EFFECT OF SOME VEGETABLE BASED OIL AS LUBRICANTS ON THE EXTRUSION OF ALUMINIUM

BY

Samuel MOVEH, B. Eng. (F.U.T.Yola) 2008
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NIGERIA.

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DECLARATION

I declare that the work in this thesis entitled "EFFECT OF SOME VEGETABLE BASED OIL AS LUBRICANTS ON THE EXTRUSION OF ALUMINUM" was carried out by me in the Department of Mechanical Engineering under the supervision of Dr. M. Dauda and Dr. D.S. Yawas. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

Name of student	Signature	Date

CERTIFICATION

This thesis entitled 'EFFECT OF SOME VEGETABLE BASED OIL AS LUBRICANTS ON THE EXTRUSION OF ALUMINIUM' by SAMUEL MOVEH, meets the regulations governing the award of Master of Science (M.Sc) in Production Engineering of Ahmadu Bello University,Zaria and its approved for its contribution to knowledge and literary presentation.

Dr.M. Dauda	_____	_____
Chairman Supervisory Commitee.	Signature	Date
Dr.D.S. Yawas	_____	_____
Member,Supervisory Commitee.	Signature	Date
Dr.M. Dauda	_____	_____
Head of Department.	Signature	Date
Prof. Adebayo.A. Joshua	_____	_____
Dean, School of Postgradute Studies.	Signature	Date

DEDICATION

I wish to dedicate this thesis work first to GOD ALMIGHTY for his faithfulness all through my class work and research work. Also to my wife Mrs. Favour Moveh, my wonderful parents Mr. and Mrs. Move and my brothers and sisters.

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Finally, I pray that God's face will continue to shine upon them all and their various works of life, for it is through God that we were able to do all that we have done in this work. So to God alone is all the Glory.

ABSTRACT

Four vegetable based oils were used as trial lubricants in the extrusion of aluminium billet through four different die geometries. These oils were extracted from Castor seeds, Neem seeds, Jatropha seeds and Cotton seeds respectively. Results obtained from this work as compared with other works done in the area shows that these oils were found to be suitable as lubricants in the extrusion of aluminium because of their heat reduction abilities and good surface finish. Extrusion dies with semi die angles of 30^0, 45^0 and 60^0were used; good quality surface finish and hardness of extruded billets were obtained. The coefficient of friction between the billet and the container wall was calculated for each process; Castor oil with good heat reduction ability and gave the least co-efficient of friction of 0.100 and 0.107 respectively. Also for all the geometries of billet extruded, round and triangular billets gave good surface finish for all the oils except for castror oil which gave the best surface finish. Based on previous experiments carried out on the extrusion of aluminium, surface cracking were major defects caused by the rise in temperature as the process proceeds. This research experiments indicated that the surface quality is good even though the temperature may be high during extrusion process.

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Symbols Used

P - Extrusion Load

a, b, h - Dimensions of Dies orifice for the various die sections

L_1 - Original length of billet

L_2 - Extruded length of billet

D - Billet diameter

μ - Coefficient of friction between billet and container wall

Y -Yield stress of aluminum

A_1 - Crossectional area of billet

A_2 - Crossectional area of extruded billet

d_1 - Horizontal diagonal (mm)

d_2 - Vertical diagonal (mm)

d - Mean diagonal (mm)

HV - Vickers hardness

B - efficiency factor

P_0 - frictionless extrusion pressure

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CHAPTER ONE

INTRODUCTION

1.1 Background to study

Metal forming includes a large group of manufacturing processes in which plastic deformation is used to change the shape of metal work pieces. Deformation results from the use of a tool, usually a die in metal forming, which applies stresses that exceed the yield strength of the metal. The metal therefore deforms to take a shape determined by the geometry of the die. Extrusion process is used to describe the process by which a block of metal either in the solid state or semi molten state is converted into the same metal which is of different surface orientation of a different cross sectional area of continuous length. This process involves plastic deformation process in which a work piece is reduced by the application of compressive forces to it, causing it to flow through a hole in a shaped die (Ibhadode, 1997). The reduced section thus acquires the shape of the die orifice. The process may be carried out hot or cold.

In its modern applications extrusion has become a metal forming process of considerable importance. It is capable of producing components to reasonably close tolerances and at lower cost than by conventional machining methods. Furthermore, by making special arrangements, it can produce the elaborate stepped spurs and similar components which are common, in aircraft construction and are very expensive to produce by other means. The contribution of the process to economical manufacture is realized by the fact that not only can extruded lengths be used without subsequent machining but also components can be produced complete from short lengths of metal sawn from rods extruded to the requisite sectional shape.

In order to maintain maximum production at minimum cost in the face of increasingly different design tolerance, engineers have been making extensive researches to ensure that tougher materials and the demand for closer control of surface finish is achieved. Extrusion, turning and drilling and other forming operations are carried out with lubricants, which is directed over the working process to act as coolants or lubricants.

The functions of lubricants cannot be neglected for the role they perform in forming operations, as these operations cannot be carried out efficiently without the appropriate lubricants.

Lubricants are generally found in the liquid or gaseous state and are applied to the working surface to facilitate smooth extrusion of the billet and to remove the possibility of folding which usually results in deposit in the dead region of the container. These benefits extrusion in many ways, especially as it acts as a heat remover. It also helps to remove defects such as internal piping of the thin billet skin that is extruded into the extruded rod.

Conventional lubricating fluids are usually petroleum based, and since they are not bio-degradable they pollute and contaminate water and soil when discharged as waste to the ground thereby having detrimental effect on health and environment. In order to alleviate the health risk associated with the petroleum based lubricants and the need to make the extrusion process more ecologically friendly, there is the need to develop an alternative safe and environmentally friendly lubricant.

