Punch Life Improvement in Cold Forging of Nut

Raja V[1], Sornakumar T[2]
[1] Assistant Professor, Department of Mechanical Engineering
[2]Professor, Department of Mechanical Engineering
Sri Ramakrishna Institute of Technology, Coimbatore, India
Thiagarajar College of Engineering, Madurai, India

***Abstract* — Almost all fastener manufacturing industries are using metal forming process to manufacture nuts and bolts. Most of their operations depend on tools such as punches and dies, hence maintaining tool life as much as maximum will increase the profit margin. Punch service life, which defined as the maximum number of products produced before it fails. This paper focused on methodology to improve the punch life in cold forging of nut. Production cost is one of the major concerns in cold forging industry. Punches will fracture during extrusion and upsetting process. The metallurgical investigation of fractured extrusion punches shows brittle mode of failure. The impact properties of punch materials need to evaluate to control the brittle fracture. It is important to note down that the impact strength increases with decreasing hardness. Hence by changing tempering temperature it is possible to change the hardness of the punch material.**

***Keywords*— Punch life, Cold forging, Impact strength, Hardness and Tempering temperature**

I. INTRODUCTION

In cold forging process, there are five stages of metal forming operation required to produce a nut. In each stage there will be a formation on punch side and die side. So the transfer mechanism is required to rotate the workpiece 180^0 at each intemediate stages. The Figure 1.1 shows the sequence of nut forging. The number at the top of the figure represents the stages or stations. At 0^{th} stage the raw material (10 B 21) is cut off to 9.21mm length and 18 mm diameter to produce standared M12X1.75 nut. At 1^{st} stage the free formation carried out on punch side and die side. And the transfer mechanism is required to change the side of the raw material. Finally at 5^{th} stage, the required dimensioned nut has been produced except internal thread.

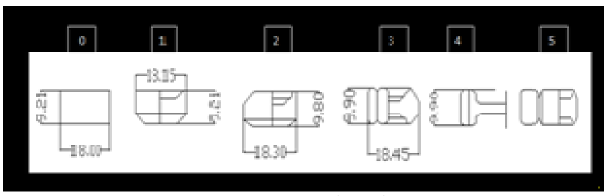


Figure1.1: Stages of nut forging

Out of 5 stages, the extrusion punch (3^{rd} stage) has to extrude and upset the raw material to a specified dimension. Hence, this punch should properly heat treated and surface treated.

The life of extrusion punches is very low as compared to other punches. Table1.1 presents the approximate punch life (in terms of number of nuts produced) taken from the cold forging industry.

Table 1.1: Punch Life

Stages	Punch life (number of nuts produced / punch)
1	130000
2	80000
3	**25000**
4	75000
5	75000

Hence the aim of this paper is to improve the life of 3^{rd} station punches without increasing the punch production cost so much. There have been several literatures referenced to explore the importance of impact loading in cold forging tool materials.

The Cold forging process is characterized by high forming and a high impact on the tool; therefore, the materials that are selected for cold forging tools have to be of high strength and high toughness [12]. Y.Zhang et al [12] conducted strain controlled fatigue test on Cr-Mo-V matrix type HSS at room temperature. Ryuichiro Ebara [8] presented the paper on Fatigue crack initiation and propagation behavior of cold forging die steels with respect to steel hardness. M. Dubar et al [6] Conducted wear analysis on AISI M2, and concluded that the CVD coating provides better performance than the PVD coating. K.V. Sudhakar [5] analyzed the fractrographic microstructures for extrusion die punches. It was observed that the fracture toughness property of the material should be evaluated rather than evaluating the material property with hardness. Yi-Chi Lee, Fuh-Kuo Chen [4] investigated the fatigue life of cold forging tools with respect to change in hardness property of the material. The relationship between the tool material properties such that yield strength, fracture strength and material hardness were constructed for various tempering temperature.

The research gap identified that the effect of impact property in cold forging tools should be analyzed. In this study, the comparison between existing (AISI M2) and selected high speed tool steel (AISI M42) were investigated. The most of cold extrusion punches being fractured in brittle nature. The Figure 1.2 presents the brittle fractured cold extrusion punches of material AISI M2 and their relative hardness in the range of 58-62 HRC.

