Fabrication and Performance Evaluation of a Simple Laboratory Metal Extrusion Machine

Adefidipe Ebenezer Rotimi[1], Abe Peter Olumuyiwa[2], Omojola Temitope Bamidele[3]

[1]*Welding and Fabrication Department, The Federal Polytechnic, Ado-Ekiti*
[2]*Mechanical Engineering Department, Osun State University, Osogbo, Nigeria*
[3]*Mechanical Engineering Department, Afe Babalola University, Ado-Ekiti*

[1]adefidipe_er@fedpolyado.edu.ng

Abstract - Fabrication and performance evaluation of a simple laboratory metal extrusion machine were carried out. The fabrication involved different manufacturing processes such as cutting, welding, machining, casting, finishing etc. The project is aimed to fabricate a simple extrusion machine that can be used for experimental and laboratory purposes. In the course of the work, locally sourced materials were used and various engineering workshop techniques were applied to construct the machine.
The extrusion machine was tested to ascertain its function-ability with six different dies of different diameters to produce extrudates from a constant diameter specimen. The result obtained from the machine showed that the higher the diameter of the workpiece the lower the required time taking to extrude.
The success of this project helped to gather experience in the application of various engineering techniques in machine fabrication. The extrusion machine will be of benefit to carry out extrusion analysis in the laboratory by applying various parameters applicable to metal extrusion techniques. The cost at production is ₦615,500

Keywords: *Fabrication, Extrusion Machine, Extrudates, Extrusion Ratio, Strength Coefficient.*

1.0 INTRODUCTION

Extrusion, though one of the most important manufacturing processes today, is a relatively young metalworking process. Commercial extrusion of lead pipes started early in the 19th century and it was not until near the end of that century that it was possible to extrude even brass. This was largely because the heavy and sustained pressures necessary for extrusion were not available. The extrusion process can be done with the material hot or cold. Commonly extruded materials include metals, polymers, ceramics, concrete, modeling clay, and foodstuffs. The products of extrusion are generally called "extrudates". The extrusion process began in the 1800s by preheating the metal and forcing it through a die via a hand driven plunger known as squirting (Rauwendaal, 2001).

Extrusion process may involve many stages through a single hole die or multiple hole die to obtain the final shape of a component. Dies of appropriate shape and sizes are then required to impart the right shape and specified tolerance in their respective passes. A welding chamber die (bridge, spider etc.) under hot condition is common for extrusion of hollow component. Square dies for single and multi-hole extrusion under hot condition have been widely used. Continuous dies such as streamlined, conical, elliptical, hyperbolic and cosine dies are becoming important for manufacture of better plastic product, in plastic extrusion, the required shape of the product is produced with a die. Extrusion through multiple hole dies, using a high capacity extrusion press is preferred for reasons of economy and high productivity (Junting, 2009) . Extrusion machine can be classified based on the types of extrusion process. It can be classified by Direction; by operating temperature and by equipment (Junting, 2009) (Deepam, Goyal and Nitesh, Parmar, 2014)). Extrusion is one of the major manufacturing processes where complex shapes that cannot be fabricated locally or good surface finishing is required.

Mohammed defines extrusion machine is an electrically or hydraulically driven machine that pushes or pulls cold metals billets, hot metals, molten metal or plastics through a cavity called barrel with piston or screw conveyor and forces the material out through a regular hole called die to form a length shape that conforms to the shape of the die. (Mohammed, 2014)

Extrusion is done by squeezing metal in a closed cavity through a tool, known as a die using either a mechanical or hydraulic press. Extrusion produces compressive and shear forces in the stock. No tensile is produced, which makes high deformation possible without tearing the metal. The cavity in which the raw material is contained is lined with a wear resistant material. This can withstand the high radial loads that are created when the material is pushed the die (Cold Extrusion, 2005).

Many research had been carried out on extrusion in the recent times. Juntin et al (Junting, 2009) investigated the cold extrusion forming of copper/aluminum clad composite based on the low pressure casting billet. In the report, the technology was studied by using the experimental investigation and the finite element method. It was discovered that the drop-in phenomenon occurred in aluminum during the extrusion forming process. The result of the product was having good quality when the extrusion ratio is 5.45 and the extrusion modular angle was 30°. The crack appeared on the head of product when the extrusion ratio and extrusion angle was larger than the aforementioned values.

Chi et al. researched on cold extrusion process and die of vehicle gear sleeve with spline, optimized the cold extrusion process of the part using finite element method (FEM analysis), which gives us a theoretical basis for further exploration on the cold extrusion, and selecting optimum process parameters. Their optimized results were verified by experiments and mass production. They analyzed the effect of the punch shape of gear container to metal flowing. Their result showed that plastic flow could be controlled by the selection of the punch shape of gear container which reduced the resistance to deformation, and the gear profile was full without folding defects (Chi , Xin , & Rong , 2011).

Ghaemi et al. discussed that one of the most important design parameters in extrusion process is the shape of die profile (Ghaemi, Ebrahimi, & Hosseinifar, 2013).

This work becomes necessary to demonstrate that an extrusion can be fabricated locally with available materials to enable students familiar with design and fabrication processes as well produce an extrusion machine that can be used in the laboratory to demonstrate the process involved in extrusion of metals.

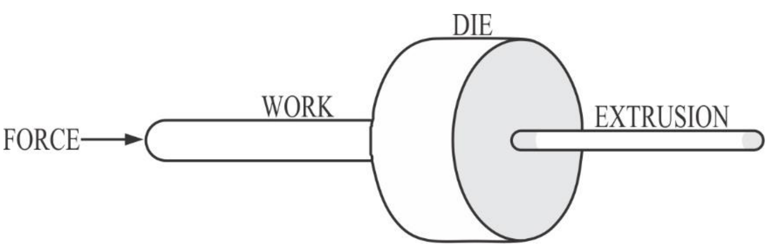


Figure 1: Description of Extrusion.

