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Investigation of Extrusion of Lead experimentally from Round section through Equilateral Triangular section Converging dies at different area reductions during Forward Metal Extrusion Process

[1]Debabrata Rath, [2]Dr. Sushanta Tripathy
[1]*(Mechanical Engineering Department, CMJ University, India)*
[2]*(School of Mechanical Engineering, KIIT University, India)*

ABSTRACT :*The changes of die angle, area reduction in dies, loading rate on the final extruded products, extrusion pressures of lead of circular cross sections has been investigated experimentally. The proposed method is successfully adapted to the forward extrusion of the equilateral triangular section from round billet through converging dies of different area reductions. Computation of extrusion pressure at various area reductions and calculations of different parameters (stress, strain etc.) in wet condition.*

Keywords *- Extrusion of Triangular section, Converging Dies at different area reductions, Friction Factor, Extrusion Pressure*

I. INTRODUCTION

The extrusion process has been performed by various experimental, analytical and numerical methods for determining the extrusion pressures. For many metal working processes, exact solutions are not available and many attempts have been taken for approximate methods to estimate the loads necessary to cause plastic deformation. Now it is becoming essential to pay greater attention to the extrusion of section rod from round stock, as this operation offers the promise of an economic production route. Despite the advantage of converging dies, only a few theoretical approaches to the extrusion or drawing processes for 3D shapes have been published. Nagpal and Altan [1] introduced the concept of stream function to express three dimensional flow in the die and analyzed the force of extrusion from round billet to elliptical bars. Basily and Sansome [2] made an upper-bound analysis of drawing of square sections from round billets by using triangular elements at entry and exit of the die. Yang and Lee [3] proposed kinematically admissible velocity fields for the extrusion of billets having generalized cross-sections, where the similarity in the profile of cross-section was assumed to be maintained throughout deformation. They analyzed the extrusion of polynomial billet with rectilinear and curvilinear sides. Johnson and Kudo [4] have proposed upper bound for plain strain axis-symmetry extrusion, for extrusion through smooth square dies. in this case materials was assumed to be rigid, perfectly plastic and work hardening effect being neglected. Hill et al. [5] proposed the first genuine attempt to develop a general method of analysis of three dimensional metal deformation problem choosing a class of velocity field that nearly satisfies the statistically requirements, by using the virtual work principle for the continuum. Prakash and Khan [6] made an upper-bound analysis of extrusion and drawing through dies of polygonal cross-sections with straight stream lines, where the similarity in shape was maintained. The upper-bound technique appears to be a useful tool for analyzing 3D metal forming problems when the objective of such an analysis is limited to prediction of the deformation load and study of metal flow during the process. P.K. Kar and N.S Das [7] modified this technique of discretizing the deformation zone into elementary rigid regions to solve problems with dissimilar billet and product sections. However, their formulation was also limited to problems with flat boundaries and as such; the analysis of extrusion from round billets is excluded from their formulation. However P.K. Kar and S.K. Sahoo [8] used the reformulated spatial elementary rigid region (SERR) technique for the analysis of round-to-square extrusion by approximating the circle into a polygon and successively increasing the number of sides of this approximating polygon until the extrusion pressure converged by using tapper dies. Narayanasamy et al. [9] proposed an analytical method for designing the streamlined extrusion have the cosine profile and an upper bound analysis is proposed for the extrusion of circular section from circular billets.Hosino and Gunasekara [10] made an upper bound solution for extrusion and drawing of square section from round billets through converging dies formed by an envelope of straight lines. Boer et al. [11] applied the upper bound approach to drawing of square rods from round stock, by employing a method of co-ordinate transformation. Kang et al. [12] have performed finite element simulation of hot extrusion for copper-clad aluminium rod to predict the distributions of temperature, effective stress, and effective strain rate and mean stress for various sheath thickness, die exit diameter and die temperature and validated with experiments. A.K. Rout and K.P.Maity [13] investigated the optimum pressure during extrusion of square sections from square billet by using curved dies. In addition to this the principle laid by Johnson and Mellor[14], the strain in the present case was calculated from the empirical relation.

