Orbital Cold Forming Technology - Combining High Quality Forming with Cost Effectiveness - A Review

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Abstract

Objectives: This review presents a short communication of cold orbital forging process, its characteristics and compare with classical forging. Methods/Statistical Analysis: Orbital forging have special progressive motion permits the contact space between tool and workpiece to be smaller and thus, lowers forming load and friction. Therefore orbital forming in some cases makes it potential to provide the specified part in exactly one operation, whereas in classical forging quite one operation would be needed. Findings: Cold orbital forming is more useful and preferable in comparison to other manufacturing processes as we can manufacture more number of gears with better surface finish in less time. Thus, cold orbital forming has much higher efficiency. The process is less time consuming and saves labor costs too. Hence, better finished gears can be manufactured in bulk and it also turns out to be more economical than the other manufacturing processes. Current review illuminates the techno economical advantages of the orbital forming process and how advantageous it is over classical forming process. Application/Improvements: This review includes the forming time and distribution of stress and strain on the workpiece and also the die.

Keywords: Cold Orbital Forging, Conventional Forging, Forming Time

1. Introduction

Orbital forging could be a methodology of warm or cold working of components, which relies on ways. The primary machine, permitting the production of parts exploitation this methodology, was manufactured in sixties of the 20th century. Within the same time, Marciniak and followed by Barnet developed an innovative mechanism driving the upper die what allowed for the belief of the orbital formation process with exploitation totally different schemes of the die movement.

As industrial technology developed, preciseness forging or net-shape forging has become progressively popular with savings in material, energy and final steps. However, several of the new parts, due to their advanced shape and sophisticated tool design with high load needs are difficult the traditional forging technology. There’s a revived interest in progressive forming to fulfill the required demand, particularly in rotary progressive forming processes, like swaging, ring rolling, spinning and rotary forging. It is a novel feature of the orbital forging process that the upper die axis is inclined by some angle from the major axis. As a result of this die inclination, an exact reduction within the upper die and workpiece contact area is obtained. During cold orbital forging process, the upper die oscillates around the vertical machine axis. At the same time, the lower die pushes the workpiece vertically at a relentless feed rate therefore on subject the workpiece to axial compression, whereas the upper die oscillates and lower die presses workpiece with an explicit axial feed making the material to more and more flow into the die cavity, ultimately the required form of gear are going to be completed perfectly Figure 1. The die precessions are often performed with or while not the accompaniment of rotation. The inclination angle is often variable or constant and is always greater than zero. Contact area between die and workpiece is smaller than in classical forging which ends up in lower forming load and die pressure. Cold

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Orbital forming process offers variety of benefits, particularly in manufacturing of parts with massive diameter to height ratio.

1.1 Need for Study

Gears are generally manufactured by the process of hobbing. However, the fatigue life of the gear decreases when it is manufactured by hobbing. Cold orbital forming is more useful and preferable in comparison to other manufacturing processes as we can manufacture more number of gears with better surface finish in less time. Thus, cold orbital forming has much higher efficiency. The process is less time consuming and saves labor costs too. Hence, better finished gears can be manufactured in bulk and it also turns out to be more economical than the other manufacturing processes. Current review illuminates the techno economical advantages of the orbital forming process and how advantageous it is over classical forming process. This review includes the forming time and distribution of stress and strain on the workpiece and therefore the die.

1.2 Process and its Technical Characteristics

The primary factors that create orbital forming technology thriving is that the requirement for fewer force combined with excellent forming performance. In single die-forging stage, you'll turn out workpieces with high dimensional and geometrical accuracy together with an excellent surface finish. There is a unit many different variants of orbital forging. Workpiece is positioned between the upper tool and also the lower tool in vertical press machine, wherever the axis of the upper tool is slightly inclined at an angle (generally 1-2°). Upper tool performs solely movement and lower tool moves upwards. The tool is in full contact with the lower surface of the workpiece, whereas the surface of contact between upper workpiece surface and upper tool is tiny compared to classical forging, owing to the axis being tilted. The remittent contact surface ends up in lower forming load. Comparison between classical and orbital forging is illustrated in Figure 1a. In classical forging angle γ = 0° and there is no rotation of the die. Contact area between upper tool and workpiece is relied on inclined angle of upper tool axis: The larger the angle, the smaller the contact surface and therefore, lower forming load. Larger the angle, additional complicated is that the machine maintenance and with greater frame deflection, it becomes additional advanced to keep constant forming preciseness.

Figure 1. General scheme of orbital forming.

Figure 1a. Principal difference between classical and orbital forging.

