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Studies on Raw Material Optimization in Cold Forging By Reverse Extrusion Technique

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Abstract: -- **Process improvement is the proactive task of identifying, analysing and improving upon an existing process within an organization for optimization and to meet new quotas of standards and efficiency. The part field housing cup that houses starter solenoid in tractors goes through several processes related to machining and plating. The focus is on bringing down the waste in the cold extrusion process that the part undergoes by restricting free flow of material onto unwanted runoff which is later cut off in CNC machining. Cold extrusion is a push through compressive forming process with the starting material at room temperature. In forward extrusion, the material flows in the same direction as the punch displacement and the material movement cannot be restricted in this process easily, hence a considerable amount of material is wasted as free flow in unwanted areas. The aim is to bring down this waste material by restricting unwanted material flow in cold forging process. In the forging process the material movement was initially in the direction of die and caused runoff of extra material in the direction of punch, which had to be machined out later. Restricting the material movement by minor design changes resulted in bucking of the slug and increases pressure on die and die sleeve. The extra material movement was thus restricted by redesigning the process to reverse forging where the part design was incorporated in the punch thus reducing the need to restrict material movement and also eliminating unwanted runoff. A considerable reduction in cost and reduction in material wastage was brought about in the extrusion process. There has been a 19.35% reduction in the weight of raw material from 465 grams to 375 grams and the production cost of the part was reduced by 16.15% from initial cost of Rs. 29.89 to Rs. 25.02. Several constraints and gaps in the process were addressed such as buckling of the slug, sticking of part to the punch, material waste due to extra stock material and breaking of the sleeve due to pressure of reverse extrusion. Further reforming the designs for reverse extrusion process, the stresses on the tools were also reduced (counter punch and die) which upon failure would bear very high costs. Thus a methodology was devised to restrict material run off into unwanted areas without increasing the stress on die and punch.**

Keywords - **cold forging, extrusion, process optimization, waste reduction, reverse forging.**

I. INTRODUCTION

In recent decades the utilization of forging has gained traction over other forming processes. This can be credited to the various advantages that forging process has over other methods forming like improved strength, geometric precision, and little loss of materials. Forging has lesser material loss during the production process over other alternates which mainly rely on material removal to form the final net geometric shape of the part. In most metal forming processes the trend is towards near-net-shape and net-shape manufacturing, resulting in savings in material, energy and a few finishing operations. In many instances such near-net-shape forging is not possible even after a series of forging operations and thus some amount of material has to be machined out, thus increasing the amount of scrap waste. Several studies have been made [1] on the workability of metals in cold forging and it is observed that the workability always depends on the geometry and friction associated with the part, thus near net shape forging is part specific. But within a family of processes like upsetting, the criteria depending on cumulative specific plastic energy adjusted suitably with the maximum tensile stress are the most reliable ones in the estimation of workability limits. Design optimizations in cold forging process in automotive industries have been carried out [2] where the aim was to minimize the possibility of the initiation of tensile fracture in the outer race preform of a constant velocity joint manufactured by cold forming operations. But the specific problem of arresting free flow of material to unwanted areas is not widely studied, arresting movement by simple die modification is not possible in forming because of the stress it will induce die resulting in tool failures, studies on FEA analysis on tool failures on trim dies [3] have been carried out. Hence this research focuses on reduction in scrap by restricting material movement into unwanted areas in cold forging. A solution is articulated with experimentation on a solenoid starter coil housing that is manufactured by forming and machining operations.

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II. MATERIALS AND METHODS

A. Problem statement

The part under study is housing for solenoid starter coil which is used in tractors. It is observed that there is an excess free flow of material at some unwanted areas in extrusion which cannot be restricted because it leads to the breakage of the punch sleeve. This results in utilization of excess raw material which is then later cut off in machining process further down the production line. The major issues with the current forging operation are as follows. (Fig. 1)