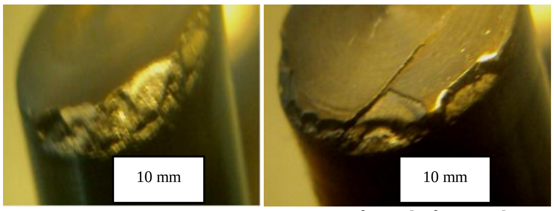


Figure 1.2: Macro view of Brittle fractured Punches

II. PROBLEM FORMULATION

In total production of a forged product, around 30% of cost incurred for tool production. Hence, it is important to notice tool life while performing forging operation. The forging machine has the ability to produce 155 nuts / min, but frequent stoppages due to punch failure, the production rate reduced to 137 nuts / min. In the competitive environment the tool maker should produce punches at low cost, but without degrading its quality. In the current forging industry, the punch material AISI M2 is purchased at annealed state.

The chemical composition (wt %) of AISI M2 (Material A) is given in Table 2.1. In order to increase the hardness of the material, it is first hardened by heating the material to austenite state and then sudden cooling or quenching with nitrogen gas. After hardening, the material hardness obtained in the range of 64-66 HRC. In order to reduce the retained austenite and increase the ductility of punch material, the process of tempering is important to consider.

Table 2.1: Chemical Composition of AISI M2

C	Mn	Si	Cr	Ni	Mo	W	V
0.92	0.3	0.3	3.5	0.3	5.2	6.0	2.0

Hence it is important to select the materials having high toughness and high hardness and also consider the availability of that particular material for an industry. The red hardness of the punches is primarily due to the presence of tungsten (W), chromium (Cr), vanadium (V) and molybdenum (Mo) [5].

III. METHODOLOGY

The adopted methodology is to increase the production rate but without increasing the cost of the product. By selecting appropriate punch material and effective heat treatment provides better life.

3.1 Material Selection

The alternative punch material was selected from the available punch material as AISI M42 (Material B) against the conventional punch material AISI M2. This material has greater amount of cobalt, molybdenum and carbon than the conventional material. The chemical composition of material B is given in Table 3.1.

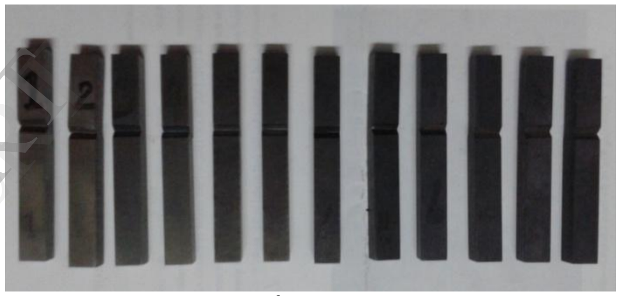
Table 3.1: Chemical Composition of AISI M42

C	Mn	Si	Cr	Ni	Mo	W	V	Co
1.08	0.21	0.18	4.03	0.3	9.72	1.64	1.06	7.59

Higher the content of molybdenum increases hot hardness, hardenability and toughness of the material. Cobalt content increases hot hardness and wear resistance of the material.

3.2. Experimental Setup

The Izod-impact test specimens have prepared for various tempering temperature [4]. The Figure 3.1 shows the impact test specimen. Top side of punch has been attached with punch holder, so this set up assumed as a cantilever, then the izod impact test had been selected for the analysis.



Before impact

After impact

Figure 3.1: Izod Impact Test Specimens (ASTM E23)

3.3 Tempering process

The samples further allowed for hardening and tempering processes. The hardening of AISI M2 has following stages,

First Preheating	- 650°C
Second preheating	- 870 °C
Third preheating	- 1050 °C
Austenising	- 1200 °C
Quenching	- Nitrogen

And the hardening of AISI M42 material has the following stages,

First Preheating - 650°C
Second preheating - 870 °C
Austenising - 1180 °C
Quenching - Nitrogen

For both materials, during hardening, the transformation of Austenite-Pearlite-Martensite [4] is required. The tempering temperature for material A is 530 - 570 °C. Hence, the range of tempering temperature was set to 200 - 700 °C for both the materials. To control retained austenite and increase ductility of the material, 3cycle tempering has been followed. The soaking time at every cycle set as 30min [4].

3.4 Hardness Test

Hardness test was done by using Digital Rockwell hardness tester (RASN-E) with Diamond ball indenter of 150 kg (hardened tool steels 'C' scale). This hardness is taken at three different surfaces of the impact test specimen and the precision value has been taken for the further analysis. The results were plotted in the graph, and the Figure 3.2 represents the hardness value against the varying tempering temperature.