Vegetable oils among other options could be investigated in developing a new lubricating fluid where high performance in forming operations with good environmental capabilities could be achieved. The most important characteristics of vegetable oil are their safety and biodegradability. Compared to petroleum based oil (mineral oil),

Vegetable oil has been shown to replace mineral oil as lubricants in previous researches carried out (Syahrullail et al 2011),. Also it has higher flash point and natural viscosity than mineral oil, thus improving the surface finish and extending tool life. It also does not contribute to health hazard via toxic mist and skin cancer and does not pollute the environment.

1.2 Problem statement

Since the issues of environmental pollution and hazard to workers have risen, there is need to investigate safe and efficient metal working lubricants which are environmentally friendly, cheap and readily available. This is because chemically based oil lubricants used nowadays are costly and have adverse effects on operators and the environment compared to the environmental friendly vegetable based lubricants which are cheap and readily available.

1.3 The present work

It is of interest to note that many previous researchers Hafis et al, (2012), Elena, (2011), Syahrullail et al (2011), Hafis et al (2011), Jabbar, (2010), Solomon, (2010), , Ibrahim (2000), investigated extrusion processes, die geometries and the use of some edible vegetable oil as lubricants (palm oil, groundnut oil, soya oil etc.). The focus of this present research is to experimentally determine the properties of 4 vegetable oils (Neem oil, castor oil, cotton oil and jathroper oil) and compare their effects of coefficients of friction and surface finish on the extrusion of aluminum using the 4 oils as lubricants.

1.4 Aim and objectives

The aim of this research work is to evaluate the effect of four(4) vegetable based oils (neem oil, castor oil, cotton oil, jatropha oil) as lubricants on the extrusion of aluminum.

The specific objectives are:

(i) To extract oil from seed of neem, castor, cotton and jatropha and determine their chemical and physical properties.

(ii) To design and construct four different die cross sections (round, square, rectangle and triangle) through which the aluminum would be extruded

(iii) To carry out extrusion using these vegetable oils as lubricants

(iv) To determine the effect these four oils would have in the extrusion of aluminum through various die sections (round, square, rectangle and triangle).

(v) To establish the surface finish quality of the aluminum after the extrusion process using the extracted oils as lubricant.

(vi) To determine the least coefficient of friction between the billet and the container wall for the four oils.

(v) To establish the most suitable and eco-friendly biodegradable oil lubricant.

1.5 Justification of the study

Extruded products constitute more than 50 % of the market for aluminum products in Europe of which construction consumes the majority. Aluminum extrusions are used in commercial and dwelling buildings for window and door frame systems, prefabricated houses/building structures, roofing and exterior cladding, curtain walling, shop fronts, etc.

Furthermore, extrusions are also used in transport or airframes, road and rail vehicles and in marine applications (Elena, 2011)

Vegetable oils are highly desired as alternative lubricants for metal working operations. However, vegetable oils have limited ability to be utilized in the metal working application because it is mostly utilized in food industries. It was proved that the biodegradability levels of vegetable oils are better compared to petroleum-based lubricants (Syahrullail et al 2011) today.

1.6 Scope of the research

The research only involved:

(i) Extraction of vegetable oils from the seeds of castor, cotton, neem and jatropha

(ii) Extrusion of aluminum through four (4) different die sections using these oils as lubricants

(iii) Analyzing the effects of these oils on the extrusion of aluminum

CHAPTER TWO

LITERATURE REVIEW

2.1 Extrusion

Extrusion is used to describe the process by which a block of metal either in the solid state or semi molten state is converted into the same metal which is of different surface orientation of a different cross sectional area of continuous length. This process involves plastic deformation process in which a work piece is reduced by the application of compressive forces to it, causing it to flow through a hole in a shaped die Ibhadode, (1997). The reduced section thus acquires the shape of the die orifice. The process may be carried out in hot or cold form

2.1.1 Applications of extrusion

Owing to the nature of the deformation of the metal in the extrusion process, which is triaxial, the quality of the product is extremely good, as no part of the material is at any time subjected to tensile forces. Therefore, a much higher measure of deformation is possible in one operation than in other hot forming processes. Extrusion is particularly applicable in the following cases:

i. Where the material cannot be worked easily or even worked at all by orthodox tube production means.

ii. Where the shape or configuration of the desired section or profile makes other methods of production impracticable such as in externally and internally finned tubing. Sometimes the ability to produce solid and non-circular hollow profiles as well as tubes from one installation is a valuable additional feature. Furthermore, there is no other process which allows the production of long seamless tubes having very thin walls (Ibhadode, 1997).

iii. Where the use of hot stretch-reducing allows the utilization of the optimum billet from a given press size and enables subsequent work to be done in the hot state ,which would be more laborious and costly when carried out in the cold state as was normal hitherto in many instances.

iv. The extrusion process, due to its ability to use a high ratio of elongation or deformation permits the use of billets with a large diameter relative to the product diameter. Thus if a continuously cast material is used, this ability to use billets with large diameter, relative to product diameter results in effective reduction of inspection, cleaning and sometimes turning cost.

2.1.2 Types of extrusion

a. Hot Extrusion:

This is basically a hot working process. Hot working is defined as working above the recrystallization temperature so that the work piece re-crystallizes as it deforms. Hot working takes advantage of decrease in flow stress at higher temperature to lower tool force and consequently equipment size and power requirement.

b. Cold Extrusion

This on the other hand is the process of extrusion of billet at their initial temperature and in most cases in the cold extrusion we have the dry and the lubricated type, where the dry extrusion is that in which no lubricant is used and the lubricated type is when lubricants are applied to the billet and container surfaces to reduce the high pressure that accompanies the process. However cold extrusion is used due to its economic advantages which includes

(i) Reduction or elimination of machining and grinding operations because of good surface finish and dimensional accuracy of cold extruded part.

