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Developing the Effect of Hot Forging Parameters Material Flowing in Closed Die

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Abstract:- This research will investigate the effect of operating parameters in the hot forging process on material flowing in closed die forging and get the quality of the workpiece including mold die performance by using computer simulations to assist in the analysis. Hot forging of symmetrical workpieces around an axis and the general numerical model were validated by comparing them with the comparable experimental data. The effect of both types of parameters were then studied such as tapered angle and punch radius which are parameters in the part of closed die designing and study the effects of the load. It is a parameter in the production process. The stresses, strains, and forces acting on the mold die were compared. Based on the investigation, a new mold design approach for such parts has been proposed, which can increase the height by 50% from the original factory utilization.

Keywords*: Closed die design, Hot forging process, Effect of parameter*.

1. Introduction

Hot forging process applied in the automotive part manufacturing that product has not complicated shape. The advantage of hot forging is that workpieces have high finished and tolerance surfaces. The other benefit is less waste material and energy consumption because the hot forging process is high-temperature forging thus It greatly affects the material flowing[1], [2],.

The mold design process is an essential step. Various parameters both for mold and production process that must be designed properly designed to allow better metal flowing and to reduce friction to the desired part. in order to obtain a work piece without defects Such parameters can be classified as Parameters for the mold (Die Design Parameters) and parameters for the production process. as shown in Fig. 4

For the designed parameter, it is related to the dimension and geometry of the closed die. From the literature review, it has widely many published papers about how to implement finite elements in the hot forging process. This method predicts high-accuracy results such as analyzing the effect of press on the thickness of the flashing workpiece, the effect of flashing on material flowing, die wearing and model validation with experiment therefore the author needs to study the effect of parameters on the step-by-step of hot forging process. In this article, this work will investigate parameters such as taper die angle, fillet radius, and friction coefficient. Method of this work, Firstly, the finite element and finite volume software will be implemented to develop a mathematical model and validate it with experimental data. Secondly, a mathematical model will be applied to run the sensitivity analysis. Finally, it will be the conclusion step.

2. Objective

1. To investigate problems in the hot forging process.
2. To find a solution for solving the effect of parameters in hot forging process.

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3. Methodology

3.1 Work piece

The final product is automotive part in seat that make from a curve bulk pipe. Material was used S45C. Dimension and shape are referred to as Figure 4. When the hot forging operation is completed. It needs to operate cutting and milling.

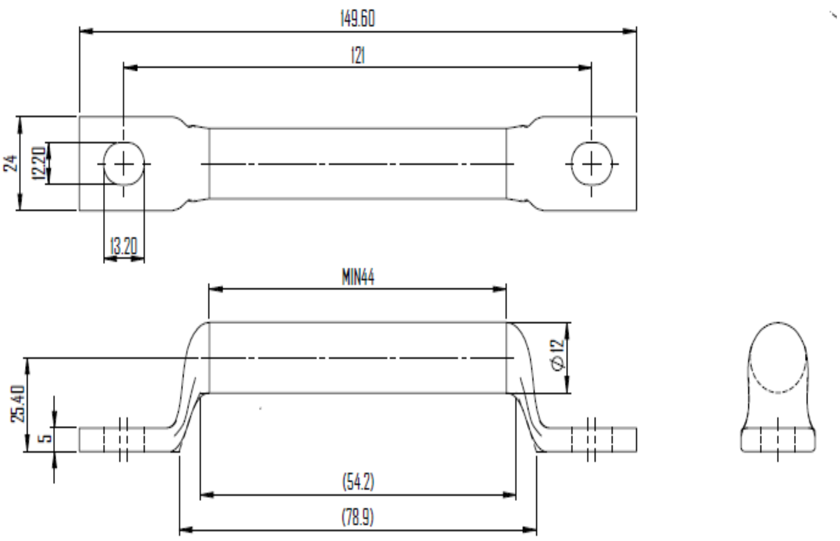

Fig 4 Finished product after hot forging operation

3.2 Characteristic shape of closed-die forging

Designing the method of closed-die forging in this work which consists of an upper die and lower die. Those mold dies have curved parts and closely combine. The upper die and lower die have convex curvature and inner concave curvature respectively.