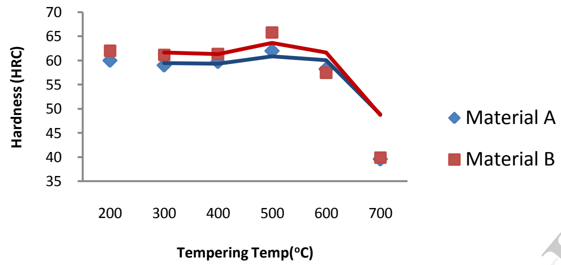


Figure 3.2: Hardness Vs Tempering Temperature

3.5 Impact Test

The impact test has been taken out in Izod-impact Testing Machine (300N). The samples of at different tempering temperature are prepared for the impact test. At each temperature two samples were taken and their average impact strength (Joules) is taken and plotted in the Figure 3.3.

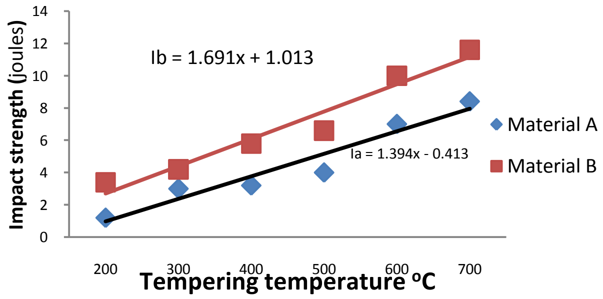


Figure 3.3: Impact strength Vs Tempering temperature

From the results, observed that the impact strength of the material B is higher than material A for the same tempering temperature. Impact strength is determined from the amount of energy required to fracture specimen. The Figure 3.4 represents the effect of izod-impact value changes over changing the hardness value by varying the tempering temperature.

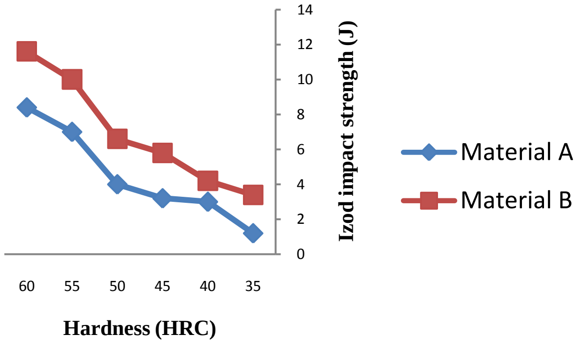
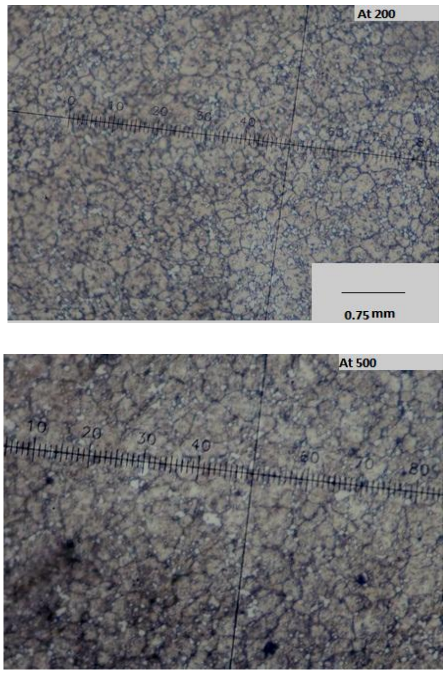


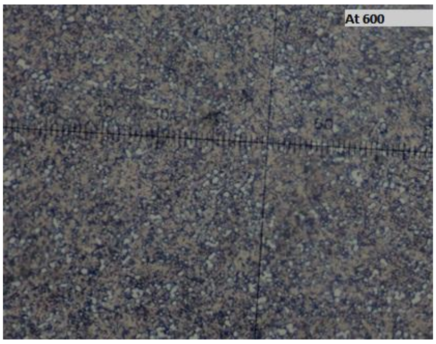
Figure 3.4: Izod impact strength Vs Hardness

The above graph shows that the effect of izod-impact strength for varying hardness of the punch material. Both Material A and Material B were increasing with increasing hardness. At the same time, the material B having greater amount of absorbed energy for the same hardness achieved in material A. hence Material B (AISI M42) is selected as a best alternative punch material as compared to Material A (AISI M2).

3.6 Microstructure

Microstructure analysis had been taken from metallurgical microscope. Fig 3.5 shows microstructures of material B at 200,500, 600 and 700°C.