(ii) Material saving

2.1.3 Extrusion equipment

Most extrusions are made with hydraulic presses (Wick, 1984) and are classified as vertical and horizontal presses depending upon the direction of travel of the ram. Vertical extrusion presses are generally built with capacities of 300 to 2000 tones. They have the advantages of easier alignment between the press and ram and the tools, higher rate of production and the need of less floor space than horizontal presses. Horizontal extrusion presses are used for most commercial extrusion of bars and shapes. They have capacity of 1500 to 5000 tons are in regular operations, while a few presses of 1400 tons capacity have been used in recent times (Wick, 1984)

2.1.4 Extrusion parameters

The extrusion parameters of interest include the following

1. Breakthrough Pressure: this is defined mostly in the case of direct extrusion. This is the maximum extrusion pressure at which the metal begins to flow through the die. As the billet extrudes through the die, the pressure required to maintain flow progressively decreases with decreasing length of the billet in the container.

2. Coefficient of friction between billet and wall of the container.

3. Extrusion Ratio: it is defined as the ratio of the initial billet cross sectional area to the final cross sectional area. It is essentially a measure of the strain which the billet undergoes during the extrusion process. A large extrusion ratio requires higher pressure from the presses, particularly in the case of cold extrusion processes (Wick, 1984). It is denoted by R.

2.2 Design of extrusion dies

Chaudhari et al,(2012) carried out an experimental investigation on the effect of die angle on the quality of extruded product i.e. surface finish and hardness of cold extruded aluminium. The

semi die angle (α) considered for the experiment were 300, 450 and 600. The first experiment was to extrude the aluminum alloy AA6351 without lubricant. The second experiment was to extrude aluminum AA1100 with two different lubricants. The load required to extrude aluminum was found to be less at 450 die angle. The surface roughness is measured on the circumference of extruded product as well as in the longitudinal direction of the extrusion, for the first and second experiment respectively. No variations were found in surface finish by varying the die angle. Higher hardness values were found with 300 and 600 die angle. Also higher hardness values were observed with petroleum jelly

Solomon, (2010) investigated the geometric shape of the tools and was of the opinion that careful design of the extrusion die profile can therefore control the product structure and can be used to minimize the amount of inhomogeneity imparted into the product. He suggested that the possibility to minimize the amount of product inhomogeneity is by the use of a flat die with a fillet radius in front to the bearing surface which leads to a minimum dead zone and consequently to a minimum friction at billet-container interface. In the case of aluminum alloy type 2024, for an extrusion ratio of R=8.5, good results were obtained with a fillet radius of 3.0 mm.

Ahmed, (2010) reviewed the work carried out in the design of extrusion dies. It investigated the effects of temperature, die entrance angle and type of lubricant used on the flow of extruded lead. He was of the opinion that designing dies requires an accurate knowledge of flow characteristics of the particular material to be processed. The designer must determine the precise shape of the flow channel(s) in the die, and the exact shape of the exit orifice. He concluded that the effect of these parameters are assumed to affect the flow of the extrudate and hence the performance of the die.

2.3 Use of vegetable based oil lubricants in metal forming process

Syahrullail et at, (2011) investigated the use of vegetable oil and its application as a lubricant in metal forming processes, because it is a renewable resource and has high biodegradability compared to mineral oil. According to the Organization for Economic Cooperation and Development for the European Union 301C (OECD) testing method, the biodegradability levels of vegetable oils are better compared to petroleum-based lubricants. He was of the opinion that Palm oil is used more often than other vegetable oils. The purpose of his study was to evaluate the viability of palm oil when used as a lubricant in cold work such as the forward plane strain extrusion process and compared with additive-free paraffinic mineral oil. Experimental work with a plane strain extrusion apparatus with a symmetrical work piece was carried out at room temperature. The material of the work piece is annealed pure aluminum A1100. The visio-plasticity method was used to calculate the velocities and effective strain in the deformation zone of the work piece. The results obtained from the experimental work showed that palm oil has satisfactory lubrication performances, as compared to paraffinic mineral oil, and has advantages in reducing the extrusion load.

Ibrahim, (2000) carried out extrusion using 4 vegetable based oils (palm oil, shear butter oil, palm kennel, groundnut oil) as lubricants in order to compare their temperatures, and found out that of all the oils palm oil was the best with temperature reduction abilities

2.4 Analysis of extrusion parameters

Elena, (2011) investigated the process of direct aluminum extrusion analysis using two methods "Finite element method (FEM)" and analytical methods for calculation of main process parameters. Experiments were conducted and error values from the analysis between the different used methods were compared and the following conclusions were made comparing the

Finite Element Method and the analytical ones - Method of the homogeneous deformation and the Upper bound limit method, errors between each of them were reported and analysis with the design of experiments technique was performed. For all three pairs of comparisons the factor which influences most the error is the friction coefficient and after it comes the extruded part radius .Even small changes in the value of coefficient of friction are causing big variation in the value of the error.

Jabba, (2010) studied and showed that the large development that happens in computers technology leads to the use of modern programs and pollutant about different forming processes from through design and analysis for geometric forms by using Finite Element Method F.E.M, which gives accurate results which approaches experimental results. His study depends on local coordinates system by using rotation of local coordinates for nodes on region contact length between metal and die. This is to calculate relative extrusion pressure and study the effect of relative die length on the relative extrusion pressure for reduction of area (20%, 40%, 60%, 80%) with friction factor (0.1) by using software ANSYS program. The results of this study are compared with experimental result and upper bound theory and have shown a good agreement with a minimum discrepancy through using the finite element method by technique of local coordinates system for extrusion of circular section.

1. The optimum die length gives less relative extrusion pressure for reduction of area different (20%, 40%, 60% and 80%) and friction factor (0.1)

2. The reduction of area leads to the increase of plastic deformations in the forming region, also lead to increase of relative extrusion pressure.

3. The choice of optimum geometrical shape of die is needed to less extrusion pressure.

4. Technique of local coordinates system is need of less time to calculate extrusion pressure if it is compared with another method.

5. Local coordinate's system technique shows a good agreement with the available experimental results comparing with the upper bound theory.

