Republic of Iraq
Ministry of Higher Education and Scientific Research
Middle Technical University
Technical Engineering College – Baghdad

EFFECT OF PARTICULATE ADDITIVES TO DEEP DRAWING DIES LUBRICANTS IN FORMING ALUMINUM SHEETS

A THESIS SUBMITTED TO
THE COUNCIL OF THE TECHNICAL ENGINEERING COLLEGE-BAGHDAD IN A PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF TECHNOLOGY IN DIES ENGINEERING TECHNOLOGY

By

Munaf Hashim Ridha

SUPERVISOR

Dr. Nasri S. M. Nimer

Asst. Prof.

SUPERVISOR

Dr. Haidar Akram Al-Sabti

Asst. Prof.

August 2015

Dhu al-Qidah 1436

Supervisors Certification

We certify that this thesis was prepared under our supervision in a partial fulfillment of requirements for the degree of Master of Technology in Dies Engineering Technology.

Signature:
Name: **Dr. Nasri S. M. Nimer**
(Asst. Prof.)
Date: 23/8/ 2015

Signature:
Name: **Dr. Haidar Akram Al-Sabti**
(Asst. Prof.)
Date: 23/8/ 2015

Linguistic Certification

I certify that I have read this thesis entitled "**Effect of Particulate additives to Deep Drawing Dies Lubricants in Forming Aluminum Sheets**" by "**Munaf Hashim Ridha**" and I examined the language of the thesis and in my opinion it's adequate as a thesis for degree of Master of Technology in Dies Engineering Technology.

Signature:
Name: **Ayad Jihad Shamsuddin**
(Asst. Prof.)
Date: 2 /9/ 2015

Signature:
Name: **Dr. Hassan H. Mahdi**
(Asst. Prof.)
Head of the Dies and Tools Engineering Dept.
Date: 3 /9/ 2015

In view of the available recommendation, I forward this thesis for debating by the Examining Committee

Signature:
Name: **Dr. Haidar Akram Al-Sabti**
(Asst. Prof.)
Deputy Dean for Scientific Affairs and Postgraduate Studies
Date: 3 /9/ 2015

Certification

We are the members of the Examining Committee certify that after reading this thesis (**Effect of particulate additives to deep drawing dies lubricants in forming aluminum sheets**) and examining the student " **Munaf Hashim Ridha** " in its contents. We think it is adequate for the award of the Master Degree of Technology in Dies Engineering Technology.

Signature:

(Chairman)

Name: **Dr. Abass Khammas Hussein**

(Asst. Prof.)

Date: 14 / 1 /2016

Signature:

(Member)

Name: **Dr. Hani Aziz Ameen**

(Prof.)

Date: 12 / 1 /2016

Signature:

(Member)

Name: **Dr. Hamed Ali Hussein**

(Lecturer)

Date: 13 / 1 / 2016

Signature:

(Supervisor)

Name: **Dr. Nasri S. M. Nimer**

(Asst. Prof.)

Date: 12 / 1 /2016

Signature:

(Supervisor)

Name: **Dr. Haidar Akram Al-Sabti**

(Asst. Prof.)

Date: 12 / 1 /2016

Signature:

Name: **Dr. Faris A. Kubba**

(Asst. Prof.)

(The Dean)

Date: / /2016

بسم الله الرحمن الرحيم

وما أوتيتم من العلم الا قليلا

صدق الله العظيم

سورة الاسراء

آية 85

ACKNOWLEDGEMENT

Firstly, all the praise be to Allah the most gracious and merciful for His uncountable blessings.

I am greatly indebted to my supervisors Asst. Prof. ***Dr. Nasri S. M. Nimer*** *and Asst. Prof.* ***Dr. Haidar A. Al-Sabti*** *for their valuable guidance, help and encouragement throughout this work.*

My sincere thanks go to the Asst. Prof. ***Dr. Faris A. Kubba***

I wish to express my thanks to the Technical College staff, Especially Messers ***Dr. Hatim Mahmmod , Dr. Sabah Khammas , Dr. Juhain Jawdat, Dr. Abdulhadi N. Khalifa****, and Lecturers****, Isam Tariq , Suliman Mustafa, Kareem Queen, Ahmed Jasim, Muhammed Khazall, Ahmed Ibrahim , Jumana Wassfee, Haneen Majed, Hala Zidan,*** *for their advice during my experimental work. Also, I would like to express my thanks to:* ***University of Technology, Central Organization For Standardization And Quality Control, Institute of Technology, Company of Electric Industries, Midland Refineries Company\ Refinery Al Durra*** *for the use of their facilities.*

Thanks to everyone who has helped me in this work by advising me or showing me the way for success.

Munaf Hashim Ridha August 2015

Dedication to:

My Parents

My Brothers, Sister

And my wife

ABSTRACT

The executed work as a whole has shown an urgency and favorable prospects of practical use of firm powder additives on the basis of (graphite) and soft metal (Copper) powders at a range of concentration (2–5) %wt and (1–3) %wt respectively. Improving the characteristics of liquid lubricants was experimentally revealed at friction contact surfaces by using the composite additive powders of the graphite – copper (mixing) in comparison with a case of separately introduction of the same of graphite and copper powders, entered separately. The given effect took place in deep drawing process of aluminum alloy type AA2024-T4 by using two types of lubricants, die and castor oils. The antifriction ability of powder lubrication and the state of powder layer are strongly related to the service conditions. Therefore, the effects of sliding velocity and normal load under powder lubrication were studied using a pin on disc contact apparatus according to ASTM G-99 specification.

The theoretical concept according to which introduction in the base lubricant environment of graphite and copper in quality thin layer covering the surface of contact should lead to increase anti-frictional and anti-wear efficiency of the lubricants in comparison with a case when metal and nonmetallic additives are entered separately was put forward. The tribotechnical characteristics of investigated graphite and copper additives to lubricants were received during wide range of experiments. Optimum lubricating effect concluded at concentration of the graphite and copper additive powders are (3) %wt and (2) %wt respectively, by the formation of protective boundary layer between the sliding tribo-surfaces that prevents wear.

Tribological characteristics significantly improved i.e. the wear rate dropped about (89%) for die oil and about (99.7%) for castor oil compared with the case of using the lubricant oils without additives. The effect of applied load vs. wear rate for all wear tests with and without lubricant and at all %wt of particulate additives submitted to second order polynomial equation model with high correlation coefficient more than 97% and lowest standard deviation ≤0.1.The hybrid optimum percentage of powder additives (2% Cu + 3% Gr) with castor oil gives lowest wear rate compared with that added to die oil.

The investigated lubricant was used in deep drawing process of aluminum alloy type AA2024-T4. A circular blanks with 1.2mm thickness were drawn to cup with flange, using reverse circular drawing die in cold and dry conditions with punch nose radius and blank holder angle of (12mm) and (0º) respectively.

Results had revealed that deep drawing parameters of aluminum alloy type AA2024-T4 were significantly improved the drawing force, cup height, surface roughness and thickness distribution of the produced cups. The effect of hybrid particulate lubricants is clearly had the best deep drawing parameters with (7.2 %, ,70.5 %, and 6%) for drawing force, surface roughness and thickness distribution respectively compared with pure lubricant deep drawing process.

	Contents	Page

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Definition
Cu	Copper
Gr	Graphite
BHF	Blank Holder Force
HRC	Hardness Rockwell Cone
DIN	German institute for standardization
FLD	Forming Limit Diagram
UTM	Universal Testing Machines
ASTM	American Society for Testing and Materials

CHAPTER ONE

GENERAL INTRODUCTION

CHAPTER ONE
INTRODUCTION

1.1 *General Introduction*

The important variables that affect the formability of sheet metal in deep drawing processes are divided into the two categories, (i) Tooling and equipment factors, and (ii). Material and friction factors. [1]

1.2 *Deep Drawing*

Deep drawing process is a sheet metal forming process where punch is used to force a flat metal sheet blank to flow into the gap between punch and die surfaces. a result, the sheet metal or blank will be deformed into desired shape like cylindrical, conic, or boxed-shaped part and also complex parts which normally require redrawing processes by using progressive deep drawing dies. [2]

The deep drawing process is a popular choice due to the rapid presses cycle times. The capabilities of producing the complicated shaped and geometries with low labours requirement is also an advantage in manufacturing industries. [1]

Always the fracture at the shell of the specimens occurs and thus causes the defects in the product after the sheet metal was successful drawn in deep drawing process. The product is in defect condition and the deep drawing process must be redone using another specimen. The other defect in deep drawing process includes wrinkling in the flange of product which occurs because of compressive buckling stress in the circumferential direction. Wrinkling in the wall, tearing, earring and surface scratches, are defects which can be eliminated by using proper lubricants and sufficient clearance between punch and die, punch corner radii and die corner radii. [3]

1.3 ***Lubricants and Their Additives***

The main purpose of lubricants is to keep the sliding / moving surfaces apart, otherwise the friction causes a lot of tear and wear of surfaces and consequent destruction of material which must be minimized. Thus the main objectives of lubrication in deep drawing process are reducing extending of metal because frictional heat and destruction of material and metal cooling, reduce drawing force, good surface finish, good wall thickness profile, and reduce the maintenance cost. The lubricants can be classified based on their physical state and chemical compounds added to lubricating fluids to impart specific properties to the finished lubricants. [4]

The additives impart new and useful properties of the lubricants and increase properties that are already present, some act to reduce rate at that which undesirable changes happen in the production during its service life, Additives improve the performance characteristics of lubricating oils, which aid significantly in the development of improving prime movers and industrial machinery. Now, practically all types of the lubricating oil contained at least one additive, and some oils contained additives of severally different types. The amount of the additive used varies from a few hundredths percent to 30% or more. [5]

The more commonly used additives are graphite, polytetrafluoroethylene , tungsten disulfide, boron nitride, molybdenum disulfide , copper, zinc dithiophosphate, zinc dialkyldithiophosphate and tricresylphosphate for antifriction and anti-wear.[6]

The additives improve viscosity index of lubricants that is also function of antifriction, anti-wear and oxidation inhibitors. Additives are substances with formulated improvement of the chemical and physical properties of base oils like mineral, synthetic, vegetable or animal, which increase the lubricant activity and expansibility of the equipment life. The anti-friction additive reduces coefficient of friction it consists of molecular platelets which easily slide over each other. Anti-wear additives prevent direct metal to metal surfaces contact between the parts when the lubricant film is broken down. The using of anti-wear additives gives in longer die life due to score resistance and higher wear of components. The mechanisms of anti-wear additives reacts with the metal on part surface and forms a film. [7]

1.4 ***Thesis Outline***

This thesis consists of six chapters. Chapter one introduces the deep drawing process with the parameters that have effect on deep drawing process and the lubricants and their additives that are used in deep drawing process. explains theoretical aspects of deep drawing process, the properties of lubrications and their additives, friction and wear calculation are given in chapter two as well as the literature survey that deals with deep drawing process, lubricants and lubricant additives are represented in chapter three. Chapter four the experimental part includes; design of the die of deep drawing, the physical properties of lubricants and additives, the wear test, and the mechanical properties of blank material, drawn cup surface roughness, thickness profile, height and drawing force. Chapter five includes experimental results and their discussions for deep drawing process parameters, wear tests. A summary of experimental results and list of study for future works are given in chapter six.

CHAPTER TWO

THEORETICAL ASPECTS

CHAPTER TWO
THEORETICAL ASPECTS

2.1 ***Introduction***

All parameters that are measured, calculated, and affect deep drawing process and wear in the presence of lubricants with and without lubricant additives are discussed in this chapter.

2.2 ***Blank Material***

Aluminum alloy, AA 2024-T4, is heat-treatable Al-Cu alloy, which is available in many types of products forms and tempers. The properties vary markedly with temper; T4 type tempers are noteworthy for their very high strength and high toughness. This alloy has creep resistance at elevated temperature, very good properties and has very high resistance to corrosion. [8]

The AA 2024-T4 is used in aircraft fittings, missile parts, munitions, rectifier parts, orthopedic equipment and structures.

2.3 ***Additives***

Graphite and copper particles are used as additives in lubricants. The graphite additives are widely used because they have a flat plate like structure and their layer sheets are arranged one above the other and held together by weak Van der Waal's forces. These parallel layers which can easily slide one over other, also have tendency to absorb oil. While copper additive film separates two friction surfaces and avoids their direct contacts. Furthermore, the low hardness of the film results in the reduction in friction, while the low elastic modulus increases the elastic deformation of the contact surface and reduces wear. [4]

2.4 ***Deep Drawing Process***

Deep drawing process is one of the most important processes for sheets metal forming parts. It is widely used for mass production of hollow shape parts in the automotive industry, packing industry [9]. It is known a tensile-compressive sheet metal forming process in which a blank material is formed into a hollow part which is open from one side with a smaller cross section area, "deep drawing in one step", "Deep drawing process in a single draw" is the forming of a blank (plane sheet section) into an open hollow shape, the forming of open hollow shape into one with a smaller cross section,is called "Redrawing" [10].

2.5 ***Blank Holder Force (BHF)***

The blank holder force has the maximum effect on the wrinkling, thinning strain, the coefficient of fiction, product quality, material flow, strain path, stress distribution and plastic strain ratio. Also the strain-hardening exponent depends on BHF [11]. A tooling system has been developed to investigate material flow, which is capable of controlling the distribution of blank holder pressure. The cup height improvement and the processing time reduction have been chosen as the object functions for evaluation of fracture functions. It has been proven that the new combination of punch speed (SPD) and (BHF) fuzzy control system has improved performance with increased productivity with 25% forming time reduction. It is evident that even small changes in (BHF) which can lead to failure during the process [12]. The blank holder force required for deep drawing is calculated from:

$$\boldsymbol{F_B = (D^2 - d^2).P} \qquad \dots\dots(\mathbf{2.1})$$

Where:

$\boldsymbol{F_B}$**:** Blank holder force (N)

$\boldsymbol{D}$**:** Blank diameter (mm)

***d*:** Punch diameter (mm), and

***P*:** Specific blank holder pressure (N/mm^2), 2.5 for steel, 2.0 – 2.4 for copper alloy and 1.2 – 1.5 for aluminum alloy.

2.6 ***Punch Force***

The axial pushing force is exerted on the brim of the blank by a pushing ring, this reduces radial tensile stress at the sidewall and the risk of occurring fracture can be reduced considerably. The radial stress at punch-die zone increases with friction and bending; this reduces tangential stresses and thus reduces wrinkling. Also loading capacity of sidewall is enhanced due to strain hardening effect [13]. For drawing round parts in a single drawing, the maximum drawing force F_U can be calculated by the following equation:

$$F_U = \pi\, d \cdot t \cdot (UTS)\left(\frac{D}{d} - 0.7\right) \qquad \ldots\ldots\ldots(2.2)$$

F_U : Drawing force

t : Original blank thickness

UTS : Tensile strength

D : Blank diameter

d : Punch diameter

2.7 ***Drawing Speed***

Drawing speed is a speed at which the punch moves through the blank during drawing. It is very important parameter in drawing because higher speeds are sometimes detrimental, particularly harder and less ductile materials are likely to be excessively thinned out due to excessive drawing speeds.

2.8 ***Friction***

Friction is an important factor in metal forming processes which affects the loads (drawing and blank holder force), stresses, strain distribution, metal flow, energy consumption and surface quality of the products. Friction and lubrication are very important in deep drawing process among the metal forming processes. Strain distribution is strongly affected by the friction, since the sheet metal cross-sectional area is very small compared to the contact area with the tool. Thus, the formability of sheet metal depends on the friction at the tooling/workpiece interface in addition to its material properties [14]. The dry coefficient of friction can be calculated by standard ***Male*** and ***Cockcroft's*** ring of 6:3:2 [15] as:

$$R_n = R_o \sqrt{\frac{\left(\frac{R_i}{R_o}\right) + \left(\frac{\Delta R_i}{\Delta R_o}\right)}{\left(\frac{R_o}{R_i}\right) + \left(\frac{\Delta R_i}{\Delta R_o}\right)}} \quad \ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

$$m = \frac{-1}{2\frac{R_o}{T}\left(1 + \frac{R_i}{R_o} - 2\frac{R_n}{R_o}\right)} * \ln\left[\left(\frac{R_i}{R_o}\right)^2 \times \frac{\left(\frac{R_n}{R_o}\right)^2 + \sqrt{3 + \left(\frac{R_n}{R_o}\right)^4}}{\left(\frac{R_n}{R_o}\right)^2 + \sqrt{3\left(\frac{R_i}{R_o}\right)^4 + \left(\frac{R_n}{R_o}\right)^2}}\right] \quad .(2.4)$$

$$\mu = \frac{m}{\sqrt{3}} \quad \ldots\ldots\ldots\ldots\ldots \quad (2.5)$$

Where:

R_n: Mean radius of specimen.

R_i: Specimen inner radius after deformation.

R_o: Specimen external radius after deformation.

ΔR_i: Change in Specimen internal radius after deformation.

ΔR_o: Change in Specimen external radius after deformation.

T: Height of the specimen.

m: Friction factor.

μ: Coefficient of friction.

Using lubricant film reduces the metal-to-metal contact and tooling wear. Lubrication system must be carefully controlled in order to achieve the optimum friction level at the tooling/workpiece interface and increase the production efficiency. Hydrodynamic lubrication is the aim of the tribologists and studies were concentrated on this topic. Tribological systems are designed to operate in hydrodynamic lubrication in order to eliminate wear [16]. The shear stress in the lubricant film is calculated using the film thickness obtained from the asperity deformation model, the sliding velocity a Newtonian fluid for a pure Couette flow [17]

$$\tau_{lub} = \frac{\eta_{lub}\, U}{h} \quad \ldots\ldots..(2.6)$$

Where

τ_{lub} : Shear stress in the lubricant film (Pa)

η_{lub} : Viscosity of lubricant (Pa.s)

U : Deformation velocity (mm/s)

h : ½ height of asperities (mm)

The friction factor value for the mixed lubricated contact calculated from the shear strength of the solid and the lubricant part is given by [17]

$$f = \frac{\alpha_s\, \tau_{sol} + (1-\alpha_s)\, \tau_{lub}}{F} \quad \ldots\ldots\ldots(2.7)$$

Where

f: Friction coefficient value for the mixed lubricated contact.

α_s: The ratio of height to low asperities.

τ_{sol}: Friction factor = m in dry condition **.**

τ_{lub} : Shear stress in the lubricant film.

F : Drawing force.

2.9 *Wear in Sheet Metal Forming*

Wear is the removal of material from one, or both, of two solid surfaces in contact. For sheet metal forming (SMF), wear is detrimental for the process, as friction often increases and the quality of the produced parts is deteriorated. Similar to friction, wear is a system response and changing of any parameters may change the operative mechanism. It involves both transfer of sheet material by adhesive wear and scratching due to abrasive wear. [18]

2.9.1 *Adhesive Wear*

In adhesive wear, particles are transferred from one surface to the other and are either permanently or temporarily, attached to the surface. By oxidation and deformation hardening, the transferred particle may gain in hardness and cause a transition to abrasive wear. The adhesive bonds originate at the asperity contacts, Figure (2.1) which constitutes the real area of contact Due to the imposed relative movement between the sheet metal and the tool, the bonding is torn apart. If separation does not occur along the interface, separation occurs inside the volume of the softer material and thus initiates material transfer [18].

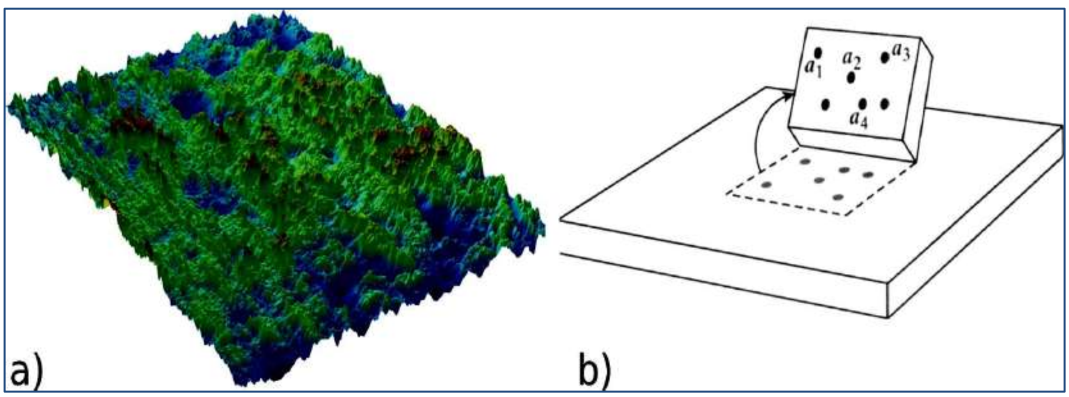


Figure (2.1) Concept of area of contact; (a) surface asperities (b) real area of contact. [34]

To avoid or reduce adhesive wear, the surfaces have to be separated, which, similarly to the chemical component of friction, often is achieved by adding of a lubricant. Additionally, different materials possess different susceptibility to adhesion and, hence, adhesion may be reduced by materials selection. [18]

2.9.2 *Abrasive Wear*

Abrasive wear occurs when a hard surface protrusion, or particle, removes material away from a softer counter-surface. The mechanism is distinguished into two-body abrasion, for instance as in cutting, and in three-body abrasion, where the abrading is a third loose particle. Generally, two-body abrasion leads to higher wear rates compared to three-body abrasion. [18]

If scratching occurs due to hard surface protrusions, the most straight-forward routine to reduce the wear rate is by polishing. In SMF, significant improvements in the tools performance may be achieved by polishing to an average roughness value $R_a < 0.1$ [19].