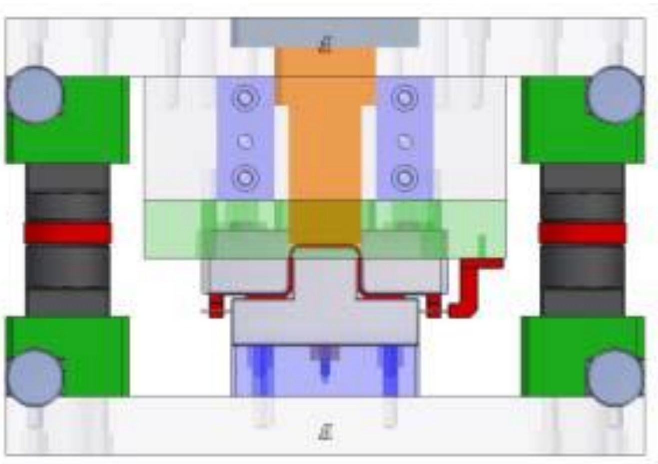

Fig 5 U-shaped mold die

3.3 Mold die testing

For mold die testing, it installs a mold die-on press machine from NCM company L200 edition that has a press load of 250 Tons and packaged load cell. The load press machine is shown in Fig 6.

Stroke Length 160 mm.

Capacity 250 Tons

Stroke per Minute 95 s.p.m

Die Height 300 mm.

Tonnage Rating Point 15 mm.

Slide Adjustment 10 mm.

Main Motor 30 Hp x 4 p

• diameter round shaft 12 mm

length 145 mm

Fig 6 Mechanic press machine

3.4 To find mold die block size

The chart method in Table 1. was implemented to find mold die block size. Engineer can select mold die height (h), minimum thickness (a) and minimum mold die height (H). The lower die has a mold die height of 35 mm therefore mold die block height (h) is 180 mm and the minimum thickness(a) is 50 mm. The upper die has a height of more than H because this cavity has some curvature. The height of the upper die is 160 mm and the minimum thickness(a) is 50 mm but both the upper and lower die need to be assembled in the Die set machine which has a height of around 45 mm and a total height of equipment for closed die forging is 200 mm. The material workpiece has yield strength lower than the mold die. It needs to modify the lower die as 64 mm and the upper die height as 46 mm and other details as shown in Fig 6.

Table 1 Die Block size [1]

h, mm (in)	a, mm (in)	a_1, mm (in)	H, mm (in)
6 (0.24)	12 (0.47)	10 (0.39)	100 (3.94)
10 (0.39)	32 (1.26)	25 (0.98)	125 (4.92)
40 (1.57)	56 (2.20)	40 (1.57)	200 (7.87)
100 (3.94)	110 (4.33)	80 (3.15)	315 (12.40)