Flitta and Sheppard (2002) investigation focuses on simulation of the extrusion process and in particular the effect of the initial billet temperature on friction and its consequences on material flow. The simulation is compared with data obtained from an experimental extrusion press. The effect of the initial billet temperature on the deformation zone pattern and its consequent effect on friction using both numerical simulation and experimental work were presented. A comparison with experiments was made to assess the relative importance of some extrusion parameters in the extrusion process. The results revealed that the friction factor increases with increase in initial billet temperature and varies from 0-65 at 300°C to a 0-91 at 450°C after reaching the peak pressure. The dead metal zone is observed to vary in form and has a greater volume at high temperatures. The increase in friction results in an increase of initial extrusion load. The finite element program appears to predict all the major characteristics of the flow observed macroscopically

Peng and Sheppard (2004) showed that surface cracking is generally recognized as one of the main defects occurring during the process of aluminum extrusion, especially in the case of the so called hard aluminum alloys. Previous experiments suggest that this type of defect is caused by the rise in temperature as the process proceeds. Some experiments indicate that the surface quality is good even though the temperature may be high during extrusion. It is also well known that crack criteria have been adopted to explain the cracking that occurs in extrusion, blanking and rolling, etc. In this study, a finite element method (FEM) is used in different ways to predict

surface cracking during hot extrusion. The crack criteria are integrated into the FEM code FORGE2.0. The effectiveness of these criteria in predicting surface cracking in the case of hot extrusion is discussed. The FEM simulation also provides some other quantitative data, such as the temperature rise during extrusion from different initial temperatures. In addition, the principal stresses at the die land area at different extrusion stages are also shown

All these researches indicate that different efforts have been made by different researchers in the analysis of extrusion process as well as investigating the use of locally available vegetable oils as lubricants in metal forming operation. It is based on this background that four oils (neem oil, jathroper oil, cotton oil and castor oil) extracted from their seeds would be used as trial lubricants during the extrusion of aluminum. The aim of this research work is to experimentally determine the properties of these oils and compare their pressure effects and coefficient of friction on extrusion of aluminum so as to achieve the desired objectives.

2.5 Theoretical analysis of metal extrusion

In the design of machines and tools it is important that the forces necessary to produce a given deformation are known. One of the methods of calculating deforming forces is to consider the equilibrium of forces acting on a small element of the deforming metal. By integrating the resulting expression between limits appropriate to the extent of the deformation, the applied stress can be obtained (Aku, 2011).

2.5.1 Determination of extrusion parameters

An early approach was based on the work done in homogeneous deformation with friction and redundant work being allowed for by an efficiency factor. The work done per unit volume W/V in homogeneous deformation is given by (Elena, 2011)

$$\frac{W}{V} = Y \int_{l_1}^{l_2} \frac{dl}{l} = Y \ln \frac{l_2}{l_1} \qquad (1)$$

Where Y is the yield strength of the material

l_1 Is the is the original length

l_2 Is the extruded length

Assuming constancy of volume that is $A_1\ l_1 = A_2 l_2$ and substituting the extrusion pressure p for W/V(W)V = pAl/Al)

The efficiency factor β is used to take account of the additional work needed to overcome friction and to allow for redundant work. The value of β can be obtained experimentally for a range of values of A_1/A_2 and in its final form. The expression for extrusion pressure becomes

$$P = \beta\ Y\ \ln\frac{A_1}{A_2} \qquad (2)$$

A second approached applicable to lubricated extrusion, combines a stress evaluation method to find the effect of friction and a semi-empirical formula for frictionless extrusion pressure.

Considering a given billet with width dx been extruded by the direct extrusion method, since the billet is rigid it can be assumed to be subjected to hydrostatic pressure p.

Resolving horizontally

$$\frac{\pi}{4} D^2 dp = \pi D \mu p dx \qquad (3)$$

Where D is the billet diameter

μ is the coefficient of friction between billet and container wall

p horizontal pressure on the billet

$\frac{dp}{p} = \frac{4}{D}\mu dx$ (4)

Integrating between limits 0 and L,

$\frac{P}{P_0} = e^{(\frac{4\mu L}{D})}$ (5)

$p = p_0 e^{(\frac{4\mu L}{D})}$ (6)

Where p_0 is the frictionless extrusion pressure?

Also another equation used to calculate frictionless extrusion pressure for short billet is given by equation (7) below

$p_0 = Y\ (0.47 + 1.2 \ln \frac{A_1}{A_2})$ (7)

Where Y is the yield stress applicable to the mean extrusion temperature

A_1 Is the cross sectional area of the billet

A_2 Is the cross sectional area of the extruded billet

Therefore by substituting equation (7) into equation (6) the extrusion pressures for the four various cross sections can be gotten.

$p = Y\ (0.47 + 1.2 \ln \frac{A_1}{A_2})\ e^{(\frac{4\mu L}{D})}$ (9)

Elena, (2011)

2.6 Local lubricants

Vegetable oils are lipid materials derived from plants. Physically, oils are liquids at room temperature; oils are extracted primarily from seeds. The vegetable oil may or may not be edible and examples of the inedible oils are castor oil and Jathropher oil. Examples of the edible oils are soya, palm oil, etc.

Castro oil: this is a vegetable oil obtained from the castor plant seed. Castro oil consists of almost entirely of the triglycerides ricinoleic acid. It is a colourless to very pale yellow liquid with mild or no odour or taste. Its boiling point is 313 C and its density is 961kg/m. There are many uses for castor oil and its derivatives. Some of these include plastics, cosmetics and hair oils, adhesives, synthetic resins, soap, grease and lubricants and dryingoils. (www.azom.com/oars.asp)

Cotton seed oil: cotton seed oil is cooking oil extracted from the seed of a cotton plant of various species, mainly Gossypiumhirsutum and Gossypiumherbaceum. Cotton grown for oil extraction is one of the big four genetically modified crop grown around the world next to soy, corn and rapeseed (conola). Its fatty acid profile generally consist of 70 percent unsaturated fatty acid (18% monounsaturated and 52% polyunsaturated) and 26% saturated fat. (Nutrient data for 04502, US Department of Agriculture).