2.0 Materials and Methods

The study involved the identification of the essential materials and design considerations. These were followed by the conceptual and detailed design of the machine using existing design theories.

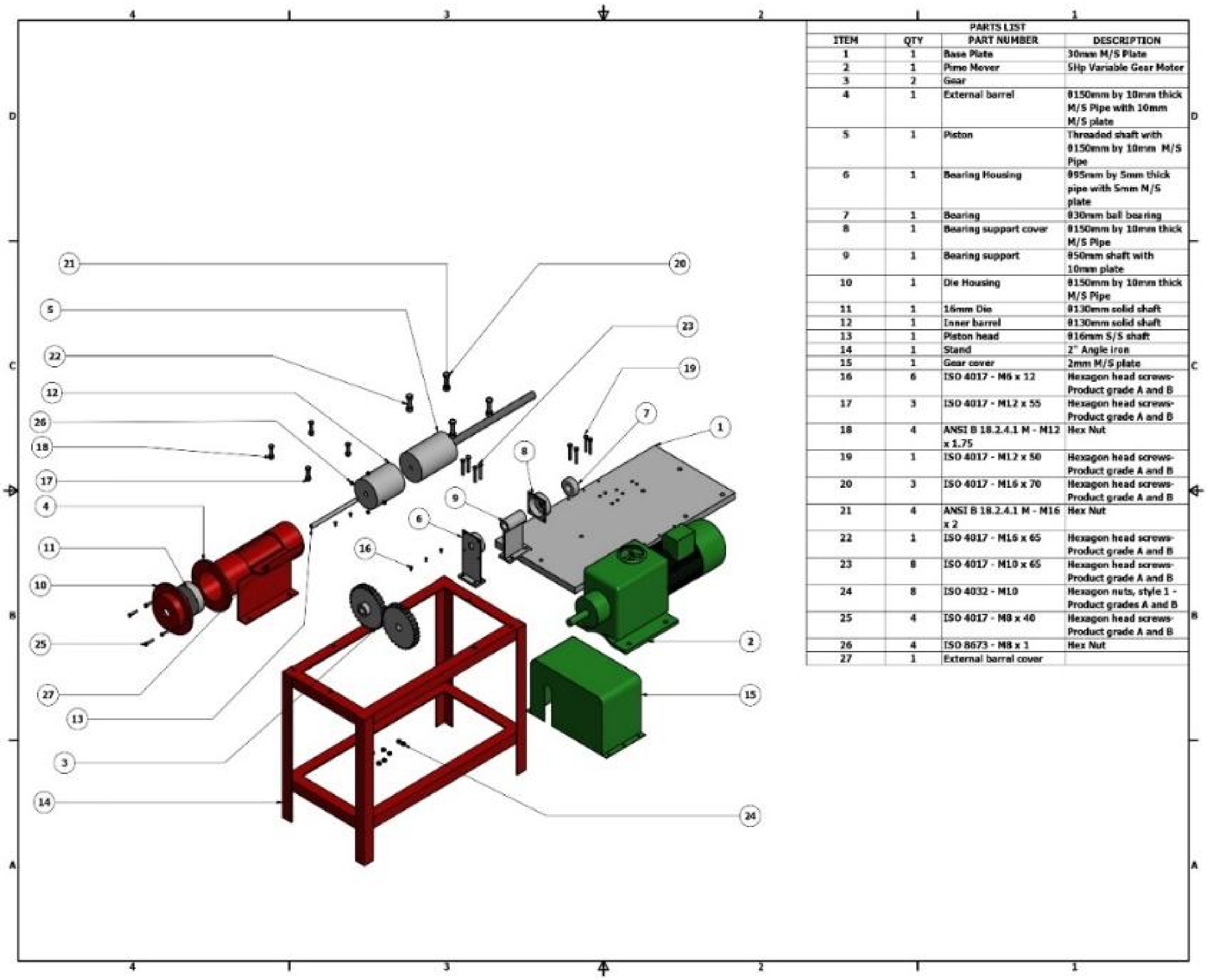
2.1 Design Considerations and Drawings

2.1.1 Design Considerations

The general consideration in designing this metal extrusion machine is to produce a machine that can be easily assembled or disassembled, a machine in which the barrel has the required thickness to allow the needed pressure for extrusion; the die is made of a mild steel and of convenient cut and exit angle that makes the extrusion possible. Forward extrusion process is adopted in this design.

Drawing & Description of Parts

The Exploded View of the Extruder



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Base Plate	30mm M/S Plate
2	1	Pimo Mover	5Hp Variable Gear Motor
3	2	Gear	
4	1	External barrel	Ø150mm by 10mm thick M/S Pipe with 10mm M/S plate
5	1	Piston	Threaded shaft with Ø150mm by 10mm M/S Pipe
6	1	Bearing Housing	Ø95mm by 5mm thick pipe with 5mm M/S plate
7	1	Bearing	Ø30mm ball bearing
8	1	Bearing support cover	Ø150mm by 10mm thick M/S Pipe
9	1	Bearing support	Ø50mm shaft with 10mm plate
10	1	Die Housing	Ø150mm by 10mm thick M/S Pipe
11	1	16mm Die	Ø130mm solid shaft
12	1	Inner barrel	Ø130mm solid shaft
13	1	Piston head	Ø16mm S/S shaft
14	1	Stand	2" Angle iron
15	1	Gear cover	2mm M/S plate
16	6	ISO 4017 - M6 x 12	Hexagon head screws-Product grade A and B
17	3	ISO 4017 - M12 x 55	Hexagon head screws-Product grade A and B
18	4	ANSI B 18.2.4.1 M - M12 x 1.75	Hex Nut
19	1	ISO 4017 - M12 x 50	Hexagon head screws-Product grade A and B
20	3	ISO 4017 - M16 x 70	Hexagon head screws-Product grade A and B
21	4	ANSI B 18.2.4.1 M - M16 x 2	Hex Nut
22	1	ISO 4017 - M16 x 65	Hexagon head screws-Product grade A and B
23	8	ISO 4017 - M10 x 65	Hexagon head screws-Product grade A and B
24	8	ISO 4032 - M10	Hexagon nuts, style 1 - Product grades A and B
25	4	ISO 4017 - M8 x 40	Hexagon head screws-Product grade A and B
26	4	ISO 8673 - M8 x 1	Hex Nut
27	1	External barrel cover	

