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Simulation and Experimental Analysis of Combined Extrusion Forging

Prakash Kumar Gupta-Madhur Srivastava

[1]M.*Tech (CAD CAM) Scholar, Department of Mechanical Engineering, Ambalika Institute of Management & Technology, Lucknow, Uttar Pradesh, India*
[2] *Assistant Professor, Department of Mechanical Engineering, Ambalika Institute of Management & Technology, Lucknow, Uttar Pradesh, India*

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Abstract- The modern manufacturing sector faces several obstacles in its quest to create goods with high strength, low production costs, and resistance to heat, corrosion, and fatigue. When compared to other manufacturing processes like machining, casting, etc., the combined extrusion-forging method is used to overcome these issues by achieving enhanced material qualities, high production rates, and reduced material waste. The Combined Forging and Extrusion Process is a sophisticated method of metal formation in which the required result is obtained by forcing an initial billet through die punch setups for both extrusion and forging. The shape of dies, the percentage area reductions, and the frictional conditions at the workpiece/die contact are the key determinants of the metal flow pattern. Because of the complexity of the study and the sheer quantity of process elements involved, generating load estimation in this process can be challenging. It is widely used in the aerospace and automotive sectors. The current study focuses on estimating the forming load required to employ this procedure to make the product, a collet chuck holder. Both computational and experimental study have been done on the metal flow pattern and die cavity filling. For 3D modelling, Solidworks is the modelling programme of choice, while Deform3DTM is utilised for Simulation. Numerous experiments have been conducted in order to compare the outcomes of the Simulation process. There is a strong correlation between the outcomes of the Simulation analysis and the experimental.

Keywords: Finite Element Analysis (FEA), forming load, metal flow pattern, effective strain, Combined extrusion and forging process, and extrusion forging process.

1. INTRODUCTION

In addition to their strength, availability, and other qualities, metals are important in modern technology because they are easily moulded into useful shapes such as sheets, rods, and tubes.

Three basic procedures may be used to make extensive use of metal shapes:

- By metal casting, which involves preparing and pouring molten metal into a mould.
- By use of plastic deformation process, which maintain the mass and quantity of metal, the metal moved and flowed plastically in different directions.
- By machining procedures, which involve removing material to form it into the appropriate shape, or by removal of metal.

Application of the Combining Extrusion and Forgingmethod to a collet chuck holding is a manufacturing method that combines two different processes into one high-quality product.

A billet of material is driven through a die during the extrusion process to create a continuous profile with a consistent cross-section. This technique is often used to produce tubular or cylindrical objects with good surface polish and regular proportions.

In contrast, The process of forging metal involves applying high compressive forces. Usually, the material is heated to increase its malleability before being pressed or hammered into the required form. By aligning the grain structure and enhancing the material's strength and toughness, forging may improve its mechanical qualities.

Manufacturers may achieve higher mechanical qualities, dimensional precision, and surface polish in collet chuck holders by combining the benefits of forging and extrusion. This hybrid technique ensures the durability needed for demanding applications and enables the economical manufacturing of complicated forms with tight tolerances.

A number of procedures have developed for specific uses in metal working. These procedures can be divided into a few groups according to the kinds of forces that are applied to the workpiece. The following are these categories:

Compared to casting and machining, deformation methods yield metal geometries with superior mechanical qualities. Advanced metal forming usually involves casting the metal into a shape that is almost identical to the final product, then further deforming it into the desired shape. In this approach, the number of stages in the deformation process may be minimised, leading to more consistent metal deformation.

2. LITERATURE REVIEW

The impact of process factors like friction factor and geometrical characteristics like gap height and fie corner radii was examined by Farhoumand et al. He came to the conclusion that When the height of gap or die corner radius increase, the materials flows radially. Furthermore, he concluded that variations in the friction factor have an impact on the materials are flow into the fast forward and backward parts, even and if the materials are flow into the radial component is essentially to independent of the friction factor.

Plancak and colleagues looked at the radial extrusion of gears-like parts. We noticed that the load rises sharply in the final stage of the load stroke diagram. Additionally, he noted that the highest and lowest strain values had been found, respectively, at the teeth and centre portions of the billet.

The analysis of gear-like component lateral extrusion was done by Jafarzadeh et al. [9]. He noticed that while friction factor has some effect on the forming load, gap height has a greater effect. He came to the conclusion that the effective Strain increased with an increase in frictions coefficient and became heterogeneous with a decrease in billet diameter. Additionally, when the billet height increases and the frictions coefficient falls, the degree of barrelling reduces as well.