Neem seed oil: neem oil is a vegetable oil pressed from the fruit and seed of a neem (Azadirachtaindica) an evergreen tree. It is perhaps the most important of the commercially available products of neem for organic farming and medicine. Neem oil is generally red as blood and has a rather strong odour that is said to combine the odour of peanut and garlic. It comprises mainly of triglycerides and large amounts of triterpenoid compounds which are responsible for the bitter taste. It is hydrophobic in nature and inorder to emulsify it in water for application purposes; it must be formulated with appropriate surfactants (www.azom.com/oars.asp).

Jathropher oil: Jathropher oil is a vegetable oil produced from the seed of a jathropercurcas, a plant that can grow in marginal land. The oil gotten from a jathropher plant can be further processed into a high quality biodiesel that can be used in a standard diesel car (www.azom.com/oars.asp).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

In order to carry out extrusion, the main components needed include the main power supply unit which is the press, die, container, die holder, punch, mild steel and aluminum (billets). In this work however the universal testing machine was used in place of the press. All these except the universal testing machine were designed and produced in the workshop using available materials (mild steel). Mild steel was sourced from Samaru market, Zaria and was used for the construction of the tools (dies, punch, containers); hence a case hardening process was applied to the dies and the punch.

Aluminum (Al), the most abundant metallic element in Earth's crust. With atomic number of 13; the element is in group 13 (IIIa) of the periodic table. Aluminum is a lightweight, silvery metal with atomic weight of 26.9815; and melts at 660°C boils at 2519°C and has a specific gravity of 2.7. Aluminium is a strongly electropositive metal and extremely reactive. In contact with air, aluminium rapidly becomes covered with a tough, transparent layer of aluminium oxide that resists further corrosive action. For this reason, materials made of aluminium do not tarnish or rust. Aluminium weighs less than one-third as much as the same volume of steel. The only lighter metals are lithium, beryllium, and magnesium. Its high strength-to-weight ratio makes aluminium useful in the construction of aircraft, railroad cars, and automobiles, and for other applications in which mobility and energy conservation are important. Because of its high heat conductivity, aluminium is used in cooking utensils and the pistons of internal combustion engines.

3.2 General concept of die design

An extrusion die is a shaped orifice made in a block of steel or other suitable material that is wear and corrosion resistant. The function of the die is to receive billet stream emerging from the

extruder screw and to reshape it to the required form. In some instances, this is the final shaping operation, and in others, post-die shaping equipment completes the shape to the required form. Designing dies requires an accurate knowledge of flow characteristics of the particular material to be processed. However, the precise shape of the flow channel in the die design was determined as well as the exact shape of the exit orifice.

3.3 Construction procedures for the various die sections

The dies were first of all marked out and then two holes, conveniently situated within the rectangles were drilled and then triangular and flat needle files were employed to file the holes to the boundaries of the rectangle hence achieving the required orifice. A similar process was applied to the square and triangle. As for the rig, punch and boltster, they were produced on the center lathe.

3.4 Tool design (The extrusion die)

The die is a steel disc having an orifice which is of the same contour as the desired product, except that the extruded product has a slightly bigger cross-sectional area than the die orifice due to spring back effect. For the purpose of this work, aluminum was to be extruded hence mild steel was employed for making the dies which were case hardened. Rectangular, square, triangular and round shape where designed and constructed using the design calculations shown in table 3.1 below. The working drawing of the various die geometries are show in appendix I to appendix IV.

Table 3.1 Design calculations for the various die geometries

INITIAL DATA	CALCULATIONS/SKETCHES	RESULTS

for round die r = 6.2 from r = $\frac{d}{2}$ where d = 12.4mm	A = Πr^2 , 3.142×6.2 =120.778mm^2	A = 121mm^2
for triangular die b = 12.4mm h = 12.4mm	A = $\frac{1}{2} b \times h = 76.88$	A = 76.88mm^2
for square L = 12.4mm b = 12.4mm	A = L×b , 12.4×12.4 = 153.176mm^2	A = 153.76mm^2
for rectangular L = 15.5mm b = 12.5mm	A = L× b , 15.5 × 12.5 = 193.75mm^2	A = 193.75mm^2

3.5 Design of rig (container)

In carrying out the design, the diameter of the bore where the billet is to be placed before extrusion was chosen in respect to the available billet diameter. The available billet diameter chosen was 18mm (Do) before machining them to the various cross sections; hence the bore

diameter was taken to be 19mm so that the clearance between the billet and the rig wall just allows for sliding. This was thus chosen to prevent a situation where the billet might buckle and hence might require higher extrusion pressure. The length of the billet chosen was 45mm and that of the rig was 70mm. This is to allow for proper punch guidance and initial contact between the punch and the billet. Toward the bottom part of the rig another 40mm portion was provided with thread to screw in the die holder which locks up the die in place, locating the die orifice symmetrically to the rig's central axis as shown in appendix V.

3.6 Design of boltster (die holder)

As mentioned in the foregoing section, the die holder primarily holds the die in place and gives support against the high pressure applied by the ram. Its dimensions were chosen bearing in mind the high pressures it would be subjected to. The working drawing of the die holder is shown in appendix VI

3.7 Design of punch

The main data used for the design of the punch was the billet diameter, which was the diameter of the punch. The punch's height chosen was 80mm. This was to allow for an initial advance of the punch to avoid it's slipping off, and at the end of the extrusion process the punch will not be completely in the rig, but some portion of it will still be outside the rig to allow for the appropriate contact with ram. The punch was made of mild steel and later carburized and case hardened to impart the required hardness to withstand the high pressures applied to it. This is shown in appendix VII

3.8 Locking keys

The die holder was designed in such a way that it is screwed all through in place into the space provided for it, at the bottom part of the rig. In order to screw and unscrew it easily, two

cylindrical keys were made for that purpose. The keys are placed in two holes of diameter 5mm along the diameter of the holder for the screwing purpose as indicated in the drawings.