Figure 1b. Numerous motion possibilities of upper tool's axis.
Different motion designs conferred in Figure 1b\(^2\) are often performed by the tilted upper tool's axis. Orbital (circular) motion is most ordinarily used, particularly once comparatively thin parts are forged, as high deformation is needed throughout the complete part volume. The elements that have large ribs and flanges, planetary motion becomes most applicable. For components within which most material flow happens in central region, spiral motion is most suited and straight line motion is most convenient for long, narrow parts. The angle of inclination of upper die in relation to the vertical axis is one of the most parameters which have impact on process development. Larger angle ends up in lower contact surface between upper die and workpiece and consequently, in lower total load\(^4\). Larger the inclination angle, additional is the vibration, once there's robust lateral loading of the machine and tooling and unbalanced method development in general\(^5\). Materials used are carbon and low-alloy steels, metal alloys and brasses and chrome steel. It's conjointly referred to as rotary forging, swing forging or rocking die forging. In some cases, the lower die might also rotate\(^6\).

2. Comparison between Orbital Forging and Conventional Forging

For better understanding of cold rotary forging process the distinction between cold rotary forging and conventional forging has to be processed and studied\(^3\). Following advantage that are offered by cold rotary forging are lower level of noise, vibration, uniform quality, smooth surface, close tolerance and sizable saving in energy and material force. Additionally because of the eccentric load in cold rotary forging, the strain state of cold rotary forging press is incredibly complicated and also the lifetime of the gear is comparatively low\(^7\).

According to\(^2\) deals with the comparison of cold rotary forging with conventional forging on the subsequent topics, it had been found that:

2.1 Metal Flow Analysis

In typical forging, metal flows in exactly 2 directions specifically axial and radial as in Figure 2a\(^4\). However, in cold rotary forging process is asymmetrical besides axial and radial flow the metal conjointly flows in circumferential direction Figure 2b\(^3\).
2.3 Force and Power Parameters

There are 2 totally different stages in conventional forging at the start the force will increase considerably from zero to some value and then step by step increase similar linearly, the forging movement is zero throughout. There are 3 stages in cold rotary forging process at the primary stage forging movement and axial forging force increase quickly from zero to certain value. In second stage it reach up to a max value indicating that the cylindrical workpiece has reached steady deformation stress, at the last stage movement and forging force decrease sharply as the lower stop the axial feed whereas the upper die still oscillates, therefore leading to less metal to participate in plastic deformation.

2.4 Dynamic Contact Condition

There are 2 contact pairs in cold orbital forming. One is that the contact pair between the cone-shaped surface of the upper die and also the upper end surface of the cylindrical workpiece. The other one is that the contact pair between the higher end surface of the lower die and therefore the lower end surface of cylindrical workpiece. These 2 contact pairs are outlined as surface to surface contact kind that permits sliding between the surfaces. In addition relative sliding existing between the dies and workpiece contributes to explain friction condition.

2.5 Constraint and Load

The upper die is constraint to rotate solely concerning the global 2-axis whiles its different degree of freedom our constrained. Similarly, the lower die is constrained to translate solely on the global 2-axis whiles its different degree of freedom our constrained.

3. Economical Features

Orbital forging has technical and important economic benefits as compared to classical forging in manufacturing of parts wherever radius/height ratio is large.

With impact extrusion Figure 3a, friction at the die surfaces presents an obstacle to the radial material flow. The tension (surface pressure) is greatest in the centre of the workpiece and diminishes towards the exposed edge. The greater the friction, the greater the maximum tension (σ max) becomes. In conventional impact extrusion pro-
cesses, it can reach a level several times higher than the yield stress ($\sigma_f$). Whereas in cold orbital forming significant changes in shape can be achieved in a single operation Figure 3b without intermediate annealing, there is no need for expensive multi-stage dies of the type needed for traditional impact extrusion or for the time-consuming setting up and adjusting that. This means that even your short and medium production runs will be highly cost-effective. Orbital forging is way additional economical for series up to 23000 pieces when all costs are accounted (machine prices, needed space prices, tool costs) per economical analysis 3. The Figure 3c shows production costs in performs of production series for classical and orbital forging for this instance part. Classical forging is additional economical for series with over 23000 parts, principally because of lower production times 3.

Figure 3c. Production cost in function of production series 3.

4. Distribution of Effective Strain

The effective strain distribution at totally different stages of the orbital cold forging process is studied. The contact is formed between upper die insert and lower die insert with the billet at the start. Plastic deformation zone is initial formed within the area that satisfy yield condition with time height of the workpiece decreases and also the metal flow close to the upper die is over that close to the lower die, therefore the side diameter increase significantly 7,9. This factor is named “mushroom shape” effect, that is that the main deformation characteristics of cold orbital forging 7, with the continuation of forging process the workpiece enters a gradual deformation stage and the gear profile form is step by step deformed. In final stage, resistance of radial flow will increase remarkably due to which the flash grows slowly and keeps the metal from flowing outward. This flow resistance forces the remaining metal to require the trail of effort, that could be a different route, therefore leading to filling the small-end gear shape 4. The central cavity portion is strain hardened the foremost at the tip of forging Figure 4.