Fig. 2: Exploded View of the Extruder

2.2 Description of the Machine Parts and Material Selection

The frame and the base plate
The frame is made of 50mm by 5mm thick mild steel angle iron and the base plate of 30mmX450mmX750mm. It was cut to the required dimensions with the aid of Hand grinder. The length, breadth and height are 900mm, 460mm and 6000mm respectively. Following the working drawings of the design as shown fig. 3, the cut members were welded together using arc welding with mild steel electrode.

Material for the barrel
The barrel is a thick hollow shaft that houses both the billet and the piston that pushes the billet for extrusion. Its wall is 10mm thick so that it can withstand the extrusion pressure generated from the extrusion process.

Shaft
The shaft is the plunger that move the piston in a to and fro movement inside the barrel. It is threaded and connected to the gear coupling of the motor. The rotation of the gear which has a thread hole makes the threaded shaft to rotate as well, move in forward and backward direction with the aid of clockwise and counterclockwise switch of the motor

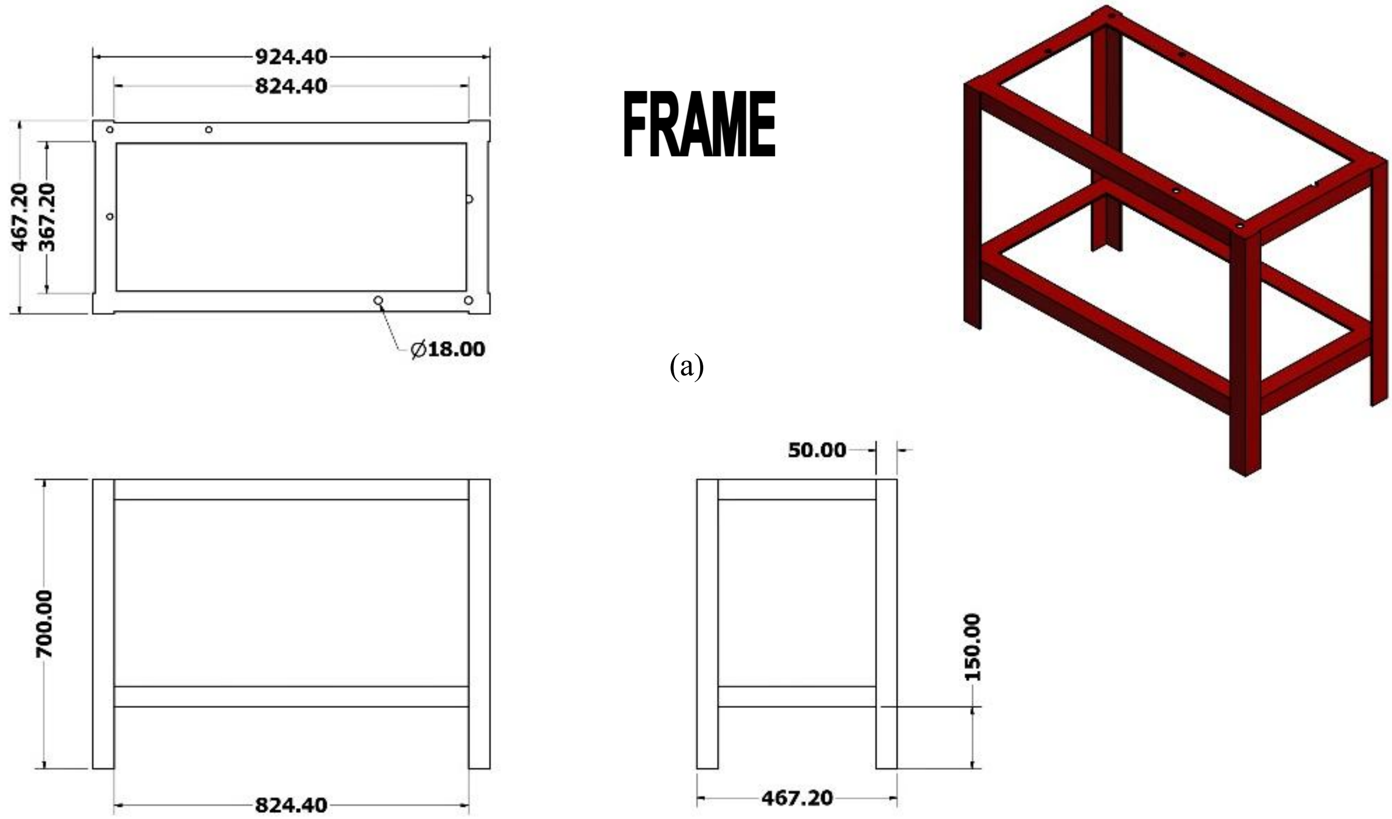
Piston
The piston is connected to the end of the shaft towards the hole of the barrel. It serves as ram that forces the billet through the die. Its action is enabled by forward and backward movement of the shaft. The torque of the electric motor provides the required force needed for the extrusion.

