirely, let's remove 40 % of the flash volume. This is 144,000 mm³. This is 4 % of the billet volume.

Our initial billet is 110 mm square, with edges rounded with r=5 mm and a length of 305 mm. Its volume must be reduced by the volume as calculated. Its new length is then 293 mm. Since only the length of the billet is modified and not its cross-sectional geometry, this modification can be easily carried out.



2. MODIFICATION: LOWER DIE FOR PREFORMING OPERATION

The second modification requires a die modification. As Fig. 6 indicates there is more excessive flash in the lower part of the workpiece. To keep the costs of modifications as low as possible as few as possible dies should be modified. To have a more balanced pre-distribution of the material it was decided to slightly modify the lower die of the preforming operation, which is shown in Fig. 7.

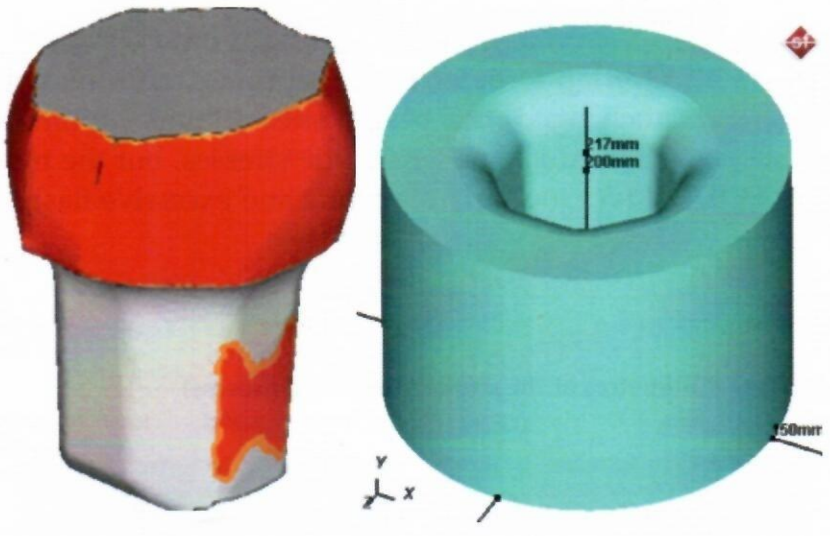


Fig. 7. Preform and the lower die for the preforming operation

The lower die geometry was scaled in x and z direction by a factor of 0.978 which reduced the volume of the cavity by approx. 4 %.

VERIFICATION OF OPTIMISED PROCESS

These two modifications require only a few minutes of pre-processing work in Simufact.forming and then the modified process was simulated.

Fig. 8 shows the die filling of the finisher and compares it to the original process. It is clearly visible, that the excessive flash was reduced and the part is still completely filled and surrounded by flash around the its entire circumference. The die cavity is filled at 0.9 mm stroke before the final stroke is reached.

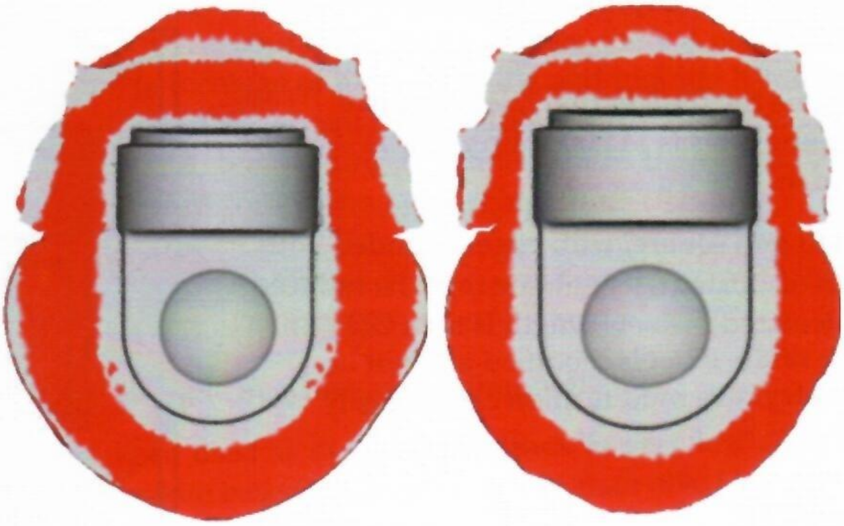
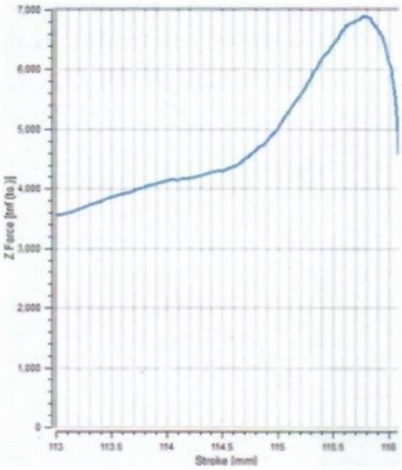


Fig. 8. Finisher at final stroke with original (left) and optimised (right) process

The simulated press forces are shown in Fig. 9 for the optimised process layout of the finisher. The peak force is now just below 7,000 T, whereas the peak force of the original process was 10,000 T as shown in Fig. 6. The 4 % smaller billet volume effectively reduced the peak force by 30 %.



A de-coupled die stress analysis was carried out to compare the max. tensile stresses in the dies for the original and the modified process. The max. tensile stresses of the original and the optimised process are compared in Fig. 10.

Overlap to outer tool to optimise pre-stressing conditions was left unchanged - this bears some additional optimisation potential to further reduce the tensile die stresses, but the most effective way is to reduce too early die filling and excessive flash.