2.9.3 *Wear Calculation*

Wear mechanisms in a real deep drawing operation are analyzed by investigation of damaged dies and sheets. The die materials were cast nodular iron and tool steel, used in forming of medium-strength carbon steel sheet. Wear is calculated from pin on disc wear test as follows in equations (2.8) to (2.10)

$$WR = \Delta W/SD \qquad \dots\dots\dots(2.8)$$

$$SD = V \cdot t \times 100 \qquad \dots\dots\dots(2.9)$$

$$V = \frac{2\pi\, r \cdot n}{60 \times 1000} \qquad \dots\dots\dots(2.10)$$

Where:

WR: Weight loss wear rate (gm/cm)

ΔW: Weight difference of sample before and after each test (gm).

SD: Total sliding distance (cm)

V: Linear sliding velocity (m/sec).

t: Time of running (sec).

r: Distance from the center of sample to the center of disc (mm).

n: Disc rotational speed (rpm)

2.10 ***Forming Limits Diagram***

Forming limits are one of the important parameters in deep drawing and it is dependent on process parameters. A lot of works have been reported to find forming limits and forming curves like that shown in Figure (2.2) to find the effect of hydro-forming deep drawing parameters on drawability of different metals. [20] Wrinkling in case of hydro-forming is very severe failure as compared to conventional deep drawing. Increasing the total thickness of a material its resistance to deformation increases .[21]

Forming limit curves are representation of maximum strain as function of major and minor strain in the sheet plane that a material can sustain without failure [22].

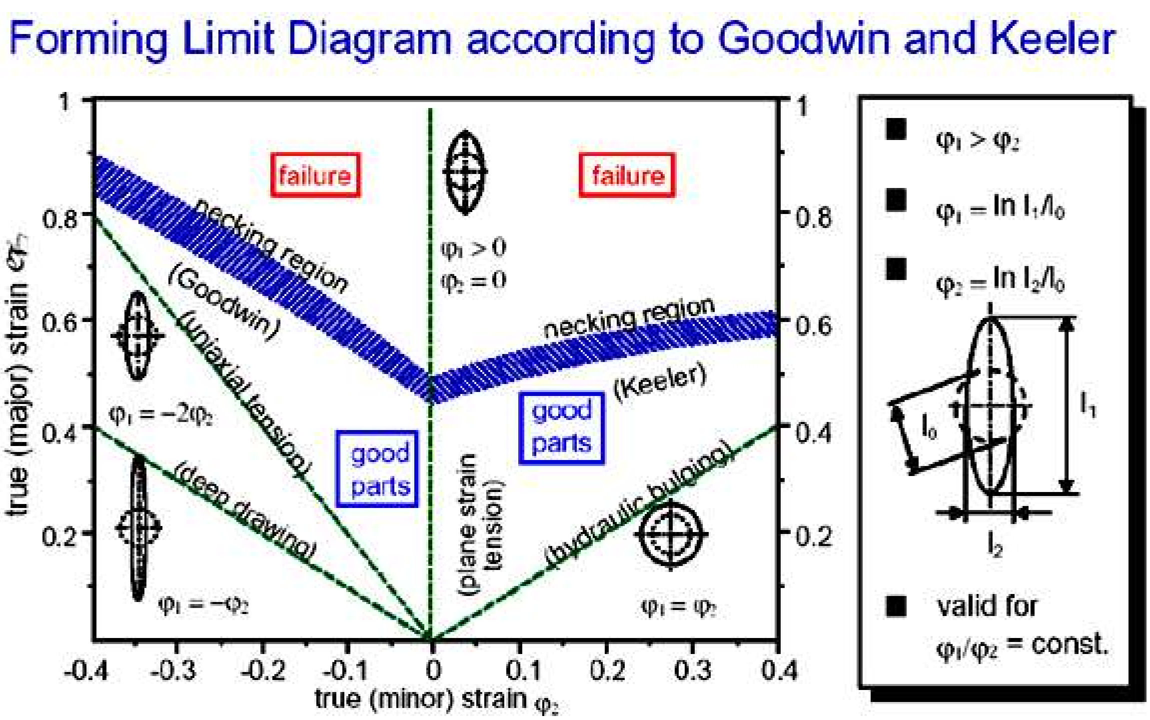
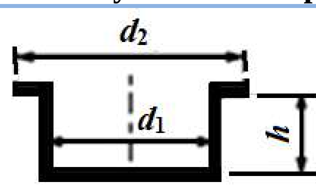
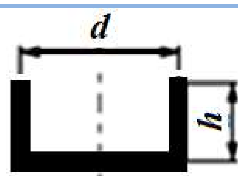


Figure (2.2) Forming Limit Curves (FLCs). [18]

2.11 ***Blank Shape and Size***

Blank shape is one of the important parameters in deep drawing process as the quality of deep drawn product, thickness distribution, forming limits, minimizing the defects and material costs can be improved by having optimum blank shape **[**18**]**. To determine the desired final part geometry and die layout the form and size of the blank metal must be calculated, To calculate the blank diameter, it is necessary to divide the entire axisymmetric parts into various types of individual axisymmetric components. The total surface area of product calculated from individual areas enables the calculation of the blank diameter $\boldsymbol{D}$ of a container shape with or without flange listed in Table 2-1. [18]

Table 2.1 Blank Diameter Calculations. [18]

Container Shape (Cross-section) **Rational Symmetric Shapes**	**Blank Diameter *D* =**
	$\sqrt{d_2{}^2 + 4\,d_1 \cdot h}$ ... (3.11a)
	$\sqrt{d^2 + 4\,d \cdot h}$ ... (3.11 b)

2.12 ***Draw Ratio***

The draw ratio $\boldsymbol{\beta}$ is an important numerical value for cylindrical draw parts in determining the required number of drawing steps. The draw ratio is the ratio of the diameter (D) of the initial blank form to the diameter (d) of the drawn part (punch diameter) as expressed in equation (2.12). [18]

$$\boldsymbol{\beta} = \frac{\boldsymbol{D}}{\boldsymbol{d}} \quad \ldots\ldots\ldots (2.12)$$

2.13 ***Thickness Variation***

Thickness variation depends on process parameters, where in deep drawing the thickness of sheet metal varies throughout the process. Amount of draw and flange thickness variation have been determined numerically and verified experimentally, for this the circumferential and radial strains have been calculated [23]. There is some thickening at the flange due to circumferential stresses during the deep drawing processes and this feature should be considered. The proposed analytical approach has the capability to calculate rate of thickening of the blank, the current radius, the current stress applied at blank holder and the current punch load [24]. Equations (2.13) and (2.14) should be using to calculate deformation:

$$\boldsymbol{\delta_{all} = 100\frac{t_{n-1} - t_n}{t_{n-1}}(1 - K_t)\%} \quad \ldots\ldots..(\mathbf{2.13})$$

$$\boldsymbol{K_t = 100\frac{t_n}{t_{n-1}}\%} \quad \ldots\ldots\ldots(\mathbf{2.14})$$

Where:

δ_{all} : Allowed deformation from table (2.2).

t_n and t_{n-1}: Wall thickness, the (***n***): the sequential number of the draw 1, 2, 3. . . ***n***

K_t: Thinning coefficient

Table (2.2) Ironing-Related Deformation (δ_{all}) (Percentages) [25]

	First draw		***Second draw***	
Material	δ_{all}	K_t	δ_{all}	K_t
Steel annealed	50-66	40-45	35–40	50-55
Steel medium hard	35-40	55-60	25-30	65-70
Aluminum	55-60	35-40	40-50	50-55
Brass	60-65	30-40	50-60	40-50

2.14 ***Deep Drawing Defects***

The defects that can occur in the products of deep drawing process are wrinkling in the flange, wrinkling in the wall, tearing, earring and surface scratching. All these defects are shown in Figure (2-3). The blank holder force should be sufficient to prevent compressive buckling which affects occurring the wrinkling in the flange Figure (2-3a). When a wrinkling flange is drawn into the cup shape, or if the clearance is very large, fore the wrinkling in the wall takes place as shown in Figure (2-3b). High tensile stresses that cause failure and thinning of the metal in the wall cup and/or sharp corner in deep drawing die are a reason for causing the tearing as shown in Figure (2-3c). Earring occurs when the property of material is varying in different directions (i.e. anisotropic materials), see Figure (2-3d). Finally, the surface scratches can be shown on the drawn parts , if the punch and die are not smooth ,or if the lubrication of the process is insufficient. [27]

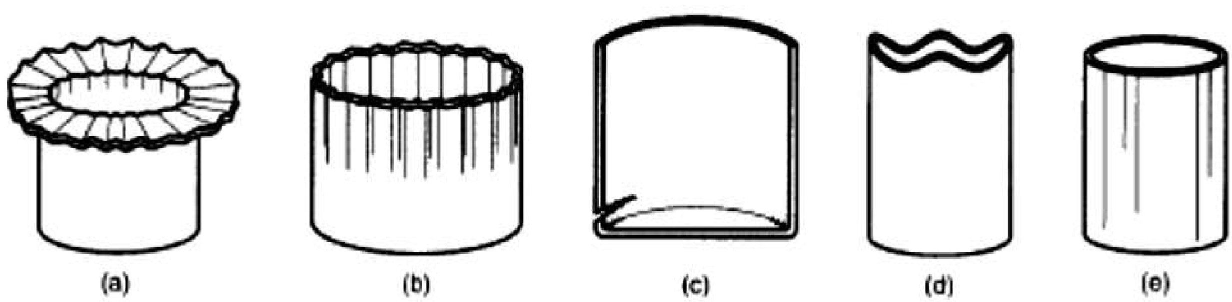


Figure (2.3) Defects in deep drawing cylindrical cups. [27]

2.15 ***Parameters Affecting Deep Drawing Process***

The parameters that affect the success or failure of a deep-drawing process are die radii, punch nose radii, clearance between punch and die, and lubrication.

2.15.1 ***Die Radius***

As the blank is struck by the punch at the start of the drawing, it is wrapped around the punch and die radii; the stress and the strain developed in the work piece are similar to those developed in bending. The force required to draw the shell at intermediate position has a minimum of three components [26]. The forces required for overcoming the frictional resistance of the metal passing under the blank holder and over the die radius, the forces required for circumferential compression and radial stretching of the metal in flange. Die radius is fourth time of the blank thickness without using blank holder, and sixth to eighth of the blank thickness when the blank holder is used. [20]

2.15.2 ***Punch Nose Radii***

There is no set rule for the provision of corner radius on the punch. It is customary to provide a radius of four to ten times the blank thickness. The excessive thinning and tearing of the bottom of the drawn cup is made due to small punch nose radius too. [20]

2.15.3 ***Clearance between Punch and Die***

The selection of the punch-to-die clearance depends on the requirements of the drawn part and on the work metal. Because there is a decrease and then a gradual increase in the thickness of metal as it is drawn over the die radius, clearance prevents burnishing of the side wall and punching out of the cup bottom. Clearance can be calculated from the following formula [20]:

$$\boldsymbol{C = 1.4t} \qquad \dots\dots\dots(\mathbf{2.15})$$

Clearance may be smaller for flanged shells than for those having no flange and then pushed out through the die. Equation (2.16) represents recommended Oehler’s formula:

$$\boldsymbol{C = t + K\sqrt{10t}} \qquad \dots\dots\dots(\mathbf{2.16})$$

Where:

C: The clearance (mm)

t: Blank material thickness (mm)

K: A constant depend on the type of material, for aluminum is 0.02

2.15.4 ***Lubrication***

When two metals are in sliding contact under pressure, as with the dies and the work metal in drawing, galling (pressure welding) the tools and work metal is likely [26]. When extreme galling occurs, drawing force will increase and become unevenly distributed causing fracture of the work piece. Selection of the lubricant depends on the ability to prevent galling wrinkling, tearing, and give in good surface roughness and thickness distribution of product during the deep drawing. [20]

CHAPTER THREE

LITERATURE SURVEY

CHAPTER THREE
LITERATURE REVIEW

3.1 ***Introduction***

This presentation of previous study will be arranged according to the time of the research. It focuses on lubricant additives, effect of lubricants on deep drawing process parameters and many factors that have effect on lubricants.

3.2 ***Literature Review***

(Feng Gong et al., 2010) used three types of lubricants, polyethylene film, castor oil and soybean oil to investigate their effects on micro deep drawing of cylinder cups. The blank material was copper alloy with 40 μm thickness and 2mm diameter. They utilized universal testing machine (UTM) at constant drawing velocity 0.1 mm/s with and without lubrications. The result shows that using polyethylene (PE) film is the proper choice as a lubricant of the three lubricants in micro deep drawing. For minimum drawing force with maximum limit drawing ratio that is obtained when using PE film lubricant. [28]

(Mevlut Turkoz et al., 2011) studied the effect of planer anisotropy to investigate the earing behavior of AA 2024-T4 aluminum alloys by means of deep drawing to produce cylindrical cups. Large amount of ears occur at relatively large planer anisotropy planar magnitudes. They found that orientation of the sheet is important and the planar anisotropy of AA 2024-T4 is high. [29]

(Milan Jurkovic and **Muslic Merima, 2011)** studied the tribological condition of deep drawing process of cold-rolled steel phosphate and non phosphate plate with constant thickness of 3mm. They used two types of lubricants molybdenum disulfide and Hydraulic oil EP50 had viscosity 50mm²/s. The best tribological conditions were achieved using molybdenum disulfide on phosphate cold-rolled steel as lubricant gave minimal values of friction force and coefficient. Molybdenum disulfide reduced process force from 8-10% to maximally 30%. [30]

(Taylan Altan et al., 2011) researched the effect of several types of lubricants on deep drawing process of four-galvannealed steel. Four types of synthetic lubrication, one type of semisynthetic lubrication, two types of water-based lubrication and four types of petro-based lubrication. They evaluated all types of lubricants for all four-galvannealed steel and the lubricants have almost the same performance on them. However, water-based lubricant performed better than other lubricants. [31]

(Shashidhara and Jayaram, 2012) evaluated two types of nonedible/ vegetable oils, Pongamia pinnata and Jatropha carcass as a lubricants in deep drawing process. These oils are plentiful available in India scenario which justified their use as lubes for deep drawing because of their higher thermal and oxidation stability and favorable fatty acid composition. They selected 304L steel as a metal sheet therefore, 200-ton capacity press to conduct their experiments was used. They measured the punch load, drawing length and wall thickness distribution for the deep drawing cups by laser scanning technique. A CAD package was used for the some cup ruptures which were observed under methyl esters of both oils. They concluded that Jatropha oil performs better than mineral and other vegetable oils. [32].

(A. Vadiraj et al., 2012) used nano boric acid and nano copper as additives to two lubricants, engine oil and transmission oil SAE 90. The friction and wear performance of both lubricants with and without additives were studied at 1:10, 2:10 and 3:10 volume ratios. The commercial additives was available in sizes 50 nm and 20 nm for boric acid and copper respectively. The observed results show that the coefficient of friction is generally increased with increases in the additives concentration in engine oil. While the friction coefficient was proportional inversely additives concentration in transmission oil. The wear has difference proportions, decreases and increases in the engine oil and transmission oil respectively when adding nano-boric acid at all volume ratios. The increasing of nano copper additives showed higher damage in both lubricants. The recommended volume ratio of both additives is 1:10 in both lubricants that is detrimental for the sliding pairs. [33]

(Murat Dilmec et al., 2013) used variable AA2024-T4 sheet thicknesses of 0.8, 1 and 2mm in deep drawing process to investigate their effects on the thickness distribution and anisotropy at room temperature. They utilized automated strain measurement to determine the anisotropy by profile-projector and grid analysis methods. The results proved approximately no effects of planer anisotropy on variable AA2024-T4 sheet thicknesses. [34]

(A. U. Obasi et al., 2014) studied the influence of the additive on the performance of engine oil. The additives that was used to achieve the desired properties of engine oil they can be obtained from properties of oil (viscosity, density, flash point) increases with increase in additive concentration, while the foaming ability decreases as the concentration of additive increases. The types of additives anti-oxidants were dithiophosphate , detergent were sulphates, salicyiates, phenates and phenolsulphide salt. Anti-wear additives were dithiphosphates, anti-form agent where silicon polymers (polymethy lsiloxanes) had found extensive use in engine oil. [35]

(J. Reeves et al., 2014) researched the effect of particulate additives on tribological performance of bio-based and ionic liquid-based lubricants. The particles additives consisted of hexagonal boron nitride (HBN), tungsten disulfide (WS_2), graphite, molybdenum disulfide (MoS_2) and multi-walled carbon nanotubes (MWNT) at variable micro and nano grain sizes. The lubricant was mixed by 5% weight fraction of solid particles. They concluded that the effective influence is dependent on particle type and independent of particle size of additives in the natural oil (avocado oil). While these effective influence is independent of particle type and is dependent on particle size additives in the ionic liquids (IL). Nanometer and submicron-sized particulate additives enhance the tribological properties [36].

(U. Pranavi et al., 2014) evaluated the influence of three lubricants and three blank holding forces on deep drawing process of 2mm AA 6061 aluminum alloy sheet. They used two different strain paths, 150×150 and 200×200 mm to find optimized lubrication and blank holder force during the deep drawing process. They found that the coefficient of friction decreases due to the effect of lubrication on punch force. The results improved the punch force for 150×150mm strain path compared with 200×200mm strain path [37].