Die
The die provides an opening through which the billet is forced out to form a lengthened shape of the die. It is positioned inside the barrel, covered at the end part of the barrel. It is made of a pair that is male and female component to enhance easy manufacturing and machining.

Barrel Cover
Barrel cover is tightened to the end part of the barrel to provide a barrier which prevents the free fall of the die. It houses the pair of the die such that it creates the require obstruction that makes the extrusion of the billets through the hole of the die possible.

Fabrication Procedure
The fabrication of the extrusion machine are described below:

The Frame and the base plate
The frame is made of 50mm flange by 5mm thick mild steel angle iron. It was cut into dimensions by angle cutter and welded together with arc welding using mild steel electrode. The base plate with size 18inches by 30inches of 30mm thick formed the base on which the assembled machine is mounted. The frame serves as support which carried the base plate upon which the machine is mounted. The details are shown in the working drawing below.



(a)

(b)

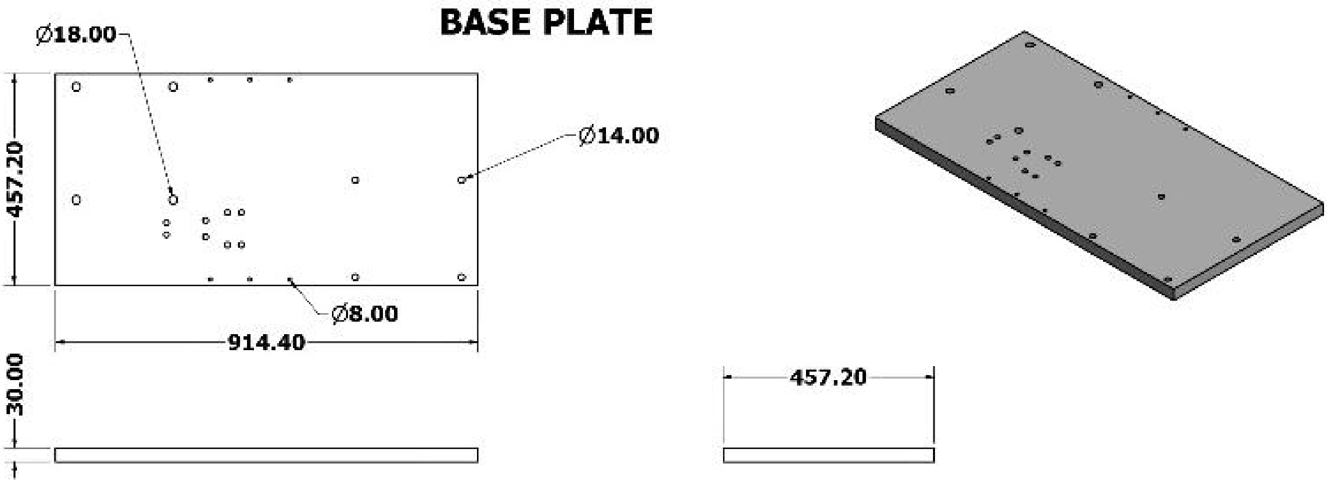


Figure 3: (a) The Frame (b) The Base Plate

2.3 Fabrication Procedure

The Barrel

The barrel is made of 100 diameter by 10mm thick mild steel pipe of 600mm length. The length is cut into two sections as shown in the working drawing below. The cutting and welding works was done with angle cutter and arc welding respectively using mild steel electrode.