The punch dies and container geometries were fabricated from structural mild steel to a standard specification and were carburized at 9500C, water quenched for hardness and a hardness value of 612VHN was obtained with Vickers hardness testing machine, this meets the wear resistance requirements. The full assembly drawing of the extrusion equipment is shown in appendix VIII

3.9 Heat treatment of tools

A case hardening process was applied to the dies and the punch. This was to make sure failure does not occur under the high extrusion pressure that was to be applied to the punch. Failure could occur in the punch by buckling. The heat treatment process was carried out in the following sequence shown below

i. Carburizing at 900-950^{o}C in carbon medium for 30mins in the furnace.
ii. Furnace cooling to room temperature. Furnace capacity of 1500^{0}C
iii. Reheating for case hardening to a temperature of 870^{o}C
iv. Removing from furnance and quenching in water.
v. Washing and cleaning.

3.9.1 Carburizing

Carburizing is a process of adding carbon to surface. This is done by exposing the part to carbon rich atmosphere at the elevated temp (nearly melting point) and allows diffusion to transfer the carbon atoms in the steel The carburized section will have carbon content high enough so that it

can be hardened again through flame or induction hardening. The objective is to produce a hard, wear-resistant case which will be resistant to both bending and contact fatigue whilst still maintaining its toughness and ductility of the low carbon core.

Therefore the method employed involved applying the carbon to the surfaces of the iron involved packing the iron in a mixture of charcoal, combination of leathers, hooves, salt and urine, all inside a well sealed box. The resulting package was then heated to a high temperature, but still under the melting point of the iron and left at that temperature for a length of time. The longer the package was held at the high temperature, deeper carbon will diffuse into the surface, and the resulting casehardened part may show a distinct correlation on the surface.

3.9.2 Hardness test

The aim of this test was to determine the hardness of the punch after carburizing and case hardening; to be sure it is hard enough to withstand any wear due to friction that will be applied to it without failure. In carrying out the test, the Vickers Hardness testing machine was used in conjunction with the Vickers Hardness tables B.S 427: part 1: 1961.

The necessary readings were taken, and tabulated as shown below in table 4.1.

Therefore, mean diagonal of the three readings = 0.303mm and the mean H.V. of the three reading from the table is 606. Since the punch is cylindrical, a correcting factor is needed to calculate the actual H.V. of the punch.

Punch's diameter D = 18mms

Mean diagonal d = 0.303mm

Therefore, $\frac{d}{D} \frac{0.303}{18} = 0.017$

Using this ratio and Tables 12 of the H.V. tables it was found that the correcting factor is 1.010. Hence the hardness of the punch expressed in H.V. is 606x1.010 HV30

= 612 HV30

Note: The HV3O shows that 301Cg weight was used for the test. Based on previous work that has been done (Chaudhari, et al, 2012), the minimum hardness value is 600HV. Therefore the result gotten from the hardness test could be considered hard enough to carry out the cold extrusion of aluminum

3.9.3 Extrusion test

Presses are normally the main machines on which the extrusion process is carried out, in which case the punch is attached to the ram of the press which enters the container and advances the material to be extruded. There are two main types of presses: viz vertical presses and horizontal presses. These presses can have capacities of up to 600KN to 1000KN but only in exceptional cases are units greater than 1500KN capacity installed. For this work, no press as discussed above was used. In place of it the universal Denison testing machine with a capacity of 500KN was employed.

3.10 Surface finish

Precise surface roughness measurements were made quantitatively with the profilometer and the brush surface analysis was used as well. The profilometer can be used to measure etch depths, deposited film thickness and surface roughness. A modern typical surface measuring instrument will consist of a stylus with a small tip (diamond) a gauge or transducer, a traverse datum and

processor. The surface is measured by moving the stylus across the surface. As the stylus moves up and down along the surface, the transducer converts this movement into a signal which is then exported to a processor which converts this into a number and usually a visual profile. (The stylus must be moved in a straight line to give accurate readings)

3.10.1 Experimental procedures:

I. To record the profile of the billet, the instrument was switched on, the coarse and fine adjustment found on the amplifier recorder was set to the mid position.

II. The magnifications for both the vertical and horizontal were set to 1000 and 20 respectively.

III. The specimen was placed in the V-block.

IV. The stylus was slowly lowered on to the specimen until it touches the specimen. To make sure that there was a touching the stylus was brought down more until the pen in the graph recorder comes to the mid position.

V. For trial, a trace was taken by pressing the switch knob down.

VI. Finding roughness average using the (Ra) meter.

VII. The specimen was held on the V-block.

VIII. The coarse and fine adjustment knobs wereadjusted to the mid position.

IX. The function knob Vv was set to the 0.8 mm cut-off length and Vv to 1000 magnification.

X. Once again, the stylus was slowly brought on to the specimen and it was ensured that it touches the specimen as previously.

XI. The start lever was pressed; reading from the Ra meter was taken



PLATE 3.1: picture of the extrusion dies



PLATE 3.2: picture of the punch



PLATE 3.3: picture of the die holder



PLATE 3.4: picture of the container



PLATE 3.5: picture of the round billets



PLATE 3.6: picture of the triangular billet



PLATE 3.7: picture of the rectangular billets



PLATE 3.8: picture of the square billets

3.11 Extrusion Experimental Procedures



PLATE 3.9: Experimental setup of the extrusion tools on the universal testing machine

The billets of length 40mm were 32 in number (8round, 8 square, 8 rectangles and 8 triangles) which were extruded through the round die, square die, rectangular die and triangular die respectively. Small extrusion ratios were chosen to withstand pressure and temperatures normally associated with laboratory facilities. The billets were degreased in acetone for about 10mins to remove all the oil grease from the machining operation. The billets were then extruded through the various die section with a crosshead speed of 2cm/mins, while the lubricants were directed over the working survface to acts as coolants. The punch travel was measured by direct connection of a rotating dial gauge and by means of a stop watch the approximate time to complete each extrusion was recorded.

The coefficients of friction between the aluminum billet and billet container wall were computed from equation (9) and tabulated. A bar chart of maximum extrusion load against coefficient of friction were plotted to show the performance of these oils.