(S. Sivarajan and **R. Padmanabhan, 2014**) used molybdenum disulphide as a solid lubricant coating the high speed steel (HSS) surface to examine thermal evaporation, the microstructure and chemical composition. Thermal evaporation is a promising technique to deposit solid lubricant on selected areas of deep drawing surfaces so as to improve their tribological performance by right choice of surfaces coating processes and processes parameters like coating material and coating properties. The coating thickness and possibly multiple layer configurations, the mechanically well functioning coating can be obtained. [38]

(Behrooz Zareh-Desari et al., 2015) investigated the performance of lubricant at the tool/blank interface of deep drawing process and added small volume fraction of nanoparticle additives to improve the tribological properties of lubricating oils. The tribological behavior of (Al_2O_3) nanoparticles is scattered. In CM202A press drawing lubricant was inspected in deep drawing process. Experimental tests were guided for different concentrations of nanoparticles. The pointing out of similarities and differences between the formed cups under different lubrication regimes was conducted in terms of surface quality and maximum deformation load. The results denote that the friction reduction capability of base lubricant is increased by adding the Al_2O_3 nanoparticles, which consequently reduced the required forming loads for improving in the surface quality of formed cups. [39]

(Chandra Pal Singh and Geeta Agnihotri , 2015) reviewed many parameters and their effects on deep drawing process to produce good quality of product that has light weight , high strength , low density and corrosion resistance. Lubrication and blank holder force (BHF) have effect on deep drawing process to control metal flow, thickness variation, strain path, stress path and wrinkling behavior. The punch speed affects product quality, production rate, blank shape influences forming load and reduces possibilities of wrinkling and tearing. Friction affects relative thickness distribution and surface quality. They concluded that lubrication prevents direct contact of surface asperity which enhances draw-ability and reduces coefficient of friction. [40]

(Tingting Mao et al., 2015) studied several different lubricants including dry lubes and wet lubes effect on deep drawing process of aluminum alloy AA5182-O sheets with 1mm thickness. Lubricant F dry film can be considered the best performing lubricant among all lubricants evaluated. They concluded that dry lubricant performs better than wet lubricant when the same amount of coating weight (1gram/m^2) is applied. The friction of AA5182-O with electro-discharge texture (EDT) is slightly better than that of AA5182-O with mill finish (MF). [41]

(Hannes Freibe et al., 2015) researched the effect of additives on manufacturing processes produced in the deep drawing tool by direct laser deposition. Aluminum bronze with ten percentage of aluminum component was used as a tool material. The hardness distribution on the cross section of generated punch was investigated. The results present the feasibility of the additives manufacturing process aluminum bronze was utilized as tool material. Afterwards the printed deep drawing process tool was successfully applied to shape circular cups with an inner diameter of 30 mm made of 1.4301 high alloys steel. The deep drawing was carried out by using lubricant and a lubricant-free dry metal forming process. [42]

(Nasri S.M. Namer et al., 2015) studied the effect of punch radius in deep drawing process on the drawing height , thickness distribution and drawing force of cup product, the finite element based DEFORM-2D software, that showed the increasing the punch nose radius reduces the sheet thinning above the punch nose region, increasing the punch nose radius increases the formability of the sheet. FEM can be used effectively to simulate the deep drawing process. [43]

(Mohd Shadab Khan et al., 2014) studied mathematical model which was developed to predict the abrasive wear behavior of Al 6061and the design of experiments (DOE) on pin-on-disc type wear testing machine, against abrasive media. A second order polynomial model has been developed for the prediction of wear loss. The model was developed by response surface method (RSM). Analysis of variance technique at the 95% confidence level was applied to check the validity of the model. This model is valid within the ranges of selected experimental parameters of orientation and applied load. The accuracy of the Response Surface Model was verified with three sets of experimental data which were never used in modeling and average percentage deviation was calculated as 2.512%. [44]

3.3 ***Concluding Remarks***

The researchers in the previous survey shown that the using lubrication in deep drawing process and using additive to lubricants for increase the physical properties of lubricant lead to decrease the disadvantage of products of deep drawing processes some researchers used green lubricants in deep drawing like castor oil, soybean oil, avocado oil, vegetable oils like Pongamia pinnata and Jatropha carcass [32]. Some researchers used additives to lubricants like nano boric acid, nano copper, hexagonal boron nitride (HBN), tungsten disulfide (WS_2), graphite, copper, molybdenum disulfide (MoS_2) and multi-walled carbon nanotubes. The blank materials used in deep drawing process with the aid of lubricants were copper alloy, AA 2024-T4 aluminum alloys, cold-rolled steel, galvannealed steel, AA 6061 aluminum alloys , AA 5182-O aluminum alloys, the abrasive wear behavior of Al 6061the design of experiments (DOE) on pin-on-disc type wear testing machine [44] .

In this research ,the wear test studied wet and dry condition, the blank material used was AA 2024-T4 aluminum alloys in deep drawing process at room temperature, the lubrication used was castor oil and die oil, with two types of particulate additives, graphite and copper, their effect on drawing force, cup height, thickness distribution and surface roughness was studied.

3.4 ***Project Objective***

1. Investigate the effects of adding fine graphite and copper particles to the lubricants at variable weight fractions on the deep drawing of die materials wear rates.
2. Study the effects of best particulate oils on deep drawing process variables, drawing force, (wall thickness profile, height, and surface roughness of drawing parts) of AA 2024-T4 aluminum alloy sheets.

CHAPTER FOUR

EXPERIMENTAL WORK

CHAPTER FOUR
EXPERIMENTAL WORK

4.1 *Introduction*

Material selection for blank sheet and drawing dies parts, friction and wear tests, basic lubricants and additive powders used, the manufacturing of the drawing die and experimental procedure on included in this chapter. Surface roughness test, thickness distribution of product test, drawing force and cups height measurements are investigated.

4.2 *Deep Drawing of Aluminum Alloy*

The methodology included drawing of the circular blank and measuring thickness distribution, surface roughness and drawing force. The methodology for the deep drawing process is presented in Figure (4.1).The methodology involves:

- measuring the drawing force and cups height using the Universal Testing Machine UTM.
- measuring thickness distribution using profile projector and surface roughness of cups.

4.3 *Material Selection*

Aluminum alloy AA2024 available in multiple forms of products, is a heat-treatable Al-Cu alloy. The variation of properties is a function of tempers T3 and T4 type that are noteworthy for their high toughness. In this work, an aluminum alloy, AA2024 ‑T4 is considered because of its elongation, tensile strength and high toughness. 80-tons universal testing machine available in **Central Organization for Standardization and Quality Control** was used to find out the tensile properties of the AA2024-T4**.**The used standard tensile specimen was according to (ASTM-E8) as shown in Figure (4.2), and their properties are listed in table (4.1).The strength coefficient (***K***) and strain-hardening exponent are obtained from true stress-true strain curve (Figure (4.3)) according to Equations (4.1), (4.2) and (4.3).Figure (4.3) gives a comparison between the mentioned researches [34], Figure (4.3) indicates the mechanical properties of the AA2024-T4 material at different natural aging times; the true stress-true strain curve coincides with that of four day aging curve.

$$\sigma_{true} = \sigma(1+e) \quad \ldots\ldots (4.1)$$

Where:

σ_{true}: The true stress (MPa)

e: The engineering strain

$$\epsilon_{true} = \ln(1+e) \quad \ldots\ldots (4.2)$$

Where:

ϵ_{true}: the True strain

By applying Holloman equation (4.3), (K) and (n) are calculated

K: The strength coefficient (MPa).

n: The strain hardening exponent .

$$\sigma = K\epsilon^{n} \quad \ldots\ldots (4.3)$$

Table (4.1): The Properties of AA2024-T4

Parameters	Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)	Hardness (BHN)	Strength Coefficient(K) (MPa)	Hardening exponent (n)
Standard	470	325	20	120	720	0.210
Actual	462	328	18	120	790	0.166

The chemical composition of AA2024-T4 alloy was obtained through the analysis in (Poly Speck) at **State Company for Inspection and Engineering Rehabilitation** as listed and compared in Table (4.2) and an compatible with literature [29].

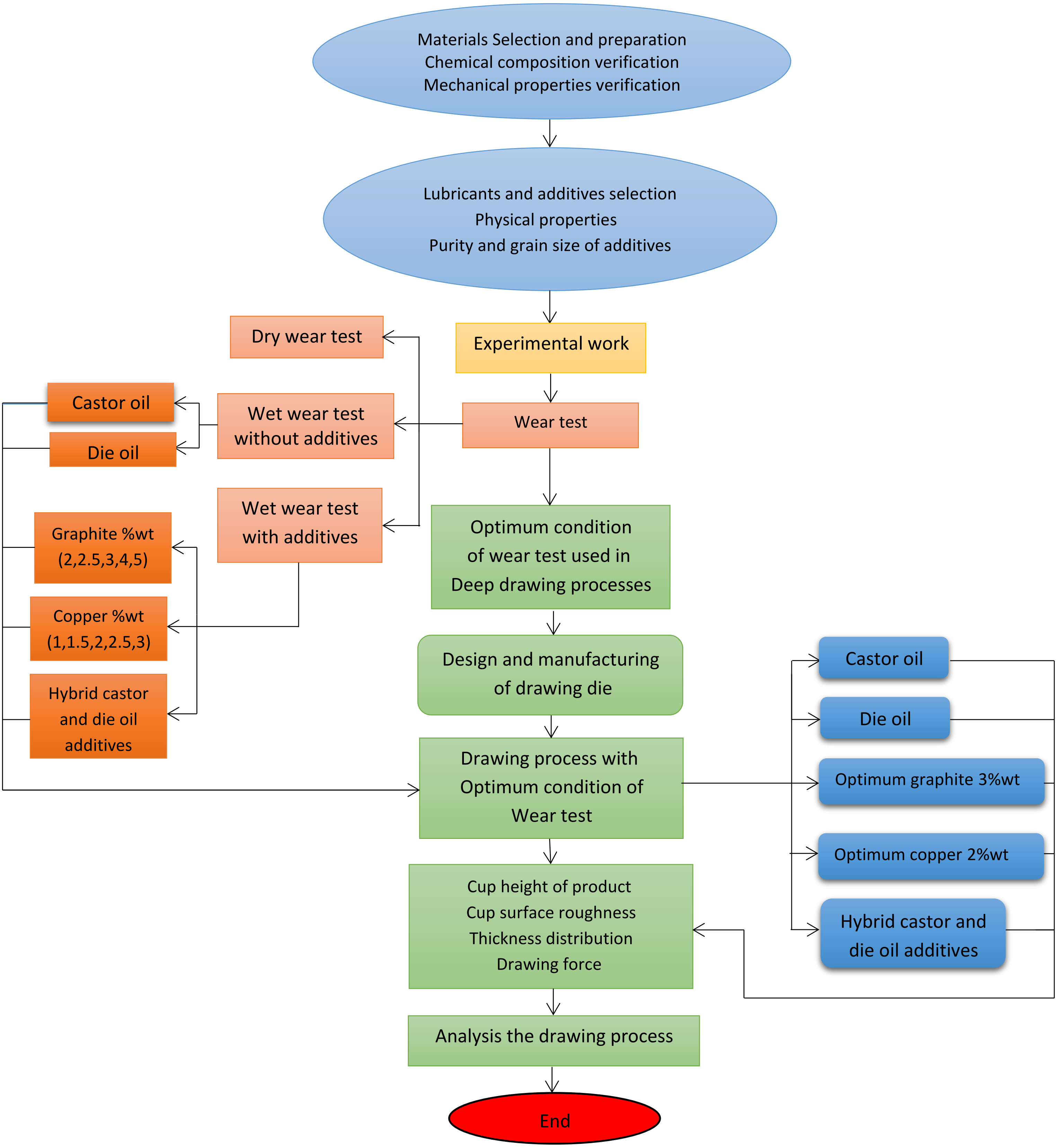


Figure (4.1) The methodology for wear test and deep drawing process

Figure (4.2) Photo of specimens

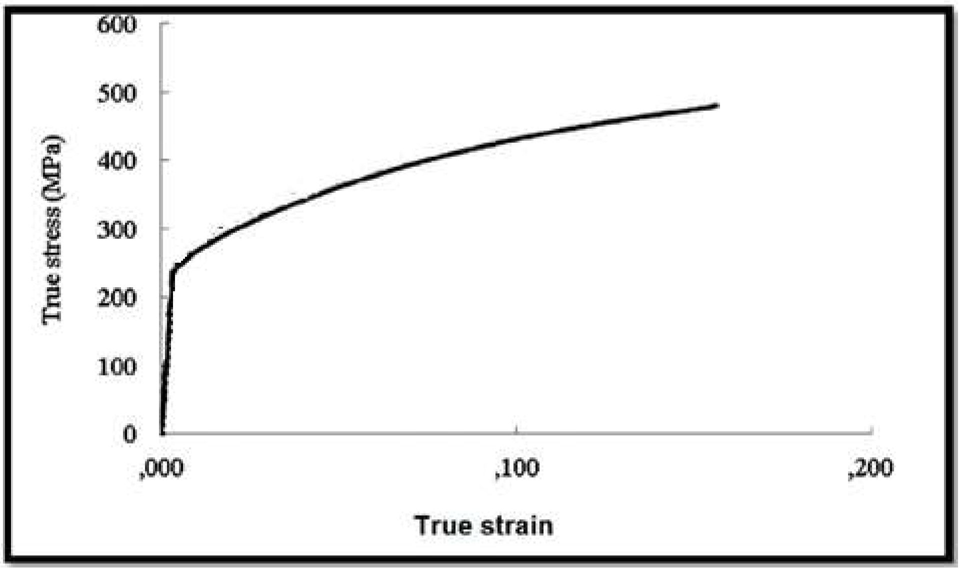


Figure (4.3) True stress-True strain Curve of AA2024-T4 [43]

Table (4.2): The Chemical Composition of AA2024-T4

Elements	Si (%)	Fe (%)	Cu (%)	Mn (%)	Mg (%)	Ni (%)	Zn (%)	Ti (%)	V (%)	Al (%)
Standard ASTM B 209M-04	Max 0.5	Max 0.5	4.9	0.6	1.8	Max 0.05	Max 0.25	Max 0.15	Max 0.05	94.7
Actual	0.113	0.352	4.6	0.534	1.6	0.014	0.049	0.022	0.01	92.7

4.4 *Die and Punch Material*

The structural and constructional steel (DIN EN 1006-2) was selected in design stage of deep drawing die used in this work. The chemical composition was tested by (Poly Speck-F) device in **Al-Tahady State Company** It is listed in Table (4.3).The selected metal has a (22 HRC) hardness number, quenching and tempering is necessary to improve its hardness. The hardness of this material is (55 HRC) when tested by (Ernst AT130 DSR) using hardness tester in **Al-TAHADY STATE COMPANY**.

Table (4.3) The chemical composition of (DIN EN 1006-2)

Elements	Fe (%)	C (%)	Si (%)	Mn (%)	Cr (%)	S (%)	Ni (%)	Co (%)	Cu (%)
Standard	96.6	0.5	0.34	0.78	1.1	0.02	0.167	0.02	0.2
Actual	96.7	0.515	0.323	0.764	1.08	-------	0.165	-------	0.2

4.5 *Deep Drawing Die Manufacturing*

4.5.1 *Die Manufacturing Stage*

Manufacturing a reverse deep drawing die is used to produce cups with flange. The die consists of six main parts (upper plate, drawing die, blank holder, drawing punch, lower plate and spring) assembled as shown in Figure (4.4).Ordinary machining operations such as turning, milling and grinding were made to produce the basic die parts to their final dimensions.

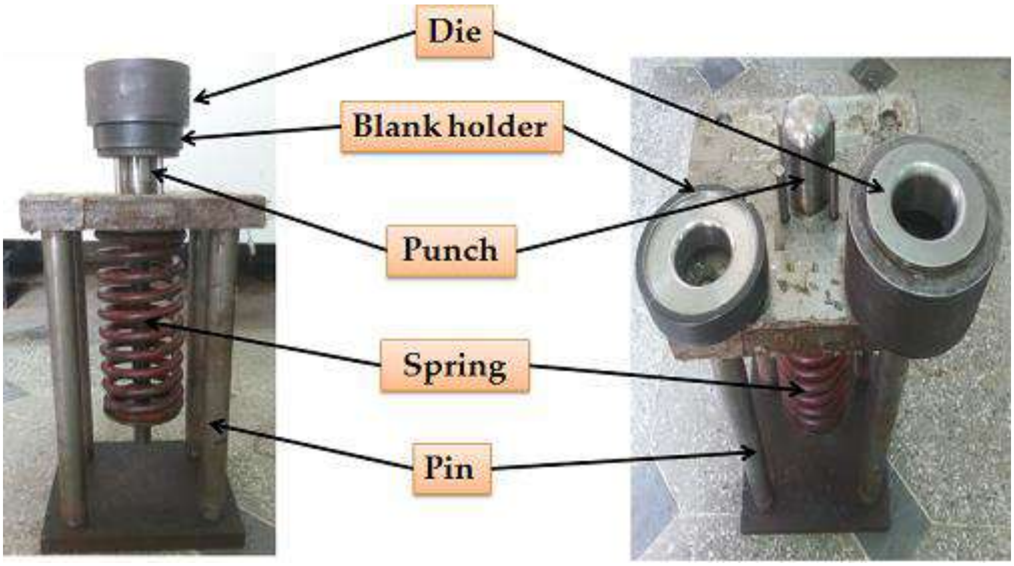


Figure (4.4) Deep drawing die

- The die design includes many stages and its parts are drawn with the dimensions by AutoCAD 2007**:**
- Clearance calculation: clearance is the gap between punch and die, Equation (2.15) calculates the clearance and in this work clearance is equal to 1.5 mm.
- Punch nose radius calculation: Punch profile radius depends on blank thickness and it ranges from 4 to 10 times of thickness [18], in this work (R_p) is set as (12 mm) as shown in Figure (4.5).

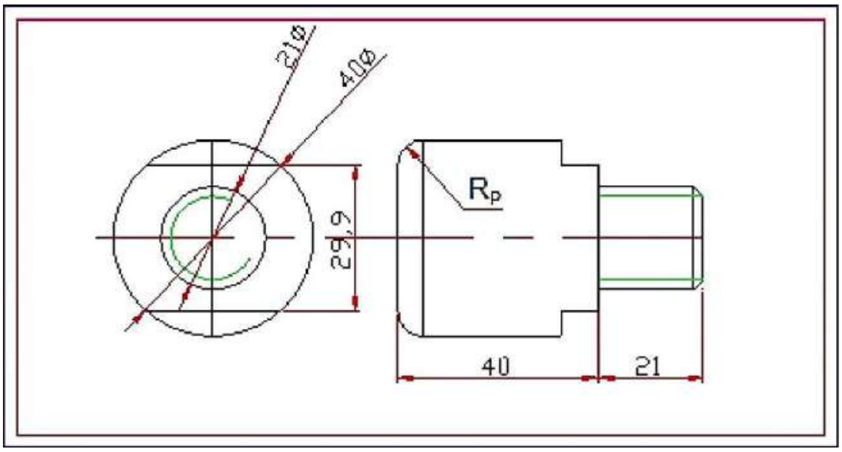


Figure (4.5) Front and top view drawing punch with dimensions

- Determining cup diameter: Cup(s) diameter for each draw can be estimated using the following Equation P = 100 (1 –dc/ Db) where P = percentage reduction, dc = inner diameter of drawn cup (mm) Db = blank diameter (mm).In this work the cup diameter is equal to 40mm.
- Punch diameter calculation is equal to the diameter of the cup to be drawn (dc).
- Set the die corner radius as (6.5 mm) in this design according to Equation Rd = 0.9 $\sqrt{(Db - dc)t}$ as shown in Figure (4.6).
- Die diameter can be determined using the following formula:
  Die diameter= punch diameter + (2 × clearance) in this work, it is equal to 43 as shown in Figure (4.6).
- Determining drawing force (***FU***): Equation (2.2) estimates maximum drawing force, which is equal to 90.522 KN.

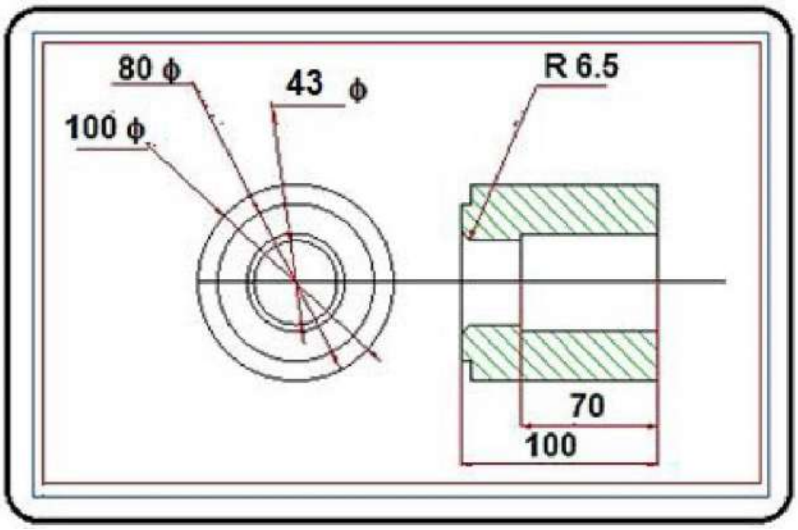


Figure (4.6) Front and top view of drawing die with dimensions

- The die has blank holder with blank holder angles (0°) as shown in Figure (4.7). Figures (4.8) and (4.9) show the other die parts like spacer and pins.