The analysis of the cold-die extrusion/forging process was done by Brayden et al. He discovered that the neutral radius, which occupies a point to achieve the least energy dissipation state, is the important component in the study. Additionally, the neutral radius's behaviour is influenced by the starting pressure and the abrupt increase in pressure that occurs throughout the extrusion process as a result of internal shear.

The simulation findings show that the proposed test can evaluate friction both qualitatively and quantitatively, according to Buschausen et al. He also found that the test conditions, which exhibit a high interface pressure and substantial deformation, are similar to those seen in industrial manufacture.

The finite element method was used by Hu et al. to characterise the deformation of a rectangular billet. He discovered that the numerical results agree well with the experimental data in terms of deformed. geometry.

Wu et al. used the finite element approach to investigate the effects of different die shapes on extrusion forging. He discovered that the extrusion loads, strain, and flow deformation were all influenced differently by the draft angle and fillet radius.

According to Vickery et al. the size of the die hole affects how the material behaves within the workpiece. The material with the bigger die hole would fill and transition first.

An experimental study on barreling aluminium alloy billets during extrusion-forging using various lubricants was conducted by Narayan Swamy et al. He came to the conclusion that under both planar and triaxial conditions, all stress levels rise with approach angles. The relationship between the axial strain and the hoop strain is shown by a straight line. The approach angle affects the barrelling radius, which changes with hydrostatic load.

After observing the lateral extrusion of hexagonal heads, Paltasingh et al. came to the conclusion that the thickness and cross sectional area of the die cavity increased the formation stress. It was also noted that as the corners of the die cavity are filled, the load rises suddenly.

An experimental study on upper limit analysis of the torsional backward extrusion process was conducted by Kim et al. Using the stream function, he produced a velocities field that was kinematically acceptable. Compared to traditional backward extrusion, thirty percent less deformation force was required.

3. FINITE ELEMENT ANALYSIS (FEA)

Finite element analysis or FEA is a potent numerical technique for simulating the behaviour of intricate engineering systems and structures is finite. It is used in many different sectors, including as biomechanics, civil engineering, automotive, aerospace, and more, to forecast how a system or component will react to particular operating situations.

Fundamentally, Finite element analysis (FEA) divides an intricate structure into smaller, more manageable components, or meshes, linked at certain locations known as nodes. These elements behave according to mathematical formulae, which are frequently based on physics concepts like equilibrium and conservation laws. FEA determines how the entire structure will react to applied loads, boundary conditions, and material attributes by repeatedly solving these equations.

Performing FEA usually entails the following steps:

i. **Pre-processing:** This entails utilising specialised software to create a geometric model of the structure. After that, the model is divided into discrete parts, and loads, boundary conditions, and material attributes are specified.

ii. **Meshing:** For 2D analysis, the structure is split up into triangles or quadrilaterals, and for 3D analysis, it is split up into tetrahedra or hexahedra. The analysis's accuracy is influenced by the mesh density; finer meshes yield more accurate findings but demand more processing power.

iii. **Applying Loads and Boundary Conditions:** In order to mimic how the structure interacts with its environment, boundary conditions—such as fixed limits or prescribed displacements—are applied. To further imitate real-world working circumstances, external loads are introduced, such as forces, pressures, or temperature gradients.

iv. **Solving:** Using iterative techniques like the boundary element or finite element methods, the system of equations regulating the behaviour of each element is numerically solved. The displacement, stress, and strain distributions inside the structure are computed in this stage.

v. **Post-processing:** At this point, the analysis's findings are presented and explained. Engineers may assess the performance of the structure and make wise design choices by looking at a variety of outputs, such as deformation plots, stress contours, safety factors, and resonance frequencies.

4. EXPERIMENTAL ANALYSIS

Numerous experiments have been conducted for the current analysis in order to compare the outcomes of the finite element Simulation with the experimental results. Initially, a setup was created and built to use a combined extrusion-forging technique to create Collet Chuck holders. Several tests have been conducted on a 600kN maximum capacity Universal Testing machine with cylindrical aluminium specimens to obtain the ColletChuck holder that is the end result. Additionally, ring and compression tests have been performed to ascertain the friction factors and stress-strain properties, respectively.

4.1. Setup for Experiment

The experimental setup consists of the base plate, and punch head, sleeve, punch rod, forging-extrusion die and die holders. It has been addressed which components were employed in the experimental setup. The EN31 steel container measures 140 mm in diameter and 100 mm in length. Its cylindrical chamber measures 50 mm in diameter and 100 mm in length. It may be done by rotating the container's outside diameter and utilising wire cut EDM to drill the interior chamber with a tolerance of ±.02 mm. During testing, the rear of the sleeve that has been inserted within the container chamber is prevented by using the cover plate. Inside the container chamber is the container sleeve, whose inner and outer diameters should coincide with the diameter of the main punch and the container chamber, respectively. The purpose of the container sleeve is to prevent the punch rod from expanding by guiding it through the container. Die holders -1 and -2, which were produced utilising comparable procedures. D2 steel was used in the manufacturing of the punch rod, circular punch head, circular split dies, and circular taper split die. Push fit alignment is used to join the punch rod-2 and the punch head. Using EN 8 steel, the foundation plate was created.

