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Squared Multi-hole Extrusion Process: Experimentation & Optimization

Chitta R. Mohapatra[1], Dr. N.C.Nayak[2]
[1]*M Tech Scholar, Department of Mechanical Engineering, Indira Gandhi Institute of Technology, Sarang- 759146.*
[2]*Associate Professor, Department of Mechanical Engineering, Indira Gandhi Institute of Technology ,Sarang -759146.*

Abstract:- Extrusion can be defined as the process of subjecting a material to compression so that it is forced to flow through an opening of a die and takes the shape of the hole. Multi-hole extrusion is the process of extruding the products through a die having more than one hole. Multi-hole extrusion increases the production rate and reduces the cost of production. In this study the ram force has calculated experimentally for single hole and multi-hole extrusion. The comparison of ram forces between the single hole and multi-hole extrusion provides the inverse relation between the numbers of holes in a die and ram force. The experimental lengths of the extruded products through the various holes of multi-hole die are different. It indicates that the flow pattern is dependent on the material behavior. The micro-hardness test has done for the extruded products of lead through multi-hole die. It is observed that the hardness of the extruded lead products from the central hole is found to be more than that of the products extruded from other holes. The study suggests that multi-hole extrusion can be used for obtaining the extruded products of lead with varying hardness. The micro-structure study has done for the lead material before and after extrusion. It is observed that the size of grains of lead material after extrusion is smaller than the original lead.

Keywords:- *Extrusion, ram force, ram travel, hardness, grain size, extruded length*

I. INTRODUCTION

Extrusion is an often-used forming process among the different metal forming operations and its industrial history dates back to the 18th century. In 1797, Joseph Bramah an English inventor patented the first extrusion process for making lead pipe. It involved preheating the metal and then forcing it through a die via a hand driven plunger. In the past 30 years, its economic importance has increased primarily as a result of technological advances that have drawn on extensive practical experience and on numerous fundamental investigations into the extrusion process, tooling, and metal flow [1]. Several important dates mark the path to the versatile process used today for both nonferrous metals and steel. Manufacturing is a transformation of materials and information into goods for the satisfaction of human needs. There are several manufacturing processes available to-day to make a given component. Such manufacturing processes are casting, forming, machining, welding and powder metallurgy. However metal forming processes have become increasingly important in almost all manufacturing industries for its certain special advantages: (i) its ability to create uniform cross-sections and work materials that are brittle, because the material only encounters compressive and shear stresses, (ii) forms finished parts with an excellent surface finish [2].

1.1 Comparison of ram force

The ram force required for direct extrusion is more than that for indirect extrusion. When the billet will travel the entire length of the container the frictional force produces. Because of this the greatest force required is at the beginning of process and slowly decreases as the billet is used up. At the end of the billet the force greatly increases because the billet is thin and the material must flow radially to exit the die. But in case of indirect extrusion there is no relative motion between the billet and container due to which less frictional force is produced and hence less ram force is required.

1.2 Multi-hole Extrusion Process

Multi-hole name itself shows that more than one number of holes is there in a die. When a multi-hole die will be used in extrusion process then this is known as multi-hole extrusion. As the number of holes on the die, the same number of products will extrude at a time during extrusion... The process has great importance for producing micron-size parts. In order to increase the productivity, the multi-hole extrusion process is also considered by the practicing engineers to design an efficient extrusion tooling. Multi-hole extrusion is having some advantages over single-hole extrusion process as follows,

- Increases the production rate

- Reduce the cost of production
- Reduce the time.