Fig. 9. Force during the last few millimetres of the stroke (optimised process)

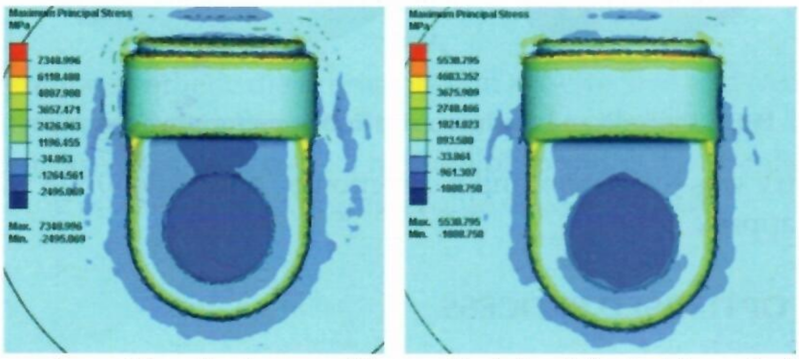


Fig. 10. Comparison of tensile stresses of lower die, left original, right optimised process

Reducing excess flash as studied here requires the initial billet geometry to be cut or crop- sheared with higher precision to match the optimised input volume. Neglecting this requirement might result either in more frequent under fills or reduce the die life gains.

CONCLUSIONS & OUTLOOK

This study shows several benefits which can be easily achieved for the forging processes which have been laid out manually without the help of modern simulation tools by optimising the initial billet size and preforming operations. In this study three main benefits have been achieved:

1. 4 % lower material requirement per forging
2. 30 % lower press force requirement in the finisher stage
3. 25 % lower dies stresses increasing die life five to ten times

Not only these, but also secondary benefits are achieved as follows:

1. The efforts and costs to handle the trimmed flash will be reduced
2. The lower press force requirement also results in energy saving. It also allows to use a smaller press which has lower operational costs. Furthermore, larger forgings can be produced on the same press, which will increase the product range which can be produced on the available presses
3. Lower die wear due to reduced contact stresses and lesser material which needs to flow into the flash.

Since this optimisation can be done already in the design phase for a new forging component as well as for products already in production the utilisation of the simulation software will be high and a fast return on the investment can be such that the investment in this simulation software can be recovered within a year.

Besides the fundamental optimisation of the billet volume and optimisation of the preform geometry numerical simulations can be used for further optimisations like:

- Optimisation of the position of the cavity within the die to reduce eccentric forces acting on the press
- Optimisation of pre-stressing of the die by optimisation of the shrinkage assembly to further increase die life.

The importance of tight billet weight tolerances has been briefly discussed. A detail study of the impact of the cutting weight tolerances during the shearing / cutting of the billets will be the content of our next publication in the Focus magazine.

SOURCE:

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Energy Efficient Induction Heating For Modern Forge Shops With Elotherm's Izone™ Technology

Mr. Jochen Gies, Dirk M. Schibisch
SMS Elotherm GmbH, Jarmany

ABSTRACT

A growing number of forge industry leaders have taken advantage of the improved energy efficiency, higher productivity, and eco-friendliness offered by the newest generation of innovative induction heating technologies. The advent of intelligent induction furnace zone control, known as iZone™ technology, marks a significant milestone in the ongoing pursuit of manufacturing excellence.

Germany produces about 2.3 million tons of forged parts each year, with an energy consumption of about 1300 MW-h/year to heat these parts to the proper forging temperature. With a typical energy price of 0.10€/kW-h, the annual energy bill adds up to 130 million Euro (about $190 million), underscoring the potential benefits available to forge operators deploying new high-efficiency induction furnace technology. In response to rising energy costs and the desire for greater environmental stewardship, iZone™ induction heating technology sets new standards for efficiency, productivity, and resource conservation.

The key to unlocking higher induction heating efficiencies was the development of an entirely new generation of converters featuring L-LC (inductor-inductor/capacitor) resonance circuits with switching at the inverter output (Figure 1). Comprised of an unregulated rectifier, intermediate circuit capacitor, IGBT inverter, and output choke, this converter has a real-world operating efficiency of 97 % and a power factor (cos φ) across its entire output power range.

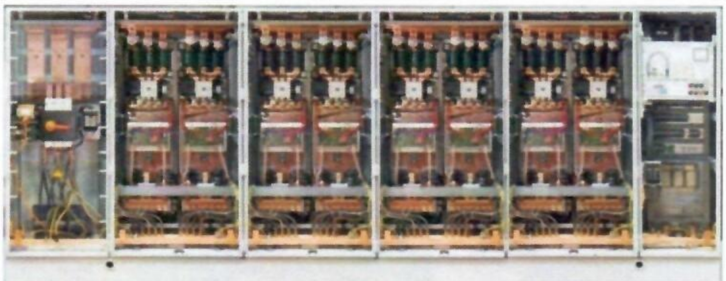


Figure 1: The 97 % efficiency L-LC induction furnace converter with eight zones

The following paragraphs describe how the iZone™ induction furnace has been successfully integrated with a hot shear to achieve greater production flexibility and productivity in the forging of large workpieces.

PROCESS REQUIREMENTS AND EQUIPMENT LAYOUT

A magazine delivers individual bars (bar dimensions: Ø120mm - 300mm, or Ø4¾ "- 12",

with a maximum length of 12m, or 40 feet) to a roll table, which transports the bars to and through an induction furnace consisting of nine 1100mm-long (44"-long) heating coils, followed by one 1800mm-long (71"-long) soaking coil at the furnace exit. The hot shear then cuts the precisely and uniformly heated bar into billets ranging from 150mm to 1000mm (6"-40") in length. The required throughput ranges from 1.5 to 9 metric tons per hour.

