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DESIGN OPTIMIZATION AND MINIMIZATION OF RAW MATERIAL FOR BURRLESS FORGING IN COLLAR BOLT MANUFACTURING

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Abstract:

The collar bolts are most widely used in engineering applications. It is has more strength when loaded with the engineering components and also useful where the thermal stress experienced by the fastener is high. The wastage produced during the manufacturing of the collar bolt in the forging operation is generally more. In this article, the manufacturing modification is made on the forging die to optimize the process as well to minimize the raw material cost. This changing in the die design of die eliminates the additional burr removal operation. Also the process optimization enhances the material hardness and strength and hence the improvement in raw material yieldin the bolt manufacturing system.

Key Words: Bolt Manufacturing, Raw Material Reduction, Design Modification, Cost Minimization & Improved Strength

1. Introduction:

In the current scenario of globalization, buying and selling are emerging rapidly. The customers are demanding the suppliers for "On time delivery, with correct quantity and quality". Here even though the above things were met by the most of the suppliers, there is always one more important aspect that is to be considered by the supplier. Normally, the conventional method of fastener forging is done by trimming process. In this method, the raw material is taken more than the required volume and excess material is trimmed off from the sample and the sample is finished. Here the excess raw material that is trimmed-off from the product is called "trim burr" and is directly wasted. The trimming of excess material from the product drastically reduces the yield percentage. In mass manufacturing the wasted trim burr of raw material will give huge impact in reduced percentage of yield and in terms of money. Hence it is very much important that optimum utilization of input raw material into value added product. H. C. Lee et al [12] investigated an model to predict the tool life of the cold forging process by considering the high-cycle fatigue and material wear is also identified in the form of mechanical properties of the used work piece. They designed the wear model in the form of increment and implemented as finite element model with simulations, empirical relations for estimating the tool life based on wear and fatigue models were obtained. Z. Li and D. Wu[13] investigated the ratio of high strength to low yield of cold forging of steel using thermo mechanical simulator. The results obtained showed that the microstructure of multiphase contained polygonal ferrite, dispersed pearlite, granular bainite and retained austenite was also identified by thermo mechanical processing (TMP). They identified that the cold forging steel can be directly used to fabricate bolts from hot rolled bar due to its low yield ratio, and the mechanical properties of the finished bolts can meet the standard of class 8.8 bolts without heat treatment. U. Ince and M. Güden [14] conducted finite element simulations based on the set of coefficients of temperature-dependent friction to maximize the cold bolt forgingaccuracy. They have first attained coefficients of friction at various temperatures and calibrated with the different iterations between the experimental and thermo mechanical model extrusion tests. In this study, friction coefficients were the functions of temperatures and were then implemented to simulate the cold bolt-forging processes. The calibrationsand the validations of the model were based on the measurement of temperature on the work piece at the real bolt-forging processes.

J. S. Choi [15] investigated an equal channel angular extrusion (ECAE) for producing the bulk nanostructured alloy AA1050 at room temperature. In the aim of investigating the formability effects of ECAE routes, the conventional and ultra-fine grained specimens were prepared and measured using the compression test. Based on the the formability effects obtained using the compression test thesequences of bolt forming were developed. The developed is in the form of three stages which is applied for the production of high strength bolt. In this work raw material, material cost, labour cost, are minimized by introducing an alternative design on the method of bolt manufacturing. In this regard a burrless forging process modification has been introduced, implemented and tested for its effectiveness.

2. Existing Trimming Version of Bolt Manufacturing:

The Sundaram Fasteners Ltd is one of the leading indian company manufacturing the fasteners for the all engineering sectors. Most specifically many of the automobile industries like FORD, BMW, GM-INDIA, FIAT, OPEL, MARUTHI SUZUKI, ASHOK LEYLAND, TAFE, BAJAJ, TATA, HONDA, ESCORTS, SKODA AUTO, HERO HONDA etc are major customers of them. Some kind of the collar bolts which are used by the above companies are manufactured in this industry. These bolts are manufactured normally in the conventional forging and is finished by trimming process. In this method the raw material is taken more than the required amount and excess material is trimmed off from the sample and the sample is finished. Here the excess raw material that is trimmed called trim burr and it is directly wasted as burr. This wastage of material drastically reduces the yield percentage of raw material processing. The trim burr weight varies according to the product size and shape. The yield percentage in the trimming process is about 92% maximum. For high volume producers like Sundram fasteners, they considerably reduce the profit margin, since 4 to 5 Cr. quantity of products are manufactured in krishnapuram (Madurai) unit alone per month in bolt segment, and 35% of the total quantity are flange screws and flange bolts only ranging from M6 to M20. For example in an average of minimum 5 grams per product goes as trim burr, for the quantity of 17500000 pieces it will be around 87500000 grams = 87.5 Metric tons. On an average the steel cost which is in increasing trend is around Rs 60000/ton.