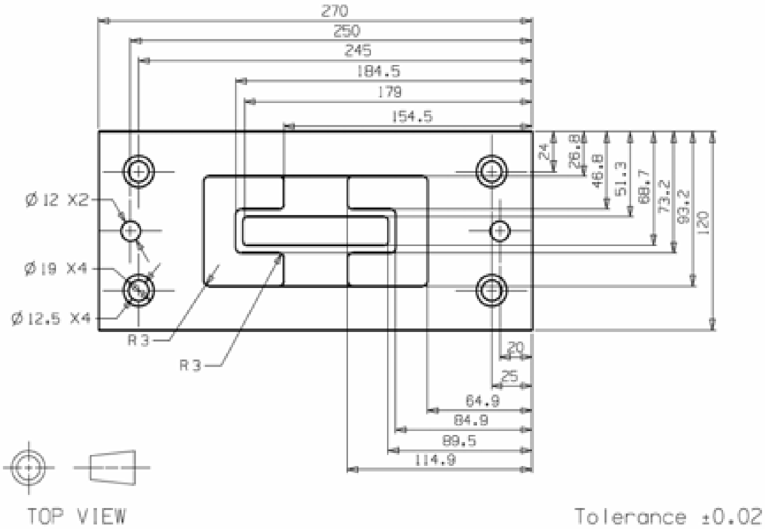

Fig 6 Top view of the lower die

3.5 Tolearance of the mold die cavity

Tolerances of the mold die cavity can be found with material shrinking combined misalignment of the mold die and minus with die wear. The aluminum material shrinking depends on a temperature deviation of 1 % when it is minus room temperature. workpiece weight is no more than 4.5 kg, tolerance of mold die is 0.4 mm and tolerance of mold die cavity is 4 %.

4. Effect of Material Testing at High Temperature

4.1 The validation of the forging simulation result

To validate mathematical models from finite element software. It needs to be compared with experimental data from the manufacturing process as Fig 8

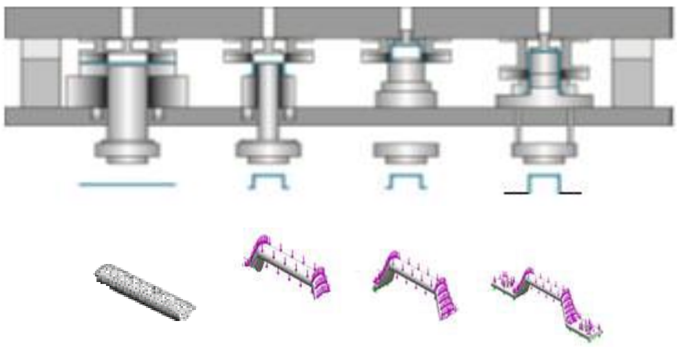

Fig 8. Material flow of multistage hot forging process

The comparison of sleeve piston wall has a difference height of around 3 % or it matches with numerical data. The material flow of each machine operation is shown in Fig 8. The billet diameter is more than the mold die diameter therefore it did not contact with the lower die. When the punch slides down at 35 % total distance of the punch operation. The workpiece did not contact with the lower die and material flow had a constant value of 58 % when the workpiece contact with the lower die. It slows down because of limited constraints of lower die stroke. During punch contact with the workpiece. It has fast material flow back at the cavity zone of the side of the punch near the center base of a workpiece. It has low material flow when punch stoke reaches to lower die. Fig 9. shows stress and temperature distribution during machine operation. It reveals that the right side of the workpiece has the high strain and high strain at the outer side of the workpiece because this zone has a high strech section from high operating temperature. This zone is like a hot spot and plastic deformation region. The angle of the punch has a high temperature and hurts mold die lifetime. From the simulation result, the angle zone of the mold die is considered to be critical region Fig 9. shows the diaram of punch force at z direction which has high force at the outer punch during the first step of operation because the workpiece did not contact with lower die at the initial process. The punch force acted on the outer punch, but the workpiece contact with the lower die. The force in the z-direction has suddenly increased as Fig 9. It shows that the workpiece wall increased the force in the z-direction of the outer punch.