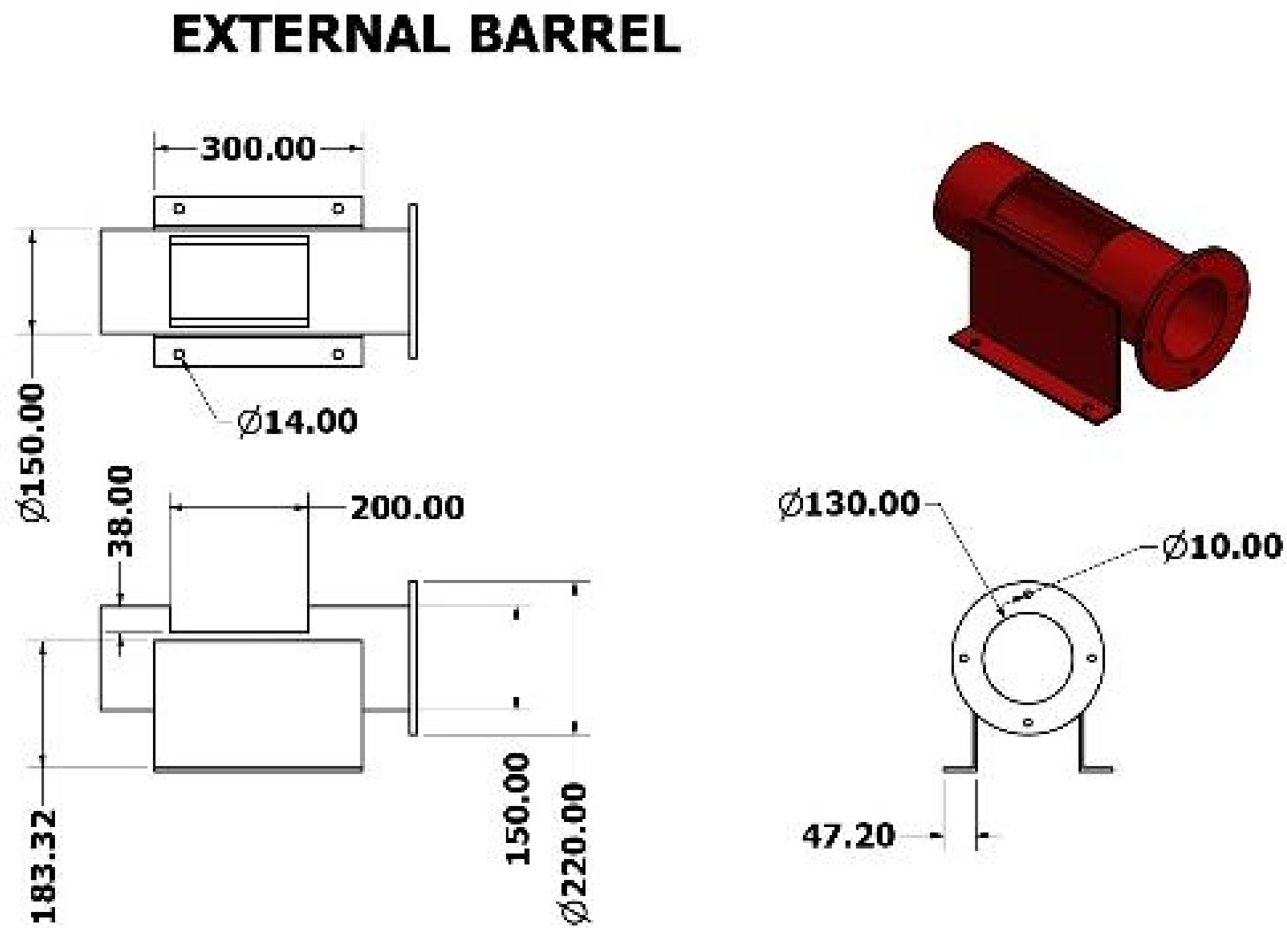


Figure 4: The Barrel

The Shaft

The shaft is made of threaded mild steel shaft connect to the gear coupling and the piston. The cuttings was carried out with angle cutter and the machining was done on centre lathe as shown in Fig. 5.

The Piston

The piston or ram is made of mild steel pipe of 10mm thick, cut appropriately and turned on the lathe.

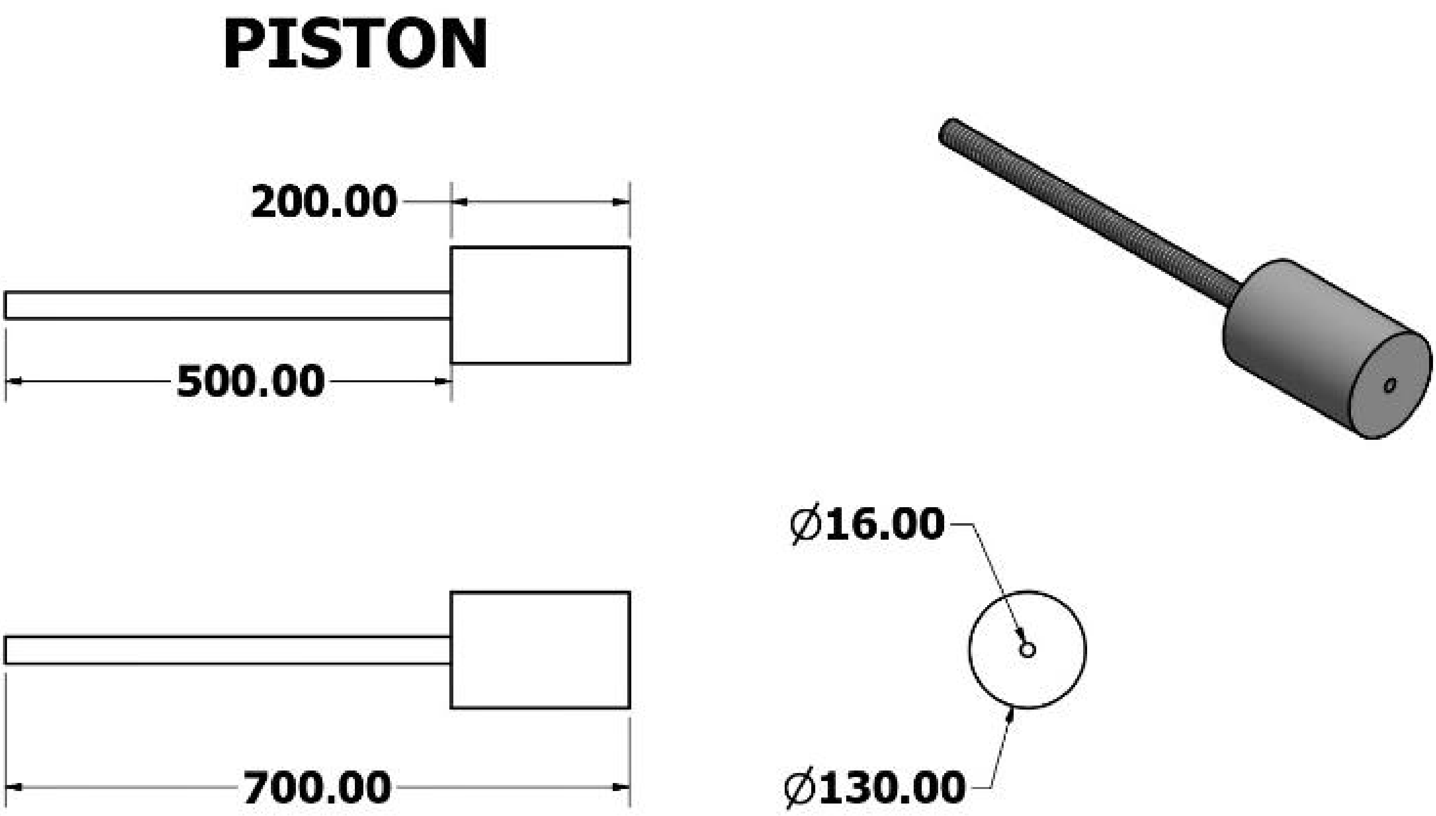


Figure 5: The Piston and the Shaft

The die

Mild steel of 15mm thick was used to form the dies. The plate was cut to form the shape of the die using angle cutter and cut and exit angle was created using lathe machine.

