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Extrusion of Circular Billet through Circular, Triangular and Square Multi-Hole Dies

Rita Kumari Sahu, Ratnakar Das and Bharat Chandra Routara

***Abstract**: In extrusion with multi-hole dies, more than one product is produced from the same billet and quite suitable for improving the productivity and to produce small dimensioned products. Many operating parameters like number of holes present on die, hole profile, length of die land, die pockets, extrusion speed and friction condition affect the surface finish, bending and mechanical property of the products get extruded. The equivalent size of products produced by multi-hole extrusion process does not exist in literature. The objective of this research work is to produce the products of equivalent dimension from different profile holes by multi-hole extrusion. In this experimental study, the products of circular, triangular ads square profiles have been produced. The dies of 2-hole, 3-hole and 4 holes have been used. The extrusion load requirement, hardness of the final products and the change in length of parts extruded are investigated. The extrusion with squared holed dies needs more extrusion load than circular and triangular holed dies. The hardness value varies along the extruded product length. The variation in length of the extruded parts is more for the products obtained from dies with squared hole dies.*

***Keywords**: Multi-hole extrusion, extrusion load, micro hardness, coefficient of variation.*

I. INTRODUCTION

Extrusion process is widely used in metal forming industries for production of many metallic and non-metallic products. Extrusion is the process in which the workpiece (billet) is compressed in the container with the help of a ram or punch and allowed to pass through a die orifice. The product gets the shape of the die hole profile during extrusion process. The generation of high pressure is an important feature of extrusion process. The shaped die profile, effective lubrication and the state of working temperature condition help to minimize the extrusion pressure. The research works on forward, backward, forward-backward and lateral extrusion are decades old. In multi-hole extrusion (MHE) a die with more than one orifice is used by which the productivity can be improved obtaining many products from the same billet. The MHE also helps in producing micro-metallic components which have wide applications in aerospace, medical instruments and other precision engineering systems. The MHE needs low force as compared to single hole extrusion for same extruded product diameter and this is an advantage for use of press of low capacity. An experimental study carried out for MHE with died having 2,3 and 4 holes and observed that the extrusion load requirement depends on the die having different number of holes and as well as the position of holes on die [1]. With development of computational facilities, the modeling of MHE process was carried out [2-8]. These research works on MHE explain about different process parameters like die profile, die land length, friction condition etc and their effect on extrusion load, extruded product profiles and the extruded product quality. The experimental study on the multi-hole extrusion gave the information about the number of holes on die and the extruded product quality [9]. The die land length effect in MHE was studied for extruded parts [10]. The pockets on the die hole which are generated on the holes at entry side to ease the material flow into the die hole has been studied for 2, 3 and 4 hole dies. The authors calculated the extrusion load, mean stress developed effective strain and varied product length by simulating of the process using DEFORM3D [11]. Generation of a shaped die profile becomes extremely difficult when the hole diameter is less. However, a finite element simulation has been carried out for 2, 3 and 4 hole multi-hole extrusion with different conical profiles dies (10°, 20° and 30°). The load required for extrusion and the effective stress on extruded parts are studied [12].

II. RESEARCH SIGNIFICANCE

Multi-hole extrusion process is a very good alternative to improve the productivity while producing components of comparatively smaller diameter from a larger billet diameter. The previous research works are limited to circular profile products except some exceptions. Other extruded product profiles are also used widely as many parts and components. Production of different profiles of extruded products using MHE is not well explored. The present experimental research work focuses on extrusion of circular billet to produce square, triangular and square shaped products using 2, 3 and 4-hole dies. The extrusion load requirement, hardness of the extruded parts and changes in length of the parts extruded are studied.

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* Correspondence Author
Rita Kumari Sahu, School of Mechanical Engineering, Kalinga Institute of Industrial Technology (Deemed to be University), Bhubaneswar, Odisha, India.
Ratnakar Das*, Department of Manufacturing Engineering, National Institute of Foundry and Forge Technology, Ranchi, Jharkhand, India. E.mail: ratankd@gmail.com
B. C. Routara, School of Mechanical Engineering, Kalinga Institute of Industrial Technology (Deemed to be University), Bhubaneswar, Odisha, India.

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III. EXPERIMENTAL SETUP AND PROCEDURE

In the present experimental study, multi-hole extrusion of 2, 3 and 4-hole dies has been used. The hole profiles are of circular, square and triangular type. For the circular profile, each hole diameters of 3 mm has been selected and the holes are located on the 10 mm pitch circle diameter of the die face. The equivalent dimensions for triangular and square profiles are used for a comparative study. The dies, container, punch and the support plate of die are made of H13 steel. The dimensions of punch, container and the die support plate are designed considering factor of safety to prevent any kind of failure. The different holes have been produced by EDM for getting better quality of the holes. The circular, square and triangular electrode of required dimensions were made of copper and used in making the holes on the dies.