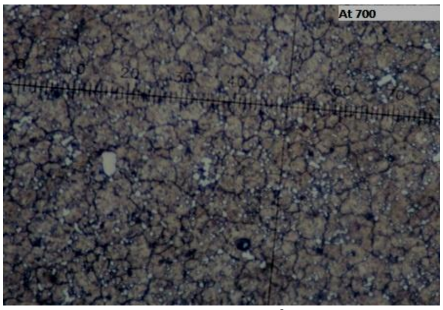


Figure 3.5: Microstructure of AISI M42

The correct temperature for material A was found as 550-570°C. At 700 °C, the structure becomes carbon growing; hence this effect leads to decrease the hardness property of the material. By analyzing its microstructure, it was found that the temperature between 500-600°C becomes best structure. The even distribution of carbon and iron in martensite provides better strength to the material.

IV. RESULTS

For molybdenum based tool steels (M-type), the tempering temperature ranges from 550-590°C becomes best combination of hardness and microstructure. Table 4.1 shows punch life for different trials.

Table 4.1: Punch Life at Different Trials

	Trial 1	Trial 2	Trial 3
Tempering Temp °C	520	550	570
Hardness HRC	62.9–64.8	65.6 – 66	63.4 – 65.2
Punch 1	31256	62675	42651
Punch 2	27805	67893	46547
Punch 3	25729	63543	39265
Average Punch Life	**28263**	**64703**	**42812**

The total cost incurred for producing punches including material cost, machining cost, heat treatment cost, CVD coating cost and polishing cost. Table 4.2 presents the various cost incurred for producing punches.

Material cost = Raw material cost (Rs) / Kg X Material Weight (Kg)

For material A = 750 x 0.28 = Rs 210
For material B = 1500 x 0.28 = Rs 420

Table 4.2: Cost Estimation

Particulars	Material A	Material B
Material Cost (Rs)	750x0.28 = 210	1500x0.28= 420
Machining Cost (Rs)	220	220
Heat Treatment Cost (Rs)	77	77
CVD (Rs)	308	308
Polishing Cost (Rs)	120	120
Total Cost / Punch(Rs)	**935**	**1145**

The total cost for preparing Material A is Rs.935 and for Material B is Rs.1145. Punch producing cost for Material B is increased to 22.45% compared to Material A. Hence an extra cost required for material B is 210 / punch. Eventhough the material cost is increased for material B is compensated and advandageous when comparing the punch replacement cost. Table 4.3 presents the effect of punch replacement cost.

Table 4.3: Cost Savings

Particulars	Material A	Material B
Cost/Installation (Rs)	935	1145
No. of Replacements/day	12	4
Total installation Cost/day (Rs)	11220	4580
Total Savings/day (Rs)	-	**6640**

Due to failure occurred in third station punche, the number of replacing and installing new punches has been increasing daily. If the 3rd station punches replaced for every 20000 pieces, then for 1 shift, it should be replaced 12 times daily. Due to this problem, the change in installation after every failure increases operator's fatigue.

For material A = 12 punches / day
For material B = 4 punches / day

The absorbed impact energy is more for material B compared to material A. Hence material B's replacement cost decreases and the total savings increases. Then, the operator fatigue decreased and the scrap due to punch failure were decreased.

Table 4.4: Production Rate Comparison

Particulars	Material A	Material B
Production Rate / min	137	144
Production Quantity / day	197280	207360
Increased Production Quantity /day	-	**10080**

By replacing the material A with material B the prodction quantity is increased. The rate at which the productionincreases is given as,

% rate of production increased / day = 5.11 %.

V. CONCLUSION

The fractured punches shows that the failure occurred due to inability to withstand impact strength. Hence, the material having high impact property had been selected and the material also checked for, in which hardness and tempering temperature the impact strength is higher for the material. The graph between impact strength Vs tempering temperature and impact strength Vs hardness were presented. Then, the microstructure of selected punch material and the using material at different tempering temperature is given. The microstructure shows the optimum tempering temperature is lies between 500- 600^{o}C. Then the test trials were conducted at these tempering temperatures. From the trial results, the material (AISI M42) hardness between 65.6-66 HRC gives better result compared with other trials and material A also. Therefore the tempering temperature for AISI M42 is kept at 550 ^{o}C gives better life. Production rate is increased by 5.11% per day. And, the cost savings by changing the material is obtained as Rs. 6640 per day.

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