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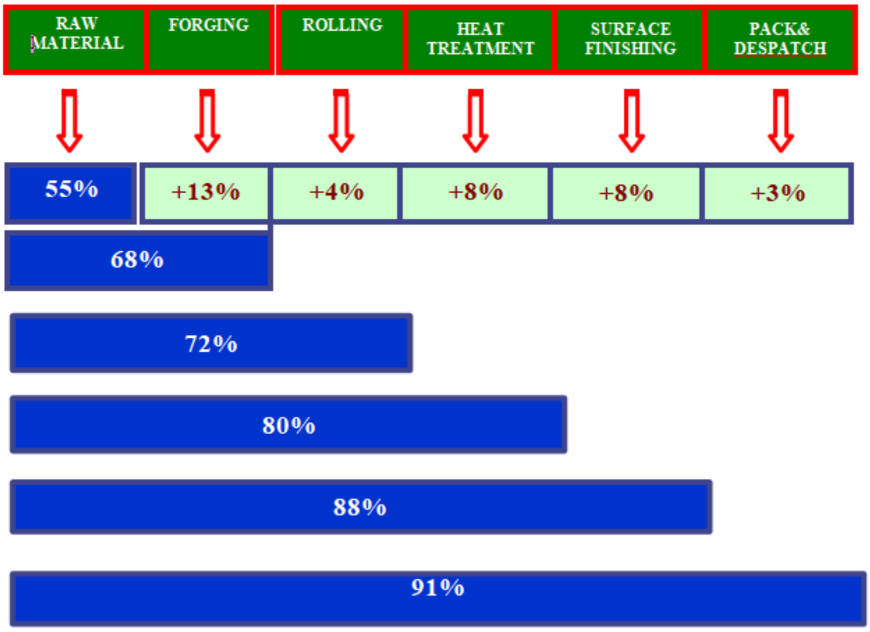

Figure 1: Value addition mapping is given as a % of selling price

Hence for 87.5 tons the costs is around Rs. 52.5 L and are scrapped. Hence this providea great opportunity for yield improvement and cost reduction in manufacturing. From the value addition mapping (fig.1), it has been concluded thatraw material and forging consumes more addition of values among all other processes and the both process put together contributes 68. Since the Raw material is Basic input of the process and consumption of Raw material takes place only in the Forging process, we have chosen this process is a vital area and scope for improvement. We have selected one product among the M8 collar bolt's family and have taken all the data's related to this part. PART NO. : M71160 – M8 x 1.25 x 38 collar bolt. Month Quantity: 75000 to 100000 numbers Customer: TELCO

In the conventional method, forging is done by trimming process (fig.2). In this method the raw material is taken more than the required amount and excess material is trimmed off from the sample and the sample is finished. Here the excess raw material that is trimmed called trim burr, and it is directly wasted as burr, which drastically reduces the yield percentage.