Pure lead has been used for making the billets for carrying out the experiments. The lead material was melted first and then casting was done to make 25 mm diameter and 220 mm length pieces. For casting, a permanent mould made of cast iron was used. Machining was carried out to produce billets of 20 mm length and 20 mm diameter. Thereafter the machined billets are treated in boiled water for 30 minutes and allowed to cool for removal of any kind of residual stresses generated during casting and machining. The container, punch, lead billet were cleaned properly with acetone and MoS_2 was used for lubrication before experiments. All the parts of the experimental setup are shown in fig.1.

Fig.1 Different parts of experimental setup

Universal testing machine (Make: Fine Spray associates & Engineers Pvt Ltd, Model - TUF-C 1000) was used as extrusion press in the compression mode shown in fig.1 The extrusion speed was maintained about 1.2 mm/min so as to get a strain rate of 10^{-3} s^{-1} and to avoid the strain rate effect during the process of extrusion.

Fig.2 UTM used as press for extrusion

After the setting of experimental setup and placing it properly on the flat platen of UTM, the operating valves are opened carefully to maintain the extrusion speed of 1.2 mm/min throughout the experiment. The billet is extruded up to 50% of its height and the extrusion setup is removed from the press. The extruded parts are carefully cut and kept for further study. The load data are saved from data acquisition system. The extruded products are cut carefully for further study. On the extruded products, indication marks are made to indentify the sections as the extreme end and the part nearest to the die exit for studying the hardness distributions. The measurements of the extruded products are also carried out for studying the variations in length of the products. The hardness was measured with Vicker's hardness testing machine (Model-ZHVμ-S). For hardness testing the samples were cut from the extreme end and nearest section of the extruded products. The cut pieces were placed in the mixture of acrylic powder and resin for proper holding. Thereafter the samples were polished as per the standard polishing method before the hardness testing was carried out.

IV. RESULTS AND DISCUSSION

In multi-hole extrusion process, the extruded products come out through the holes made on the die. The extrusion load decreases as the number of holes increases on the die for same billet dimension when extruded with other process parameters kept constant. The flow of the billet material does not obey the uniform flow pattern into the holes although the number of holes of the die at a particular location (pitch circle diameter). This non-uniform material flow result the variation in the product length, mechanical properties and many more. In the present study, the different hole profiles such as circular, triangular and square has been used. The variation of product lengths, hardness distribution on the extruded profiles are investigated for the extruded products obtained from these three types of dies.

A. Extrusion load

The loads required the extrusion of the billet of 20×20 mm circular billet through the different dies are shown in table 1. The loads given in the table are the maximum loads obtained during extrusion of the billet through different dies.

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Table.1 Extrusion load

No. of holes on die	Extrusion load (kN) for different hole profiles		
	Circular	Triangular	Square
2-hole	98	114	115
3-hole	95	96	105
4-hole	88	86	92

It is observed that the extrusion load decreases with increase in number of holes. The extrusion ratio is inversely proportional to the number of holes of the die and the load required for extrusion decreases with decrease in extrusion ratio. The extrusion load is also a function of the different hole profiles. For the die with circular holes on it gives lowest load as compared to triangular and square dies. The sharp corners of the triangular and square profile holes hinder the flow of billet material during extrusion process. For same extrusion ratio (i.e. for a selected number of holes on the die), the square hole profile die requires highest load. Positioning of the triangular and square holes (shown in fig.1) on the die is also important. A preliminary simulation work was carried out to understand the positions of the apex and/or edges of the triangular and square profiles on the extrusion process using DEFORM 3D. It was observed that the edges located towards the pitch circle provide better results in terms of extrusion load and the straining of extruded products. With these results the dies used for experiments have all the holes with their edges towards the defined pitch circle.

B. Hardness study

The mechanical property of the parts extruded depends of the amount of straining the extruded parts experienced during the extrusion process. The extrusion ratio decreases when the number of holes increases on the die for extrusion of same billet diameter.

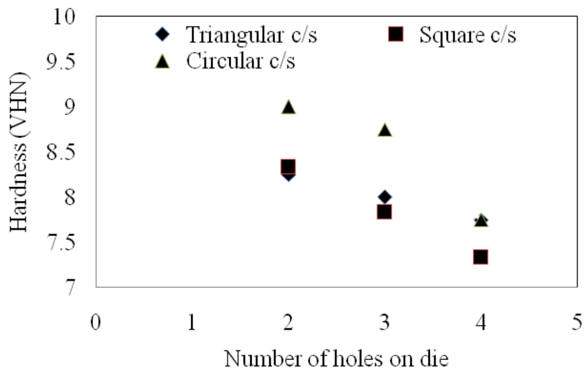

Fig.3 Hardness of the extruded parts near the die exit.