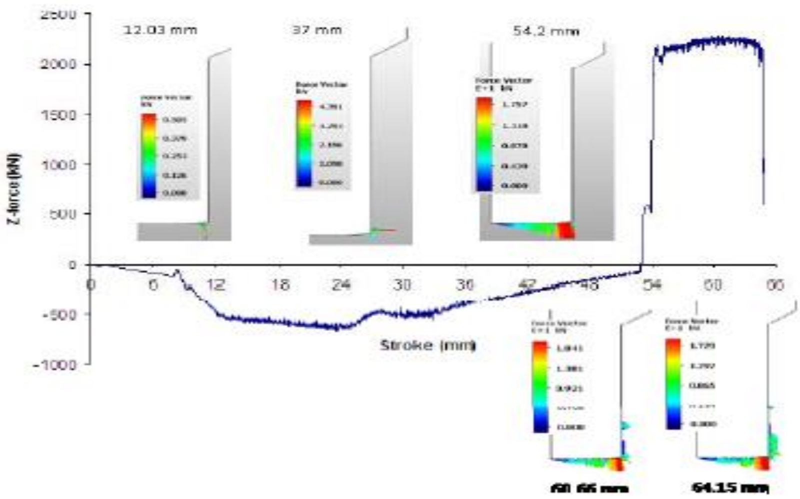

Fig 9. Diagram of punch force in the z-direction.

4.2 The material testing at high temperature

The flow curve of the workpiece material was tested by experiment testing. In the hot forging process, it needs to collect data and create a flow curve of a workpiece that shows stress-strain in Fig.10

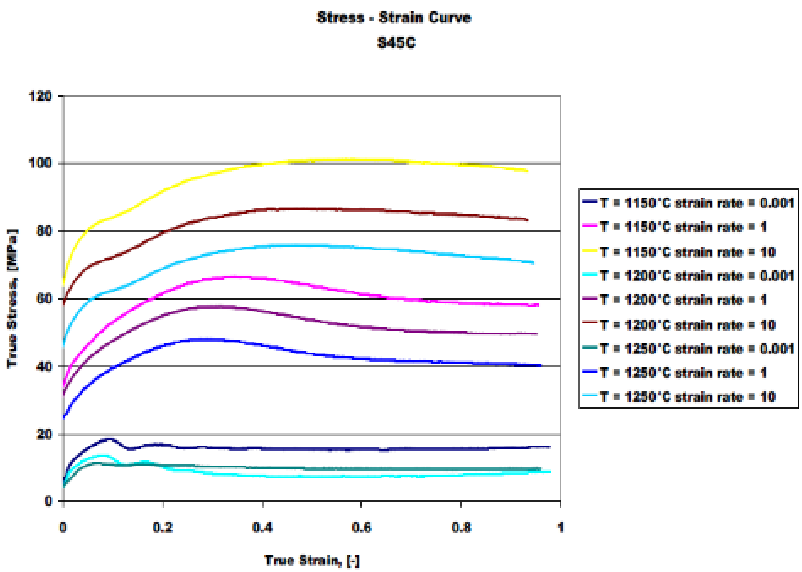

Fig 10. Flow curve of material workpiece S45C at different temperature

When it receives stress-strain curve of workpiece to build constitutive equation. The correlation can use to explain material behavior and has consistency and best fit with mathematical mode from finite element software. The model testing was done by the least square regression method. Finally, it gets all parameters at different temperatures and strains as Table 2 All parameters input filled in simulation software and extrapolated to find material strength when the strain rate data range has no numerical value in the experimental database. Fig 11.

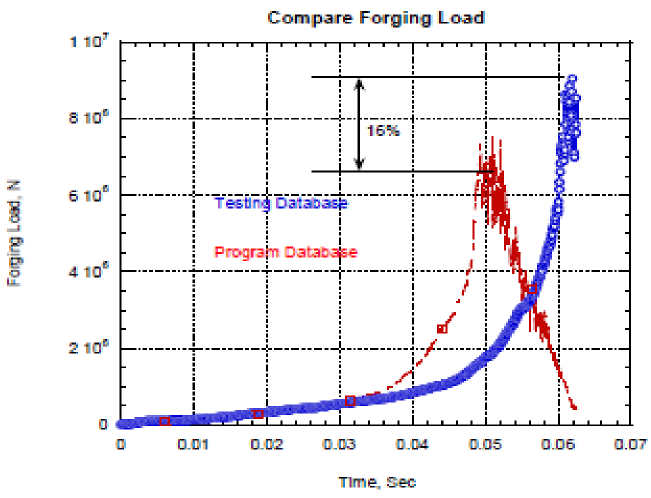

Fig 11 The comparison between the forging load of simulation software and experiment.