Figure 2: High performance induction furnace for large bar heating

Two L-LC converters provide the 4200kW heating power required for the specified 9 t/h throughput. Each converter drives four independent furnace zones (eight zones in total). The first five coils comprising the furnace entry section are individually driven, making up the first five independent furnace zones. The sixth and seventh coils are grouped together in one zone, as are the eighth and ninth coils. The tenth coil (the soaking coil) makes up the eighth and final independently controlled furnace zone. All eight zones share the same control architecture, and all nine heating coils are identical and fully interchangeable for maximum flexibility and machine availability with minimal spares requirements. Only two spare coils are needed to support the entire furnace, saving both money and valuable floor space.

ENERGY-EFFICIENT START AND STOP SEQUENCES

Heating large bars from room temperature to 1250 °C (2280 °F) can require up to 50 minutes until the first billet can be hot sheared. The bar progresses from one heating coil to the next in about five minutes. The iZone™controller tracks the bar location, activating each zone as the bar enters. Energy and money are thus saved by driving only the loaded furnace zones. (Figure 3) Analogous to the start sequence, the stop sequence turns off each furnace zone as the bar exits that zone. (Figure 4)

Figure 3: Production Start Sequence: Cold bar entering the furnace from the left (green panel indicates energized furnace zone). Each zone is automatically turned on as the bar enters.

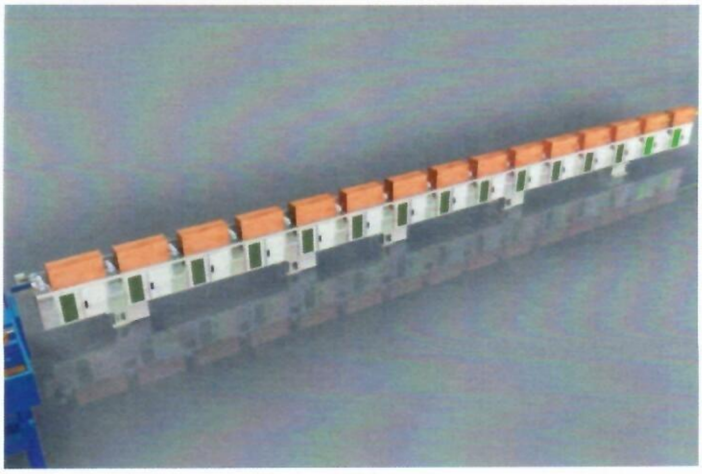


Figure 4: Production Stop Sequence with final bar exiting the furnace (green panels indicate energized furnace zones). Each zone is automatically turned off as the bar exits.

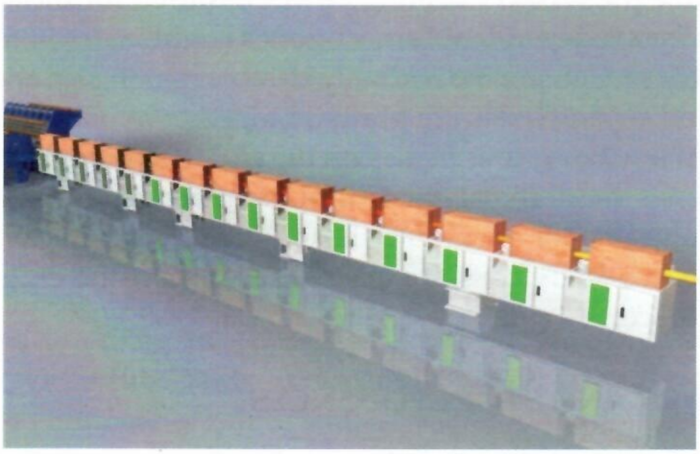


Figure 5: Flexible Throughput Rates (Green panels indicate energized furnace zones) 300 mm (12') diameter bars are heated to forging temperature at a reduced throughput of 6 t/h. 20 % energy savings are realized through iZone™ recipe optimization vs. conventional furnace operations, and scale formation is minimized.

USER-FRIENDLY GUI FOR AUTOMATICALLY ACCURATE SETUPS

iZone™ offers forge operators a variety of heating strategies, including options for reduced scale formation and "soft" heating (heating with reduced thermal gradients in the workpiece). The intelligent controller behind the operator-friendly GUI (graphical user interface) automatically optimizes the heating profile and furnace parameters in response to operator selections. With the press of a button, individual furnace zones are energized at the right moment with the right power, frequency, and load matching capacitance. (Figure 6)

Figure 6: iZone™Graphical User Interface (GUI)

"SOFT" HEATING OF CRACK-SENSITIVE STEELS

Certain bearing steels, such as 100Cr6, are prone to internal cracking induced by thermal stress during the heating process. Conventional induction furnaces required a set of custom "soft heating coils" to reduce the heating rate below the Curie temperature and avoid thermal cranking. Because the iZone™ controller can drive each furnace zone independently, it is able to create a soft heating profile with standard heating coils. No custom heating coils are required. iZone™ simply and immediately fine-tunes the furnace to match the requested throughput and heating profile, eliminating the cost and delay of maintaining and swapping multiple sets of custom heating coils. (Figure 7)

Figure 7: Soft Heating of Crack-Prone Steels (Green panel indicates energized furnace zone.) Zones one through three provide soft heating below the curie temperature to prevent thermal cracking, without using special soft heating coils.