II. LITERATURE REVIEW

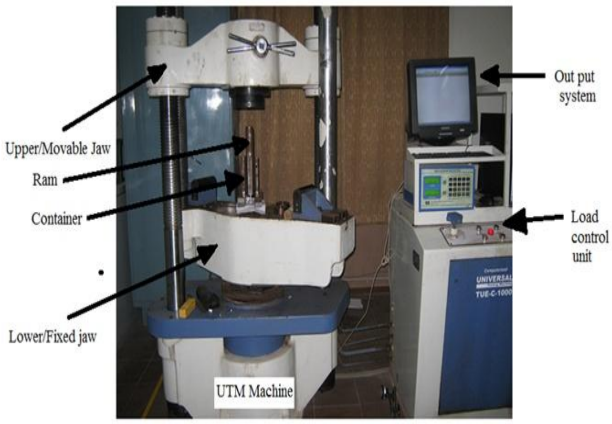
Dodeja and Johnson [3] carried out experiments to cold extrude pure lead, tellurium lead, pure tin and super pure aluminium through square dies containing up to four holes arranged in different patterns. They provided empirical expressions for the calculation of the ram force of multi-holes die. M. Zhang, et al. [4] have done the experiment of multi-holed dies as an alternative to single-holed dies with 1, 6, 33 and 137 holes and investigated the characteristic processing velocity for the onset of liquid phase migration for each die configuration and supported the hypothesis that LPM was caused by suction effects. Ulysee and Johnson [5] have presented analytical and semi-analytical upper bound solutions for plane-strain extrusion through an eccentric hole and unsymmetrical multi-hole dies. Gang Fang, et al. [6] have done the FEM simulation of aluminium extrusion through two-hole multi-step pocket dies. They found that the flow ability of metal increases, increases the extrusion speed and extrusion pressure decreases as the number of pocket steps increases. Fuh-Kuo Chena et al. [7] were examined both the single-hole extrusion and the multi-hole extrusion of aluminium-alloy tubes by finite element analysis and found that the a higher extrusion speed, or a lower extrusion temperature. M.K. Sinha et al. [8a, 8b] have proposed a model for estimation of the ram force and the extruded lengths from various holes in a multi-hole extrusion die. They found that increasing the number of holes in a multi-hole extrusion process decreases the ram force. The extruded lengths for lead are the smallest for central hole and the largest for holes nearest to the die walls. As The micro-hardness and uni-axial tension tests of the extruded products indicated, the strain-hardening of the material is the highest for the central hole and lowest for the holes near the die walls. Guo-Bao Jin et al. [9] have designed and carried out experiments of extrusion die for polypropylene five-lumen micro tube. They found that ovality of the tube profile, especially the ovality of the lumens, was affected by the air injection velocity most obviously, and then die temperature and finally screw speed. Y.Z. Du et al. [10] were examined the effect of double extrusion on the microstructure and mechanical properties of Mg-Zn-Ca alloy and observed the grain was refined from 12 μm of the single-extruded alloy to about 4 μm, 2 μm and 1 μm after second extrusion at 350 C, 300 C and 250 C, respectively. The mechanical properties of the double-extruded alloy were obviously improved, attributing to the finer grains and more homogeneous microstructure.

III. EXPERIMENTAL SETUP

Extrusion is the process of confining the metal in a closed cavity and then allowed it to flow through an opening so that the metal will take the shape of the opening. For the extrusion process we need a setup which has to be prepared. The parts of setup required for extrusion process are container, ram, die, dummy block and billet.

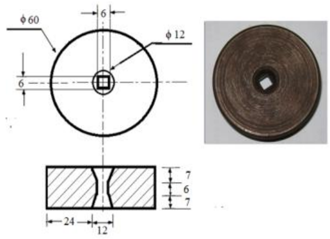
Two parts of the container before assembling

Two parts of the container assembled with bolts

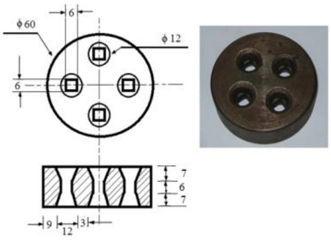


Experimental Setup

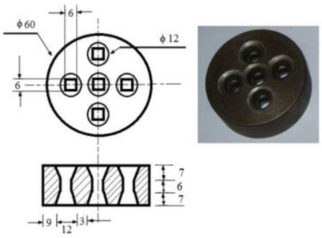
Ram



Single hole die



four hole die



Five hole die

IV. EXPERIMENTAL PROCEDURE

The die having different holes (i.e. five holes, four holes and one hole) have placed in the container for each test. Then the billet has placed on the die. For applying uniform load on the billet a dummy plate has kept on the billet. The two parts of the container has bolted tightly. As the dummy plate is inside the ram, the force cannot be applied directly on it so the ram is placed on it. Then the whole setup has kept on the universal testing machine (Model: TUE-C-1000) machine to apply a continuous load. During the force applied by UTM the graph (Force Vs Cross head travel) has plotted in the computer which has attached to this UTM machine. When the force has increased the billet has passed through the holes and the square shape products were produced. The ram force has obtained experimentally by extruding the billet through the holes of each die on the universal testing machine.

