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ORBITAL FORGING – A PLAUSIBLE ALTERNATIVE FOR BULK METAL FORMING

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ABSTRACT

Orbital forging is a relatively new technology in which parts are produced by specific movement of tools. Special incremental motion enables smaller contact area between tool and workpiece and therefore, lower forming load and friction. Hence, orbital forging in some cases makes it possible to produce a desired part in only one operation, whereas in classical forging two or more operations would be required. However, orbital forging has number of setbacks, such as more complex machine maintenance and production times. This paper presents a brief overview of main orbital forging characteristics and comparison with classical forging. Numerical analysis has been performed. Load – stroke diagram for specific workpiece for classical and orbital forging is presenter as well.

Keywords: orbital forging, bulk metal forming, FE analysis

1. INTRODUCTION

In orbital forging, plastic deformation of workpiece is performed by inducing compressive pressures to the billet in incremental manner. Contact area between die and workpiece is smaller than in classical forging which results in lower forming load and die pressure. This technology offers a number of advantages, especially in the manufacturing of parts with large diameter to height ratio.

Orbital (rotary) forging has been a subject of numerous investigations. In [1] rotary forging is compared with conventional forging. Investigation was conducted by using 3D elastic-plastic dynamic explicit FE code. Kinematic of the process is highlighted in [2]. It has been concluded that rotation angle has a great influence on the process parameters. Authors in [3] investigated incremental bulk metal forming operation. Special focus was placed at the appropriate numerical methods for analysis of this kind of metal forming.

Current paper illuminates main techno – economical features of the orbital forging. Furthermore, numerical analysis of the process has been conducted in order to predict forming load. Comparison with classical forging was carried out.

2. TECHNICAL CHARACTERISTICS OF THE PROCESS

There are several different variants of orbital forging. In most common, workpiece is positioned between upper and lower tool in vertical press machine, in which the axis of the upper tool is slightly tilted for a specific angle (typically 1 - 2° [4]). Upper tool performs only rotary motion and lower tool moves upwards. Lower surface of the workpiece is in full contact with the tool, while the contact surface between upper workpiece surface and upper tool is smaller compared to classical forging, due to tilted axis. Repercussion of the decreased contact surface is lower forming load. Comparison between classical and orbital forging is illustrated in Figure 1a. In classical forging angle $\gamma = 0°$ and there is no rotation of the die.

Contact area between upper tool and workpiece is depended on tilted angle of upper tool axis: the bigger the angle, the smaller the contact surface and, therefore, lower forming load. However, larger angle causes more complex machine maintenance as well as greater frame deflection, which makes it more difficult to keep constant forming precision [5].

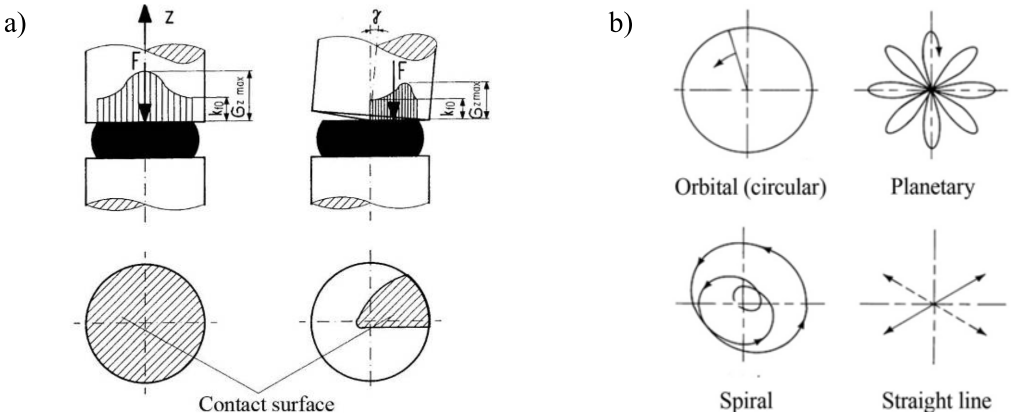


Figure 1. Principal difference between classical and orbital forging and various motion possibilities of upper tool's axis [4]

Tilted upper tool's axis can perform various motion styles presented in Figure 1b. Orbital (circular) motion is most commonly used, especially when forging relatively thin parts, where high deformation is needed throughout the whole part volume. For parts with large ribs and flanges, the most appropriate motion is planetary. Spiral motion is suitable for parts in which most material flow occurs in central region and straight line motion is convenient for long, narrow parts.

Figure 2a shows some typical parts manufactured in orbital forging process: hub, clutch part, bevel gear and breech ejector.