STOP AND GO OPERATION WITH HOLDING MODE

In the past, disruptions in forge process pacing (faults, pauses, and outages) usually required that the induction furnace be purged of all in-process material, resulting in wasted energy, time, and money. By contrast, iZone™ can maintain partially heated bars at the appropriate intermediate temperature until production resumes with no down time and no loss of product. This Stop and Go operation allows warm charging, holding, and soaking of partially heating bars based on the workpiece heat content (enthalpy) in each of the furnace zones. Oscillation (continuous forwards/backwards cycling motion of the bar) essentially eliminates residual thermal gradients (zebra-striping) along the bar length. Strategically located pyrometers verify the bar temperature and provide input to the iZone™ adaptive controller. (Figure 8)

Figure 8 : Warm charging & soaking for immediate recovery after a production stoppage (green panel indicates furnace zone operating in "holding" mode)

SUMMARY AND OUTLOOK

Modern forge operators have realized significant productivity improvements through the benefits of iZone™induction furnace technology, including:

- Peak efficiency at any throughput rate in all operating modes, including
  - startup,
  - soaking,
  - shutdown and
  - continuous production
- Simple and fast (less than two minute) product/process changeovers
- Adaptable heating profiles for reduced scale formation, crack prevention, etc.
- Stop and Go operation for fast, efficient re-starts following production pauses
- Reduced heating coil inventories and spares requirements

iZone™ has been particularly well received by European forge operations wanting to boost productivity while reducing costs and emissions, and by Asian forge operators working with limited power availability. Meanwhile, new technologies for even greater induction heating efficiency are under development, and will soon be incorporated into robust furnace systems for the forging and long products industries.

Courtsey: **Dipl.-Ing. Jochen Gies**, Projektleiter Vertrieb, SMS Elotherm GmbH

Dipl.-Wirt.-Ing. Dirk M. Schibisch, Bereichsleiter Vertrieb/ Marketing, SMS Elotherm GmbH

Forging Materials: Micro alloyed Forging Steels

Like all steels, micro alloyed steels are iron-based metal alloys. Normally, they are plain carbon or low-alloy steel with small additions (i.e. a micro alloy) of one of three special elements. These steels were developed in the 1960s and used for plate and pipeline applications. It was not until the 1980s, however, that forgers began to produce micro alloyed steel components in signify can't quantities. Micro alloyed steels have higher strength and higher toughness as compared to low-alloyed steels with the same microstructure. They do not have the same high strength/toughness combination of quenched-and-tempered alloyed steels, but their properties can be quite suitable in many applications. The real advantage of micro alloyed steels is in the cost savings realized by the elimination of heat treatments, since a properly designed and forged micro alloyed steel part will not require any subsequent heat treatment. Thus, the elimination of the need for austenization, quenching and tempering after forging helps offset the additional cost associated with a micro alloyed steel.

CHEMISTRY AND MICROSTRUCTURE

Micro alloyed forging steels typically have carbon contents of 0.15- 0.55%, with manganese ranging from 0.60-1.65% and silicon 0.15-0.65%. The three micro alloy elements that are added in small quantities to form micro alloyed steels are vanadium, niobium and titanium. Most micro alloyed steels have a ferrite-pearlite microstructure. Some steel producers also add a small amount of molybdenum to these steels to produce a bainitic micro alloyed steel directly after forging. These are sometimes referred to as the third generation of micro alloyed steels. Vanadium (V), added in the range of 300 to 1,000 ppm (0.03-0.10%) to the steel, has a very high solubility in the austenite phase of the steel. Thus, when the steel is heated to forging temperatures, all of the V dissolves into the austenite phase (similar to sugar dissolving into water when the water is hot). When the steel is forged and subsequently cooled in a controlled manner, the V will react with carbon and nitrogen to form vanadium carbonatites, which precipitate out as fine particles in the microstructure. These particles provide a significant boost in the strength of the room-temperature steel. This strengthening process is called precipitation, or dispersion, strengthening.

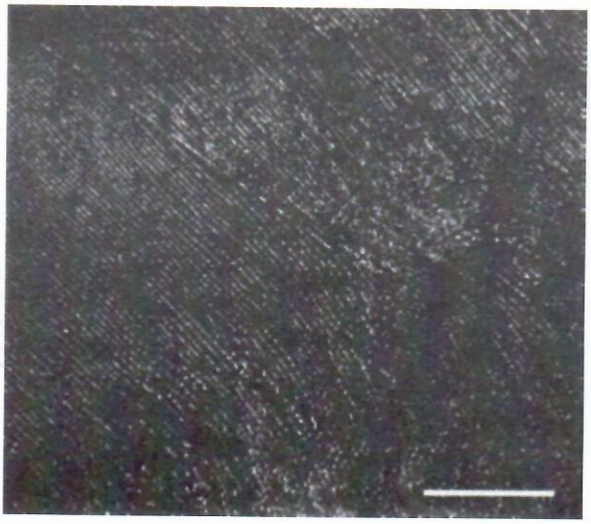


Figure 1. A high-magnify cation picture showing the very fi ne precipitates in a vanadium micro alloyed steel. Note that they are dispersed throughout the microstructure.

Figure 1 shows a transmission electron microscope (TEM) image of vanadium micro alloyed steel. The fi nely dispersed white particles in the image are the vanadium carbo-nitrides (V(CN)). They are Nano-sized particles, indicating that micro alloyed steels are really part of the current nanotechnology effort. The other benefit vanadium provides is that it can form vanadium carbonatite precipitates on MnS particles that are within the steel. These MnS particles with V(CN) on their surface form nucleation sites for ferrite, causing ferrite to form inside the grains (intergranular) of austenite and be present inside the final pearlite colonies. The intergranular ferrite can contribute to a small increase in the toughness of the steel.