CHAPTER FOUR

RESULTS

4.1 Results

Table 4.1 below shows the readings recorded during the hardness test using the Vickers hardness testing machine. While table 4.2 and 4.3 gives the percentage of oils in seed as well as the chemical properties of the oils. Table 4.4 show the results of the extrusion load, the time it took for the each extrusion process ant the result of the surface finish test that were conducted on the extruded billets.

Table 4.1: Hardness test results

Readings	1	2	3
Horizontal diagonal d1 (mm)	80	0.311	0.327
Vertical diagonal d2 (mm)	0.280	0.314	0.305
Mean diagonal d (mm)	0.280	0.313	0.16
Vickers Hardness HV	710	568	557

Table 4.2: Percentage of oil in seed, saponification, iodine, values and the specific gravity of local oil

Lubricant	**% of oil in eed**	**Saponification value**	**Iodine value**	**Specific gravity**

Castro oil	45-50	177-187 OH-160	83-86	0.945- 0.965/25^{0}C
Neem oil	40-50	175-200	65-80	0.915- 0.922/30^{0}C
Jathropa oil	30-40	191-202 OH 4-20	82-98	0.918- 0.923/15^{0}C
Cotton oil	18-25	191-196	103-15	0.915- 0.926/15^0

Table 4.3: Fatty acid content of the four vegetable oils

Fatty acid	**Neem oil**	**Castro oil**	**Cotton oil**	**Jathropa oil**
Myristic	**0.2-2.60**	**-**	**0.4**	**0.5-1.4**
Palmitic	**13.6-16.2**	**2.0**	**20**	**12.0-17.0**
Arachidic	**0.8-3.4**	**-**	**-**	**0.3**
Oleic	**49-62**	**7.0**	**35**	**37-63**
Linoleic	**2.3-15.8**	**5.0**	**42**	**19-41**
Stearic	**14.4-24.0**	**1.0**	**2.0**	**5.0-9.5**

Table 4.4: Results of surface finish

Oils	Billets	Extrusion (KN) Load	Extrusion (Sec) Time	Surface Roughness Ra (μ)
Castor	Round Square Rectangle Triangle	44 180 270 88	120 209 260 200	0.8 3.2 3.2 1.6
Neem	Round Square Rectangle Triangle	53 185 200 72	149 220 220 184	1.6 3.2 3.2 1.6
Jatropha	Round Square Rectangle Triangle	58 120 280 70	153 200 300 180	0.8 1.6 1.6 0.8
Cotton	Round Square Rectangle Triangle	47 183 260 84	133 206 258 195	1.6 3.2 3.2 1.6

Figure 4.1, 4.2, 4.3 and 4.4 shows a bar chart representation of the effect of extrusion load to extrusion time below. The values of extrusion load and extrusion time for all the geometries of billets extruded showed in table 4.4 above where used to plot the bar charts.