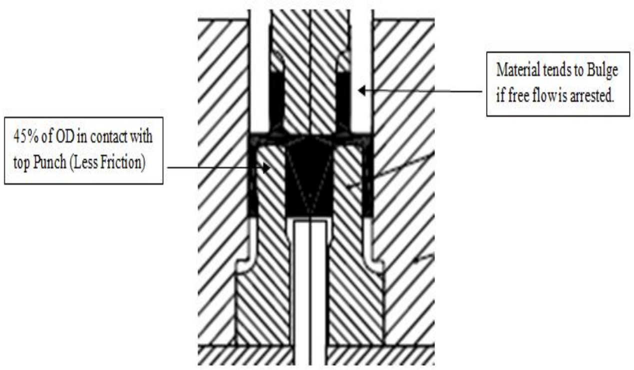

Figure 1: Assembled diagram of initial forward extrusion process

There is the issue of the part sticking to the punch which is because 45% of the outer diameter of the part is in contact with the top punch side because of which friction in this part decreases. Due to a decrease in friction, the part tends to stick to the punch leading to failure. A part stuck to the punch takes up two hours of extra time just to be separated from the punch hence resulting in wastage of production time. The buckling of the slug is due to the fact that there is free flow of material at the punch side. When this free flow is arrested, the material tends to buckle and in turn causes a crack in the Punch Sleeve. A Stock of more than 20mm is left in the slug when not more than 10mm is required. Thus resulting is lot of scrap generation. In order to achieve near net shape forging the process needs to be redesigned so that the excess material movement is eliminated. And other issues are also addressed

B. Eliminating material movement by reverse extrusion

A simple modification die design was not sufficient to address these aforementioned issues. Hence a completely different approach is considered in order to reduce the waste. The modified process that is proposed is that of backward extrusion instead of Forward Extrusion. In Backward Extrusion, also known as Indirect Extrusion, the billet and container move together while the die is stationary. Because the billet moves with the container the frictional forces are eliminated. This leads to advantages such as a 25 to 30% reduction of friction, which allows for extruding larger billets, increasing speed, and an increased ability to extrude smaller cross-sections. The tendency for extrusions to crack is reduced because there is no heat formed from friction. The billet is used more uniformly so extrusion defects and coarse grained peripherals zones are less likely.

Upon further investigation a few disadvantages in this modified process were also identified. But a process is truly optimized only after all the disadvantages are accepted and their effects minimized to meet the standard requirements. The following are the disadvantages of Backward Extrusion. Impurities and defects on the surface of the billet affect the surface of the extrusion. These defects ruin the piece if it needs to be anodized or the aesthetics are important. In order to get around this the billets may be wire brushed, machined or chemically cleaned before being used. This process isn't as versatile as direct extrusions because the cross-sectional area is limited by the maximum size of the stem. Thus all the parts of the process were designed in line with backward extrusion. And simulations were carried out

C. Trial of modified process assembly

After successful simulation of the CAD models, the process was implemented it in the real environment. Before the modified process was applied in the production line, a trial is conducted with all the parameters of the actual process to judge how the modified process performed. A trial is conducted for five days by different operators and the data collected in the trial is illustrated in Table 1

Table 1: Production and rejection data from Trial

Date	Shift	Operator	Produced quantity	Rejection quantity	Accepted quantity	Remarks
21.03.2017	1st	Selvamani	1700	43	1657	43 time job broken
22.03.2017	1st	Mahendran	4986	17	4975	17 time job broken
23.03.2017	3rd	Basker	2355	32	2323	32 times job broken
24.03.2017	1st	Selvamani	9250	87	9163	87 times job broken
25.03.2017	1st	Mahendran	830	103	727	103 times job broken

From the above Table it is clear that, the number of defects have reduced to a great extent in the modified backward extrusion process. But it is also observed that the number of defects increase with time. To attend to the problems occurring in the new modified process, FMEA is employed with an 1-10 scale for severity, occurrence and detection to identify the failure modes in this new process. In Table 2, the

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FMEA has been constructed for the backward extrusion process where failure modes, its causes and control prosesses are graded on a scale of 1-10