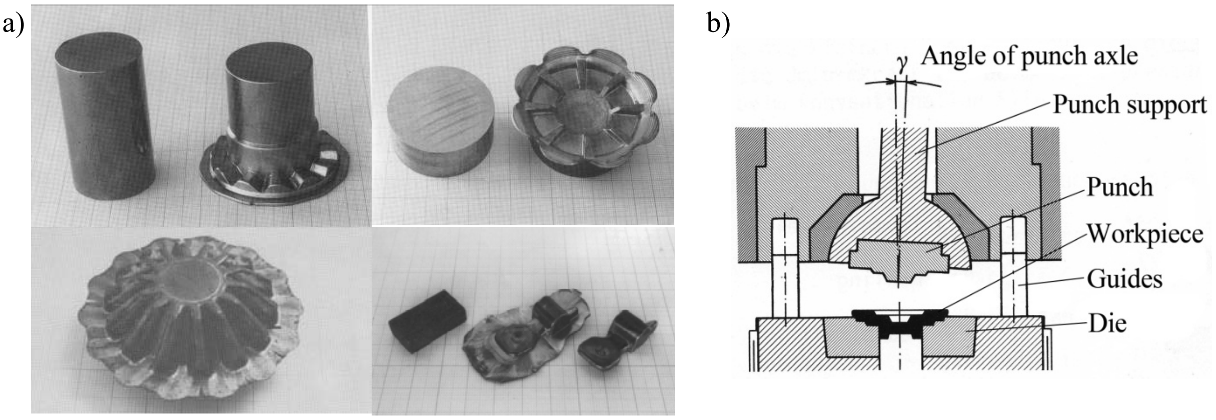


Figure 2. Parts obtained by orbital forging and tools for orbital forging [6]

The most important advantage of orbital forging is lower forming load which leads to decreased deformation of the machine and lower friction on tool/workpiece interface. Due to lower friction, wear of the tools is decreased as well, which enables longer tool's work-life and higher precision of the forming process. Lower forging loads in cold orbital forging also enable production of parts that conventionally required classical hot forging. Environmental hazards, such as vibration and noise, are much lower compared to classical forging. However, due to specific motion of the tools, orbital forging is a slower process and requires significantly more complex machine design. In Figure 2b typical tool configuration of orbital forging is presented.

There are a numbers of parameters that influence orbital forging process and thereby, the quality of final product. All influential factors can be divided into four different groups:

1) Workpiece material (chemical composition, microstructure, deformability…)
2) Tools properties (tool construction, workpiece positioning, contact surface properties…)
3) Machine properties (load – energy, production capacity, cinematic, level of automation…)

4) Technical factors (forming load, temperature, contact conditions, deformation level, workpiece shape…)

3. ECONOMICAL FEATURES

In manufacturing of parts where radius/height ratio is large, orbital forging has, along technical advantages, significant economical advantages in comparison to classical forging. These advantages can be illustrated in Figure 3a, which presents two different production possibilities for one axi-symmetrical part with large radius/height ratio.

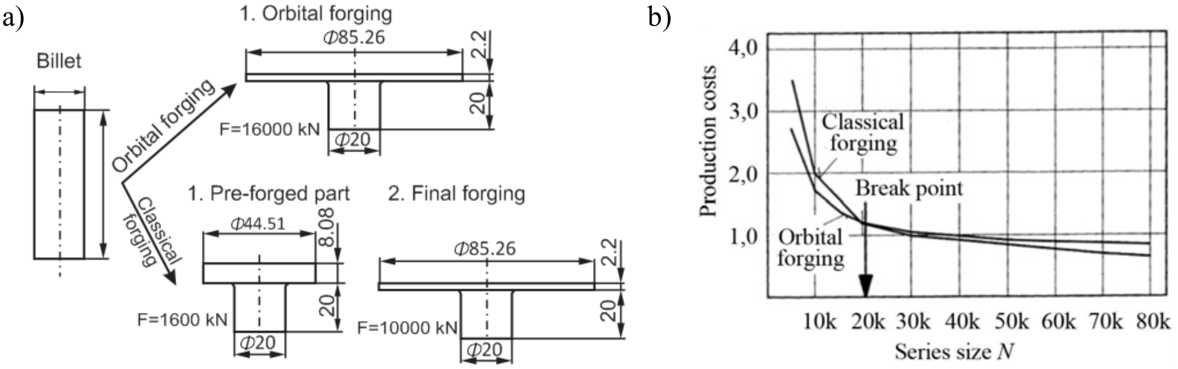
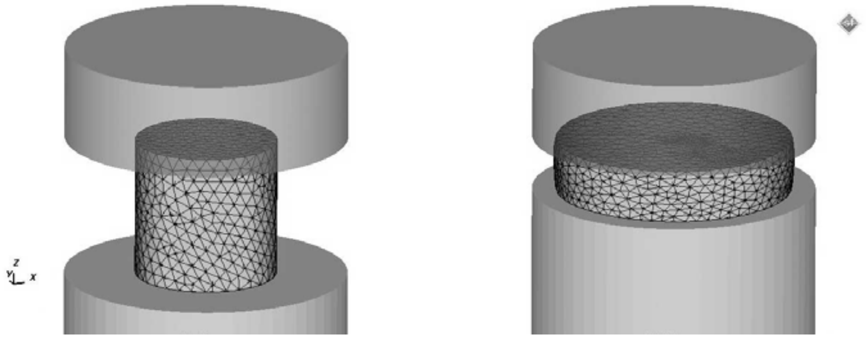