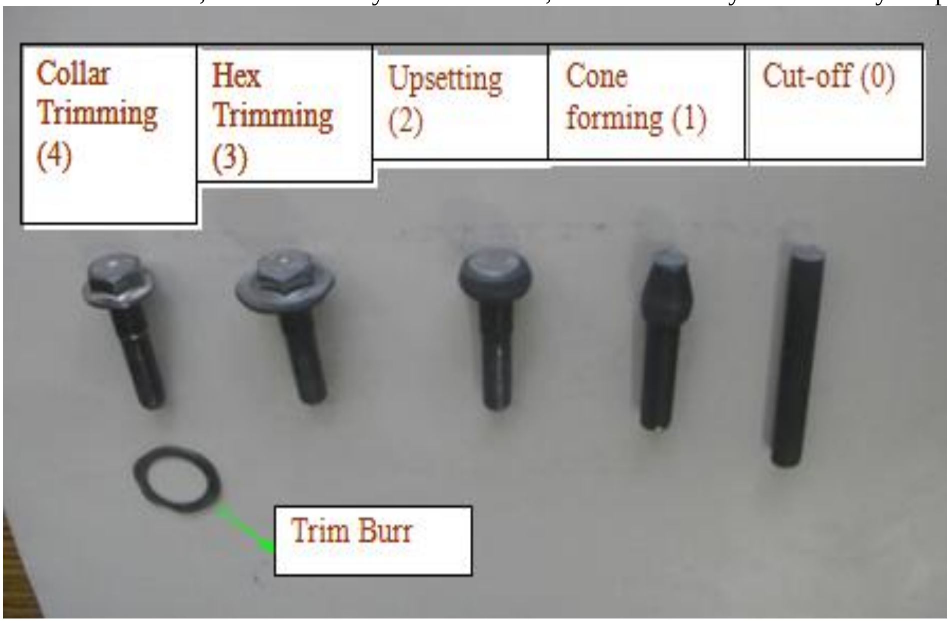

Figure 2: Stage Samples of Forging (trimming Version)

During the process of collar bolt forging, the product input Raw material required is 23 grams/product and the after finishing the product weighs to 21.2 grams/product, balance 1.8 grams were wasted as Trimming Burr. This figure. 3shows the stage wise forging from cut-off to finished blanks. We have analyzed the forging process for various contribution of cost to minimize the manufacturing cost. The existing forging method without modification have taken and analyzed for various design modification in die and contribution of cost. The loss of cost bar chart is arrived based on the one month data as shown in figure.3 From the cost pareto chat it has been identified that the major manufacturing loss cost is around 37% for Raw material alone and all others are comparatively lesser. So a predictive measure is needed to consider for minimizing the raw material cost by improving the manufacturing method of the bolt forging.

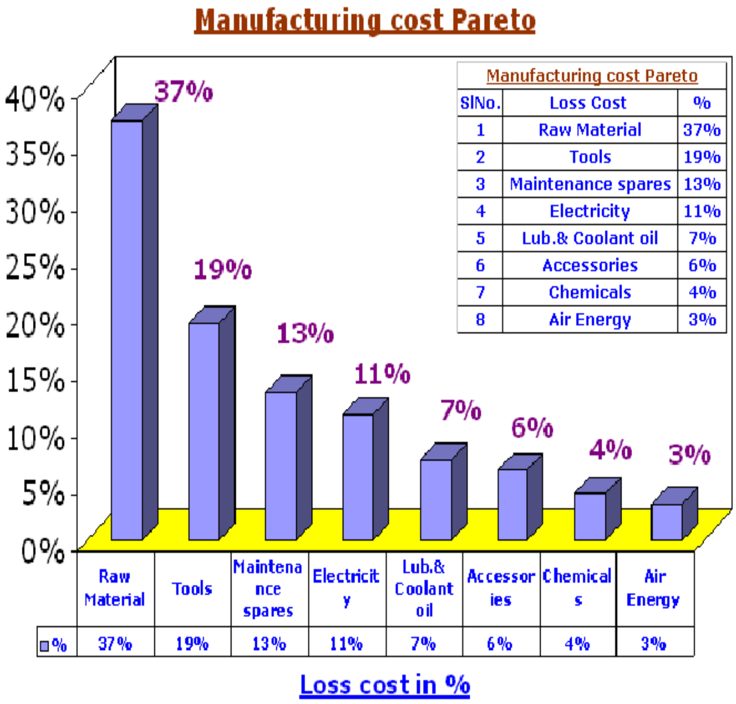

Figure 3: Manufacturing Cost Pareto for existing Forging methods

3. Proposed Methodology and Implementation:

To minimize the form error and the manufacturing cost the existing method of manufacturing is replaced by the new method. This has been done by implementing the changes in the die design. The problem occurred for the increased manufacturing cost is process related and the process which would considerably reduce the burr weight by modification of design. So the die design is completely modified such that the final process would give the collar shape on the bot head.Root cause analysis is made on the problem identified and an effective idea has been sparked to lead the new method of burr less forging. From the below available templates, a trial has been made on the M8 collar bolts and the following are concluded.

- ✓ Length / Diameter ratio: L / D within limits.
- ✓ Upsetting ratio : Within Limits.
- ✓ Extrusion ratio : At maximum limit.