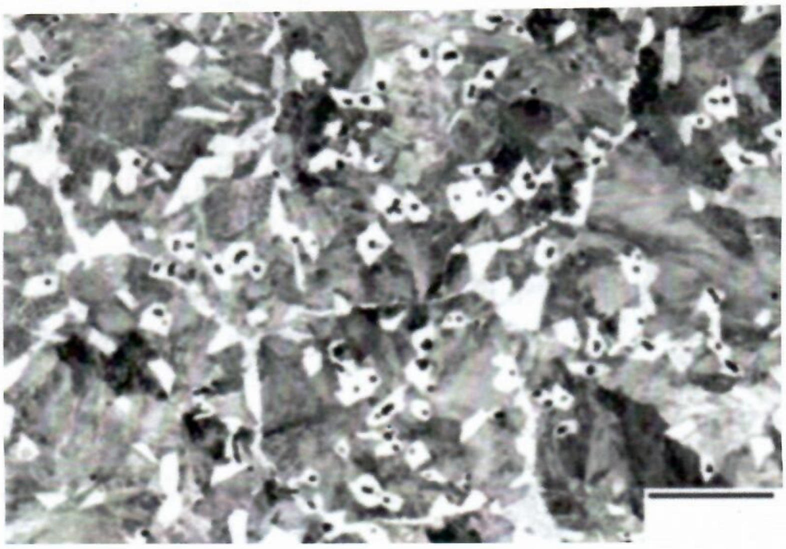


Figure 2. The microstructure of a medium-carbon vanadium micro alloyed steel. The addition of vanadium allows the ferrite (white) phase to form on the MnS particles (black bull's eyes in the ferrite) and break up the large pearlite (black) colonies in the microstructure.

Figure 2 shows a microstructure of a vanadium-micro alloyed steel with intergranular ferrite. Niobium (Nb), sometimes referred to in the U.S. as columbium (Cb), is not as often used in forging steels. It is a very common micro alloy element in high-strength controlled-rolled plate steels. In forging steels, Nb is added at the levels of 200 to 1,000 ppm (0.02-0.10%). The solubility of Nb in austenite is very temperature sensitive. At high forging temperatures, most of the Nb will dissolve and precipitate out when cooled in a fashion similar to vanadium. At lower forging temperatures, the Nb will not fully dissolve. If itis present as fi ne precipitates at these lower forging temperatures, these precipitates will provide grain-boundary pinning of the austenite and not allow the austenite grain size to grow too large.

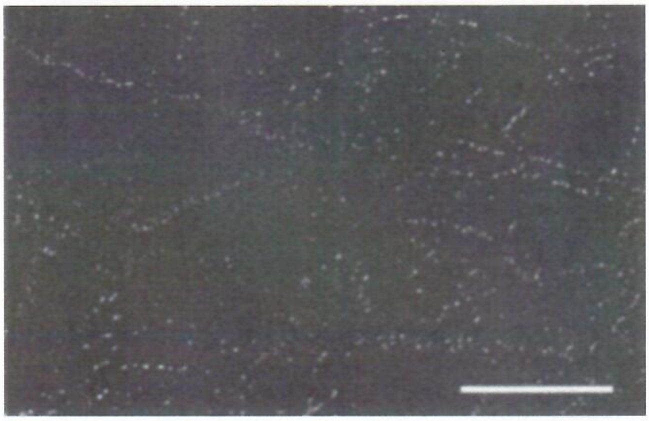


Figure 3. A high-resolution micrograph of niobium-micro alloyed steel.

The precipitates (white particles) are not dispersed throughout the microstructure but occur primarily along the prior austenite grain boundaries. These precipitates on the grain boundaries prevent the austenite grain size from growing too large when at high temperatures.

Figure 3 shows a TEM image of a niobium-micro alloyed steel. Notice, in contrast to Figure 2, the fi ne niobium-rich precipitates are not dispersed throughout the structure but primarily reside along prior austenite grain boundaries. The size of these prior austenite grains is on the order of about

1 micron, which is indeed very fi ne. If fi ne austenite grains are present, then the transformation products (ferrite, pearlite or bainite) upon cooling will also have a very fi ne grain structure. Small grains provide not only an increase in the strength of the steel, they can also increase the toughness at the same time. This grain refinement is the only known mechanism that increases strength and toughness simultaneously. We would get an increase in strength but a decrease in toughness with all the other known strengthening mechanisms in metals. The control of these niobium-rich precipitates is much more difficult in a forge shop. The processing window for good forging product with a niobium-micro alloyed steel is much smaller than with vanadium. So, in spite of the lower cost of niobium as compared to vanadium, vanadium is the normal micro alloy element of choice for forgings. Titanium (Ti) is the third major micro alloying element used in forging steels. The amount of Ti in forging steels is very low - 100 to 200 ppm (0.01-0.02%). Titanium has very low solubility in austenite even at high temperatures. It reacts readily with any nitrogen in the steel and forms titanium nitrides (TiN). These TiN particles usually form during the solidification process in the steel mill. If TiN precipitates are very finely dispersed, they will pin the austenite grain boundaries during heating and forging, creating a very fi ne austenite grain size. Similar to the low-temperature forging of niobium micro alloyed steels, the fi ne austenite grain size leads to a fi ne grain structure in the final product, increasing both the strength and toughness of the steel. Table 1 gives a summary of the behavior and effect of the three primary micro alloy elements in steels.

APPLICATIONS

Forged micro alloyed steel components are used in a number of applications. They are used extensively in automotive applications including crankshafts, connecting rods and a variety of drivetrain components. They are also used in hand tools. The vast majority of micro alloyed steel forgings are high-volume, moderately sized (1-10 pounds) products, which is the "sweet spot" for automotive parts. In non-forged products, micro alloyed steels are used extensively in high-strength plates, high-strength pipe and in structural components for ships, cars and trucks. In the U.S., the use of micro alloyed, forged components in automotive applications lagged behind their use in Japan and in Europe. This delay was not due to technical limitations of the material but primarily due to potential legal issues that the U.S. automotive companies were not willing to assume. For many years from their initial development until the early 1990s, these micro alloyed forging steels were classified as experimental grades of steel. It was not until 1992 that they received an official designation as ASTM A-909 and were not long in the experimental category. U.S. automotive companies were reluctant to use steels that were classified as "experimental" no matter how well proven they were. Forging of Micro Alloyed Steels, The hot-forging temperature required for micro alloyed steels is the same as that used for the plain-carbon or low-alloyed steels. Some companies have successfully coupled warm forging (temperatures about 1800oF or less) with micro alloyed steels to produce a high-quality product. The forging loads may be a little higher than for the non-micro alloyed grades. If warm forging is employed, then the loads can be signifying higher. Figure 5 shows the temperature range for these micro alloyed steels. Virtually all applications are induction heated because they involve high production volumes and moderate to small part size.