4.1 Extrusion of plasticine

Single hole extrusion

Four hole extrusion

Five hole extrusion

4.2 Extrusion of wax

Single hole extrusion

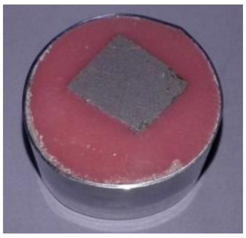
Four hole extrusion

Five hole extrusion

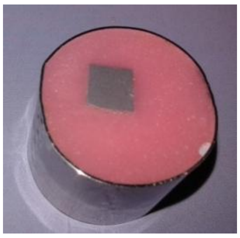
4.3 Extrusion of lead

Five hole extrusion

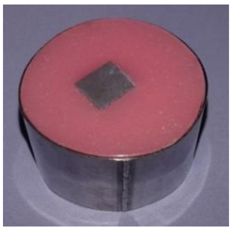
4.4 Preparation of sample for micro-hardness test micro-structure study



Before extrusion



After extrusion (Central hole)



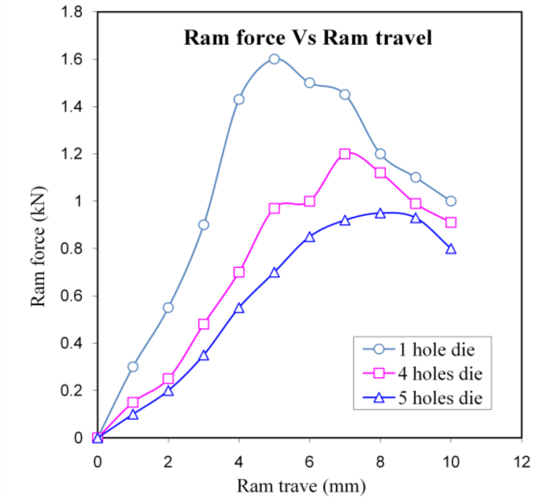
After extrusion (Outer)

V. RESULTS AND DISCUSSION

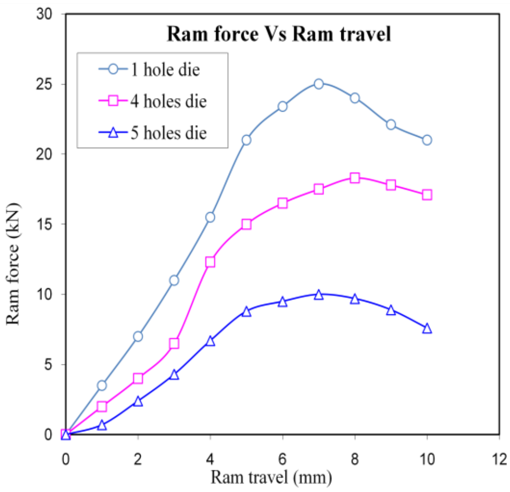
The experiments of square multi-hole and single square-hole extrusion have been carried out using various materials like plasticine, wax and lead. For the feasibility of the square shape extruded products of these materials, the ram force of single hole and multi-hole have been studied and also length of extruded products obtained through different holes have been discussed. In this work the results of micro-hardness for the lead products and grain size of lead before and after extrusion have been discussed.

5.1 Optimization of experimental ram force

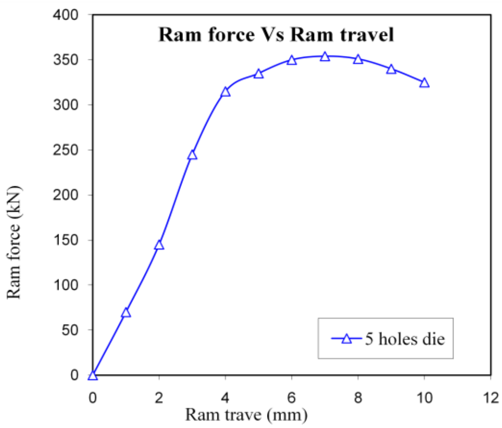
In this present work plasticine, wax and lead have been used as billet material. Ram force required for the different billets i.e. plasticine, wax and lead have been calculated experimentally. From this it can be observed that the ram force is gradually increasing to a ram travel of 5 mm and then decreases at a slower rate.