The Design modification starts from the 2nd station of both punch and Die side assembly. The Process flow chart for both Trimmed version and Formed versions are described hereunder

Design Modification Die Kick-out (K.O) pins:

In order to successfully implement proposed idea, some change in tool design has been followed. In trimmed version process the Die K. Opin face was flat and circular that has been modified as chisel based (fig.4) that easily pull out the product from the die bore

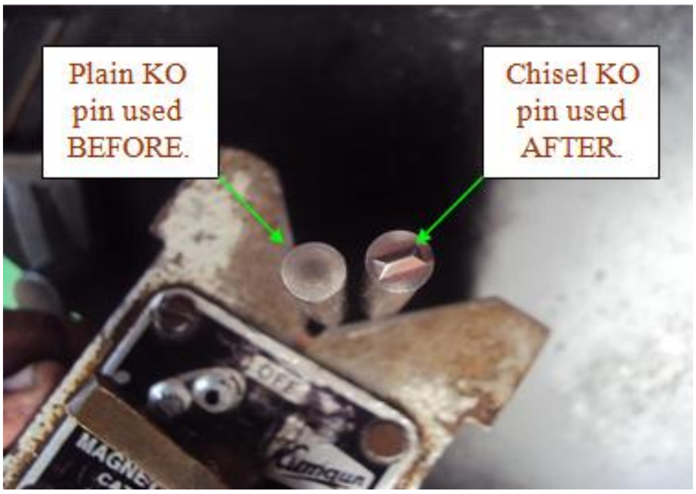

Figure 4: Ejector pins used to pull the product in station 2

In the station-3, Hex trim die assembly was the toolused in Trimmed version process which has been now for Burr less forging this tool design is modified as Hex pre-forming toolas shown in the figure 5.

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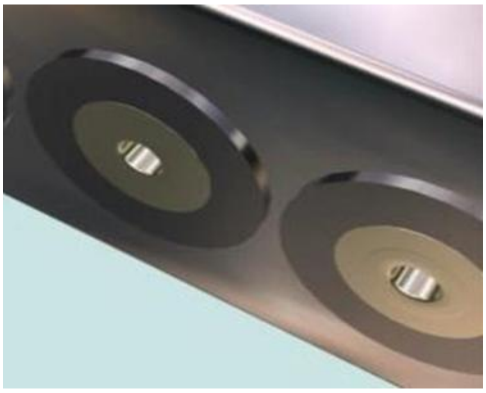
a.



b.

Figure 5: Die Assembly at the station 3 and 4 for a) trimming and b) forming version

After modification of the 2nd, 3rd and 4th die stations the bolts are produced using the forming version and the product has been analysed for its effectiveness. The fig.6 shows the different stages of the bolt when it is produced through forming of the collar bolt head.

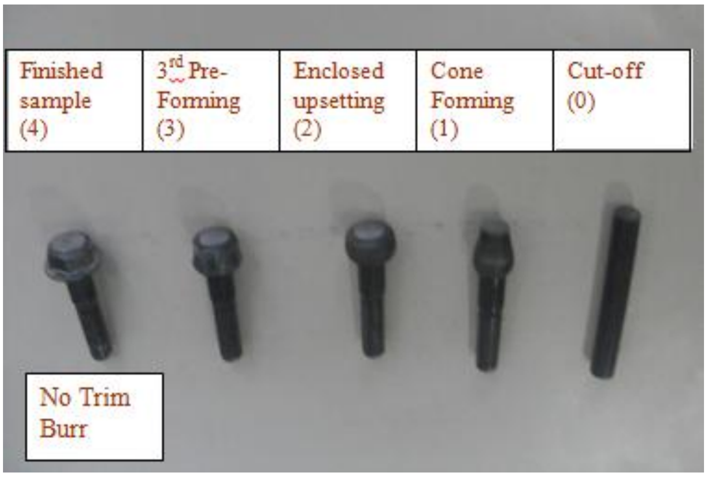


Figure 6: Bolt Formed production from the new method

4. Results and Discussion:

Further analysis made for the produced formed version product, and they are explained below. We have compared grain flow of trimmed version and formed version products through destructive testing, and the results shows that there is an improved strength in the case of formed version of the product. The grain flow of the products are given below. In the Grain FlowComparison Test, the samples of the trimmed and formed versions of the bolts were compared forgrain flow through destructive testing, the micro structure of the grain flow (fig.7) shows the better and contiounous grain flow for the structural stability in the formed version whereas in the trimmed version ths grain flow is discontinous.