Figure 3. Two different production possibilities (orbital and classical forging) and comparative analysis of classical and orbital forging in terms of production series

In orbital forging (Figure 3a, upper solution) part can be produced in only one operation, whereas in classical forging (Figure 3a, lower solution) proper production requires two different operations by using press with two positions. Economical analysis show that, when all costs are accounted (machine costs, required area costs, tool costs…), orbital forging is more economical solution for series up to 23000 pieces [4]. In Figure 3b production costs in function of production series are also shown for classical and orbital forging for this specific example part. Classical forging is more economical for series with more than 23000 parts, mainly due to lower production times.

4. NUMERICAL SIMULATION OF ORBITAL FORGING (CYLINDER UPSETTING)

Numerical simulation of orbital forging, which was conducted at University of Novi Sad – FTN, was performed in Simufact Forming 10.0 software package. This FE program has specific module that enables orbital movement simulation of the tools. In FE simulation, billet with initial dimensions of Φ30x30 mm was upset by orbital forging to a final height of 10 mm ($\varphi = 1.09$ in the final position). Figure 4 shows initial position of the billet and workpiece position after tool stroke of 20 mm. Steel C45E was used as workpiece material ($K = 289.68 + 668.76 \cdot \varphi^{0.3184}$). Upper and lower tool were set as rigid bodies. In simulation, process was conducted in room temperature environment with coefficient of friction $\mu = 0.11$. Lower tool performed axial translator movement with 1mm/s velocity, while upper tool conducted orbital movement (250 rotations/min). Total of 4990 elements divided the workpiece and *slMesh Tetra* with *Tetrahedral* element type was used (Figure 4). Tilted angle of upper tool was 1°.



s = 0 mm *s = 20 mm*

Figure 4. FE simulation in Simufact Forming 10.0

5. CONCLUDING REMARKS

Orbital forging is a typical incremental bulk metal operation which offers a number of advantages when compared with other manufacturing technologies. Load reduction, lower noise and vibration, uniform quality of the workpiece and lower energy consumption are the main characteristics of orbital forging.

Present paper outlines the main features of this process, including economical aspect. Numerical analysis, using FE code, has been performed with the aim to compare classical and orbital forging.

Figure 5 presents load – stroke diagram for classical and orbital forging with angle of $\gamma = 1°$. As it can be observed, load required for classical forging is significantly higher than in orbital forging (≈2800 kN compared to ≈1000 kN for 20mm stroke in final stage of deformation).

In further activities on this subject manufacturing of workpieces with more complex geometries by orbital forging will be considered. At University of Novi Sad an ongoing research involves investigation of possibilities and preconditions for production of elements like universal cross joints by orbital forging (Figure 6). Results of these investigations will be presented in relevant literature.

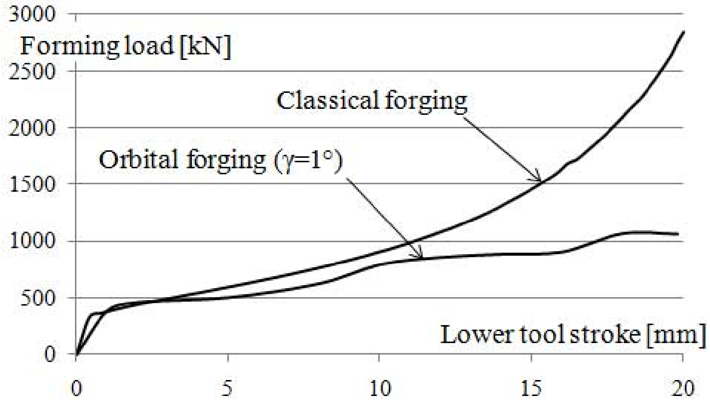


Figure 5. Comparison between classical and orbital forging with different axle rotation angles (numerical analysis)

Figure 6. Cross joint part manufactured by orbital forging

6. ACKNOWLEDGEMENT

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