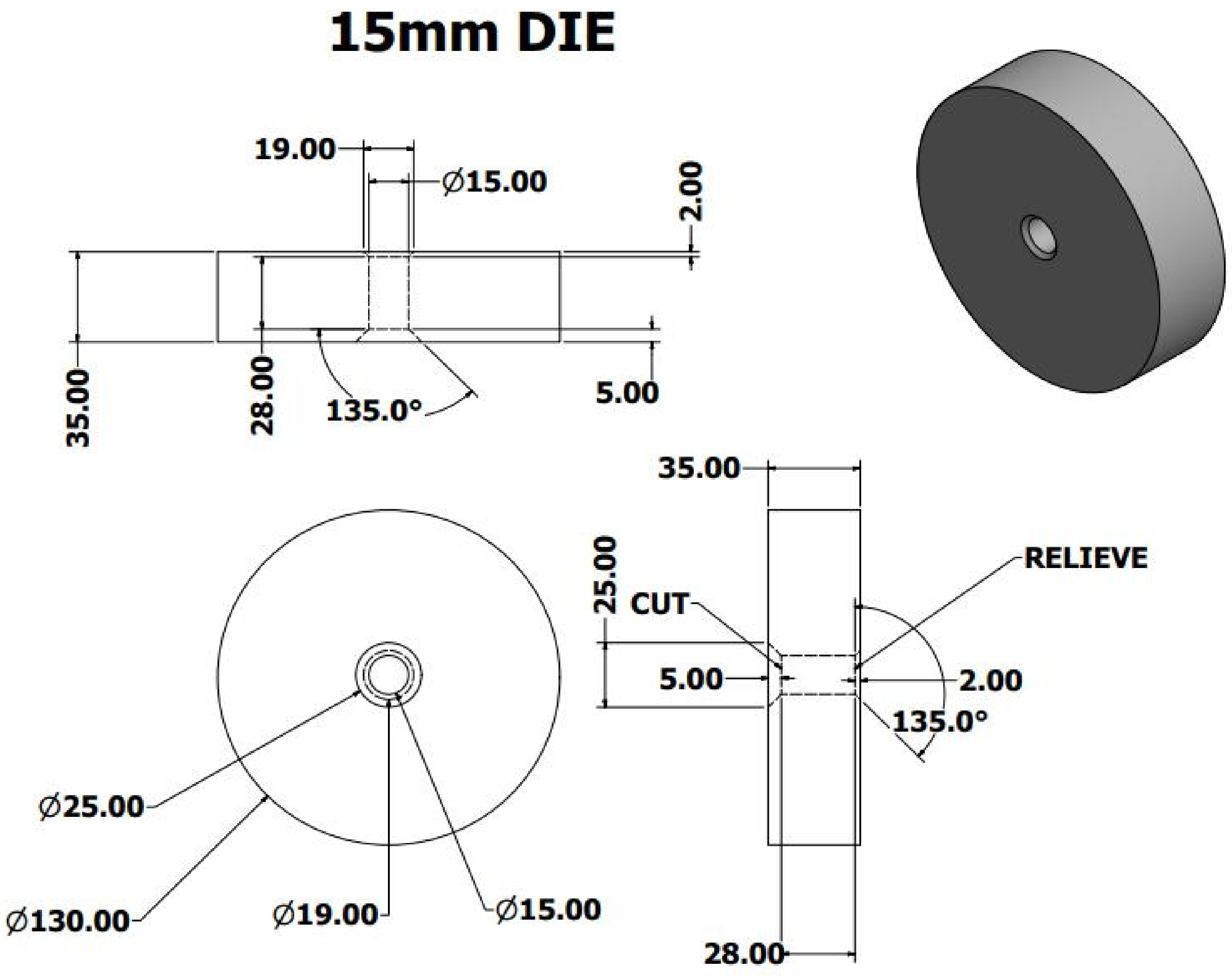
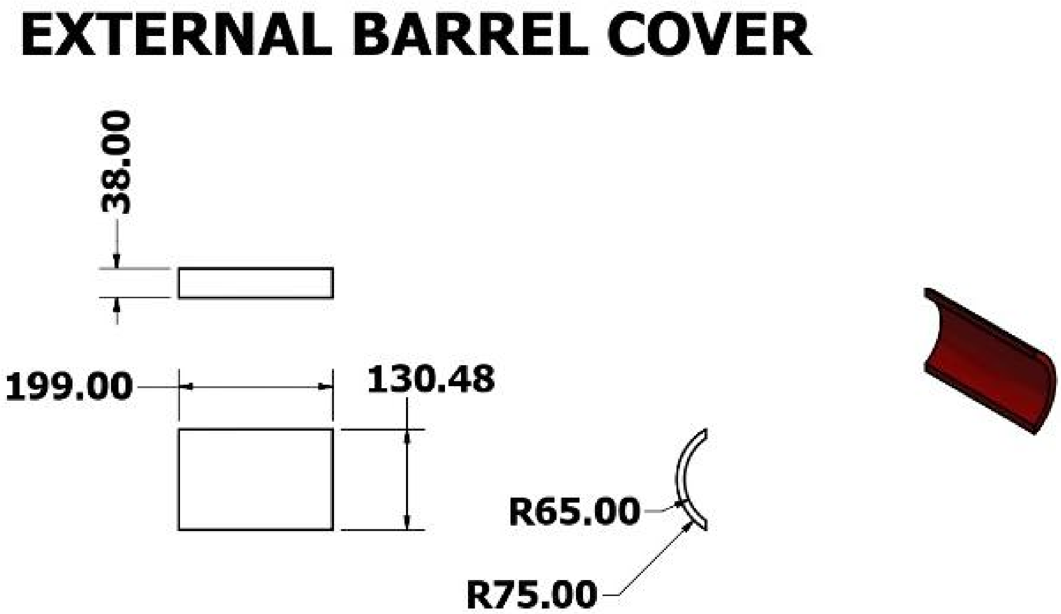