Table 2: Failure Mode Effect Analysis of reverse extrusion Priority

Process Function	Potential Failure Mode	Potential Effects of Failure	Severity	Potential Causes of Failure	Occurrence	Current Process Controls	Detection	Risk Priority Number
Positioning of the Slug	Slug not Inserted in correct position	Incorrect part produced	9	Operator not trained	2	Operator training and instructions	5	90
	Slug not held properly	Incomplete plastic deformation	6	Improper machine set up by operator	2	Operator training and instructions	5	60
Forging eqipment setup	Punch not fastened properly	Improper plastic deformation. Incorrect forging force	8	Absence of Pola Yoke.	4	Operator training and instructions	4	128
	Positioning of the die	Incorect part produced due to iproper shape	9	Absence of Pola Yoke.	4	Operator training and instructions	3	108
	Placement of ejector pin	Inability to remove the part	6	Operator not trained effectively	3	Operator training and instructions	5	90
Starting the process	Operator feeding incorrect parameters	Defective part produced or failure of part	8	Operator not trained	2	Operator training and instructions	5	80
During the operation	Cracks on counter punch	Breaking of counter punch	9	Free flow of material beside the punch	7	CNC machining operations	4	252
Removal of part	Part removal by ejector pin	Breaking the part	8	Diameter of ejector pin	7	N/A	4	224

The failures that are arising in this problem with highest risk priority numbers are cracks on counter punch (252) and breakage of part while part removal using Ejector pin (224). In order to deal with these problems, first the cusses that are resulting in the failures are identified. The failures are caused because the free flow of material is now arrested at the counter punch, it causes the counter punch to break. The ejection of the part from the die is not very easy. And also that the part started breaking after the operation on 10 numbers while using the 12mm ejector pin which could mean that the defect is due to the size of the ejector pin. Hence several design modifications are made to eliminate the defects. The counter punch and the die are redesigned in such a way, that the arresting of the free flow is done by the die instead of the counter punch. Since the die has a larger volume than the counter punch, it can easily arrest the free flow without breaking. Cracks in the counter punch are also eliminated. The counter punch was made plain and the die was designed in a stepped manner.

The size of the ejector pin is increased from 12mm to 17mm. This is done to prevent the breaking of the part while ejecting it with the help of ejector pin. At 12mm, the part starts breaking after the manufacture of 10 parts. The breaking of the part happens because at 12mm, the die area friction is more and hence results in breakage. When increased to 17mm, the part didn't break for the manufacture of 125 parts and hence we know that the defect has been eliminated. Air vents are provided between the ejector pin and the counter punch so that ejection is easier. Negative draft is provided in the counter punch, also to make the ejection is made easier. After addressing the issues, the redesigned assembly is implemented. A CAD model was constructed of the entire assembly to check the feasibility of the design. (Fig. 2)