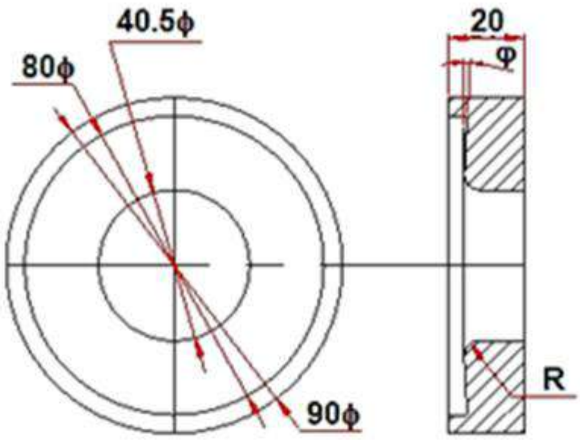


Figure (4.7) Blank holder with front and top view drawing with dimensions

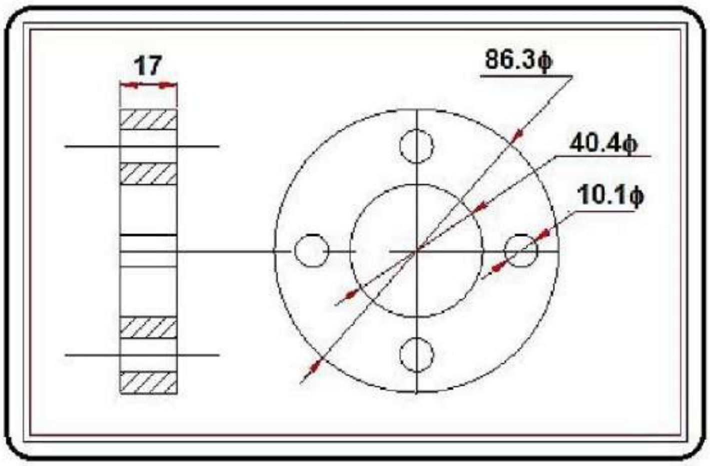


Figure (4.8) Spacer with front and top view drawing with dimensions

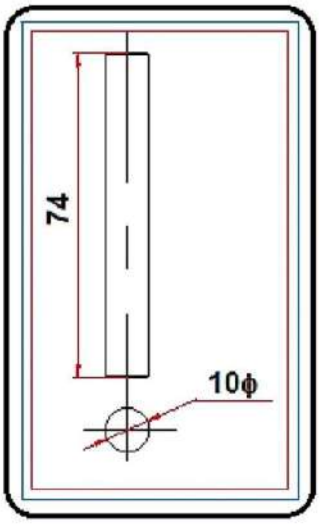


Figure (4.9) Pin with front and top view drawing with dimensions

4.6 ***Heat Treatment of the Active Die Parts***

Heat treatment process is carried out by heating the material and after that cooling it in water or oil .Quenching and tempering are the used heat treatments to improve the hardness in the active parts (punch and die) of the die. The quenching process technique is heating the metal (780 - 825) °C depending on carbon percentage. This temperature was held for some time and then the metal was quenched in water. The increasing metal hardness is the main purpose of quenching.

4.7 ***Basic Lubricants Used***

Basic lubricants used in this study are (**Castor oil) and petroleum oil (Die oil)** they tested in **Midland Refineries Company\Refinery Al Durra.**

Table (4.4) show the properties of basic lubricant used. They were examined for their effect on reducing wear, friction and tear of the surfaces by avoiding direct metal to metal contact between the rubbing surfaces.

Table (4.4) The properties of basic lubricants used

Laboratory Inspection Data	Castor Oil	Die Oil
Vis. C.st @ 40 °C	245.13	15.73
Vis. C.st @ 100 °C	19.12	3.56
VI	88	106
SP. Gravity @ 15.6 °C	0.9739	0.850
COC Flash	310	198

Digital viscometer device available in **Technical Collage Baghdad** was used for measuring the viscosity of the lubricant with additives used it's shown in Figure (4.10). and the lubricants viscosity with additive is shown in Table (4.5).

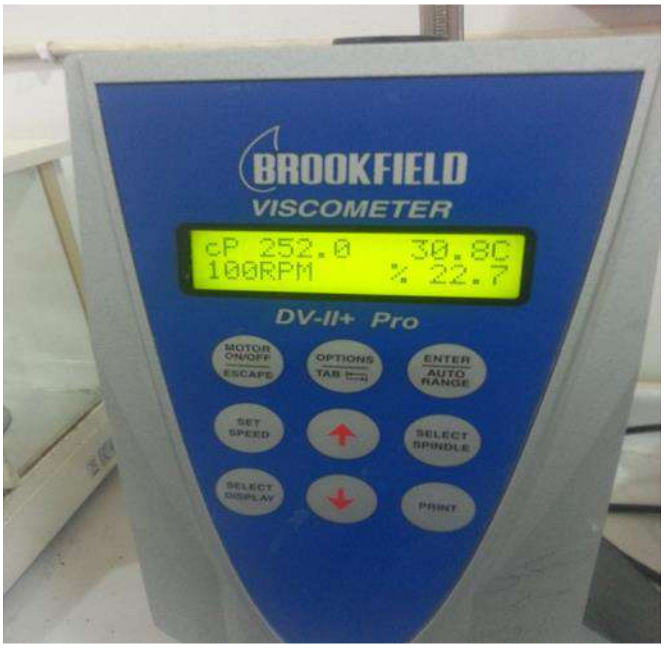


Figure (4.10) The digital visco-meter

Table (4.5) The lubricants viscosity with additive

Lubricants and additives	Viscosity	Lubricants and additives	Viscosity
Castor oil +1%Cu	249.7	Die oil +1%Cu	16
Castor oil +1.5%Cu	250.1	Die oil +1.5%Cu	18
Castor oil +2%Cu	252.93	Die oil +2%Cu	18.5
Castor oil +2.5%Cu	252.9	Die oil +2.5%Cu	18
Castor oil +3%Cu	252.9	Die oil +3%Cu	18
Castor oil +2%G	246.7	Die oil +2%G	17.8
Castor oil +2.5%G	250.9	Die oil +2.5%G	18.6
Castor oil +3%G	259.53	Die oil +3%G	19.93
Castor oil +4%G	269.4	Die oil +4%G	20.7
Castor oil +5%G	271.2	Die oil +5%G	21.8
Castor oil +2%Cu+3%G Hybrid	301.51	Die oil +2%Cu+3%G Hybrid	22.46

4.8 *Additives Selection*

Improving lubricant properties is one of the main objectives in this study. Additives are substances formulated for improvement of the chemical and physical properties of base oils. In this study, Graphite and Copper powders were used as solid lubricant additives in the range of (10 µm) and (32 µm) respectively. Graphite powder has been inspected at Ministry of Sciences and Technology, Advanced Materials Department, while copper powder has been inspected at Ibn Sina State Company, for their particle size and purity shown in Table (4.6).

Table (4.6) Physical properties of powders

Materials	**Average particle size (µm)**	**Purity (%)**
Graphite	~10	99
Copper	~32	99.9

4.9 *Ring Compression Test (Friction Test)*

A flat ring specimen of aluminum alloy AA2024-T4 was compressed plastically between two flat plates. The coefficient of friction (µ) for AA2024-T4 was gotten using this method of standard ring (D: d: h) ratio (6:3:2) of dimensions (42:21:14) mm, as shown Figure (4.11), tested by (Tenius Olsen) universal testing machine in **Central Organization for Standardization and Quality Control.** The dimensions of the ring after test are (48:19.8:10).The flow of the material inward and outward is a result of friction increasing and decreasing respectively. The friction coefficient is measured in this test by using Male and Cockcroft calibration curve or Equations (2.3), (2.4) and (2.5) .

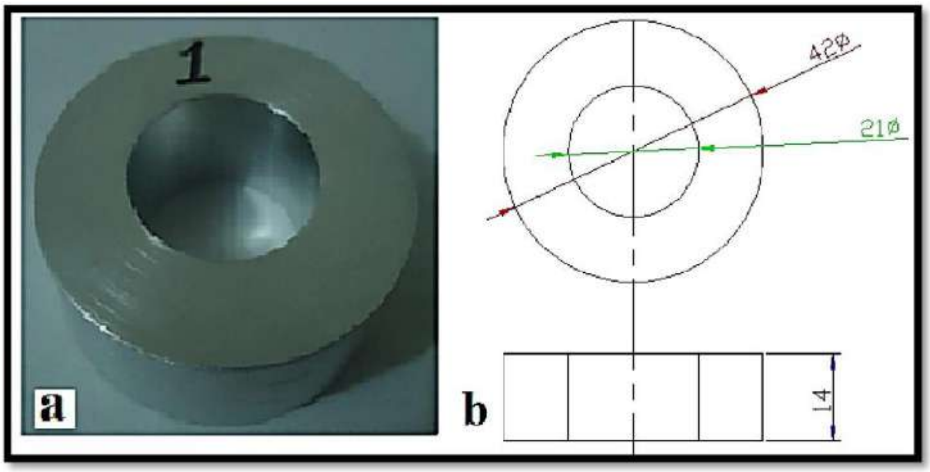


Figure (4.11) Ring compression test specimen, (a) photo & (b) schema

4.9.1 *Coefficient of Friction*

The coefficient of friction is measured from ring compression test and by equations (2.3), (2.4) and (2.5) the obtained value of friction coefficient was 0.13, which is very near to the standard friction coefficients of similar materials.

4.10 *Wear Rate Measurement Test*

The specimens (pin) were made from punch block material which was used in present work according to ASTM G-99 specification, a cylindrical pin with the device were used Figures. (4.12), (4.13) and (4.14) shows the experiments wear test device, the test was carried out at constant nominal rotation speed of (150) rpm the loads ranged from (2.5, 5, 7.5, 10 to 12.5) N. The duration of each test was 30 minutes, at room temperature. Flat-ended pin was pressed against a flat disc. The relative motion between the two was such that a circumferential wear path on the disc surface was generated .The cylindrical flat-ended pins with size (ø10mm × 20mm) were made from (punch block material) circular shaft. Surface of each pin was ground with (180, 400, 600, 800, 1200, 2000) emery papers, then the samples were dipped in ethanol to clean and dry them .Its face of disc was ground with (600, 1200, 2000) grit size of emery papers. The disc of wear test device had lubricant put before each operation that act as the lubricant that is used in punch of deep drawing process. The disc rotational speed was (150 rpm), measured by laser type device (TACHO METER) that means a linear sliding velocity of about (1.17 m/sec) which is calculated using the following formula (4.4):

$V = 2\pi \times r \times n /1000 \times 60$………………………..…… (4.4)

Where:

V: Linear sliding velocity (m/sec).

r: Distance from the center of sample to the center of disc in (75mm).

n: Disc rotational speed in (rpm).

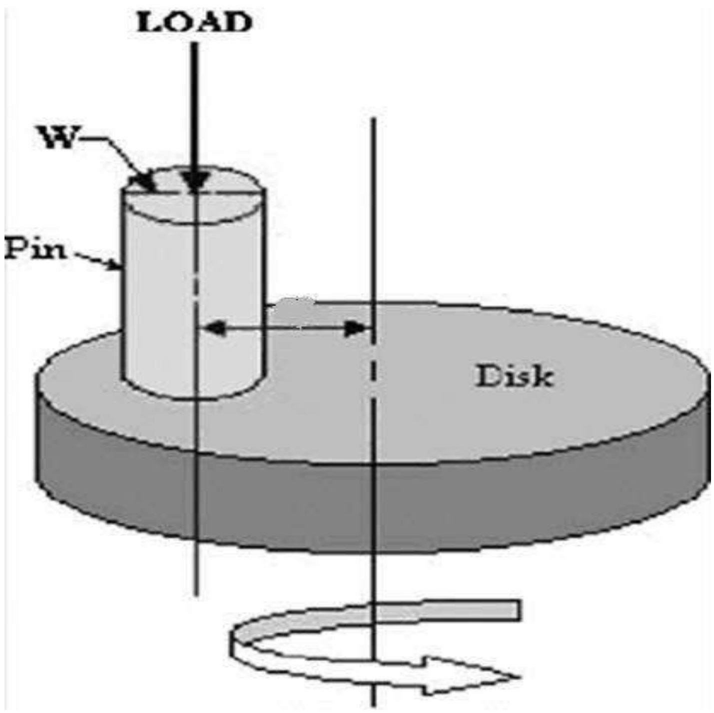


Figure (4.12) Schematic diagram of wear apparatus

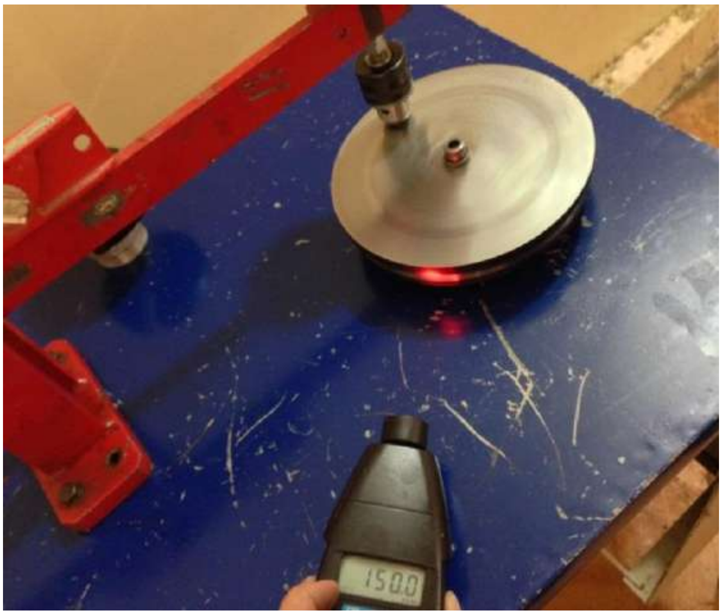


Figure (4.13) Wear Test Device

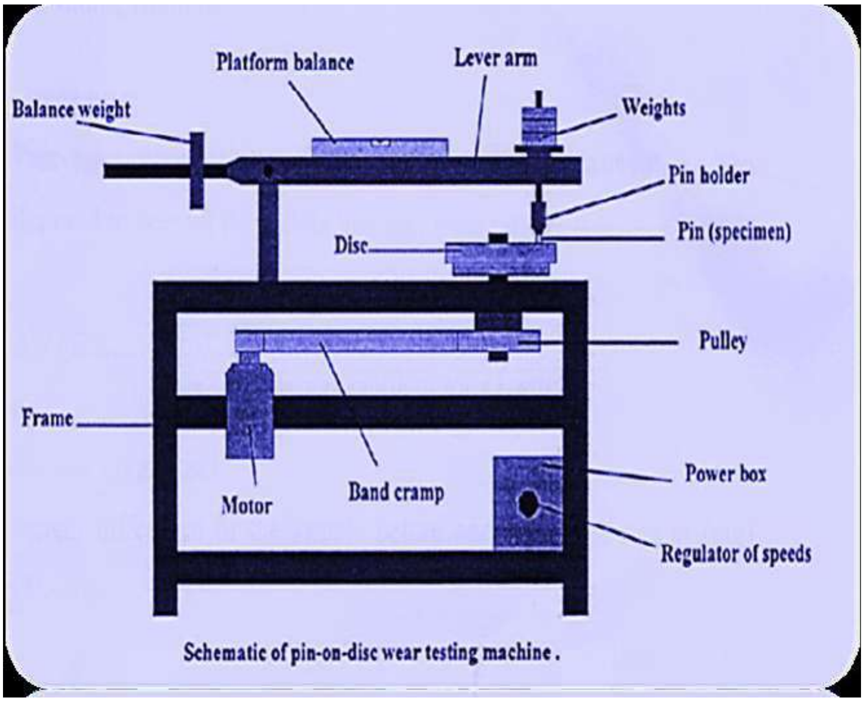


Figure (4.14) Schematic of the used pin-on-disc testing machine

4.10.1 ***Lubricant Removal***

Vegetable and petroleum oils have been used in wear test (wet friction conditions) as the same lubricant that was used in deep drawing process.

Acetone solution was used to remove lubricant from the pin and disc after each experiment of the wear test.

4.10.2 ***Wear Rate (Wr):***

Wear rate was computed by the weight loss measurement of the sample using a sensitive balance with an accuracy of (0.0001g) as show in Figure (4.15).

Wear rate (weight loss) = (ΔW / SD) gm/cm …... (4.5)

ΔW: Weight difference of sample before and after each test in gm.

(ΔW=W1-W2).

SD: Total sliding distance of (210600 cm), which is calculated as

Follows:

$SD = V \times t \times 100$ .... (4.6)

Where*:*

V: Linear sliding velocity (m/sec).

t: Time of running in (sec).

Figure (4.15) Sensitive Balance with an Accuracy of (0.0001g)

4.11 ***The Blanking Process***

Blanking is known as a metal forming process, in which a metal is removed from the principal metal strip or sheet metal, the former metal, is punched out. In a blanking process the piece of metal punched out, called the blank is the required product of the process. The process is often the first step in a series of processes. Figure (4.16) shows a die and punch provision for the blanking operation. The punch of blanking process has the same type of figure as that of die opening but that it is smaller on all sides by a volume known as clearance; the clearance is very important from sizing in the blanking process and is the purpose of the material properties and material thickness. The clearance between die and punch controls the quality and shape of the punch and die sheared edge [18].

Figure (4.16) the Blanking Process

4.12 ***Forming Limit Diagram (FLD)***

Forming limits of sheet metals are influenced by several physical factors of which the most important ones are material work-hardening, strain rate sensitivity, plastic anisotropy. Figures (4.17) and (4.18) show (FLD) of blank before and after forming respectively.

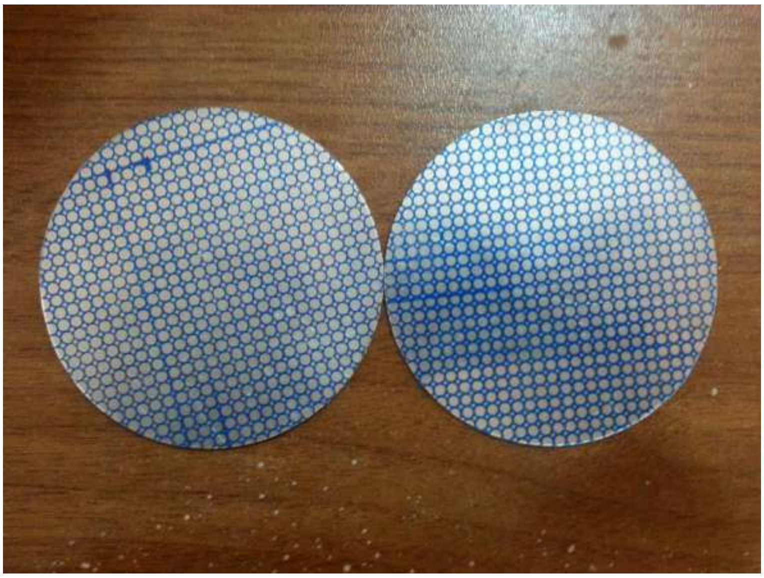


Figure (4.17) Blank with forming limit diagram

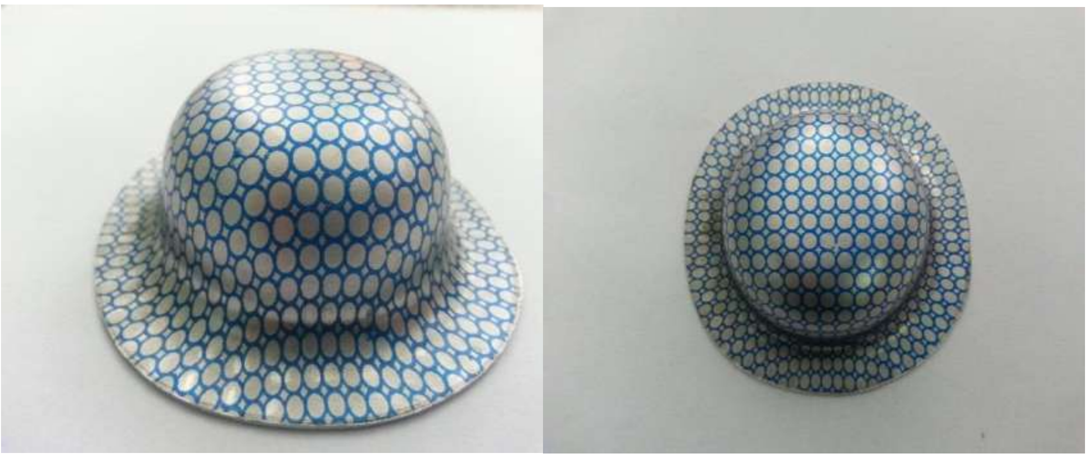


Figure (4.18) the blank after forming

4.13 ***Circular Cup Drawing***

The deep drawing processes of the blank obtained by using Universal Testing Machines (UTM) is as shown in Figure (4.19) available in **the Institute of Technology \ Baghdad** . The blank is put on the surface of the cold die and the blank holder holds it at a certain force then the drawing punch moves vertically to draw the cup, the punch returns to its initial position after the cup is formed, in this work the drawing process is performed with lubricants (wet drawing). After removing the cup from the die, it is subjected to different tests that will be mentioned later. The clearance between punch and die is 1.5mm. All performed experiments use 80mm blank diameter of aluminum alloy **AA2024-T4** with 1.2mm sheet thickness. The friction between tools and blank is one of the least known factors. For the combination of materials used, the friction coefficient is measured experimentally ring compression test at room temperature as mentioned above. Universal Testing Machine (**UTM**) gives the drawing force of the **AA 2024-T4** during deep drawing process.