4.2. Experimental Methodology

Experiments were carried out on a 600kN maximum capacity Universal Testing Machine using cylindrical aluminium billet. Once all the parts of the experimental setup have been well cleaned, lubricant (oil, for example) has to be applied to the inside surfaces of the dies, as well as the holders, punch, and sleeves. Furthermore, the punch is positioned above the billet of aluminium, which is then lubricated and placed within the die cavity. Now the container is placed on the die holder and bolted in place. The main punch is finally placed within the container sleeve, which is then placed into the container chamber. After everything is set up, the 600kN maximum capacity universal testing machine's bottom table is where it is placed (Fig. 4.1). Now turn the machine on and fine-tune its parameters, such as the maximum load, anvil height, billet diameter, strain rate, and punch movement length. The dimensions of the anvil height, billet diameter, punch movement length, and punch speed in this research project are 54 mm, 15 mm, and 1 mm/min, respectively. When the punch action reaches the prescribed length of 24.6 mm, the machine stops. A punch load is recorded for every thirty seconds of punch movement. After the experiment was over, the die sets containing the final result were removed using a progressive load, and the punch die arrangement was dismantled. The final result of the Combined Forging and Extrusion Process is a ColletChuck holder, which was the expected outcome. Various punch movement lengths have been used in experiments to look at die cavity filling and metal pattern of flows.

Figure 4.1: A photo shows the key components of the experimental setup

4.3. Determining Aluminum's Stress-Strain Properties

The flow stress was calculated using a power equation derived from the stress-strain curve, and the cylindrical aluminium billet's stress-strain characteristics were determined by the compression test. First, the cylindrical aluminium billet, which had dimensions of 18 mm in diameter and 32 mm in length, was machined from casted billet material. To help hold on to the lubricant, several oil grooves have developed on the specimen's top and bottom surfaces. The bottom table of the UTM has been adequately lubricated and covered with grease or another lubricant. The uniaxial compression test was performed by gradually increasing pressure, and the compressive force was measured at each 0.2 mm of punch movement. The machine halted once the 2 mm of compression was finished, and the compressed billet was remachined in accordance with the original billet specifications. The procedure has been carried out until the height reaches 25.25 mm. Ultimately, Fig. 4.3. displays the plotted stress-strain curve.

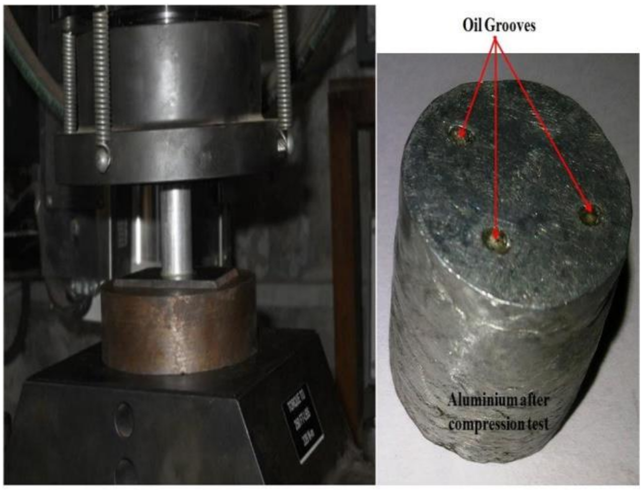

Figure 4.2: Aluminium specimen setup for compression testing

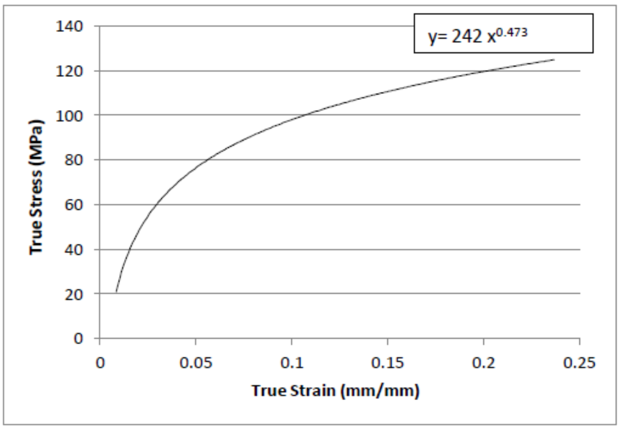

Fig. . 4.3: The typical curve of stress-strain for aluminium

According to Fig. 4.3, we are able to ascertain a suitable power equation curve, which is represented in equation (1):

