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Helical Extrusion Process of General Polygonal Section Shapes through Curved Dies

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ABSTRACT

Practically, the helical products used as a mechanical part to satisfy the needs of mechanical strength and artistic appearance. In addition, during recent 5 years it used to produce an ultra-fine grain metal structure. However, there are very little works regarding this type of extrusion so far. This work proposed a new formulation for helical deformation zone to produce general helical polygonal shapes through a streamlined die that are usually made by hot extrusion through taper die. The general die surface was represented analytically. The velocity and strain rate fields are derived depending on the volume constancy and the velocity boundary conditions. The upper bound forming pressure was obtained for various frictional conditions, area reduction, helix angle, and die length. The results show that the axis of the product does not rotate through the helical extrusion. The peak value of the strain rate is located close to the die outlet and decreases as the helix angle increases. The optimum die length becomes high as the helix angle increases. The forming pressure increases with increasing helix angle, area reduction, factor of friction, while decreases when the number of sides increases. The theoretical results were verified with previous work of zero twist and showed completely compatible. A finite element solution was done using hardening material model to verify the analytical results and metal flow and to examine the strain and stress fields in the product.

1. Introduction and background

In structure industry, the helical products used as a mechanical part to satisfy the need of mechanical strength besides the artistic appearance. In addition, they are used in the power devices such as screw pumps and superchargers. Nowadays, the helical sections are made using casting, hot forging operations or machining processes. These methods have many disadvantages, time consumes, besides their high cost. Furthermore, during recent 5 years, the material science engineering showed that the severe plastic deformation produced by torsional shear stress produces ultra-fine grain metal structures. The main advantages of that structure are free of porosity and internal oxidation [1–4].

Despite increasing demand for the application of helical sections in the industry, however, very little analytical methods have been attempted so far. In the literature, few papers talking about the profiles with helical shapes were found. Yang et al. [5–7] used conformal transformation method to create the die surface and to examine the internal metal flow by transformation of any intermediate cross section into a unit circle.

The upper bound theory was applied to find the required extrusion pressure for the extrusion of clover, elliptic, and trochoidal gear sections. They used a rigid -perfectly plastic material model. Actually, using transformation method was very difficult and contained wide coordinate transformations as well as transformation function and in most, it is impossible to apply this technique for extrusion of complicated shapes.

Salehi et al. [8,9] utilizing a Fourier approximation to find die cavity and then the admissible velocity field. The upper bound theory was used to calculate the required energy for twist extrusion of square and elliptical shapes through squared and elliptical die cross-section. In this works, the cross sections of deforming material remain unchanged throughout the twist extrusion process. Khalifa and Tekkaya [10] used a multi-segment die for hot extrusion of helical screw shaft from round billet. They used the experiments and finite element method to examine the effect of the friction and material flow against the twisting angle. There is no analytical analysis presented in this work.

It becomes clear that there is no general systematic work deals the

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