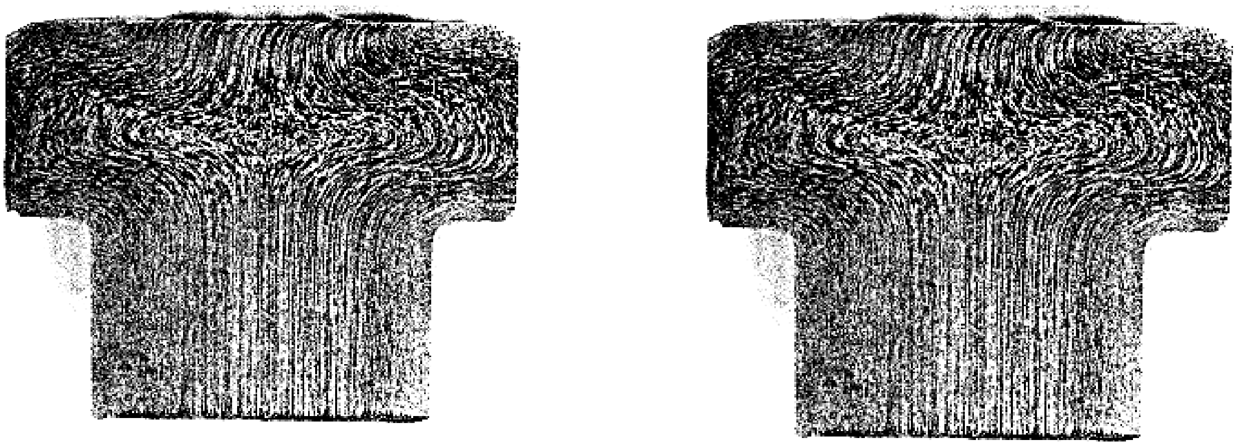
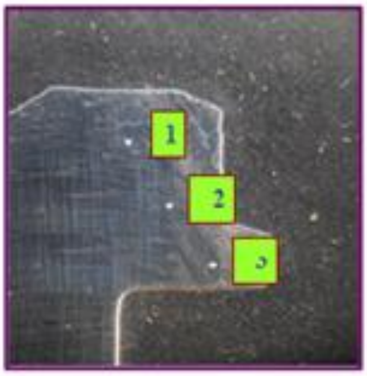


Figure 7: Proper Expanded Grain Flow at Head (Formed Version)

In the Surface Hardness Test, both the trimmed version and formed version products for surface hardness, tabulated (Table.1) and compared. The results (fig.8) show that the hardness of the both versions are well within the control limits. Specification limits are 250 to 320HV. (8.8-grade)



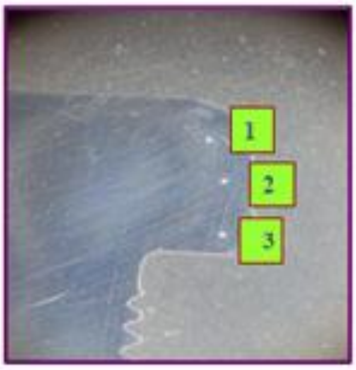


Figure 8: Hardness tested locations on the bolt

Table 1: Harness of the Products

Location	Trimmed (BHN)	Formed (BHN)
1	284	286
2	291	289
3	288	292

5. Conclusion:

A detailed analysis of the most important processes affecting the raw material yield improvement is carried out and the results and the conclusions are obtained:

- ✓ Rawmaterialyieldisimprovedfrom92%to100%forcollarbolt (M71160) through Burr less forging method (Formed version).
- ✓ Thus fullutilization of raw material is obtained through this process.
- ✓ The bolts manufactured by forming method have good surface finish when compared with that of the one manufactured by trimming method.
- ✓ The hardness of the bolt manufactured by forming method is higher than that of the one manufactured by trimming method.
- ✓ The sharp corners found in trimming method have been replaced by radiuses corners in forming method.
- ✓ The stress concentration area in the bolt head is increased in the formed method which in turn increases the tool life.
- ✓ The process of trimming is eliminated in forming, which in turn reduces the operation time and also the labor cost for processing trim burr.
- ✓ Hence, Burr less forging (Formed version) process is the best process for manufacturing collar bolt (M71160-M8) which ensures **"**No wastage of raw material**."**

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