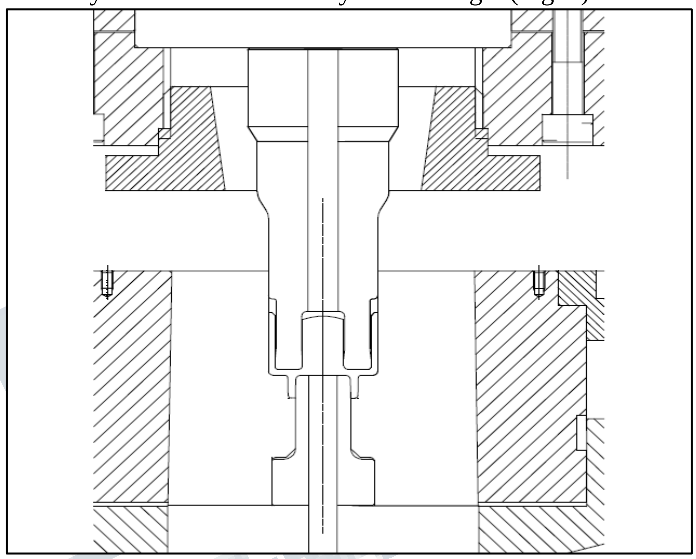

Figure 2: Final CAD model of assembly

III. RESULTS AND DISCUSSION

A methodology is devised with reference to field housing cup to restrict the movement of materials into unwanted runoff in cold forging process. Significant savings in raw material and process cost has been achieved where a reduction in cost and reduction in material wastage was brought about in the extrusion process. There has been a 19.35% reduction in the weight of raw material from 465 grams to 375 grams and the production cost of the part was reduced by 16.15% from initial cost of Rs. 29.89 to Rs. 25.02. Initially a Stock of more than 20mm is left in the slug when not more than 10mm is required. The slug diameter witnessed a reduction in size by 0.6mm from an initial diameter of 58.6mm to 58mm. The cutting burr which was initially at 46.34mm was reduced to 45.70mm. The end bit loss has also been reduced from 20.45mm to 16.83mm. The consumed weight of field cup housing was 531.79 grams and decreased to 437.53 grams after applying the modifications. This led to a decrease in scrap weight from 361.79 grams to 267.53 grams. The tonnage increases from 1897 parts per tonne to 2310 parts per tonne. The weight of raw material that is inserted into the forging machine saw a impactful reduction in size, the initial weight of slug was 465 grams which was brought down to 375 grams thus giving 90 grams of weight saving due to the arresting the material movement of nearly 15-18mm which was usually cut off in fore coming CNC operation. This saving of material weight was carried out by reducing the slug length from 22mm to 18mm (fig. 3). An entire machining operation of CNC cutting is also eliminated thus saving up on resources such as labour, machinery and power. CNC machining tools are produced in the plant itself whereas only the cutter inserts are bought from outside. The cost saved is calculated to be 1.37 Rs per part. the cost of running the machine, skilled labour and electricity should also be accounted for because these overheads are eliminated along with the elimination of parting process. the cost of electricity and manpower came up to Rs 1.86. Sticking of part in top punch and breaking of sleeve is avoided. Buckling of the slug which is due to the fact that there is free flow of material at the punch side is also eliminated by redesigning the process into reverse or backward extrusion.

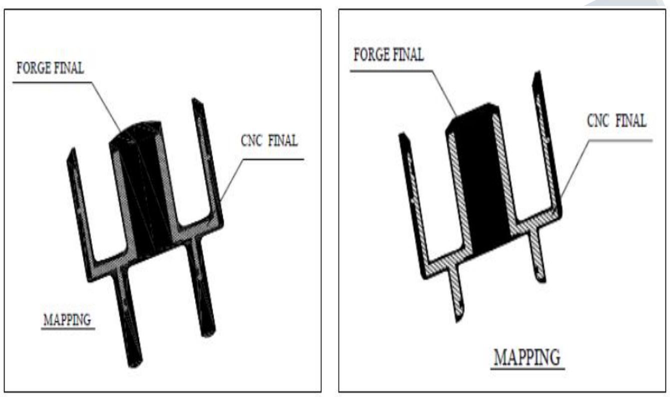

Figure 3: Mapped part before and after forging process modification

Upon the redesign into backward extrusion several other issues were revealed on the trial run. The free flow of material is now arrested at the counter punch, it causes the counter punch to break. Also the part started breaking after the operation on 10 numbers while using the 12mm ejector pin. These issues were counteracted by incorporating several design modifications such as providing the counter punch with a plain surface instead of a stepped surface so that the free flow is arrested by the die and not the counter punch. The die having a large volume can withstand the pressure and not break. Also a negative draft in the counter punch is provided. Since the negative draft will make sure the there are no sharp edges sticking to the part, there will be lesser friction between the part and the counter punch and will result in the part being ejected from the counter punch easily.

IV. CONCLUSION

The process of forward extrusion has many merits but under few circumstances, achieving near net shape forging seems not possible under this method. The application of reverse extrusion is studied and the utilization of such in order to achieve near net shape forging is explored. Backward or reverse extrusion has its merits but also comes with a considerable number of constraints which is why it is not as widely practiced as forward extrusion. This study also discusses such constraints brought up because of reverse extrusion and is overcome. Near net shape forging is the ideal result every manufacturing industry strives to achieve and this study helps understand and overcome few of the design restrictions that hinder the achievement of near net shape forging. Further research is possible in this field where alternate methodologies could be developed for other geometric figures which cannot be formed without machining out certain amount of metal from the slug.

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