Process-control requirements for micro alloyed steels are significantly greater than those required for parts that will be subsequently heat treated. In addition to the temperature control offered by an induction heating line for heating of the billets, a critical production aspect of forging micro alloyed steels is the controlled cooling of the parts after they come off the hammer or press. In order to obtain the proper size and distribution of the precipitates, the cooling rate needs to be faster than standard cooling in a bin but slower than quenching in oil or water. The correct cooling rate is critical in maximizing the properties of micro alloyed steel forgings, especially components made with vanadium additions. Cooling on a fan-cooled belt conveyor or on a conveyor with a fi ne-mist spray are typical methods of achieving the proper cooling rate. If the cooling rate is too slow, precipitates will form, but their size will be too large to be maximally effective. If the cooling rate is too quick, precipitates will not form, and the extra cost of the micro alloyed steel will be wasted because you will not obtain the strength boost from having the precipitates in the microstructure. The important temperature range is from the forging temperature to the end of the austenitic transition temperature (typically 1350°F). Below this level, the amount of precipitation is greatly diminished. Initial process development can be expensive, as forging temperature, conveyor speed and heat-transfer coefficient from fans are optimized to achieve the required precipitation after forging. The current trial-and-error development is not only expensive but can converge on a workable non-optimal set of conditions. This situation is an ideal opportunity to deploy process modeling to optimize cooling rate as a function of heat-transfer coefficient, as is done for forging in aerospace applications. Dropped billets, mishandled forgings or other delays result in scrapped parts. Occasionally, rework through subsequent heat treatment may be possible, but such rework defeats the advantage of micro alloyed steels in eliminating extra heat treatments. The process control to successfully and optimally forge micro alloyed steels is similar to the requirements associated with aerospace alloys. Forgings of micro alloyed steels need to be engineered; they cannot be produced by a simple "heat it and beat it" process!

SPECIAL CONSIDERATIONS

One criticism that occurs with micro alloyed steel parts is that they are more difficult to machine after forging. Studies have shown that the machining is not worse as compared to plain-carbon and low alloy steels, but it is a bit different. If you operate the machining equipment with the same feeds, speeds and depths of cut as you would with a non-micro alloyed steel of the same grade, then the tools will indeed wear more rapidly. The machining parameters need to be adjusted in order to obtain the same cutting-tool life.

SUMMARY

Micro alloyed steels are a relatively new class of forging material that can provide steel forgings of added strength and adequate toughness for a variety of applications. Their properties depend strongly on the control of the fi ne precipitates in the steel. This control requires special cooling conditions as the forging comes off of the hammer or press. Although micro alloyed steel is more expensive than a plain-carbon or low-alloy steel equivalent, cost savings can occur by the elimination of post-forging heat treatments Micro alloyed steels should certainly be considered in discussions with your customers when they are trying to obtain a higher-strength steel component.

New Technological Developments - Newly developed Horizontal forging machine, Hydraulics replacing mechanics

Lasco, Italy

Lasco has developed a hydraulic driven horizontal forging machine under the type designation HWS. At the EMO in Milan the novelty, which is standing out by a number of innovative solutions, was received with great interest

- Compared with the well-known mechanical horizontal forging machines of different brands, which were initially equipped with vertically and more recently with horizontally split champing jaws, the novelty from LASCO offers essential technical advantage.
- Independent hydraulic cylinders in the upsetting and clamping operation allow freely configurable sequences of motion and reduce wear that is inevitably caused on the clamping tools by overlapping sequence of motion.
- Tong motion when closing the clamping operations is avoided, thus preventing the resulting conicity in the formed area.
- The disadvantages of mechanical drives with numerous bearings and support points, clutch and brake are avoided. Thus there is almost no wear or consumption of compressed air.
- The clamping force is 50% higher than the upsetting force which avoids an opening (gaping) of the clamping tools. In special cases the clamping force can be increased even more.
- The machine is especially suited for the stepwise upsetting of volume gathering and finish-forging (e.g. of flanged shafts, rear axle shafts, steering rods, blade roots, midspans and shrouds) as well as for the extrusion of hollow parts (e.g. axle tubes)
- The forming speed for forming different alloys can be selected freely and even varied during the forming process itself.
- As volume gathering and forming different alloys can be selected freely and even varied during the forming process itself.
- As volume gathering and forming always happens in several steps, the advantages of our novelty can be fully benefited from/by automation and simultaneous use of various forming stations.

FIRST AIR OPERATED HAMMER AUTOMATED

LASCO- the pioneer of fully automatic hammer forging- has set another milestone in the development of its technology. In the USA an older air operated die forging hammer of a third party manufacturer as well as the downstream trimming press were interlinked in a fully automated process for the first time.

The synergy of Channellocks experience and knowledge of programmable die forging hammers and LASCOs automation expertise resulted in the first joint automation project of such hammers. Now the commissioning stage has been completed the two companies will go on cooperating closely in the optimization stage. Although, according to LASCO project engineers, this solution does not reach the efficiency obtainable with LASCO double - acting hammers due to limitation by its special design. Initial experience shows that the line can be operated at a much higher productivity level compared to manual operations of the line.