4.3 Numerical result

The result of finite element software shows forging force on workpieces and closed die in the hot forging process. This solution can be implemented to analyze material flow and reduce scrap material. The procedure step of the finite element method is defined boundary condition to the scope of research work because the workpiece position is not proper and placed at the center of gravity in the hot forging manufacturing process. This is the root of the cause why high stress and stress concentration on the workpiece during machine operation. Fig 11.

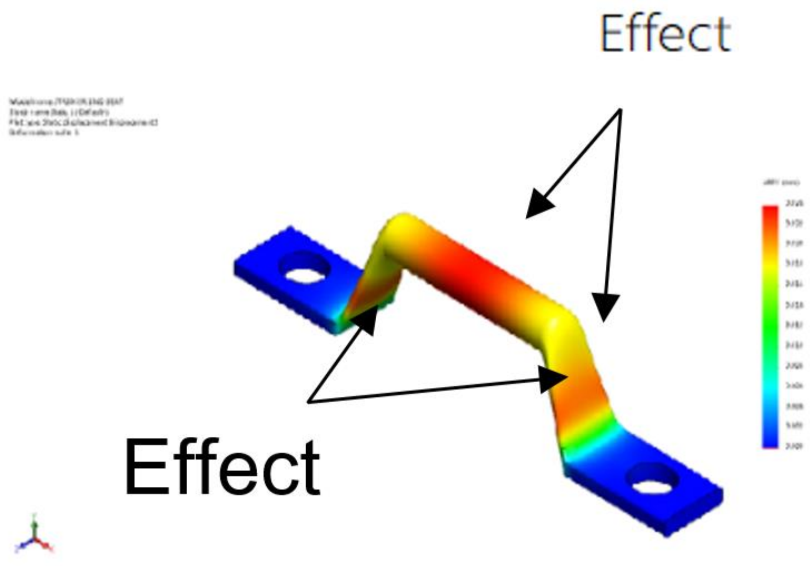

Fig 12. Effect of hot forging parameters on the shape of the workpiece

4.4 Effect of closed die parameters on workpiece deformation

This article investigated the effect of closed die parameters such as taper angle, friction coefficient, and punch fillet. It found that increasing the friction coefficient has enhanced both effective stress and effective strain however it was not significant when it increased the friction coefficient from 0.05 to 0.1, fluctuation result is around 9%. When it considers and compares workpiece height It found that effective stress and strain have increased 0.3 %. If it considers punching forging force is changing 14 %. The effect of the taper angle is revealed by the adjusted taper angle with the friction coefficient at 0.1. If it enhanced the taper angle from 0 to 15 degrees. The workpiece height increased too and had a difference result of around 5.4 %. The trend of effective stress and effective strain is decreased by 40 % and 1.9 % respectively as Fig 13. but if it considers radial stress (x direction) and axial stress (z direction). Radial stress and axial stress have increased 35 % and decreased respectively however punch force decreased trend when the taper angle increased from 0 to 15 degrees. Radial force and z-force differed 35% and 2.6 % respectively.