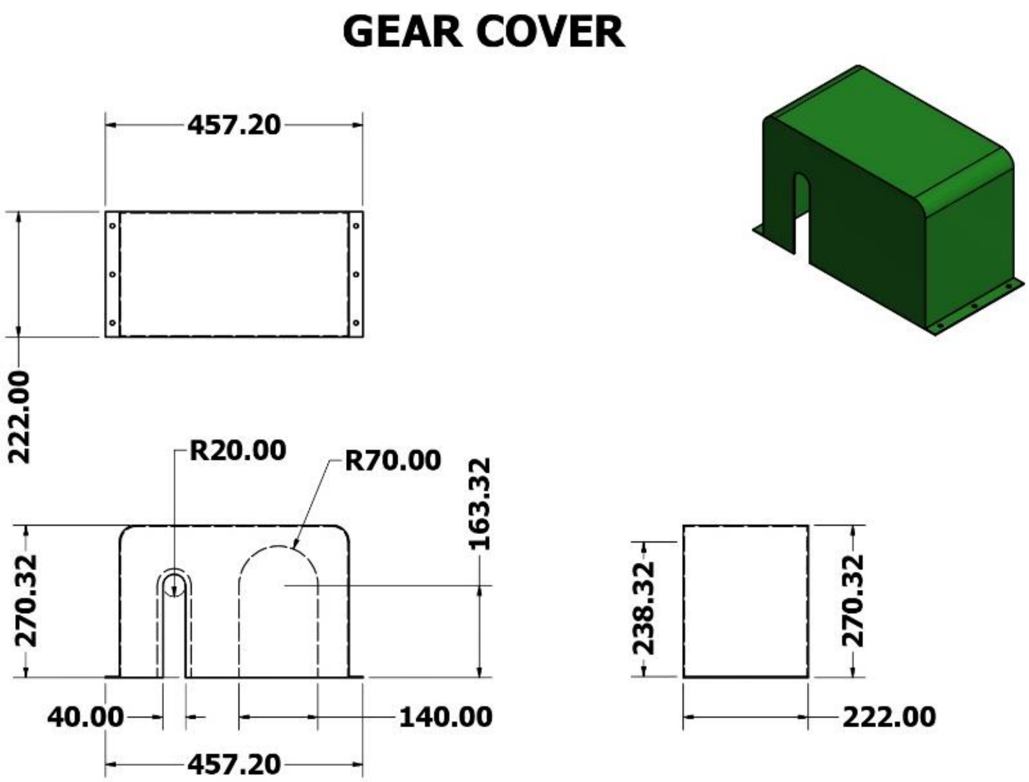
Figure 6: The Die

Figure 7: Gear Cover and Barrel Cover

The Barrel Cover

Barrel cover is made of 20mm thick mild steel material and is tightened to the end part of the barrel to provide a barrier which prevents the free fall of the die. It was machined on the lathe and welded together with arc welding machine.





Components and Assembling Process

Having fabricated all the components of the extrusion machine as described above under the components of the machine, the assembly of the extruder components is as shown in figure 8

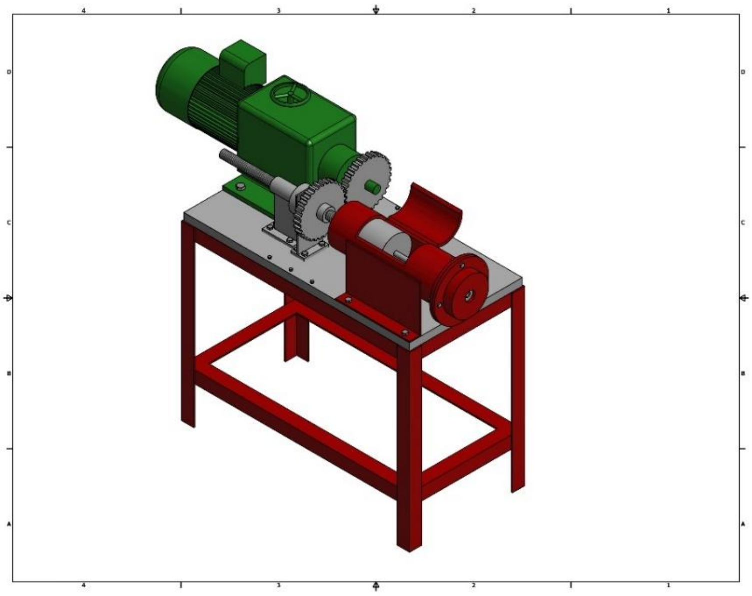


Figure 8: Assembly Metal Extrusion Machine

3.0 Performance Evaluation

3.1 The Working Principle of the Machine

The machine is basically made of variable gear electric motor of 4hp capacity, the barrel, die housing, threaded shaft with piston head, two gear teeth and a stopper. The threaded and piston headed shaft is fixed inside the barrel; the threaded shaft is connected to the gear motor by the two meshing gears. The internal diameter of the gear on the threaded shaft is also threaded. So, the rotation of the gear causes the transverse movement of the shaft, clockwise rotation cause backward movement and vice versa. The forward movement of the shaft enables the billet to be forced out through the die by the piston.