The famous US American producer of hand tools Channellock Inc. (Meadville/PA) placed the order for this modernization project which was completed successfully in October 2009. With the automation project of the Chambersburg die forging hammer and the downstream trimming operation in the trimming press Channellock was pursuing the following goals:

- Significant facilitation of work for the operation
- Consistency of the whole process
- Increase in quality

LASCO solved the task by equipping the hammer with two forging robots with special planted LASCO gripper, a ram position recognition system, a master control and a robot for feeding the trimming press as well as flash remover and other technical equipment.

Founded in 1886, channellock, INC. is a worldwide leader in the man in the manufacture of a high quality pliers and assorted hand tools, with a workforce of about 400 dedicated associates. The enterprise – run by the DeArment family in the fifth generation already- is supplier for more than 4000 wholesalers in the USA and exports its quality products to more than 45 countries in the world.

PROCESS OPTIMIZATION AUTOMATION- DOING IT RIGHT

In our earlier article on automation, we already focused on special conditions and tasks forging. This article deals with the variety of everyday situation in the forge that can be managed better by the automation.

MANIPULATION IN THE FORGING UNIT

Automatic forging on a hammer poses one of the biggest challenges for automation systems. Due to the hammer characteristics such as high ram speed ad short blow sequences high demands are made on its dynamics. Moreover, the work-pieces tend to jump off the impression- especially with hard blows. The hammer movement caused by the spring damping on the foundation is another problem and the tong holds that change after each are not easy to compensate via the electrical control.

HOW CAN SUCH A PROCESS BE AUTOMATED?

The crucial point is to furnish the forging part with the two tong holds and to hold it from 2 sides.

An important key to success of automatic hammer forging are the patented forging tongs from LASCO. They are especially conceived for the characteristics of hammer forging such as withstanding high accelerating forces, keeping forces and vibrations off the robot and compensating the changes in billet length, especially for the pre- forming blow and bending operations, just to name a few of them.

Automation in a press with several forming stations appears to be a little easier. The work pieces stay in the tools are lifted purposefully by an ejector system. Different solutions are necessary for cycling only one work piece or more work pieces simultaneously through the die cavities.

If only one work piece is transferred from station to station, the gripper must be able to take up the changing work piece safely- from the straight via the bent to the furnish forged parts with flash. If needed, various gripper jaw can be integrated in a gripper.

The challenge posed by more work piece cycled through the die cavities simultaneously, where maximally all the stations are occupied, is the very tight tool area, especially if it needs to be lubricated- as it is mostly the case. 3D CAD, motion simulation and slim grippers help to find the optimum solution.

TRANSFER FROM THE FORGING UNIT TO THE TRIMMING PROCESS

The part can be transferred by taking it out from the finishing impression of the forging press and placing it directly into the trimming operation or via a swivel arm with centring plate from the tool area. When transferring the part must be avoided by all means. For safe gripping tong holds on the flash of the work piece are necessary. Another sensitive surface of the work piece remains untouched. Layout of the production line in 3d via sensors the correct position of the part in the trimming tool can be detected. Incorrect positions of the work-piece normally lead to scrap and in the worst case to a destruction of the tool.

MAUPLILATION THROUGH THE TRIMMING PRESS WITH TWO STATIONS

Often there are stations in the trimming press with function like piercing, trimming or calibrating. After the first station the part must be fed to the first processing, operation correctly positioned. Here it is indispensable to grip the work piece itself and the tong hold sare decided upon in close co-ordination with the customer.

DISCHARGE OF THE WORK PIECE FROM TRIMMING PRESS

As for the gripping the same applies as mentioned above. Tong holds are used by transfer. This the finished parts can be positioned on a cooling line or on a conveyor belt in a targeted away.

DISCHARGE OF THE FLASH CONTAINER

Every manufacturers aim is, of course to minimize the share of flash, i.e. scrap. Hence the flash is thin, irregularly shaped and rather instable. The more complex the flash shape the higher the risk of getting caught at the trimming tool. It is important to have a single piece flash to ensure that it can be detached from its "interlocking" by titling it up. The spot where the flash is dropped can be varied to get a more homogenous distribution in the flash container. Normally the slugs are removed from the press quite easily as they are dropped from the press via a chute onto a conveyor belt.

Proactive Steps to Replace the potential Vacuum being Created by Electrification of Automotive - Focus Forging Industry

Dr Vasant Khisty,
Sammy Consulting

Forging industry is facing a concern with the major push the Governments of different country are giving towards of electrification of automobiles. 60 to 70 percent of volume business in forging Industry is comprised of Auto component forging and again 60% of the same come out of IC engine parts like Crank Shaft, Connecting rod, Engine valves, Piston. Electrification engine will further lead to automatic transmission or elimination of drive line to variable speed direct drive motors like hydraulic motors in construction equipment so that would eventually take away shifter Forks, Gears, Propeller shafts, differential components from the forging kitty. Now this is inevitable. The transition can be slow or fast and can taper off over years or be abrupt depending on how disruptive forces emerge in near future. The challenge here is on one side business is growing so as a capital equipment investor one cannot stop investing and then there is a redundancy fear in very near future where in huge investments would stand idle.

The forgers need to be proactive. They need to ride this transition from being forger to component manufacturer which uses forging. All is not lost nor there reason to panic. Forging equipment are versatile machines which can make auto components, non-auto components, ferrous and nonferrous forging with the same piece of equipment, yes the inflexibility come s out of dedicated machining line like say a connecting rod line which cannot be used to make a golf club or a hip joint.

So what do forgers do from here as a proactive action? Here are few suggestions I wish to make.