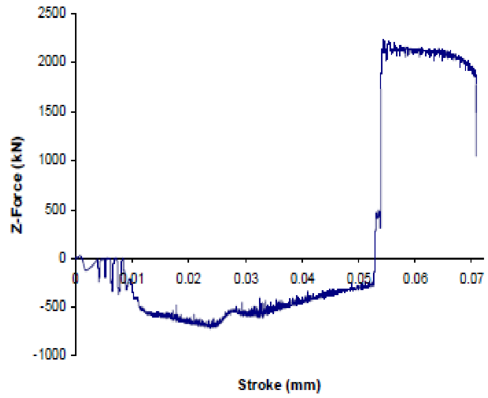

Fig 13 Punch force (a) z direction (b) y directions

Adjust the punch filler with a taper angle of 15 degrees and friction coefficient of 0.1. It was found that increasing fillet radius affected workpiece height which was enhanced when it compared fillet radius from 1 mm to 5 mm. The effective strain and effective strain have increased by 2.8 % and 22 % respectively as Fig 14. Punch force in the radial direction has increased and enhanced workpiece height with punch stroke down. This operation has suitable stress and strain and minimal effect on punch. Adjust the taper angle to 8 degrees and friction coefficient to 0.05 and increase punch force. It revealed that workpiece height has increased by 18%, effective stress was decreased and a little bit of an effective strain was as Fig 14. but at outer punch has a high strain concentration and the temperature increased too. If it is considered a punch force in the z-direction. It found that punch force in the z-direction and radial force increased by 1.85 % and 25 % respectively.

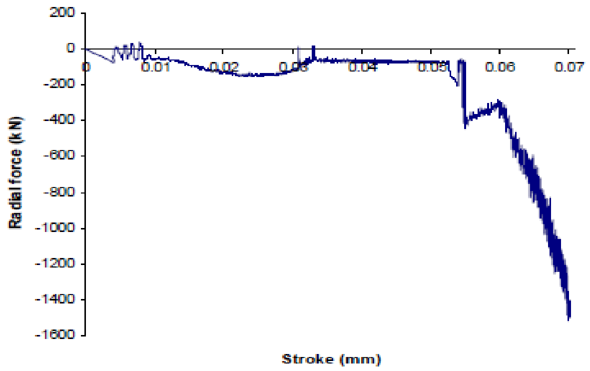

Fig 14. Radial force on punch (a) z direction (b) x direction

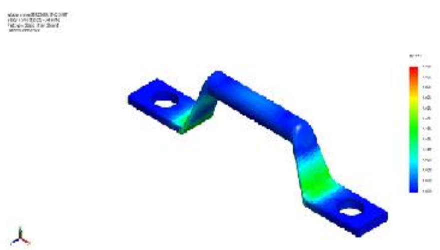

Fig 15. Full product after optimization hot forging process parameters

The exact solution of simulation software was simulated workpiece deformation from consistent shear force

5. Conclusion

Hot forging parameter investigation studied friction coefficient, taper angle, and punch radius. The result revealed that increasing friction coefficient has enhanced effective stress, effective strain, and forging force of punch. All output variable has an increased trend, but it is not significant on workpiece height. The effect of the taper angle is a positive effect on effective stress and effective strain but it hurts the forging force of the punch, and it is not significant on workpiece height. For fillet radius punch radius, it is not a significant parameter in hot forging process. Finally, all parameters were investigated and applied to improve the final product. The outcome is enhanced product height by around 10 % with know-how.

6. Recommendation

6.1 The hot forging process must operate at a temperature range of 900 – 1,100 C. It can be manufactured with high strain and no product is damaged or cracked during operation. If it operates at low temperatures at 700 and 800 C. High strain rates occur at the product surface which leads to surface cracking.

6.2 Metal microstructure has highly affected on cooling rate therefore it needs to improve product structure quality and continue research work on microstructure analysis and good mechanical strength.

Reference

[1] Lange, K. (1985). Handbook of Metal Forming, McGraw-Hill, New York.

[2] Heinz Tschaetsch, (2006). *Metal Forming Practise*, Springer-Verlag Berlin Heidelberg, Germany.