3.2 Preparing the machine for testing

3.2.1 Removal of the cap housing

In order to prepare the machine for test running, the first step is to the die cap. This is done by removing all the bolt/nuts fastening the die cap to the barrel head in order to gain access to fix the required die for testing operation

3.2.2 Removal of the workpiece sleeve

The workpiece sleeve is accessed once the cap is opened and allow for removal of the sleeve top fix the required specimen/workpiece in the machine for extrusion.

3.2.3 Fixing and aligning of the specimen

The sleeve with already fixed specimen is slide back into the barrel and aligned to ensure its centeredness to the die hole before mounting the die cap.

3.2.4 Coupling of the die cap for operation

After the alignment of the specimen /workpiece with the die hole. The cap is returned and tightened with bolt/nut to the barrel head of the machine. The machine is ready for operation.

3.3 Operation of the machine

The die was positioned inside the die housing and properly mounted. The billet was fed through the inlet opening of the barrel, the gear motor was switch on and the piston was set to forward movement. The piston then pushed the billet into the die and gradually forces it out to get the extrudate. This operational procedure was repeated for dies of 15mm, 14mm, 13mm, 12mm, 11mm and 10mm diameters using billets of the same diameters.

4.0 Results and Discussion

4.1 Results

Table 1: Test parameter of the machine

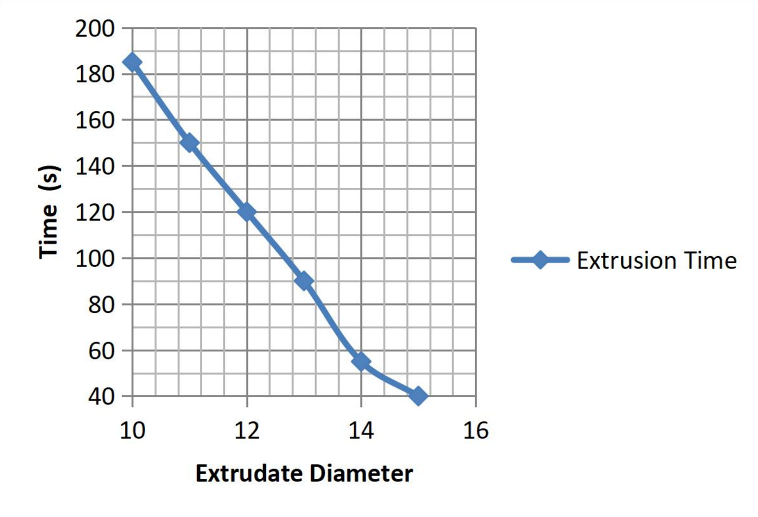


Figure 9: The graph of time against Extrudate diameter

4.2 Discussions

The graph in Fig 9 shows the relationship between the time and extruded products (extrudates) of six billets of the same diameter. The trend of the graph moves from the top left hand side down to the right hand side. This implies that the higher the die diameter the lower the extrusion time required and vise-versa. That is, with the same billet diameter, time and die diameter are inversely related in extrusion processes.

It was observed from the operation that the higher the diameter of the die, the lower the time taken to extrude on the same speed.

In the process of running the equipment for further works, various parameters can be varied and examined.

5.0 Conclusion

The design and fabrication of metal extrusion machine was done using the locally available materials. Mild steel materials were used for the machine components and aluminium steel was used as the extrusion material. The machine was tested by carrying out extrusion process by extruding six billets of the same diameter through dies of different diameter.

S/N	Initial Diameter (mm)	Speed (rev/ min)	Distance travelled (mm)	Time (s)	Final diameter (mm)
1	16	45	85	40	15
2	16	45	85	55	14
3	16	45	85	90	13
4	16	45	85	120	12
5	16	45	85	150	11
6	16	45	85	185	10

6.0 Acknowledgement

The authors acknowledge the support of the Olusegun Obasanjo Centre for Engineering Innovation, The Federal Polytechnic Ado Ekiti for providing conducive environment and necessary equipment for the work.

REFERENCES

Chi , Z., Xin , S., & Rong , X. (2011). Study on Cold Extrusion Process and Die for Vehicle Sleeve Gear with Spline. *Advanced Materials Research, 189-193*, 2832-2837.

Cold Extrusion. (2005). In M. G. Bhupatiraju Murali, *ASM Handbook* (Vol. 14A, pp. 405-418). S.L. Semiatin. Metalworking: Bulk Forming. s.l.: ASM International.

Deepam, Goyal and Nitesh, Parmar. (2014). Extrusion: A Manufacturing Process.

Ghaemi, F., Ebrahimi, R., & Hosseinifar, R. (2013). Optimization of Die Profile for Cold Forward Extrusion using an Improved Slab Method Analysis. *IJST, Transactions of Mechanical Engineering, 37*(M2), 189-202.

Junting, L. Y. (2009). Cold Extrusion Forming of Copper/AluminumClad Composite. *Applied*

Mechanics and Materials, 16-19, 441-444. Retrieved October 12, 2009

Mohammed, R. J. (2014). Effect of Die Angle on Stress Distribution in Extrusion Process of Aluminum Rod. *Basrah Journal for Engineering Sciences, 14*(2), 43-50.

Mohammed, Rafid Jabbar. (2014). Effect of Die Angle on Stress Distribution in Extrusion Process of Aluminum Rod. *Basrah Journal for Engineering Sciences, 14*, 43-50.

Rauwendaal, C. (2001). *Polymer Extrusion* (4th ed.). Munich: Carl Hanser Verlag.