II. EXPERIMENTAL INVESTIGATION

Before applying the theoretically result to any practical situation, their adequacy needs experimental verification. The objective of present work is to compare theoretically predicted extrusion load with experimental value. Experiments are performed for TRIANGULAR section using converging dies. Commercially available Lead was chosen as the working material for the experiments (extrusion). Different shape of same circular entry face and various reduction of triangular exit face were made (60%, 62%, 70%, 72%, 90%, 92%).

2.1. Determination of Material Behavoiur

The average stress state during testing is similar to that in much bulk deformation process, without introducing the problems of necking or material orientation. Therefore, in compression test, a large amount of deformation can be achieved before fracture. By controlling the barreling of the specimen ends and the anvils with lubricants the strain can be varied under limits.

2.1.1. Experimental procedure of Compression Test

Cylinders with a 50.20mm × 31.77 mm (H/D = 1.5 to 2) were used to obtain the stress-strain curve by a compression test using UTM (INSTRON 400 KN) at room temperature. The compression rate is maintained same as that adapted for the experiments. The specimen has oil grooves on both the ends to entrap lubricant during the compression test. The compression load is recorded at every 0.5 mm of punch travel. After compressing the specimen to about 10 mm it is taken out of the press, re-machined to cylindrical shape with original diameter, and tested in compression till the specimen is reduced to about 10mm. The stress-strain diagram is drawn and the curve is extrapolated beyond a natural strain 0.5. To simulate a rigid plastic material, the wavy portion is approximated by smooth line (Fig. 2.1). The average flow stress of the used lead is found to be 25460 KN/m^2.

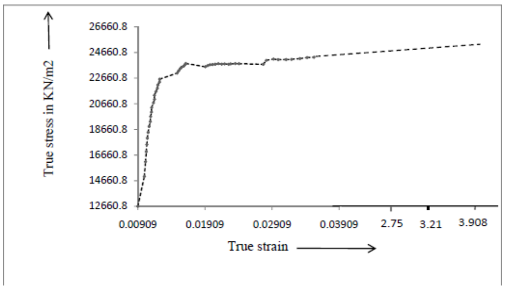

Fig 2.1.variation of true stress with true strain

2.2.Measurement of Friction Factor The coefficient of friction may actually vary through a working pass, as the lubrication deteriorates due to thinning of the film and extension of their surface. Experimental studies suggests, however that this is negligible for all well lubricated operations. There is at present no generally accepted method of measuring the value of the coefficient of friction for given surface and lubricant. Various factors can influence the result, chemical condition, lubricant film thickness; temperature, speed, environment and degree of deformation should match as closely as possible the actual conditions of the operation. The friction factor can be measured by the following methods.

- Direct measurement of friction in metal working.
- Coefficients obtained from correlation of theory.
- Measurements depending upon shape change.

2.2.1. Ring Compression Test

Ring compression test suggested by Kudo and Kungio and developed by Cockcroft utilizes axial compression of a ring between flat platens. When a flat, ring shaped specimen is upset in the axial direction, the resulting shape change depends only on the amount of compression in the thickness direction and the frictional conditions at the die ring interfaces. If the interfacial friction were zero, the ring would deform in the same manner as a solid disk, with each element flowing outward radially from the center. In case of small but finite interfacial friction, the outside diameter is smaller than in the zero friction case. If the friction exceeds a critical value, frictional resistance tooutward flow becomes so high that some of the ring material flows inward to the center. Measurements of the inside diameters of compressed rings provide a particularly sensitive means of studying interfacial friction, because the inside diameter increases if the friction is low and decreases if the friction is higher. The ring thickness is usually expressed in relation to the inside and outside diameters. Under the condition of maximum friction, the largest usable specimen height is obtained with rings of dimensions in the ratio of 6:3:2 i.e, Outer Diameter: Inner Diameter: Height. The ring compression test can be used to measure the flow stress under high strain practical forming conditions. Thus, by measuring the ratio of internal, external diameters after axial compression of a ring of standard dimensions, it is possible to obtain a measure of the friction. Fig2.2 and 2.3 shows rings before and after compression.