[3] F. Fereshteh-Saniee, A.H. Hosseini, (2006) .Journal of Materials Processing Technology **The effects of flash allowance and bar size on forming load and metal flow in closed die forging,** VOL 177, Issues 1-3, P (261-265)

[4] Chun-Yin Wu, Yuan-Chuan Hsu, **(2002).** Journal of Materials Processing Technology. **The influence of die shape on the flow deformation of extrusion forging**, VOL 124. Issues 1-2, P (67-76)

[5] T.R. Raghavendra Rao, S.K. Biswas. (1979) Journal of Mechanical Working Technology **Experimental investigation of die wear in small-batch hammer-forging under unlubricated.** VOL 3. Issue 2 P (137-150)

[6] F Fereshteh-Saniee, M Jaafari, (2002).Journal of Materials ProcessingTechnology **Analytical numerical and experimental analyses of the closed-die forging**, VOL. 125-126. P (334-340)

[7] Berna Balta (2016). Materials & Design. **Optimization of process parameters for friction weld steel tube to forging joints**, VOL. 103 (P 209-222)

[8] F. Fereshteh-Saniee, A.H. Hosseini, (2006). Journal of Materials Processing Technology. **The effects of flash allowance and bar size on forming load and metal flow in closed die forging**, VOL 177, Issues 1-3, P (261-265)

[9] F. Fereshteh-Saniee, M Jaafari, (2002) Journal of Materials Processing Technology. **Analytical, numerical and experimental analyses of the closed-die forging**, VOL 125-126, p (334-340)

[10] Heimlund O. and S. Tjøtta, (1992)..Journal of Materials Processing Technology **Finite-element simulations in cold-forging process design**, VOL 36, Issue 1, P (79-96)

[11] Heinz Tschaetsch.(2006). *Metal Forming Practise*, Springer-Verlag Berlin Heidelberg, Germany.

[12] Juan Liu. (2009). **Journal of Materials Processing Technology**. Hot forging process design and 2 parameters determination of magnesium alloy AZ31B spur bevel gear, VOL.209. P (5871-5880)

[13] Kim M. H., H. Y. Cho, G. S. Min and C. Y. Jo, (2003). Journal of Materials Processing Technology **Process design of the cold forging of a billet by forward and backward extrusion**, VOL 135, Issues 2-3, Pages (375-381)

[14] Kobayashi, S., Oh, S.I. and Altan, T. (1989). Metal Forming and the Finite Element Method,

[15] Lange, K. (1991). Handbook of Metal Forming, **McGraw-Hill**, P (13.1-15.93)

[16] Martin Franzke (2008). steel research international. **Development of a Process Model for Online-Optimization of Open Die Forging of Large Workpieces**, VOL. 79 (P753-757)

[17] Monaghan J. and C. Mc. Cormack. (2001). Journal of Materials Processing Technology**. A finite element analysis of cold-forging dies using two- and three-dimensional models**, VOL 118, Issues 1-3, Pages (286-292)
[18] Pedersen K. and O. Jensrud, (1998). Journal of Materials Processing Technology**. Cold forging of high strength aluminum alloys and the development of new thermomechanical processing,** VOL. 80-81, P (156-160)
[19] Pinaki Talukdar (2015). Applied Mechanics and Materials. **Optimization of rocess Parameters in Hot Forging of Medium Carbon Micro-Alloyed Steel**, VOL. 813-814. P (563-568)
[20] Pinaki Talukdar.(2015). Applied Mechanics and Materials. **Optimization of Process Parameters in Hot Forging of Medium Carbon Micro-Alloyed Steel**, VOL.813-814. (P 563-568)
[21] R.E. Winch. (1970). Production Engineer. **Hot forging processes**, VOL.49 (P 369)
[22] Ryszard Dindorf (2020). Energies. **Energy-Saving Hot Open Die Forging Process of Heavy Steel Forgings on an Industrial Hydraulic Forging Press,** VOL.13 (P 1620)
[23] Shimon KADOYA (2021). Transactions of the JSME (in Japanese). **Process parameters optimization for minimizing risk of crack and forging energy in cold forging**, VOL. 87 P (20-00370-20-00370)
[24] T.R. Raghavendra Rao, S.K. Biswas. (1979) Journal of Mechanical Working Technology.**Experimental investigation of die wear in smallbatch hammer-forging under unlubricated**, VOL. 3, Issue 2, P (137-150).