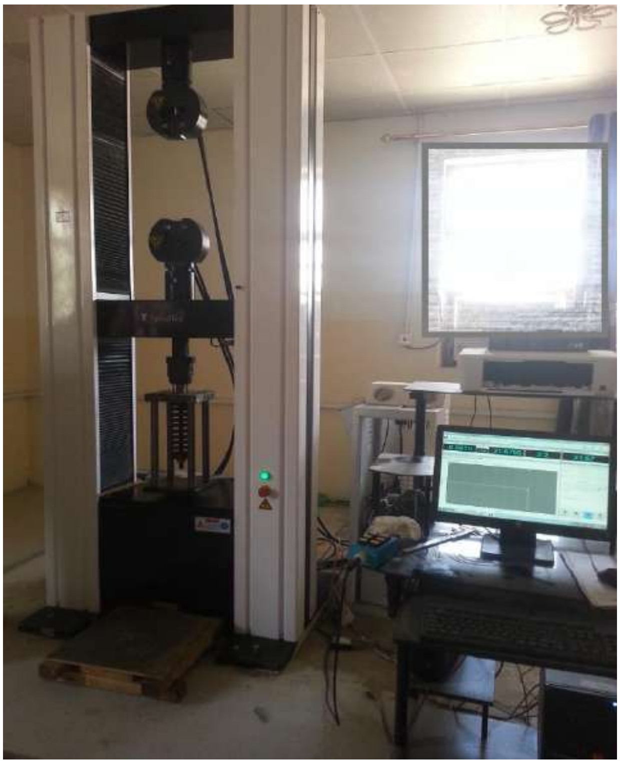


Figure (4.19) Universal testing machine with drawing die

Spring in the die devices the force of the blank holder. The value of the blank holder force which depend on the compression of the spring and it is obtained from **UTM**, the spring rate value is 200.88 N/mm. calculation is from the slope of spring-deflection curve Figure (4.20) which gives the indications of experimental blank holder force of 5kN. The spring gives cups with no wrinkles Figure (4.21). The drawing speed using in the practical work is 50mm/min that is the best speed used to draw the AA2024-T4.

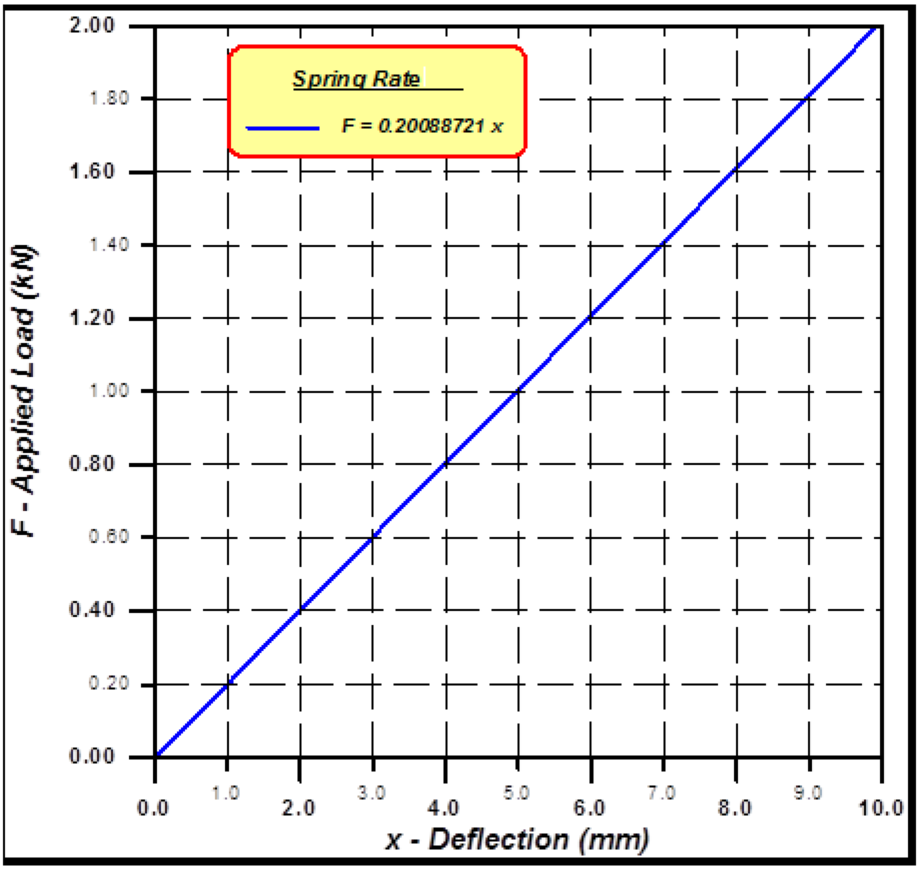


Figure (4.20) Curve of the spring deflection of BHF

Figure (4.21) the cup resulting from value of BHF

4.14 ***Thickness Distribution Test***

The cup of aluminum alloy AA2024-T4 was cut to two halves by a saw Figure (4.22) to measure the cup thickness distribution at six points as shown in Figure (4.23) by using profile projector device type (Mitutoyo RJ-A3000) shown in Figure (4.24).The measurements was carried out in the **Technical College- Baghdad**.

Figure (4.22) Cutting cups

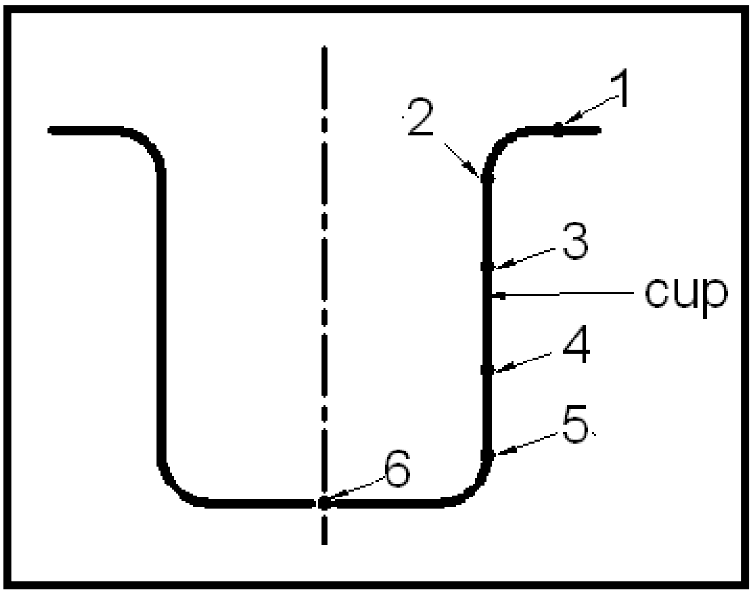


Figure (4.23) Thickness measurement locations on the surfaces of the cup

Figure (4.24) Thickness measurement (a) the method of fixing the cup, (b) the profile projector device

4.15 ***Surface Roughness Test***

The interaction of the real object with its environment that is determined through surface roughness plays an important role. Usually rough surfaces wear very quickly and have higher coefficients of friction than smooth surfaces. Therefore, the value of a high roughness is often undesirable, expensive and difficult to control in manufacturing. The decreasing in the surface roughness usually leads to increase in its manufacturing costs. This frequently results in a trade-off between the component performance in application and its manufacturing cost.

In this work, the average surface roughness of the cups ($\boldsymbol{R_a}$) was measured using roughness measuring device (Pocket Surf III) at **University of Technology** show in Figure (4.25). The ($\boldsymbol{R_a}$) value was calculated from four average roughness values at different points.

Figure (4.25) Pocket Surf III

CHAPTER FIVE

RESULTS AND DISCUSSION

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 *Introduction*

This chapter focuses on the presentation and discussion of the results, which include two sections. The first one focuses on dry and wet (lubricated) wear that existence of which was added to it later, copper and graphite particulates were separate and added together to form a hybrid particulate lubricant used in wear tests. The second section is the deep drawing of cups from AA 2024-T4 in the same conditions of wear tests.

5.2 *Wear Test*

Wear is a phenomenon in which surface materials are damaged or lost between two contact solids surfaces in sliding, rolling movement or impact. In most cases, wear is caused by the interaction of surface asperities. To reduce the energy loss and equipment damage generated due to mechanical parts friction in the operation, lubricants and lubrication technologies are used.

Two lubricants and additives were used in this work, namely; die oil (produced by Iraqi Petroleum Company) and green lubricant castor oil (vegetable oil), while the particulate additives used were graphite and copper.

5.2.1 *Dry and Wet Wear*

The comparison of wear for tool steel in dry condition and wet in the present of die and castor oil is illustrated clearly in Figure (5.1). The wear rate decreases because of using lubricants. The use of die oil gives an improvement compared with dry condition ranging from 18 to 5% from low to high applied load with average improvement of 11.5%. While the castor oil gives more improvement ranging from 30.6 to 43.7% from low to high applied load approximately with average improvement of 37.1%. This difference between the dry and wet condition of wear test comes from the reduction in contact or friction force that reduces the wear rate loss. as a result of increasing in viscosity, the using of castor oil gives more benefits to decrease the wear rate compared with die oil with ranging from 12.6 to 38.7%, and with average improvements reaching to 25.65% in wear loss rate compared with die oil.

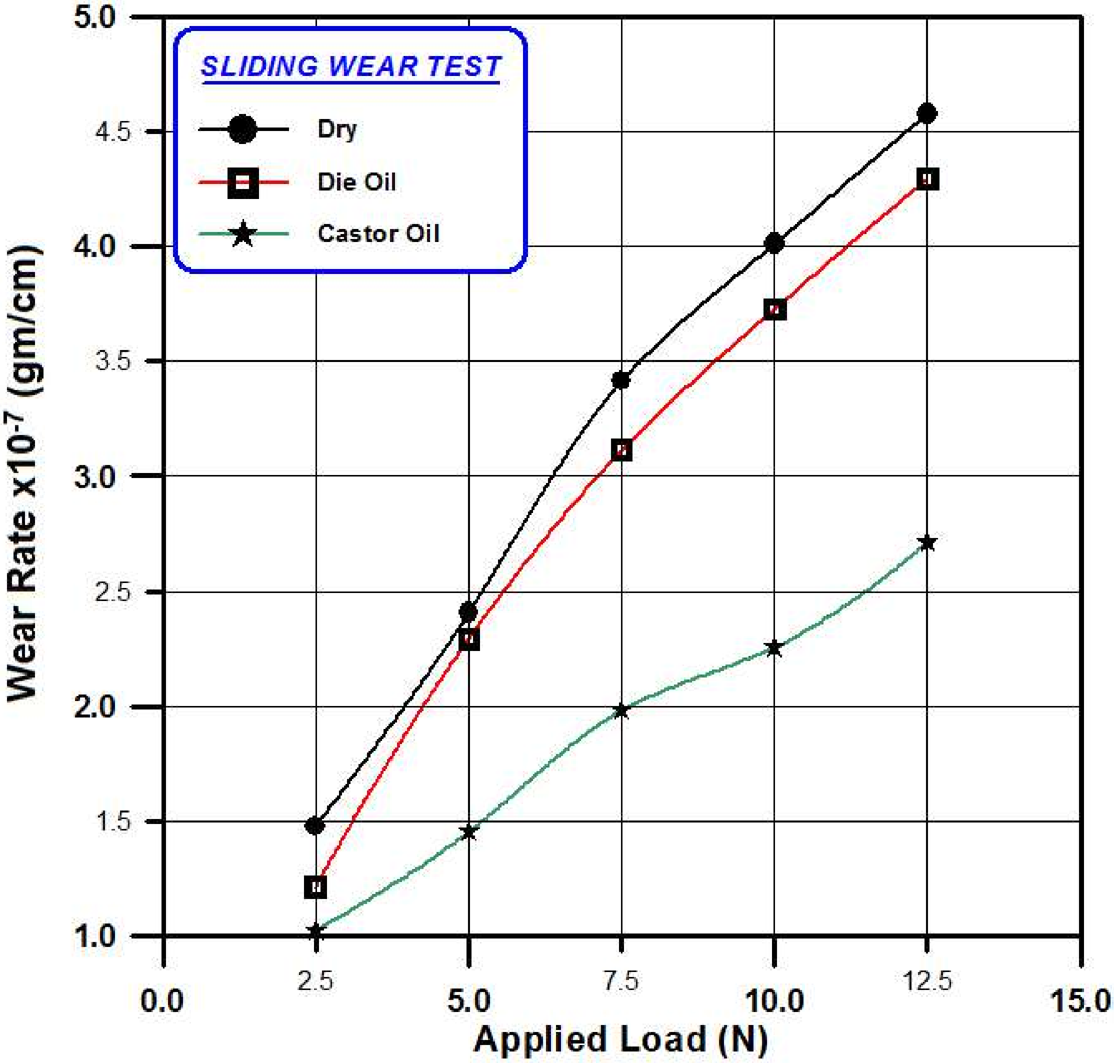


Figure (5.1) Effect of lubricants on wear rate at variable applied loads.

5.2.2 ***The Wet Wear Rate with Particulate Copper Powder Additives***

Among the five-weight fraction (1.0 to 3%) of particulate copper that was added to both die and castor oils, 2% is the best fraction in both oils as marked by star sign in the bar chart shown in Figure (5.2). The improvement of 2% weight fraction comes from the best thickness of lubricant film and more temperature stability compared with the other fractions. Also at weight fraction above 2% the increasing in film thickness leads to increasing in the hydrodynamic pressure and increasing in the friction and wear rate loose.

The result shows that the wear rate decreases by 23% and 20% when the particulate copper added at this weight fraction to die oil and castor oil respectively compared with pure oil without any additives. The reduction in friction shear stress is due to the increasing in viscosity and coefficient of friction for both particulate oils with copper additives. The wear rate loss behavior with added copper to castor oil is less than that without additives of these particles and the best weight fraction is 2% as mentioned previously, while adding these particles to die oil has the same tendency but with less reduction in wear loss at high weight fractions (2.5% and 3%).

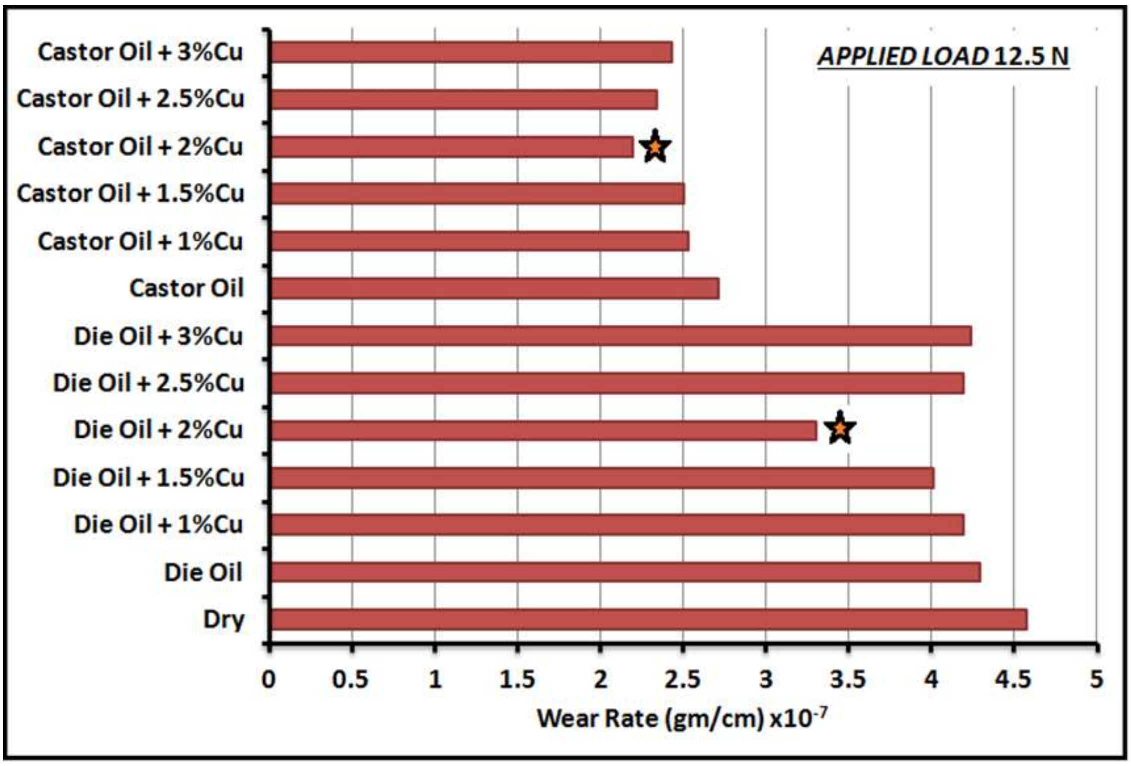


Figure (5.2) effect of added particulate copper weight fraction to die oil and castor oil on wear rate at maximum applied load (12.5 N)

5.2.3 *The Wet Wear Rate with Particulate Graphite Powder Additives*

The best weight fraction of particulate graphite that was added to both types of used oil as lubricants is 3% as marked by star sign in bar chart shown in Figure (5.3). The effect of added particulate graphite to castor oil is better than die oil according to reduction in friction as a result of high viscosity of castor oil relative to die oil. The result shows that the wear rate decreases by 60% and 29% when the particulate graphite is added at this weight fraction to castor oil and die oil respectively compared with no addition of graphite particulates (pure oil).

The behavior of graphite powder gives more improvement to decrease the wear rates when the powder is added to both lubricants compared with the copper powder added.

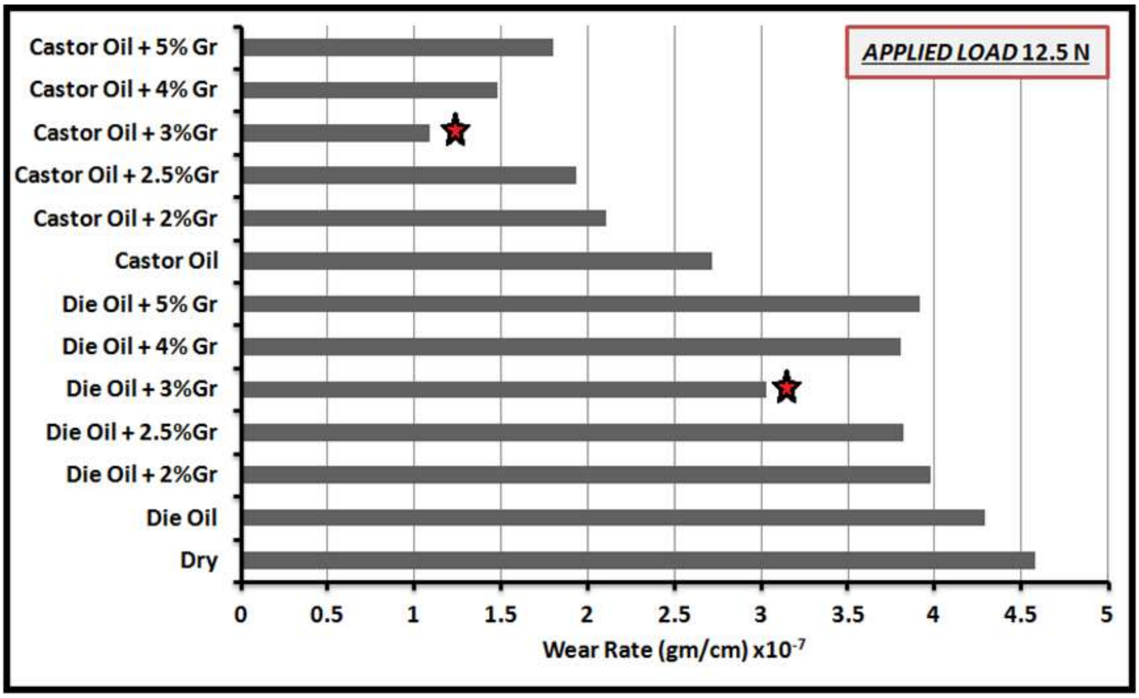


Figure (5.3) effect of added particulate graphite weight fraction to die oil and castor oil on wear rate at maximum applied load (12.5 N)

5.3 *Model of Wear Rate Curves*

A quadratic model type was proposed to represent the relationship between the wear rates and applied load [44]. The coefficients of quadratic equation (a, b and c) in equation (5.1) are represented in Table (5-1) the correlation coefficient and standard deviation for dry and wet wear tests are shown in Figure (5.4). Curve expert 1.3 software was used to determine the equation constants and their correlation coefficient and standard deviation.

$$W = a + bL + cL^2 \quad \dots\dots\dots (5.1)$$

Where,

W: Wear loose rate (gm/cm);
L: Applied Load,
a, b and **c**: Constants.