$$\sigma = 242\dot{\varepsilon}^{0.473} \qquad (1)$$

The strain hardening index is 0.473 and the strength coefficient is 242 MPa when we compare equation (1) with Holloman's equation of power. The power equation was utilised in the Simulation procedure, and the flow stress of 125 MPa was determined from the stress-strain curve.

4.4. Using the Ring Compression Test to Determine the Friction Factor

The fundamental determinant of the forming load, flow of metal pattern, and internal grain structure is the frictional condition at the billet/die contact. A flat ring specimen plastically compressed within two flat platens reveals insufficient lubrication when there is more friction, which causes the metal to flow inward; less friction indicates enough lubrication, which causes the metal to flow outward. Accordingly, in a compression test, a greater internal diameter indicates less friction, whereas a smaller internal diameter indicates more friction. Fig. 4.4 illustrates how the specimen changes form when crushed both with and without lubrication.

The ring compression test has been conducted in this study both with and without lubrication. A flat ring-shaped specimen with an OD: ID: H ratio of 6:3:2 has been taken into consideration for this ring compression test. The ratio indicates that the ring's dimensions are 18:9:6, and a ring test has been conducted. Two flat die plates with the identical interior surface conditions were compressed in order to provide an accurate assessment of the friction between the die/billet interfaces. Following the ring test, a curve was created using the recorded values. The ring test curve and the friction factor determination were compared using standard calibration curves. In the ring test, the friction factor achieved with lubrication is 0.22, and without lubrication, it is 0.28.

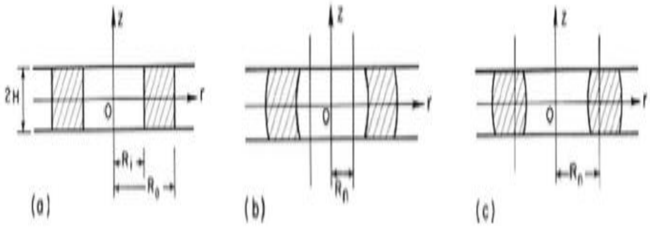

Fig. . 4.4: a. specimen before ring test, b. specimen with lubrication after ring test, and c. specimen without lubrication after ring test

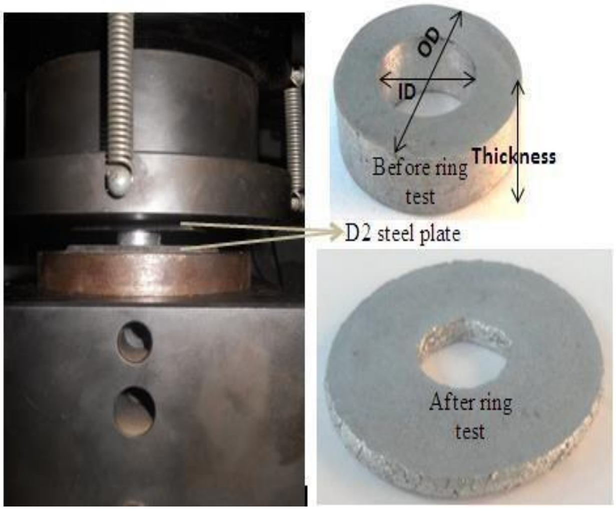

Figure 4.5: Ring test setup

4.4.1. Different phases of the Combined Forging and Extrusion Process's product production

On a Universal testing machine(UTM), experiments have been conducted to create the necessary product, a ColletChuck holder, utilising a combined extrusion-forging method. It has been noted that there are four steps in the entire compression process. The billet's initial compression is visible in the first step. The taper die's forging and a little indentation hole have been finished in the second step. The third stage sees the completion of both forging and extrusion. At this point, the last circular extrusion component is finished. The product had reached the fourth step, when flash arrived and the finishing was finished. The graphs showing the change of punch load with punch movement at various punch movement are shown in Fig. s 4.6 to 4.8.