Fig 2.2. rings before compression

Fig 2.3. rings after compression

2.2.2. Experimental procedure for Ring Test

A ring compression test was carried out at commercially available grease lubrication condition. The rings were compressed upto the 4 mm inner diameter, at each 0.5 mm of punch travel inner diameter and height was recorded. The friction factor was found to be 0.38 for the lubricated condition by comparing our result with the calibration curve of Male and Cockcroft(Fig 2.4)

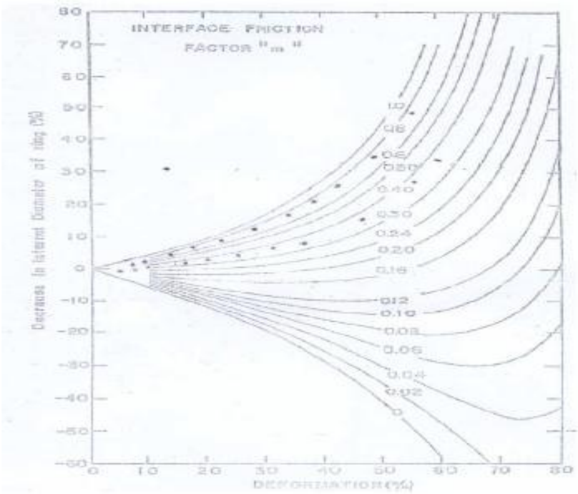

Fig 2.4. theoretical calibration curve for standard ring 6:3:2 [19]

TABLE 2.1. Dimensions of Different Dies

SL NO.	LENGTH OF SIDES(mm)	AREA (mm^2)	% OF AREA REDUCTION	HEIGHT OF DIE(mm)	MATERIAL
1	25.55	282.67	60	40	EN 8
2	24.91	268.61	62	40	EN 8
3	22.13	212.06	70	40	EN 8
4	21.38	197.92	72	40	EN 8
5	12.78	70.72	90	40	EN 8
6	11.43	56.55	92	40	EN 8

III. RESULT AND DISCUSSION

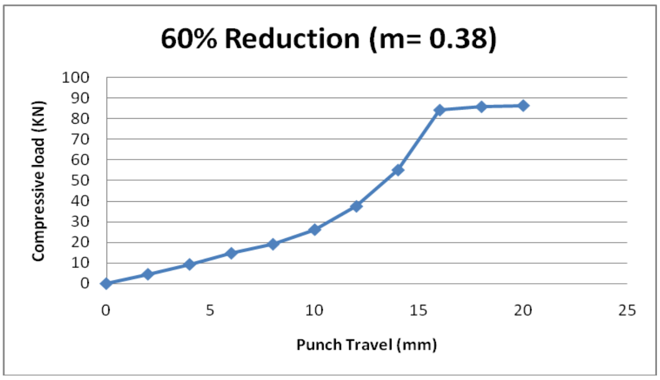

Fig 3.1. Compressive Load vs Punch Travel graph for 60% reduction (m=0.38)