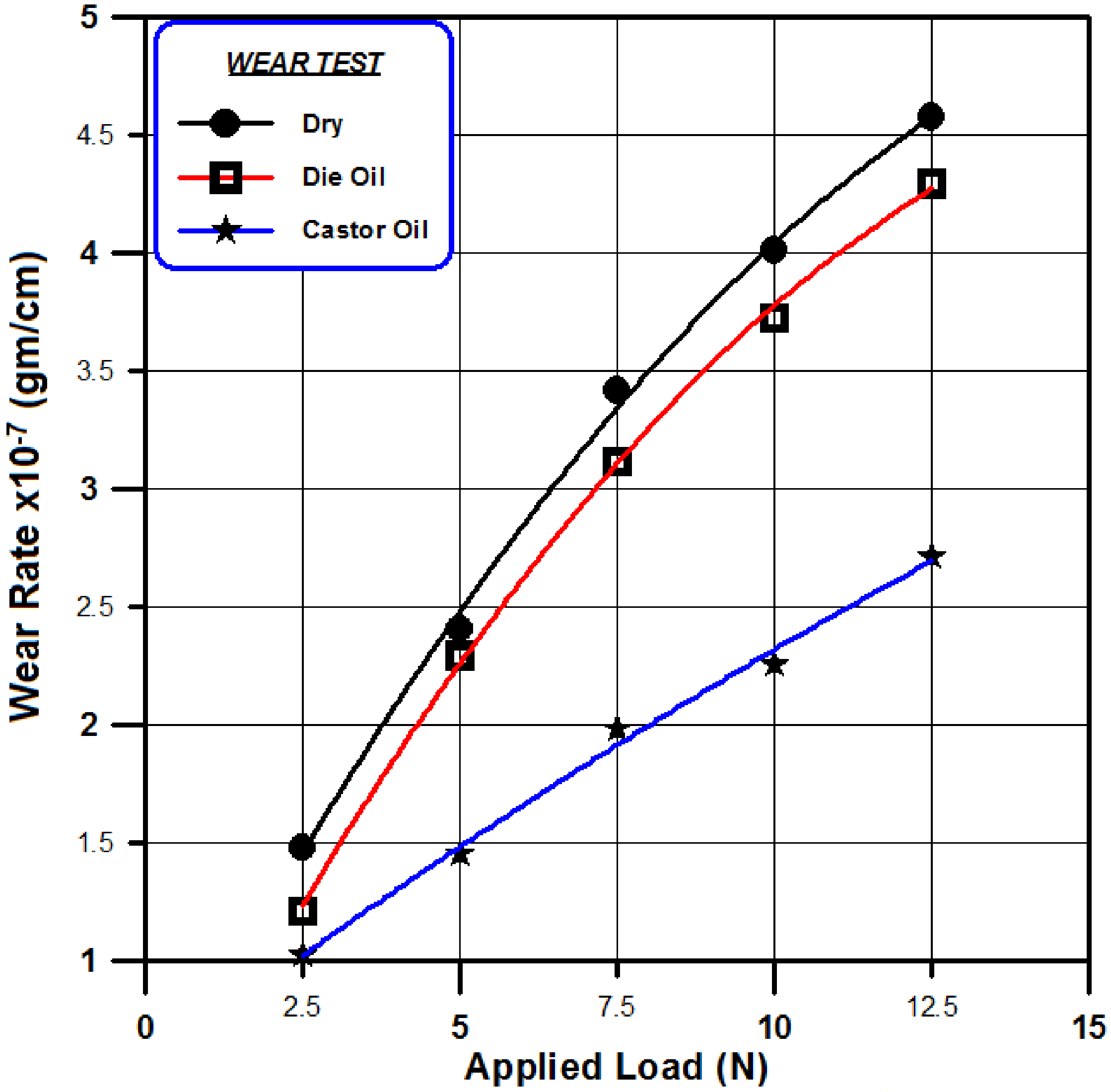


Figure (5.4) The best fitting of dry and wet wear test

Table (5-1): Quadratic Equation Constants of Wear Loose Rate – Applied load Curves (Figure 5.4) for Wear Rate with and without Lubricants.

Equation Constants	Dry	Die Oil	Castor Oil
a	+ 0.26524	+ 0.03120	+ 0.53218
b	+ 0.50785	+ 0.51575	+ 0.20119
c	– 0.01305	– 0.01413	– 0.00227
S. D. (*)	0.0784306	0.0483557	0.0696454
C. C. (*)	0.999066	0.9996025	0.9972401

* C. C.: Correlation Coefficient; * S.D.: Standard Deviations

5.3.1 *Particulate Additives to Die Oil*

The effect of adding particulate copper (Cu) to die oil that is shows in Figure (5.5) is clear on the wear loss and it is inversely proportional until reach 2.0% weight fraction and then increases as copper weight fraction increased. The increasing in copper particles weight fraction above the 2% leads to increasing in coefficient of friction and reducing in temperature stability because of increase in oil film thickness.

As mentioned previously the quadratic model type was proposed to represent the relationship between the wear rate and applied load equation coefficients are listed in Table (5-2) with correlation coefficient and standard deviation. The validity of these results are clearly shown through the values of standard deviation which are more that 99.9% for all variables and the average values of standard deviations not more than 0.086.

The adding particulate graphite (Gr) to die oil shown in Figure (5.6) has clear effect on the wear loss and it is inversely proportional until reaching 3.0% weight fraction and then increases as a graphite weight fraction increases. with the sliding behavior of graphite particles, the increasing of these particles above of 3.0% causes increasing in retardation of motion which leads to increase in temperature and friction, so the wear rate loss increases too.

Table (5-2): Quadratic Equation Constants of Wear Loose Rate – Applied load Curves (Figure 5.5) for Copper Particulate Die Oil Lubricants.

Equation Constants	Dry	Die oil	Wt. of Copper Powder in Die Oil				
			1.0%	1.5%	2.0%	2.5%	3.0%
a	+ 0.26524	+ 0.03120	+ 0.03400	+ 0.06976	+ 0.09164	– 0.07642	+ 0.15956
b	+ 0.50785	+ 0.51575	+ 0.38114	+ 0.31618	+ 0.24314	+ 0.40698	+ 0.40479
c	– 0.01305	– 0.01413	– 0.00426	-5.49E-05	+ 0.00140	– 0.00539	– 0.00641
S. D.	0.0784306	0.0483557	0.1442052	0.0448595	0.1055008	0.1295606	0.0513198
C. C.	0.999066	0.9996025	0.9967155	0.9996764	0.9974593	0.9974902	0.9995594

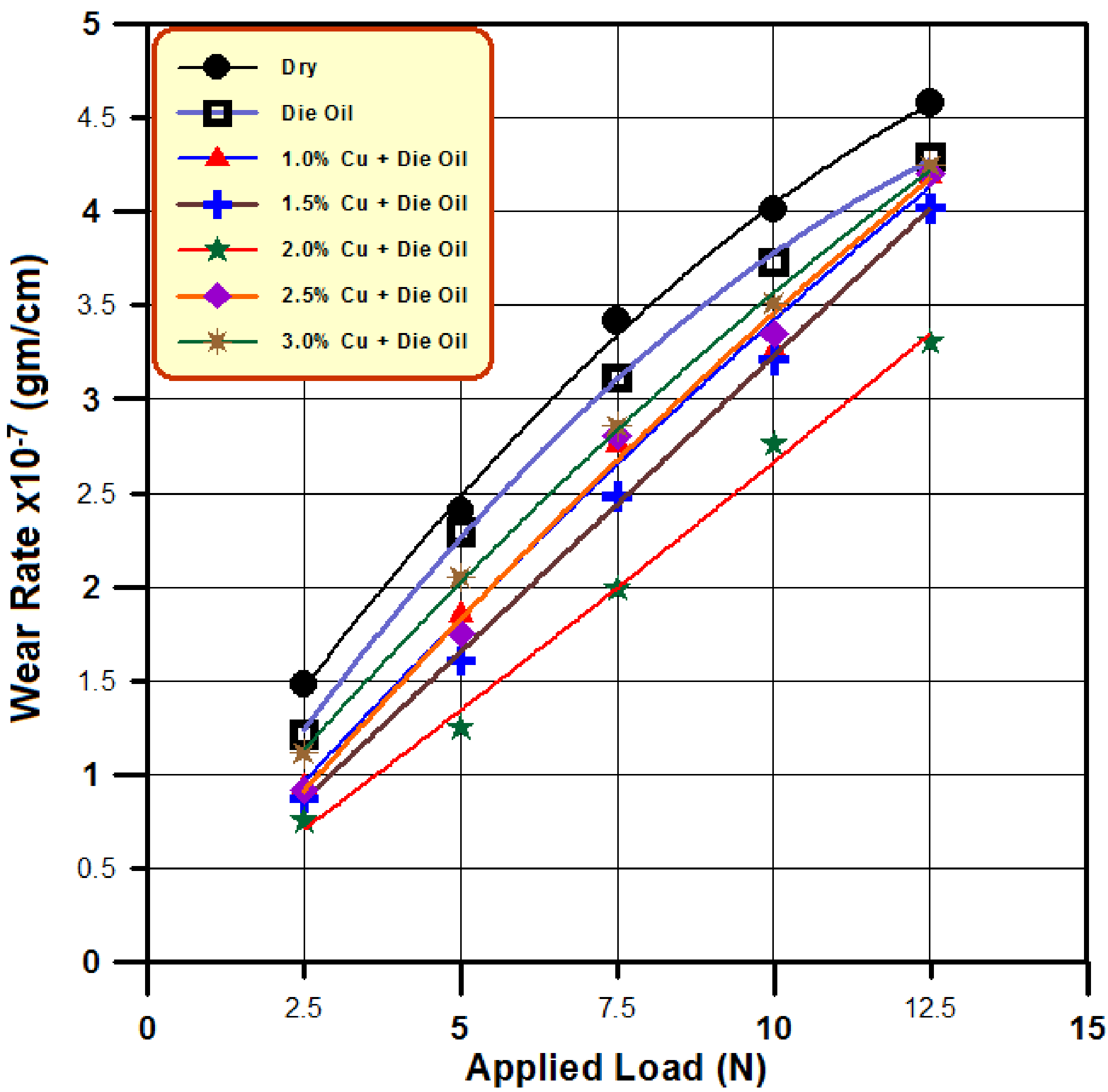


Figure (5.5) the effect of adding particulate copper (Cu) to die oil on wear rate at different loads

Quadratic model type was proposed to represent the relationship between the wear rate and applied load with equation coefficients listed in Table (5-3) with correlation coefficient and standard deviation.

Table (5-3): Quadratic Equation Constants of Wear Loose Rate – Applied load Curves (Figure 5.6) for Graphite Particulate Die Oil Lubricants.

Equation Constants	Dry	Die oil	Wt. of Graphite Powder in Die Oil				
			2.0%	2.5%	3.0%	4.0%	5.0%
a	+ 0.26524	+ 0.03120	+ 0.29062	+ 0.38608	+ 0.72574	+ 0.23498	– 0.05854
b	+ 0.50785	+ 0.51575	+ 0.36195	+ 0.28248	– 0.07166	+ 0.38060	+ 0.53030
c	– 0.01305	– 0.01413	– 0.00545	– 0.00037	+ 0.02040	– 0.00749	– 0.01677
S. D.	0.0784306	0.0483557	0.0789881	0.1279658	0.1407637	0.0565623	0.0754359
C. C.	0.999066	0.9996025	0.9987357	0.9965993	0.9946288	0.9992938	0.9988661

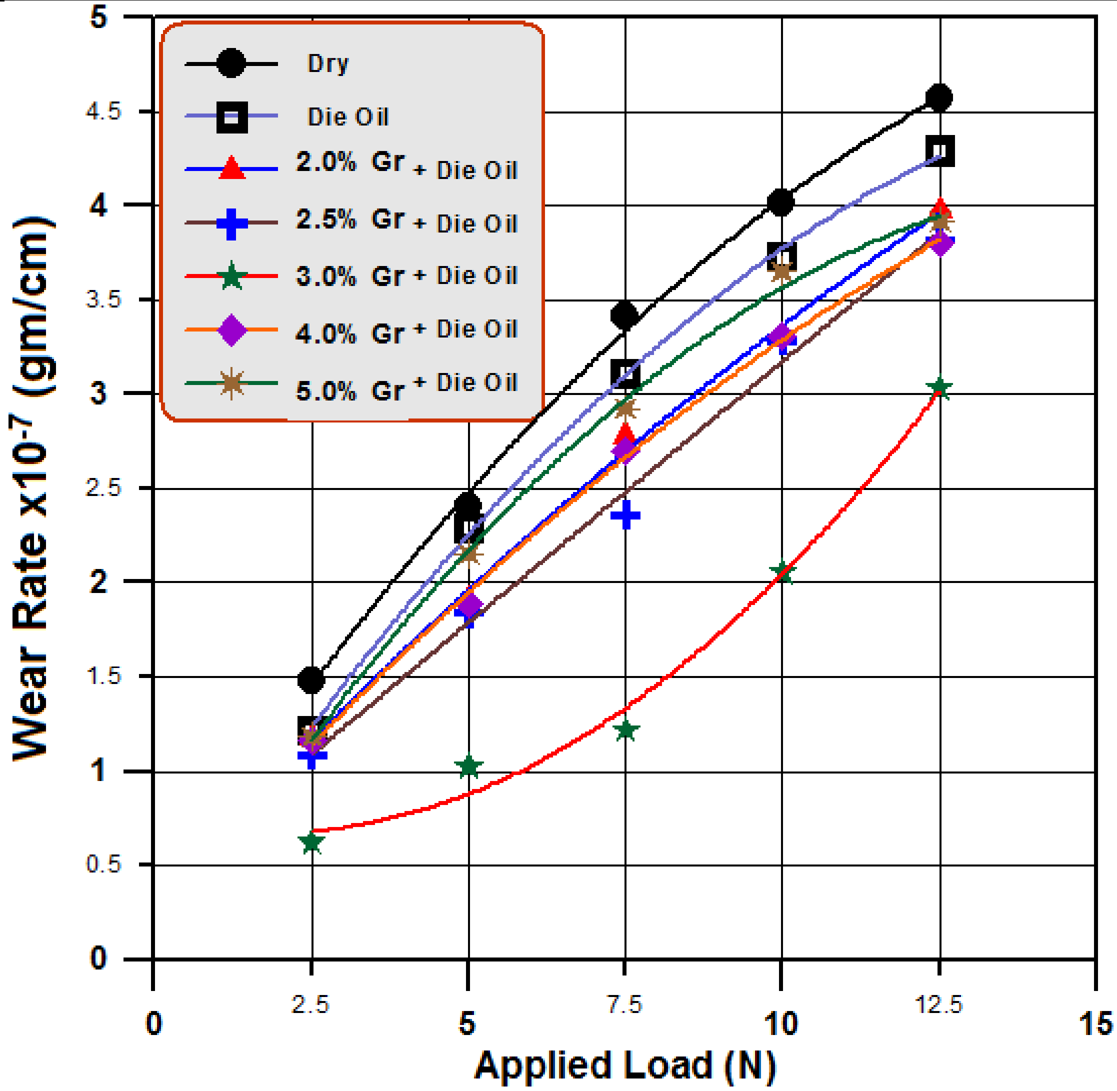


Figure (5.6) the effect of adding particulate graphite (Gr) to die oil on wear rate at different load.

5.3.2 *Particulate Additives to Castor Oil*

Copper powder is used with castor oil as a lubricant additive to achieve the efficacy of friction reduction, anti-wear and self-repairing effects. The effect of addition of copper powder on the tribology characteristics with lubricant castor oil was studied at the range of 1.0 to 3.0wt% with increment of 0.5wt% as shown in Figure (5.7). It is evident that 1.0 wt% copper in the lubricant composition is not enough to form a solid lubricating film on the metal surfaces that separates the rubbing surfaces. However, increasing the amount of copper over 3.0 wt% results in a thick loose film then increasing the coefficient of friction because the pressure and temperature stability are missed, then increasing in friction shear stress and wear rate loss. Results also, reveal that minimum wear rate was obtained at 2.0% wt of copper addition which gives an indication of obtaining the boundary lubrication or mixed lubrication that gives well lubricated interface in wear and deep drawing process.

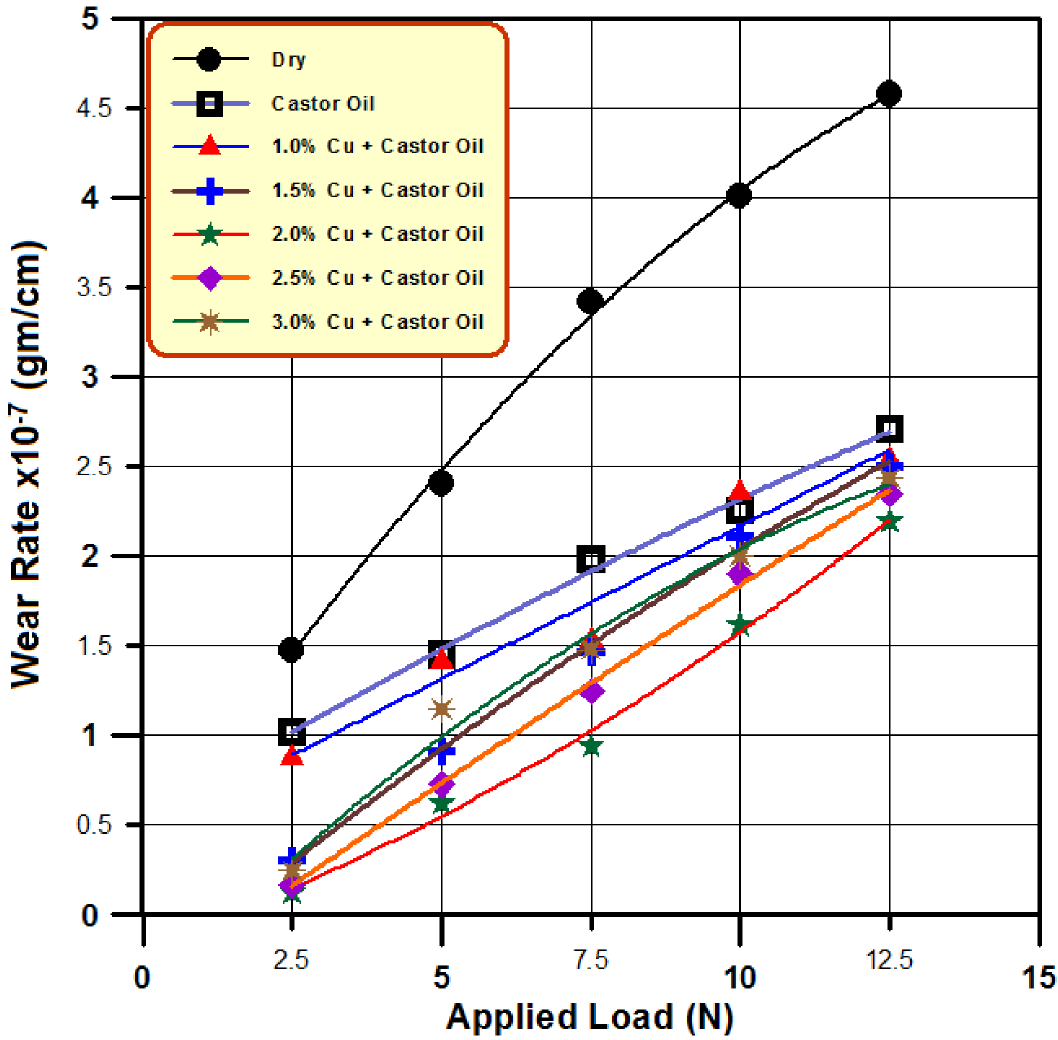


Figure (5.7) The effect of adding particulate copper (Cu) to castor oil on wear rate at different load

Quadratic model type was proposed to represent the relationship between the wear rate and applied load [44] with equation coefficients listed in Table (5-4) with correlation coefficient and standard deviation. The validity of these results are clearly shown through the average values of standard deviation which are more than 99.2% for all copper particulate in castor oil and the average values of standard deviations is not more than 0.111.

Table (5-4): Quadratic Equation Constants of Wear Loose Rate – Applied load Curves (Figure 5.7) for Copper Particulate Castor Oil Lubricants.