Comparison of ram forces between single and multi-hole extrusion of plasticine



Comparison of ram forces between single hole and multi-hole extrusion of wax.



Ram force Vs Ram travel curve of lead products extruded from 5 holes die

VHN in (kg/mm²)	
Central Hole	**Outer Holes**
11.1	10.3
11.3	10.1
10.9	10.2
10.0	9.8
11.4	10.1
11.2	9.6
10.6	9.7
10.9	9.3
10.7	9.4
11.3	10.0

Vickers Hardness Number (VHN) of the Lead products from a 5 holes die

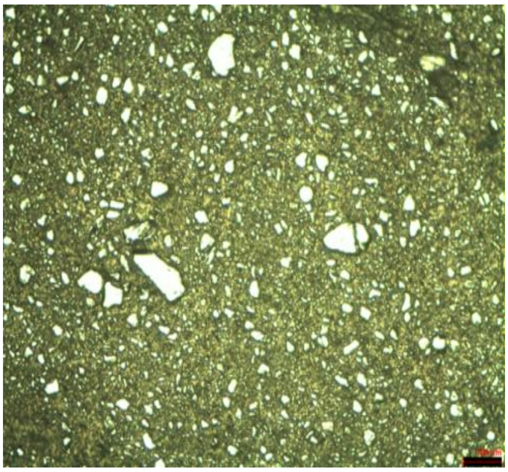
5.2 Micro-hardness Test of lead

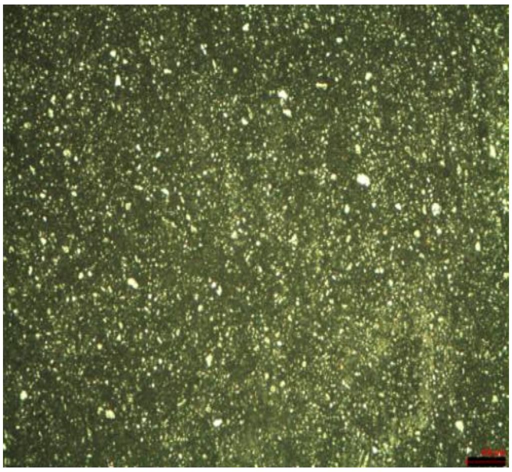
The experimental study shows variations in the hardness of the extruded lead products through the central square hole and outer square holes of multi-hole die. The hardness of the extruded lead products from the central hole is found to be more than that of the products extruded from other holes. This indicates that the material get more strained in flowing through central square hole and less strained in flowing through the outer square holes.

5.3 Observation of Extruded Length

The experimental results shows that the lengths of extruded lead products through multi square hole die were different even for the holes on the same pitch circle. Experimental lengths of extruded lead products for the Central hole and outer holes are different. It was observed that in the multi-hole extrusion of plasticine and wax material, the lengths of the extruded product are almost same from all the holes. Thus, it is observed that the flow behavior is material dependent.

5.4 Micro-structure study of lead before and after extrusion





Grain structure before extrusion **Grain structure after extrusion**

VI. CONCLUSION

It has been observed that with increasing the number of holes in multi-hole extrusion process decreases the ram force. It has also been observed that the pattern of ram force Vs ram travel in square hole is similar to the pattern of circular hole. The experimental lengths of extruded of lead are different from outer holes and central hole. For wax and plasticine the extruded lengths are almost same from all the holes. This indicates that the flow pattern is dependent on the material behavior. The hardness of the extruded lead products from the central hole is found to be more than that of the products extruded from other holes due to strain hardening effect. It has been observed that the products obtained from the square hole dies are defect free as similar to the product obtained from the circular hole dies. It has also been observed that the grains of extruded lead are more finer than the original lead. The multi-hole extrusion process can become a productive process for the mass production of small sized components.

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