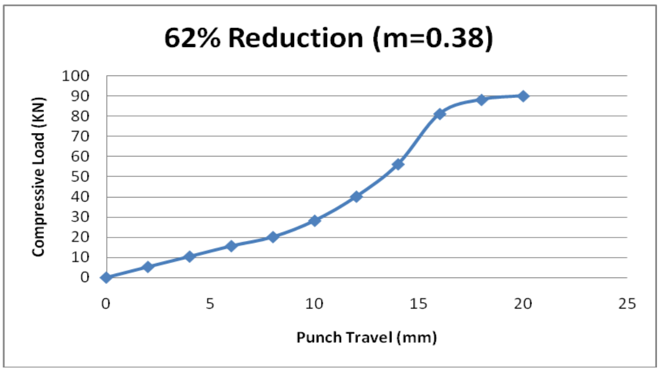

Fig 3.2. Compressive Load vs Punch Travel graph for 62% reduction (m=0.38)

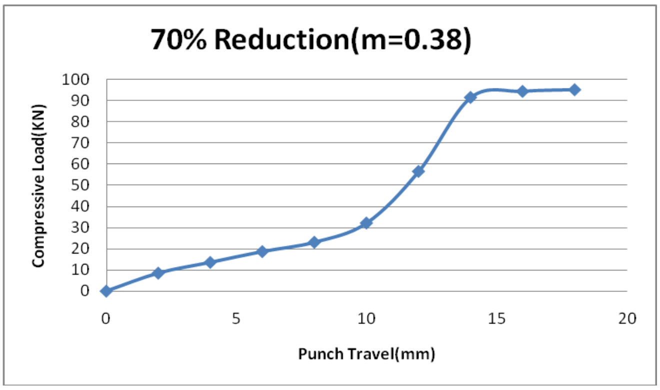

Fig 3.3. Compressive Load vs Punch Travel graph for 70% reduction (m=0.38)

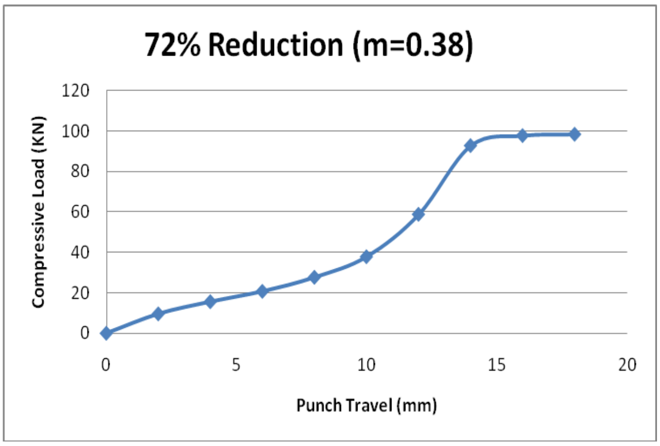

Fig 3.4. Compressive Load vs Punch Travel graph for 72% reduction (m=0.38)

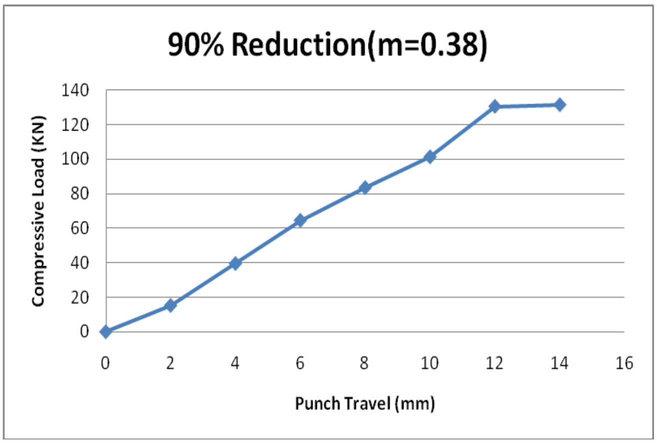

Fig 3.5. Compressive Load vs Punch Travel graph for 90% reduction (m=0.38)