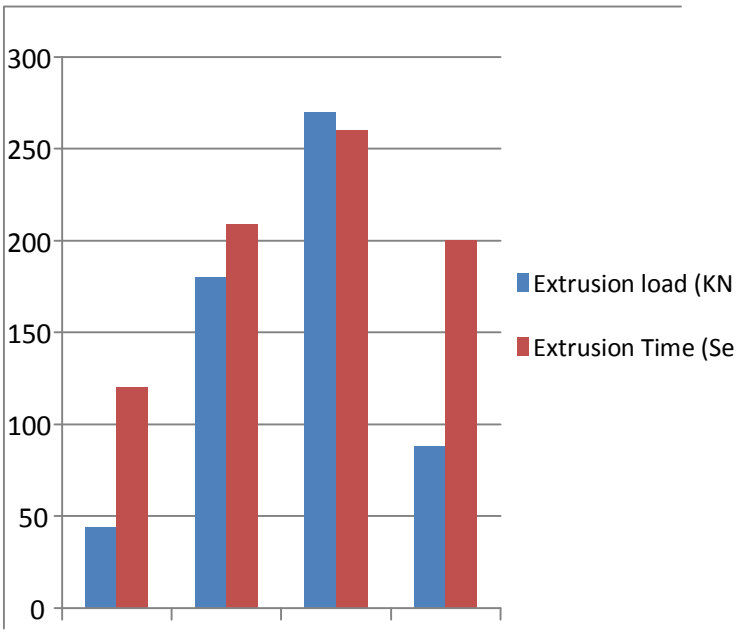


Figure 4.1: effect of extrusion load to extrusion time for

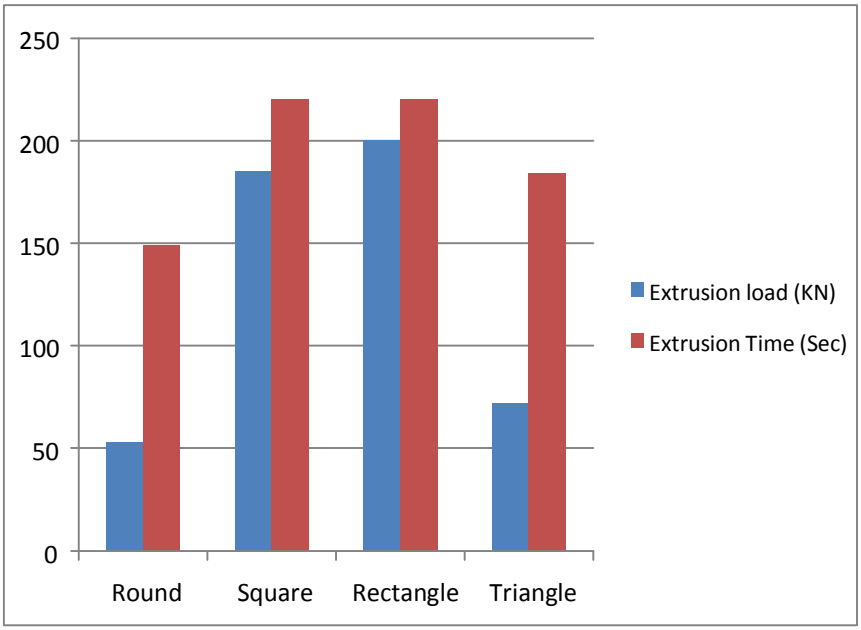


Figure 4.2 effect of extrusion load to extrusion time for neem Oil

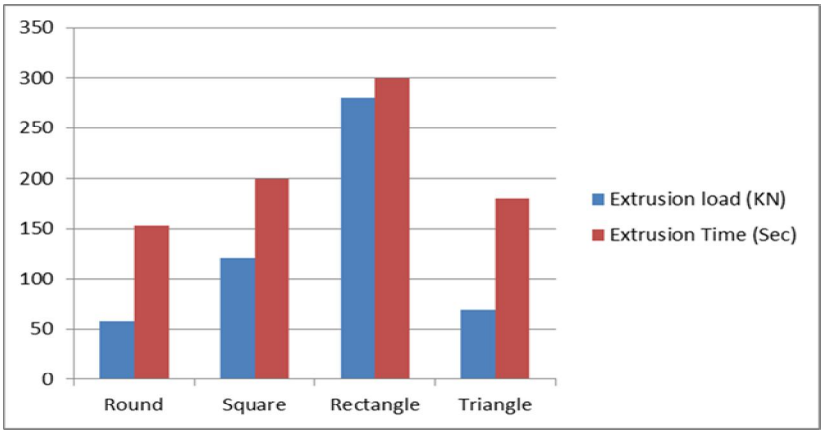


Figure 4.3: effect of extrusion load to extrusion time for jathroper oil

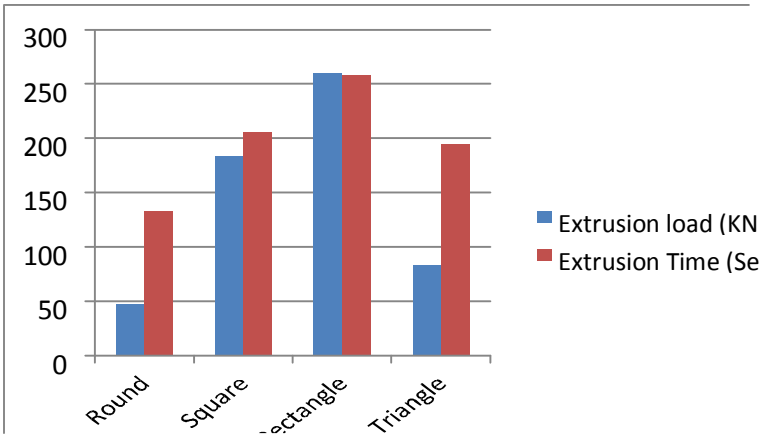


Figure 4.4:effect of extrusion load to extrusion time for Cotton Oil

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 Discussion

The extrusion process is divided into two parts the coining stage, which is the stage when the billet being extruded begins to fill up the die cavity. This stage is also of two parts, the initial container filling part and the on-set of extrusion. The second stage is the steady stage, which is when the extrusion proceeds steadily and it is characterized by a drop in load to the coring point. The above figures 4.1, 4.2, 4.3 and 4.4 gives a bar chat representation of the effect time has on the extrusion load for the various geometries of billet extruded. One of the major effects the oils showed for both square and rectangular sections was that it took longer time for the billet to be extruded compared to that of both round and triangular billet. This is because of the difference in geometry of the billet. Therefore longer time as well as increase in punch travel is required for the desired billet to be extruded.

From table 4.4 it can be seen that using castor oil as lubricant during the extrusion process ensured that tougher materials and the demand for closer control of better surface finish was achieved. I.e. to say castor oil gave a better surface finish quality for both round and triangular

billets. Also for the three other trial lubricants (Neem, Jatropha and cotton) round and triangular billets also had the good surface finish. Surface cracking is generally recognized as one of the main defects occurring during the process of aluminium extrusion, especially in the case of the so called hard aluminium alloys. Previous experiments suggest that this type of defect is caused by the rise in temperature as the process proceeds. This research experiments indicated that the surface quality is good even though the temperature may be high during extrusion. It is also well known that crack criteria have been adopted to explain the cracking that occurs in extrusion, blanking and rolling, etc. Also for some of the section of aluminium extruded, they came out curved except for the round billet. Which shows that for extrusion of different geometrical shapes guiding elements should be provided in order to have the extruded metal straight.

Based on the result gotten by Hafis, et al (2011) in the investigation of the effect of palm oil as lubricant in cold forward extrusion Therefore, in this research good surface finish products were achieved by using the vegetable oils as lubricants. Also as result of varying die angle which was employed in the design of the dies good surface finish and hardness of extruded billets were produced which is in agreement with the investigation carried out by Chaudhari et al, (2012) on the effect of die angle on the quality of extruded products.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Extraction of oil was carried out from new castor seed, Neem seed, Jatropha seed and cotton seed respectively, where 2-4littres of fresh oil was gotten. These oils were used as trial lubricants in the extrusion of aluminium and compared with other works done in the use of oil as lubricants during extrusion processes and were found to be suitable because of their availability and heat reduction abilities. Extrusion dies were constructed with semi die angles of 30^0, 45^0 and 60^0 which gave result of quality surface finish and hardness of extruded billets. The co efficient of friction between the billet and the container wall was calculated for each process, where Castor oil ranked the least with coefficient of friction of 0.100 and 0.107 respectively. Also for all the geometries of billet extruded round and triangular billet gave good surface finish, but castor ranked the best of all the oils. Based on previous experiments carried out on the extrusion of aluminium, surface cracking were major defects caused by the rise in temperature as the process proceeds. This research experiments indicated that the surface quality is good even though the temperature may be high during extrusion process because of the cooling effect of the lubricants used.

6.2 Recommendations

This work concerns itself with the analysis of the pressure effect of these oils in the extrusion of aluminium through 4 different die sections using analytical equation to compute the maximum load and coefficient of friction. Other methods such as the finite methods could be carried out using the same materials used in this research work.

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