Figure 4. Central cavity strain hardened 3.

5. Distribution of Stresses

Figure 5 shows equivalent stress distribution of the deforming billet with time 3. The first regions to be stressed at the beginning of forging are bottom and top surface of billet (Figures 5b, 5c) 4. As the lower die pushes up, the height of the billet is reduced 7. Hence the entire billet will be stressed beyond the yield point and the gear starts to take shape 7.

Figure 5. Equivalent stress distribution of the deforming billet with time 4.

6. Determination of Exact Forming Time

During the cold rotary forging process the lower die pushes the workpiece vertically at a relentless feed rate $V$ till the workpiece reaches its final height. Therefore the forming time within the amount (the axial feed time of the lower die) is expressed 4.

$$T_1 = \frac{H_0 - h}{V} \quad (1)$$

Where $H_0$ and $h$ are the initial height and the final height of the cylinder workpiece respectively. $V$ is the feed rate of lower die 4. The feed rate $V$ of the lower die can be expressed by,
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\[ V = \frac{ns}{60} \quad (2) \]

Where \( n \) is that the rotational speed of the upper die round the machine axis and \( s \) is that the feed quantity per revolution\(^1\).

From Equation (1) and (2):

\[ T_{1,60} = \frac{(H_0 - h)}{ns} \quad (3) \]

The surface of contact in between the workpiece and upper die could be a portion of an mathematician spiral surface in cold orbital forming\(^4\). Hence, once the lower die stops the axial feed, the upper die still oscillates a minimum of one revolution round the machine axis therefore on build the upper surface of the workpiece become a plane. During this period the forming time (assuming that the upper die oscillates two revolutions when the lower die stops the axial feed) are often expressed by following equation \(^4\):

\[ T_2 = 2 \times 60 \frac{\ln n}{n} = 2 \times 60 \frac{v}{s} \quad (4) \]

From Equation (3) and (4) the exact forming time is expressed as\(^5\):

\[
T = T_1 + T_2 \\
= 60 \frac{(H_0 - h)}{ns} + 2 \times 60 \frac{v}{s} \\
= 60s \frac{(H_0 - h)}{n + 2v}
\]

7. Die Stress

According to\(^3\) three types of punch profiles are proposed with different lengths of mandrel and the die stress characteristics were noted and the observations made are as follows:

7.1 Type 1 - It uses punch with long mandrel and split die

The maximum effective stress and hoop stress are 2930 MPa and -1710 MPa severally. The utmost effective stress of upper die insert is 1470 MPa. The utmost stresses of punch are terribly high and exceed the yield stress of SKD 11 (about 1600 MPa). The punch was fractured immediately. Hence, it had been concluded that the split die is good for manufacture however the die stress is additionally increased\(^8\).

7.2 Type 2 - It uses punch uses punch with short mandrel and solid die

The length of the rotating shaft was shortened to reduce the rotational constraint and torsional stress of punch. The utmost effective stress, radial stress and hoop stress of punch are 1720, -1620, -1260 MPa respectively. These stresses are smaller than the yield stress of SKD 11. The punch profiles with rotating shaft style are capable of controlling the inward material flow, however punch failure can't be prevented\(^4\).

7.3 Type 3 - It uses punch without mandrel

The rotating shaft is excluded to reduce stress. The utmost effective stress and hoop stress are 1330 and 294 MPa respectively. The contact is increased and the stresses of the tool are decreased dramatically. The tool stresses are decreased and folding defects are prevented\(^6\). Finding out the result on stress exploitation the various kinds of dies, it had been over that the die failure and product defects are often prevented by the proposed punch profile with a conical tip and appropriate preform style proper quantity of interference is crucial to reduce the utmost stress level\(^8\). A pre-stressed ring style with correct quantity of shrink fitting is useful to decrease the utmost effective stress and provides a compressive hoop stress\(^10\).

![Figure 6. Comparison between classical and orbital forging with different axle rotation angles (numerical analysis)](image)

8. Conclusion

Compare to alternative manufacturing technologies orbital forging offers variety of benefits like load reduction, uniform quality of the workpiece lower noise and vibration and lower energy consumption. It's conjointly seen that use of a die with conical tip and appropriate preform style ends up in reduction in die failure and interference of defective finished parts. The precise forming time and also the distribution of stress and strain on a gear underneath load were studied. By learning the numerical analysis we find that the load
stroke diagram (Figure 6) between conventional and cold orbital forging for \(\gamma = 1^\circ\) show that for 20 mm stroke in final stage of deformation load demand for classical forging is higher than orbital forging (\(\approx 2800\) KN compared to \(\approx 1000\) KN)\(^{14}\).

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