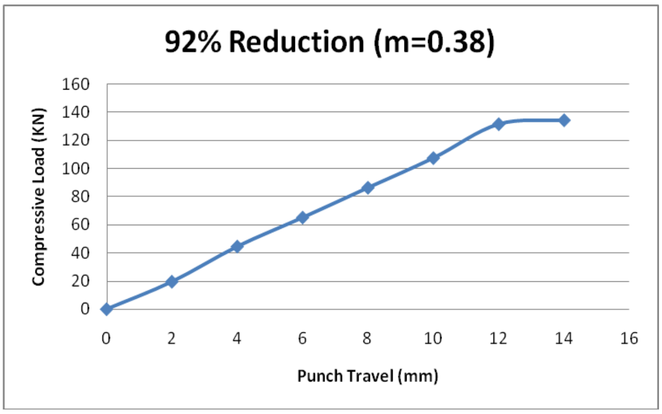

Fig 3.6. Compressive Load vs Punch Travel graph for 92% reduction (m=0.38)

Table3.1 Experimental Result tabulation for m = 0. 38

Section	Condition	Reduction (%)	ε	Punch load (N)	Area (mm^2)	Pav (N/mm^2)	σ_0 (N/mm^2)	Pav/ σ_0 (Exp.)
Equilateral Triangle	Wet (m=0.38)	60	2.174	86000	706.86	121.665	25.460	4.78
		62	2.251	92000	706.86	130.153	25.460	5.11
		70	2.606	95000	706.86	134.397	25.460	5.28
		72	2.709	98000	706.86	138.641	25.460	5.45
		90	4.254	131000	706.86	185.326	25.460	7.28
		92	4.589	134000	706.86	189.571	25.460	7.45

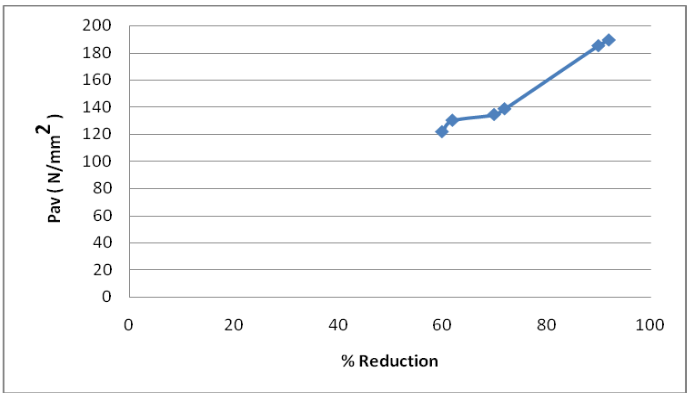

Fig 3.7. Percentage Reduction vs P_{av} graph (m=0.38)

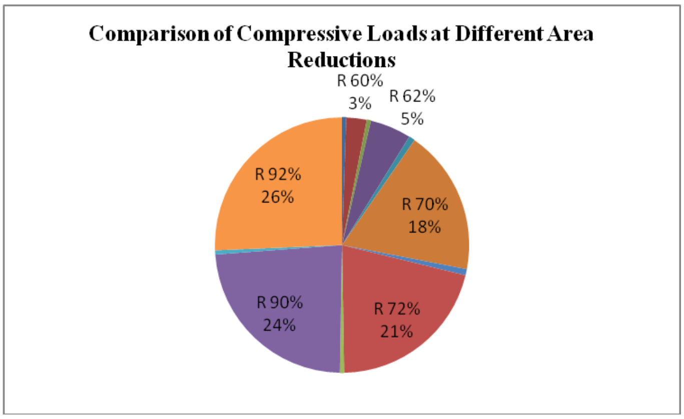

Fig 3.8. Comparison of Compressive loads at different area reductions (m=0.38)

It is indicated that the extrusion pressure increases with increase in reduction.

IV. CONCLUSION

In this study, a die profile function have been developed for extrusion of equilateral triangular section from round billet using a mathematically converging die profile. Various extrusion parameters have been investigated to determine their effects on extrusion product. It was found that extrusion pressure increases with increase in reduction. Analysis of extrusion at other different reductions may be carried out to compare the results.

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