EXPERIMENTAL STUDY AND SIMULATION OF MULTI-HOLE EXTRUSION PROCESS

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

by

Ratnakar Das

(Roll No. 07610302)

Department of Mechanical Engineering

Indian Institute of Technology Guwahati

Guwahati–781039

INDIA

January 2012

Abstract

Among all manufacturing processes, the extrusion technology has a special place because it produces parts of superior quality with minimum waste of material. The ever-increasing cost of material, energy and manpower requires that the extrusion process and tooling must be designed and developed with the minimum number of trial and the shortest lead time. Extrusion process can be broadly classified into single-hole and multi-hole extrusion processes. The multi-hole extrusion is carried out with a die having more than one hole. This process is productive for fabricating the parts of smaller length and cross section and is very suitable for microextrusion.

The present thesis explores the multi-hole extrusion process. Experimental study has been carried out to find out the effect of different process parameters on the extrusion load and quality of the extruded products. A series of experiments has been carried out with different dies (having different number of holes) with commercially available aluminum and lead alloy. Extrusion ratio, die land length, die pockets, billet length and lubrication are considered as process parameters. It is observed that the extrusion load depends on all these parameters. The reduction in die land length helps in reducing the extrusion load. The radii of curvature of the extruded products are dependent on location of the holes of the multi-hole dies, lubrication and die land length. In the present experiments, a mix of inward and outward bending of the extruded products is observed. The die pockets also affect the extrusion load and the profile of the extruded products. For a particular multi-hole die design, there exists an optimum pocket depth with which the least extrusion load is obtained. From the experimental study, it is observed that hardness, tensile strength and surface roughness of the extruded products depend on extrusion ratio, die land length and lubrication conditions. The study of multi-hole extrusion process with imposed vibrations reveals that the imposed vibrations reduce the extrusion load and improve the product quality.

Bending and unequal product lengths are common phenomena in multi-hole extrusion process, which are dependent on many process parameters. Studies on this

are based on mathematical modeling and finite element simulations, but it is difficult to design a robust die that can produce straight products. In view of it, in the present work, a constrained multi-hole extrusion process has been proposed. The constrained multi-hole extrusion set up is developed to produce equal product lengths without bend. This process is somewhat similar to combined extrusion and closed-die forging process. The mechanical properties of the extruded products obtained from constrained multi-hole extrusion process are better than the extruded products obtained from free multi-hole extrusion process under similar extrusion conditions. The constrained multi-hole extrusion process consumes more power as compared to free extrusion. However, this can be compromised for getting better quality products.

In the present work, a commercial finite element analysis package DEFORM 3D® has been used to obtain the extrusion load for multi-hole extrusion with different multi-hole dies. The extrusion load obtained by finite element analysis is compared with the experimental result and a good agreement is observed. This indicates the possibility of reducing the number of experiments and supplementing them by simulations for the purpose of die design.

Microextrusion process has been proved as a successful method to produce metallic micro pins from the small billet dimensions at low extrusion ratio. In this work, a relatively bigger billet is used and multi-hole extrusion is used to get micro products. The present experimental study on multi-hole microextrusion process investigates the effect of extrusion speed, billet length and die land length on the process. Wax and lead alloy have been extruded through five-hole micro die having average hole diameter of 350 μm. The micro hardness and micro tensile strength of the extruded lead products have been studied. The effect of extrusion speed on extrusion load is significant. The extruded product length from centre hole is larger than that from peripheral holes. These variations are due to the high friction at the container-billet contact region and die land length in contrast to meso extrusion. Peripheral products have higher hardness compared to centre products. Increase in die land length increases the hardness. Higher tensile strength is observed for the products coming out from the peripheral holes as compared to the centre hole products.