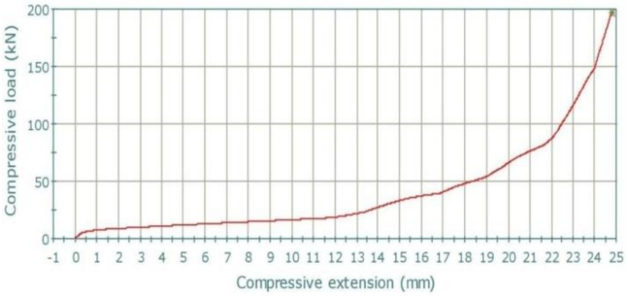

Figure. 4.6: Punch load variation with stroke for a 24.8 mm punch movement length

In The Fig 4.6. , The punch load variation with respect to punch movement at 24.8 mm of punch movement is represented by 4.6. This is the whole product that was produced using Flash. 191.22 kN of load is needed for the product to fully form.

In The Fig. 4.7, The punch load variation with regard to punch movement for a 24 mm punch trip length is shown by fig 4.7. In comparison to the 24.8 mm punch movement, there is not much variance. Here, the full product is acquired, and the flash has just begun to appear. 139.76 kN of load is needed at 24 mm of punch movement. The load for punch movement of 24.8 mm and 24 mm varies significantly. This is because the extrusion section is still unfinished and the flash has not yet developed at 24 mm of punch movement. Thus, compared to 24 mm punch movement, 24.8 mm punch movement requires higher weight.

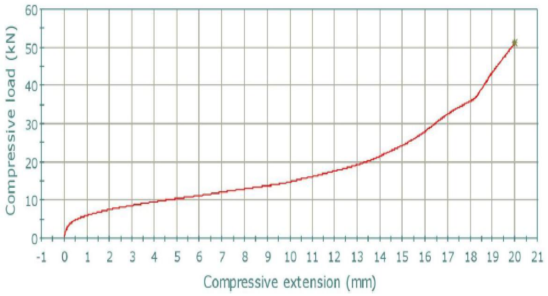

Figure 4.7: Punch load variation with stroke for a 20 mm punch movement length

Fig. 4.8 displays the punch variation in load in relation to punch motion for a punch trip length of 20 mm. At this point, only the partial development of the tapered component and the entire manufacture of the hole in the first segment have been achieved. The circular flash component and the extrusion part are not yet operational. The required forming load at 20 mm of punch motion is 51.08 kN.

The punch load variation with regard to punch movement for a 15 mm punch trip length is shown in Fig. 4.8. This phase just signifies the preliminary compression. The billet is pierced by the punch head. At 15 mm of punch motion, a load of 22.72 kN is needed.

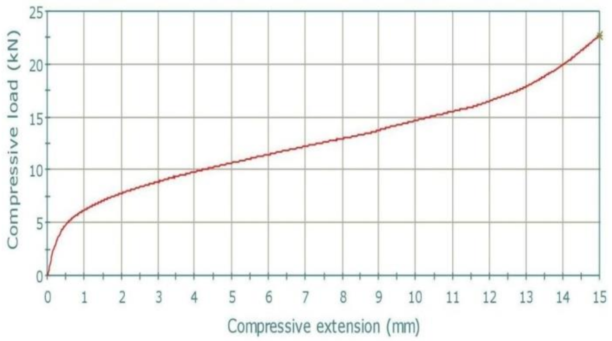

Figure 4.8: Punch load variation with stroke for a 15 mm punch movement length

5. CONCLUSIONS

In the current study, a combined extrusion forging method has been used to create ColletChuck holders through Simulation and experimental analysis. The outcomes of the experiment and the Simulation accord rather well. Based on the acquired outcomes, we may make a few deductions.

- A ColletChuck holder was constructed by simulating the Combined Extrusion and Forgingprocess using a finite element method and the DEFORM 3D application. Analysis has been done on a number of characteristics, including total velocities, Combined Extrusion and Forgingprocess, effective Strain, and metal pattern of flows.
- Various length punch movement (length of punch movement) has been investigated through experimentation and Simulation, revealing the several phases involved in metal filing in dies.
- An experimental arrangement has been created for the ColletChuck holder's combined extrusion-forging operation.
- Aluminium flow stress was computed and found to be 125 MPa, while a universal testing machine's ring test yielded a friction factor value of 0.22.
- The Simulation technique and the punch load variation in relation to the displacement curves obtained from the experiment correspond well.
- The results of the models agree well with the experimental die filling, metal pattern of flow, and load requirements.

6. FUTURE SCOPE

The current study may be expanded to investigate additional facets of the Combined Extrusion and Forgingprocess. Some recommendations for further work are included below.

- This technique was expanded to work with different materials in hot environments.
- Verification of the experimental analysis results can be achieved using upper bound analysis.
- Die stresses can be determined by extending the use of the suggested Finite element analysis (FEA).
- This technique may be expanded upon to provide analysis for other materials and intricate forms.

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