1. First and fore most start drawing an up a strategy by establishing a task force or brain storming group.
2. Keeping focus on Auto components to start with find the components that will continue to stay with electrification. The red highlighted group of parts may disappear as shown in Fig 1.
3. Find new components that may add due to electrification like electric motor shafts.

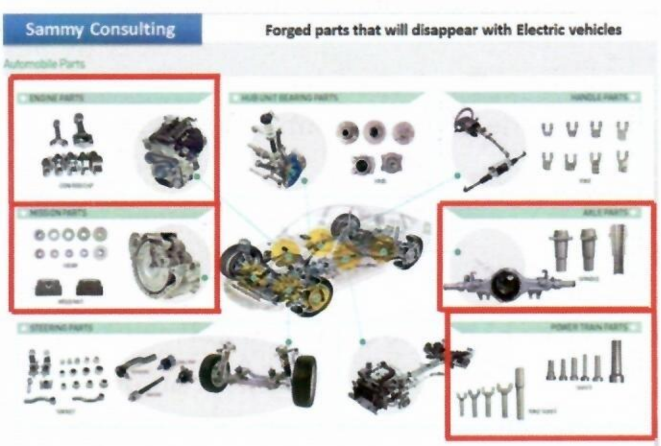


fig.1

Now since the business demand will go for automotive the forging requirement for NON IC engine components will grow and will fill the vacuum created by IC engine parts so there may not be steep decline in auto forging demand but the growth may not be visible. So we can expect stagnancy in growth for 5-10 years.

4. Identify all non-auto forging opportunity like Health care , Aviation, Oil and Gas, Shipping, Locomotive, sports, defense, House hold, Solar, Electrification, Construction equipment etc.
5. Go up the value chain in terms of offering ready to assembly parts like cardan shafts, chassis parts, steering parts and other non-auto systems.

6. Build knowledge and skills on non-steel or conventional metals like Monel metal, stainless steel, Nonferrous.
7. Develop skills on making critical non-conventional configuration like hollow elbow joints T joints etc. with Multi axis forging ability.
8. Reduce energy costs and build manufacturing efficiency by using IOT.
9. Reduce man power intervention for real time operations management
10. Eliminate waste of all kind which does not add any value
11. Introduce research and development as a driver for change in product portfolio.
12. Add product/ process engineering and validation skills.
13. Develop capability for efficient low volume high variety production.
14. Develop a transition road map from being a conventional forger to say world's largest golf club manufacturer.

As an example to the thought process of transition I am giving an example of how we can educate the customers in other markets to use forging and add value to the products. As electrification gains prominence in every field more and more electrical motors will come in use from small to big. One of the parts is a motor shaft which is the central most important part of a motor which receives input and delivers output in terms of speed and Torque. The motor shafts currently are being machined out of bars for big and small motors. These shafts can be stepped shafts. If these shafts are forged these shafts can be made with more complex configurations and also stronger than a conventional machined shaft. The weight to strength ratio can be increased thus making the motors lighter with lighter shafts. Without changing the configuration of a shaft I did some math to find that at least 30% raw material can be saved by forging a rotor shaft. With radial forging technology further machining allowances can be reduced and even hollow shafts can be designed and manufactured.

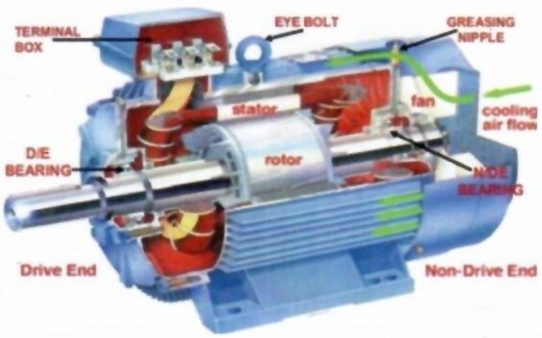
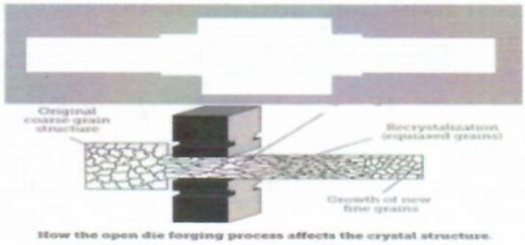


fig.2

The figure 2 shows a typical motor configuration. The rotor shaft is a target component for forging and also the aluminum impellers can be forged. Forgings weighing few tons to few grams would be required for an electric motor. These can be made by Open forging, closed die forging, cold forging and hollow radial forging. The electric motor industry needs to be educated to shift from bar stock machining to forged shafts which will provide them stronger shafts with lower cost. The figure 3 illustrates grain flows difference between a bar stock shaft and forged shaft and the continuous grain flow with smaller grain size gives additional strength to shafts thus providing the possibility to reduce shaft diameters and achieve the same strength.



Advantage of forging
1/ Raw material saving
2/ Strength due to smaller grains size
3/ Strength due to grain flow
4/ Reduction in diameter due to increased strength

fig.3

fig.4

The simple exercise above is done to show how new markets can be created in other markets for forging industry to make a transition and absorb the shock of reducing auto business. Several product lines can be eplored, like the pictures shown below. From a general purpose forge to a product line forge can be a good transition.

CONCLUSION

There is no reason for the industry to Panic. The Auto industry growth will compensate for the reduced business of IC engine forgings, as alternate energy shall have its transition over decades. Alternate source of energy like wind, solar will increase the demand for gears for planetary gear boxes and other gear driven axles. The electrical industry will increase the demand for nonferrous forgings. The Forgers need to scan the market of future and calibrate their strategy to identify other non-conventional markets with low and high volumes like the medical industry, sports, defense, aero, space, furniture, infrastructure, power transmission etc. With this article we conclude that there is no need to fear if organizations draw a transition road map and gradually diversify into non-auto segment.

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