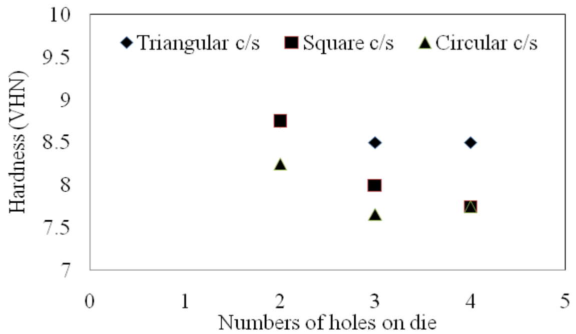

Fig.4 Hardness of the extruded parts at the free end.

From fig.3 and 4 it is observed that as the number of holes increases on all the three dies, the hardness value of the extruded parts decreases. The hardness distribution is also not uniform throughout the entire length of the extruded product. At the free ends of the extruded products the hardness is less than that at the die exit. The strain relieving is better with the triangular and square extruded products than the circular one.

B. Variation in extruded product lengths

The most challenging issue with MHE is to get the equal product lengths after extrusion. Although the holes are on a particular pitch circle of the die and placed at equidistant, still because of non uniform material flow the extruded products come out of the die with different lengths. The coefficient of variations (CoV) of the extruded parts lengths are shown in table 2.

Table 2. Coefficient of variation of the extruded product lengths

No. of holes on die	Coefficient of variation of the extruded product lengths (%)		
	Circular	Triangular	Square
2-hole	14	21	37
3-hole	10	14	16
4-hole	05	07	15

The CoV for length of extruded products is the ratio of standard deviation to the mean length and is expressed in percentage. This is useful for comparing the degree of variation in the product lengths. From the table 2 it is observed that the variation in product length decreases as the number of holes on the die increases. The die with square profile holes has the highest coefficient of variation of the products. The flow of material through the triangular and square hole profiles becomes complex as compared to the circular profile holes. Due to this, the extruded products come out of the die with different length. During the experimentation, bending of the extruded products was also observed and the severity of bending was more in extrusion with two hole dies.

V. CONCLUSION

In the present research work a multi-hole extrusion process has been carried out with dies having square, triangular and square profile holes. Three different dies; 2, 3 and 4-hole dies have been used for extrusion of lead billet material. Extrusion load, hardness of the extruded parts and the variation of extruded product lengths are studied.

1. The extrusion load decreases with increase in number of holes on the die because of decrease in extrusion ratio.
2. The die with square holes need higher extrusion load as compared to triangular and circular holes in MHE. The square and triangular hole profiles restricts the flow of material.
3. The hardness value varies along the extruded product length. For circular holes high hardness values are observed at the die exit and for the products obtained from triangular holes, high hardness values are for the extruded products at free ends.

4. Extruded products from two hole dies experience more strain hardening because of high extrusion ratio and due to this the hardness increases.
5. The variation in length of the extruded product is more for the products obtained from the square hole dies than the other two types of dies.

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AUTHORS PROFILE

Rita Kumari Sahu is working as Assistant Professor in School of Mechanical Engineering at KIIT Deemed to be University, Bhubaneswar, India. She has obtained her B.E. in Mechanical Engineering from VSSUT, Burla, Odisha, India and M. Tech in Industrial Engineering from CET, Bhubaneswar. She is carrying out her research in the area of metal forming. She has two international journal publications and three international conference papers. She is teaching subjects of Manufacturing and Industrial Engineering since last seven years.

Dr. Ratnakar Das is working as Assistant Professor in Department of manufacturing Engineering at National Institute of Foundry and Forge Technology, Ranchi, India (An Autonomous Institute of MHRD, Govt. of India). He has obtained is PhD form IIT Guwahati and Master of Engineering from Indian Institute of Engineering Science and Technology, Shibpur. He had guided one PhD and four more are continuing their PhD thesis. He has also supervised nine M. Tech theses, published twenty research publications in International Journals of repute and eighteen international and national conferences papers. He is a reviewer to many international journals. His research areas include traditional and non-traditional machining of metals and composites, micro and nano manufacturing and metal forming processes. He is teaching manufacturing related subjects since last eleven years. He is a member of Institution of Engineers (India).

Dr. Bharat Chandra Routara is working as Professor in School of Mechanical Engineering at KIIT Deemed to be University, Bhubaneswar, India. He received his Ph. D degree in Production Engineering from Jadavpur University in the year of 2008. Four research scholars have been awarded Ph.D degree under his supervision and three more continuing their PhD thesis. He has guided sixteen scholars of post graduate level and published forty-nine research papers in different International journals of repute. He has presented no of papers in different International conferences in India and abroad. He has reviewed four PhD thesis of different University and number of research papers of International Journals. He has filed one International patent in the field of nontraditional machining. His research interests are in tribology, hard machining on cryogenic cooling, surface characterization of machined surface, optimization of machinability parameters and micro machining. He has been teaching manufacturing related courses since last twenty-six years. Apart from this he holds memberships of various professional bodies like Life member Indian Society of Technical Education (ISTE), Indian Institute of Industrial Engineering (IIIE), The Institution of Engineering and Technology and Fellow member of The Institution of Engineers (India).