Equation Constants	Dry	Castor Oil	Wt. of Copper Powder in Castor Oil				
			1.0%	1.5%	2.0%	2.5%	3.0%
a	+ 0.26524	+ 0.53218	+ 0.46430	– 0.39528	– 0.18328	– 0.42388	– 0.47920
b	+ 0.50785	+ 0.20119	+ 0.17022	+ 0.28365	+ 0.11697	+ 0.23659	+ 0.33622
c	– 0.01305	– 0.00227	2.08E-16	– 0.00399	+ 0.00590	– 0.00106	– 0.00846
S. D.	0.0784306	0.0696454	0.2156009	0.0596278	0.0874725	0.0547341	0.1393987
C. C.	0.999066	0.9972401	0.9752805	0.9988695	0.9971326	0.9990179	0.9930738

The effect of adding graphite powder in the ratios of 2.0, 2.5, 3.0, 4.0 and 5.0% wt was studied. Graphite has a flat plate like structure and the layers of graphite particles are arranged one above the other and held together by weak Van der Waal's forces, thus the graphite layers can slide easily on each other making graphite as an effective lubricant. Also the layer of graphite has a tendency to absorb oil which leads to make the film as a self-lubricant bearing.

It was seen that 2.0% wt graphite in the lubricant composition is not enough to form a solid lubricating film on the metal surfaces that separates from the rubbing surfaces. Increasing the ratio of graphite, over 5.0% wt, results in a thick loose film, deleted in wear action.

Results also reveal that minimum wear rate was obtained at 3.0% wt of graphite addition. It is noted that an addition of 3.0% wt graphite powder to the lubricant oil would help to reduce friction losses and has the lowest wear loose rate as shown in Figure (5.8).

Quadratic model type was proposed to represent the relationship between the wear rate and applied load [44] with equation coefficients listed in Table (5-5) with correlation coefficient and standard deviation. The validity of these results are clearly shown through the average values of standard deviation which are more than 98.1% for all Graphite particulate in castor oil and the average values of standard deviations are not more than 0.106.

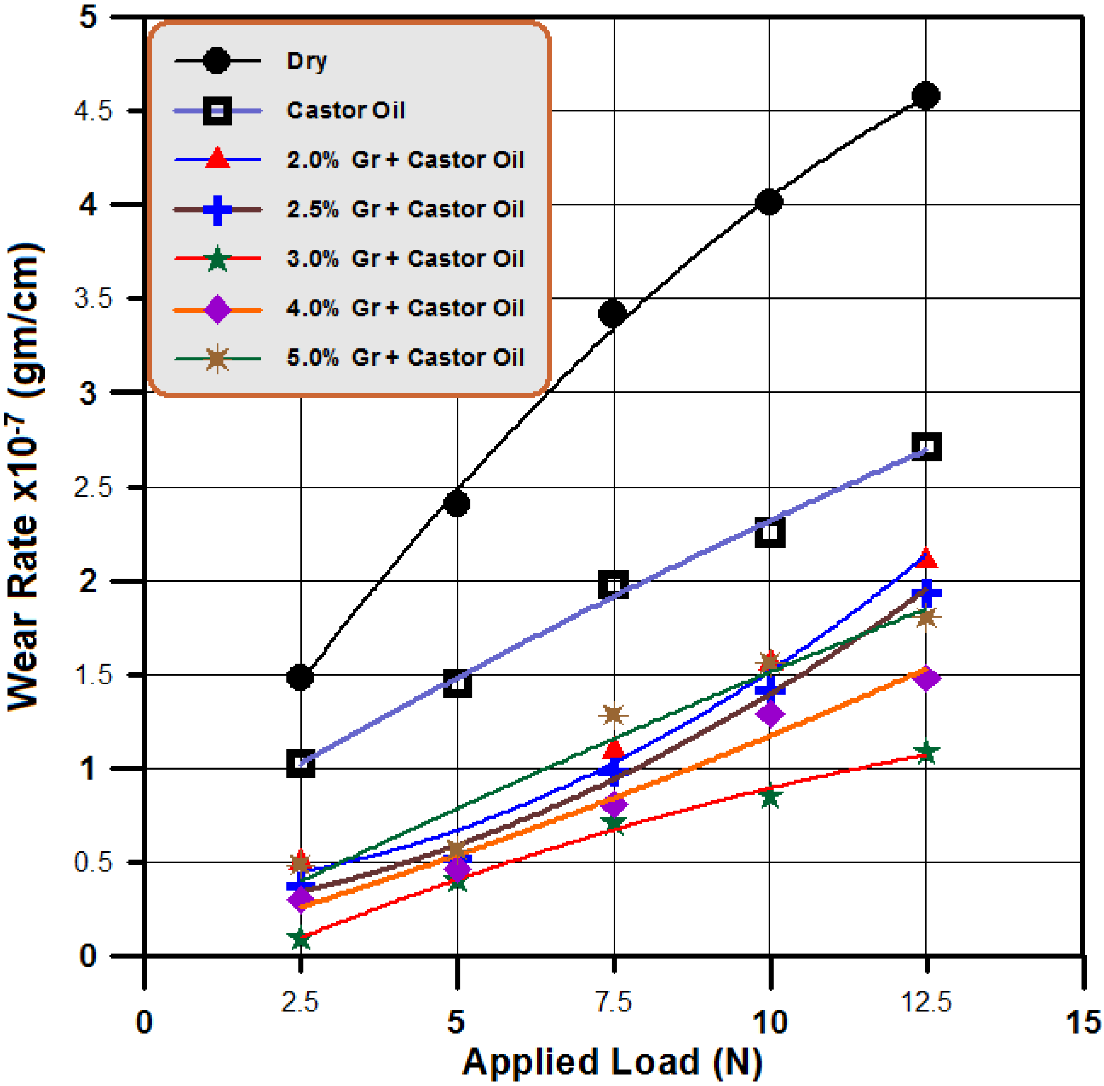


Figure (5.8) The effect of adding particulate graphite (Gr) to castor oil on wear rate at different load.

Table (5-5): Quadratic Equation Constants of Wear Loose Rate – Applied load Curves (Figure 5.8) for Graphite Particulate Castor Oil Lubricants.

Equation Constants	Dry	Castor Oil	Wt. of Graphite Powder in Castor Oil				
			2.0%	2.5%	3.0%	4.0%	5.0%
a	+ 0.26524	+ 0.53218	+ 0.35006	+ 0.19714	– 0.25506	+ 0.01144	– 0.00748
b	+ 0.50785	+ 0.20119	+ 0.01157	+ 0.03788	+ 0.14982	+ 0.09443	+ 0.16534
c	– 0.01305	– 0.00227	+ 0.01051	+ 0.00819	– 0.00351	+ 0.00216	– 0.00135
S. D.	0.0784306	0.0696454	0.1187639	0.0645602	0.0416186	0.1097811	0.1957877
C. C.	0.999066	0.9972401	0.9924683	0.9774874	0.9771130	0.9882512	0.9721121

5.3.3 *Hybrid Particulate Additives to Die Oil and Castor Oil*

After the best additive ratios of graphite and copper particles were known, as mentioned above, a hybrid additive of 3%wt graphite and 2.0% wt copper was used with die oil. The wear test shown in Figure (5.9) indicates a significant reduction in wear rate as compared with the two additives mentioned previously. Because the hybrid additive is characterized by the sliding properties of graphite and absorption properties of lubricant by copper, the figure shows a maximum reduction in wear rate. The improvement in hybrid particulate die oil compared with 2% copper and 3% graphite die oil at minimum applied load, 2.5 N was 81.7% and 63.7% respectively. While at maximum applied load of 12.5N the improvement in wear rate increased to reach 83.8% and 75.7% respectively. The average improvements in wear rate for hybrid additives to die oil are 80.4% and 58.7% relative to individual additives of hybrid components to die oil too.

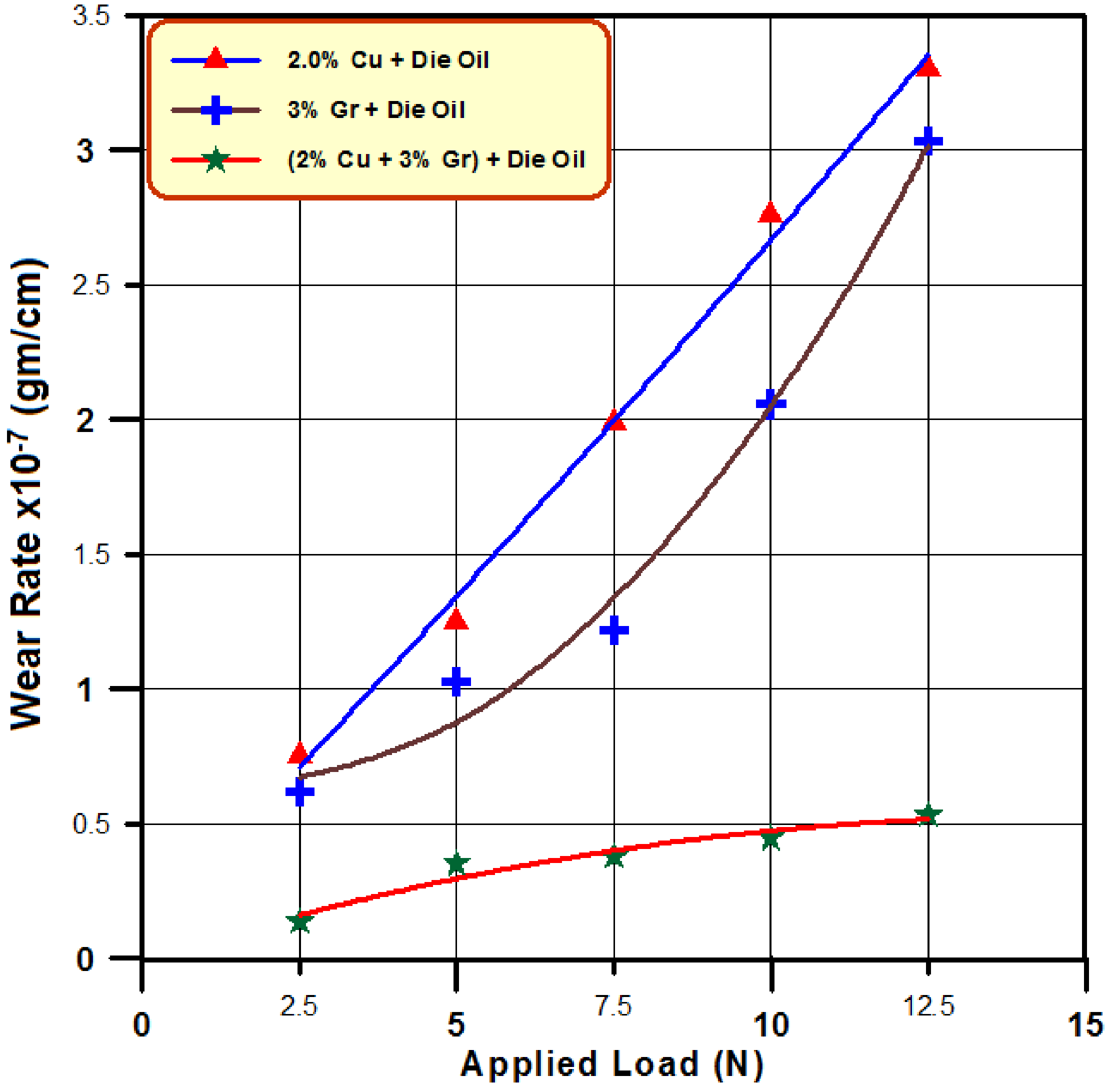


Figure (5.9) die oil lubricant with best ratio additive and hybrid

To produce hybrid castor oil lubricant the graphite and copper additives, in the best ratio mentioned previously that is show in Figure (5.10) were mixed with castor oil. The hybrid castor oil gives the best thin film of lubricant separating between metals and prevents direct contact of metal surface so it reduce wear rate.

The improvement in hybrid particulate castor oil compared with 2% copper and 3% graphite castor oil at minimum applied load, 2.5 N was 94.7% and 70.9% respectively. While at maximum applied load of 12.5N the improvement in wear rate reached 93.8% and 42.2% respectively. The average improvements in wear rate for hybrid additives to die oil are 93.8%

and 57.4% relative to individual additives of hybrid components to die oil too.

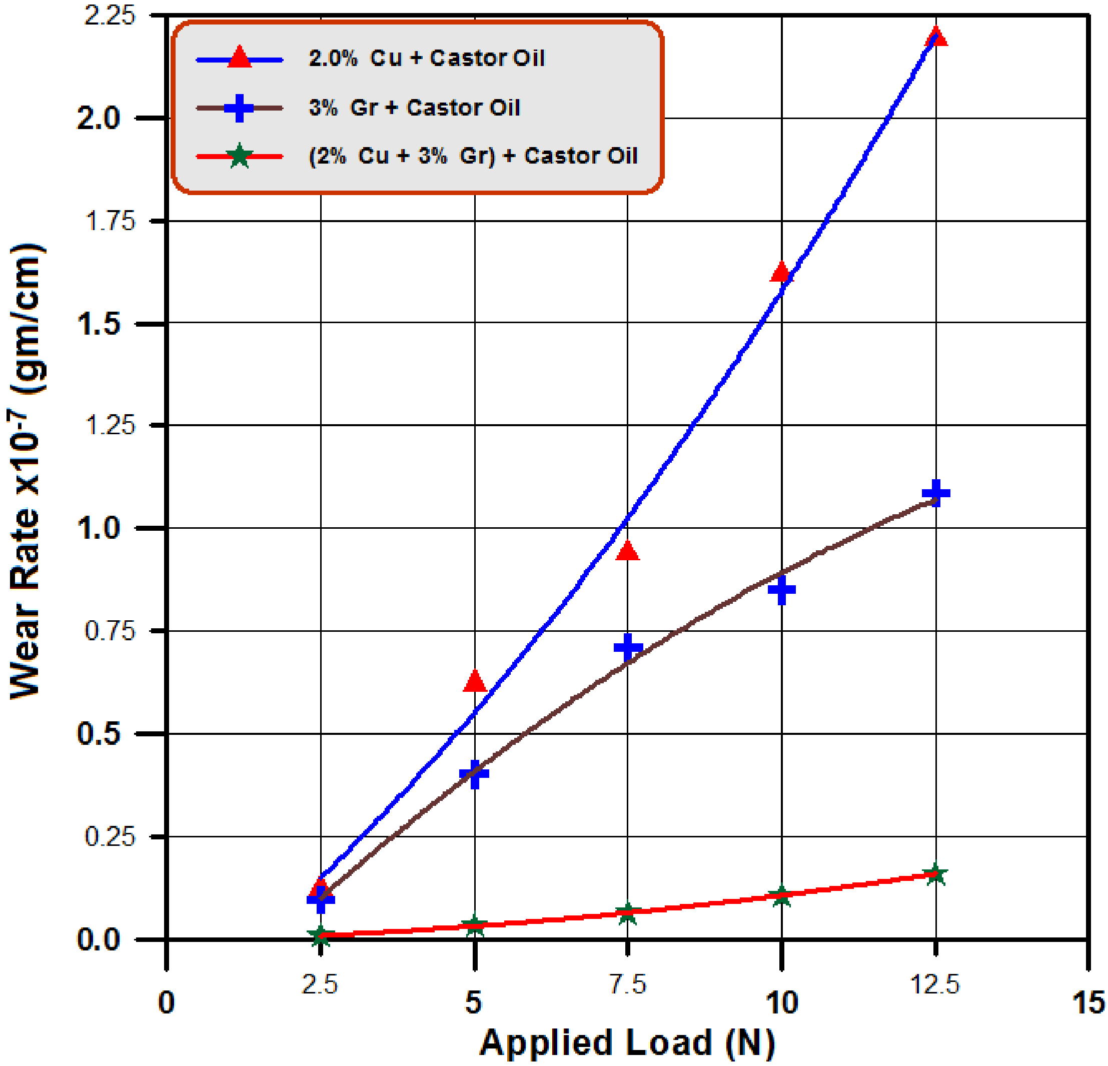


Figure (5.10) Castor oil lubricant with best ratio additive and hybrid

A hybrid particulate castor oil has more reduction in wear rate than hybrid particulate die oil as shown in Figure (5.11). The maximum improvement in hybrid castor oil is 95.2% at minimum applied load, of 2.5N and is reduced slightly to reach the minimum value of 70.3% at 12.5N. This reduction in improvement comes from increasing in the applied load, which leads increasing in film temperature by friction.

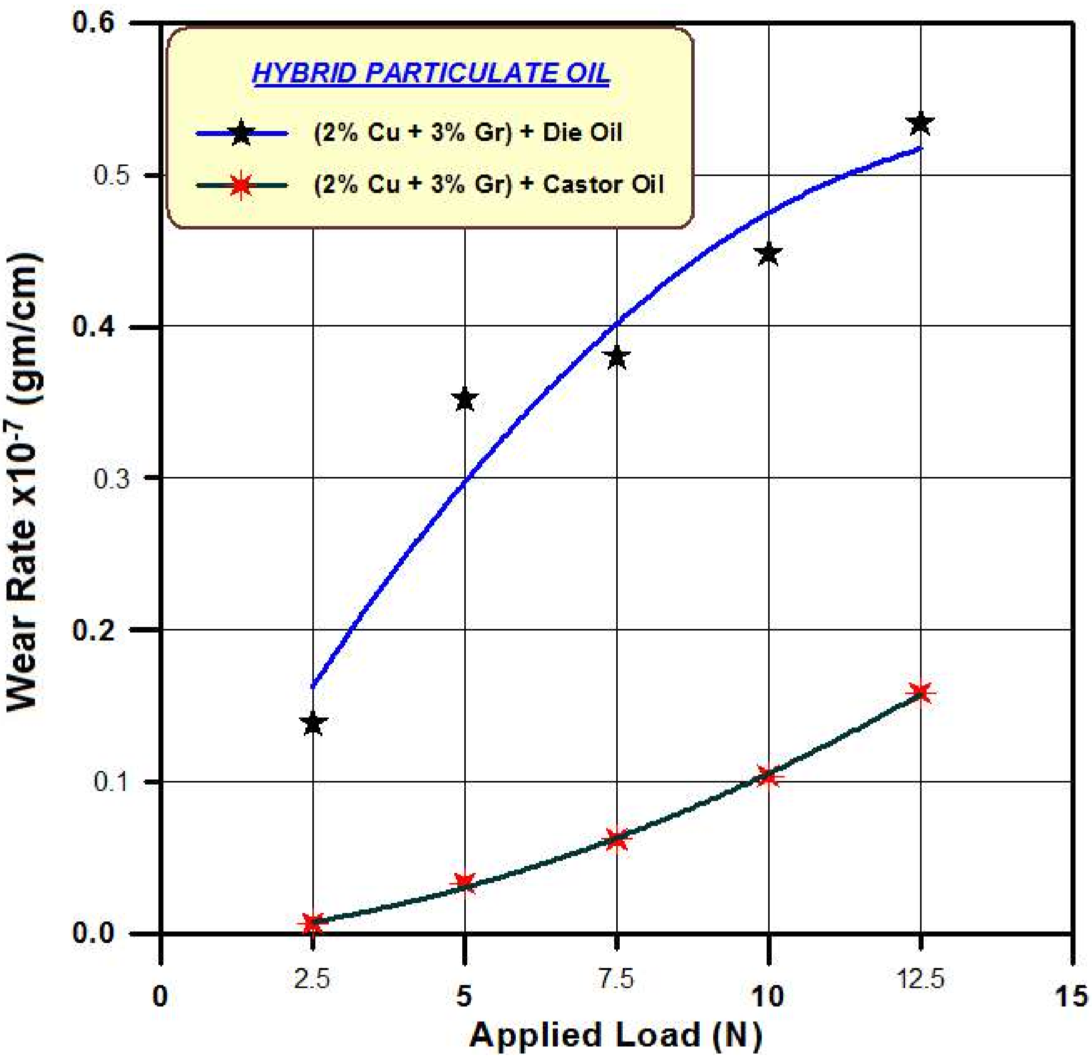


Figure (5.11) the comparison between hybrid (Die and Castor) oil

The quadratic model type was proposed to represent the relationship between the wear rate and applied load [44] for hybrid particulate oil too with equation coefficients listed in Table (5-6). In hybrid particulate castor oil the correlation coefficient is high and the standard deviation is low relative to hybrid particulate die oil as shown in Figure (5.11) because of the high density and viscosity of castor oil.

Table (5-6): Quadratic Equation Constants of Wear Loose Rate – Applied load Curves (Figure 5.9 and 5.10) for Hybrid Particulate Die Oil and Castor Oil Lubricants.

Equation Constants	Wt. of Powder in Die Oil			Wt. of Powder in Castor Oil		
	2% Cu	3% Gr	Hybrid*	2% Cu	3% Gr	Hybrid*
A	+ 0.09164	+ 0.72574	– 0.00387	– 0.18328	– 0.25506	– 0.00509
B	+ 0.24314	– 0.07166	+ 0.07259	+ 0.11697	+ 0.14982	+ 0.00317
C	+ 0.00140	+ 0.02040	– 0.00247	+ 0.00590	– 0.00351	+ 0.00079
S. D.	0.1055008	0.1407637	0.0500707	0.0874725	0.0416186	0.0024297
C. C.	0.9974593	0.9946288	0.9707416	0.9971326	0.9771130	0.9995895

*** Hybrid: 2% Cu + 3% Gr.**

The bar chart in Figure (5.12) represents the comparison between pure oils and best weight fraction of particulate additives and their hybrids to these oils at maximum applied load, 12.5N. The best lubricant is hybrid particulate castor oil because its average reduction in the wear rate is 96.7% compared with pure castor oil. While the hybrid particulate die oil additives shows the second best average reduction in wear rate of 87.3% compared with pure die oil. This is because the hybrid oil contains both of graphite and copper additives. The graphite has layers that easily slide above each other and create the homogeneous continuous film, while copper has the features of anti-wear and absorption lubricant that is released with increasing or more temperature stability.

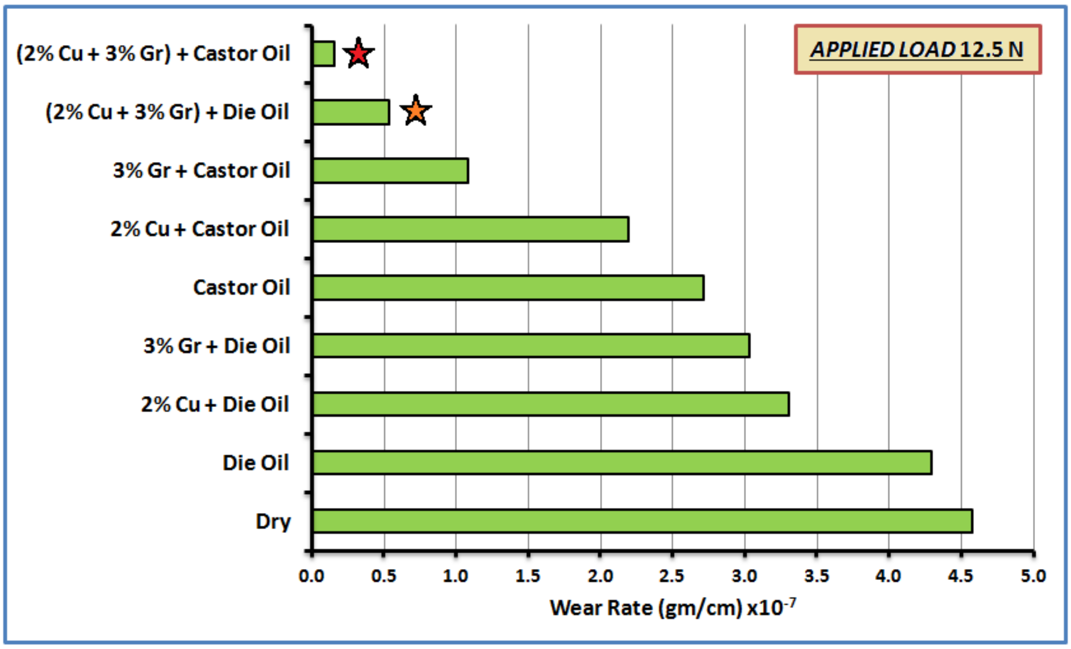


Figure (5.12) Improvement in Hybrid Particulate Lubricants Relative to Particulate Lubricant on Wear Rate at Maximum Applied Load (12.5 N)

5.4 ***Effect of Lubricant Viscosity on Wear Rate***

The viscosity of die and castor oil varies when the copper and graphite particles are added to these lubricants. The effect of adding copper particles to die oil leads to increase the viscosity until reaching 2.0% wt and then is reduced to remain constant at 2.5 and 3.0% wt, while increase little in viscosity when these particles are added to castor oil but approximately remains constant in all weight fraction of particulate oil by copper. The viscosity is proportional to the weight fraction of graphite when added to both die and castor oils. In general, the viscosity of the particulate and hybrid lubricants increases in both die and castor oil as shown in Figures (5.13) and (5.14). Maximum viscosity was obtained at both hybrid particulate lubricants used in this research work.

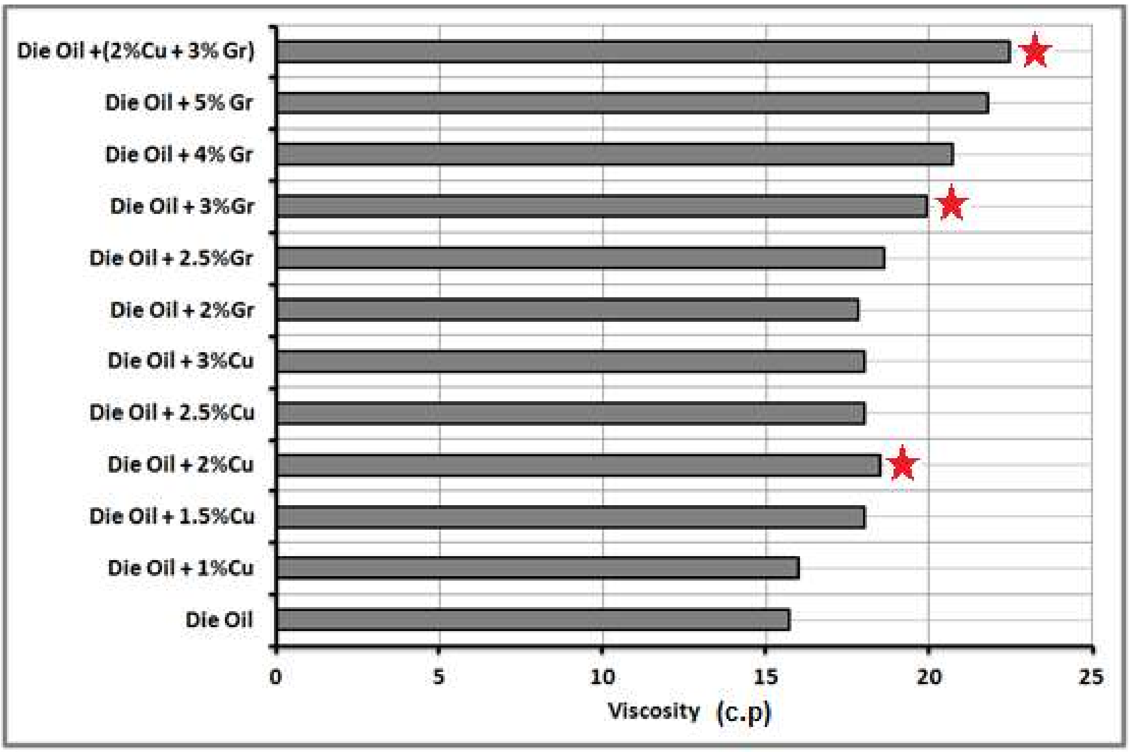


Figure (5.13) The measure viscosity of die oil with and without additives

In general, the increase in viscosity of the lubricant leads to decrease in the wear rate because the temperature stability increases and the effect of friction decreases but there is a proportionality of the film thickness with the weight fraction of particles as shown in Figures (5.15) and (5.16) for die oil and castor oil respectively.

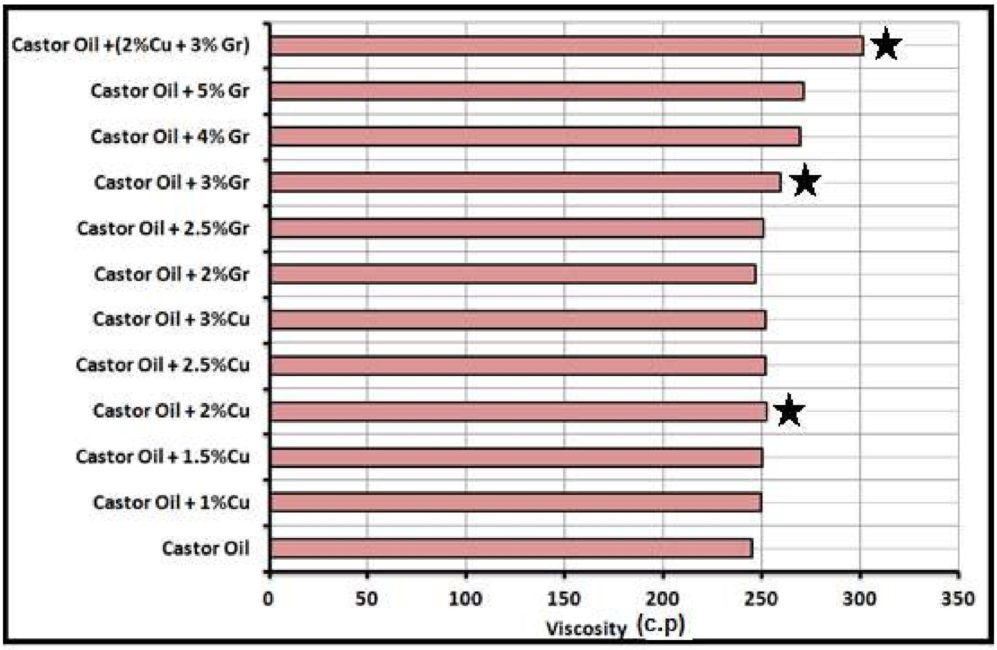


Figure (5.14) the measure viscosity of castor oil with and without additives

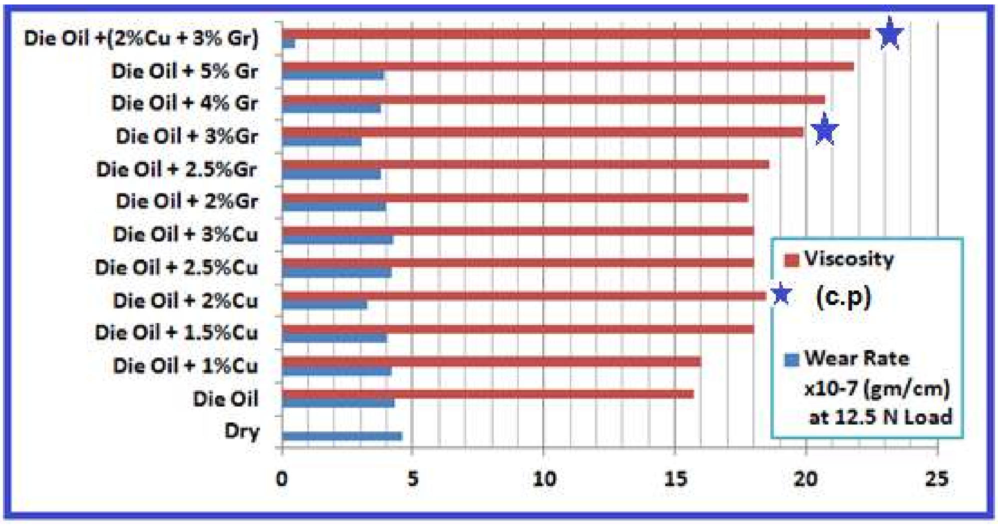


Figure (5.15) Effect of Added Particulate (Graphite and Copper) Weight Fraction to Die Oil on Viscosity and Wear Rate at Maximum Applied Load (12.5 N)

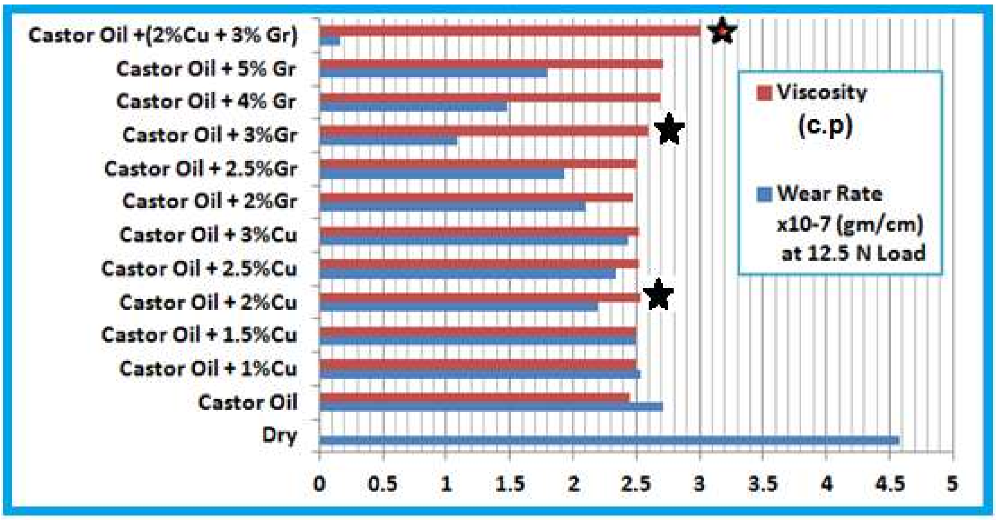


Figure (5.16) Effect of Added Particulate (Graphite and Copper) Weight Fraction to Castor Oil on Viscosity and Wear Rate at Maximum Applied Load (12.5 N)

5.5 ***Deep Drawing Processes***

The deep drawing processes were achieved by using different types of lubricants, as listed in Table (5-7) to form a cup from AA2024-T4 aluminum alloy blanks. In all processes, the exerted forces depend on the ultimate point; i.e. the used tensile machine is stopped when the sample starts to reduce after reaching its ultimate point.

Table (5-7) Types of Lubricants Used in Deep Drawing Process

Die oil	No additive	3wt% graphite	2wt% copper	hybrid
Hybrid die oil	3wt% graphite and 2wt% copper			
Castor oil	No additive	3wt graphite	2wt% copper	hybrid
Hybrid castor oil	3wt% graphite and 2wt% copper			

5.5.1 ***Drawn Cups by Die Oil Lubricant and Their Additives***

Figure (5.17) shows the effect of die oil lubricant with and without additives on the force required for deep drawing. The drawing force can be calculated from equation (5-2).

$$F_D = 47.109 + 0.9855\mu_{D.O} - 0.0403\mu_{D.O}^2 \dots\dots\dots (5-2)$$

It can be gotten from the figure that, the maximum force is for the pure die oil, while the minimum work is from deep drawing with hybrid lubricant. The maximum reduction in force required for deep drawing was 7.2% for hybrid lubricant as compared with that for pure lubricant. While there is insignificant difference between the forces used for deep drawing when using additives of 3wt% graphite and 2wt% copper.

Although deep drawing force for pure oil was the maximum, the height of product was too short, as shown in Figure (5.18), this is because most of force was consumed to overcome the friction force, rather than forming the metal sample. It was seen from the figure that, there is at least 4% increase in the length of product when using hybrid lubricant as compared with that when using pure die oil. The cup height can be calculated from equation (5-3).

$$H = 18.183 + 0.1792\mu_{D.O} - 0.00175\,\mu_{D.O}^{2} \ldots\ldots\ldots(5-3)$$

Although the difference between the forces required for deep drawing using lubricant with 3wt% graphite or 2wt% copper is very small, the length of product using lubricant of 3wt% graphite is more, this phenomenon indicates that using graphite as additive reduces the friction force, as compared with copper additive.

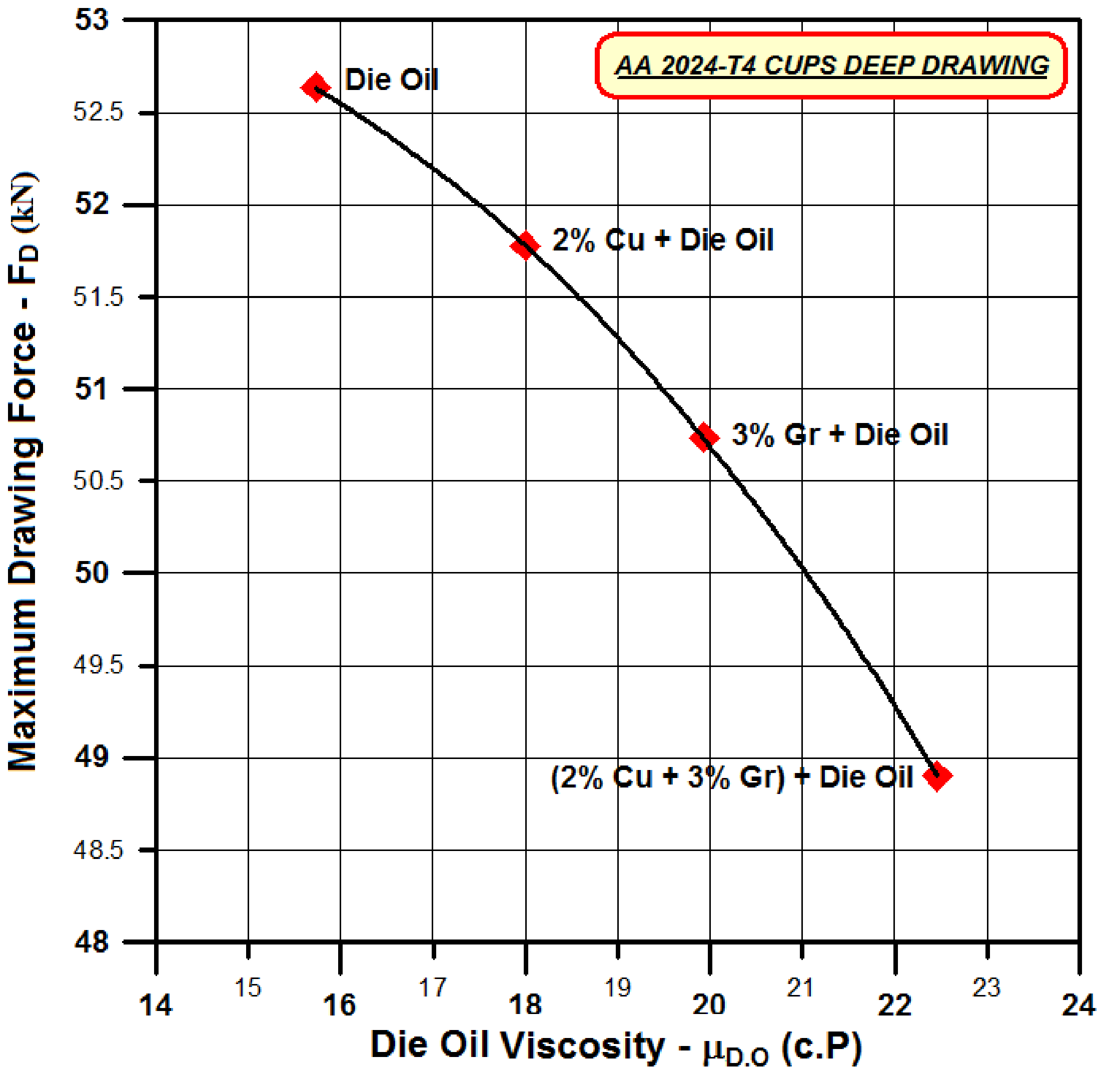


Figure (5.17) Viscosities of die oil lubricant with drawing force

The increasing friction between the die and metal, due to poor lubrication properties, causes ridging of the metal surface. This can be indicated clearly in Figure (5.19); the cup surface roughness can be calculated from equation (5-4), (5-5) and (5-6).

$$(R_a)_{Outer\ Surface} = 15.375 - 1.113\ \mu_{D.O} + 0.0217\ \mu_{D.O}^2 \ldots\ldots\ldots (5-4)$$

$$(R_a)_{Arc\ Surface} = 17.525 - 1.5556\ \mu_{D.O} + 0.03624\ \mu_{D.O}^2 \ldots\ldots\ldots (5-5)$$

$$(R_a)_{Inner\ Surface} = 8.327 - 0.687\ \mu_{D.O} + 0.0157\ \mu_{D.O}^2 \ldots\ldots\ldots (5-6)$$

It can be gotten from the figure that the poor surface properties was for the cup produced by deep drawing using pure oil, While the best surface properties were for sample produced using hybrid lubricant. Figure (5.20) shows the point measure of outer, arc and inner surfaces.

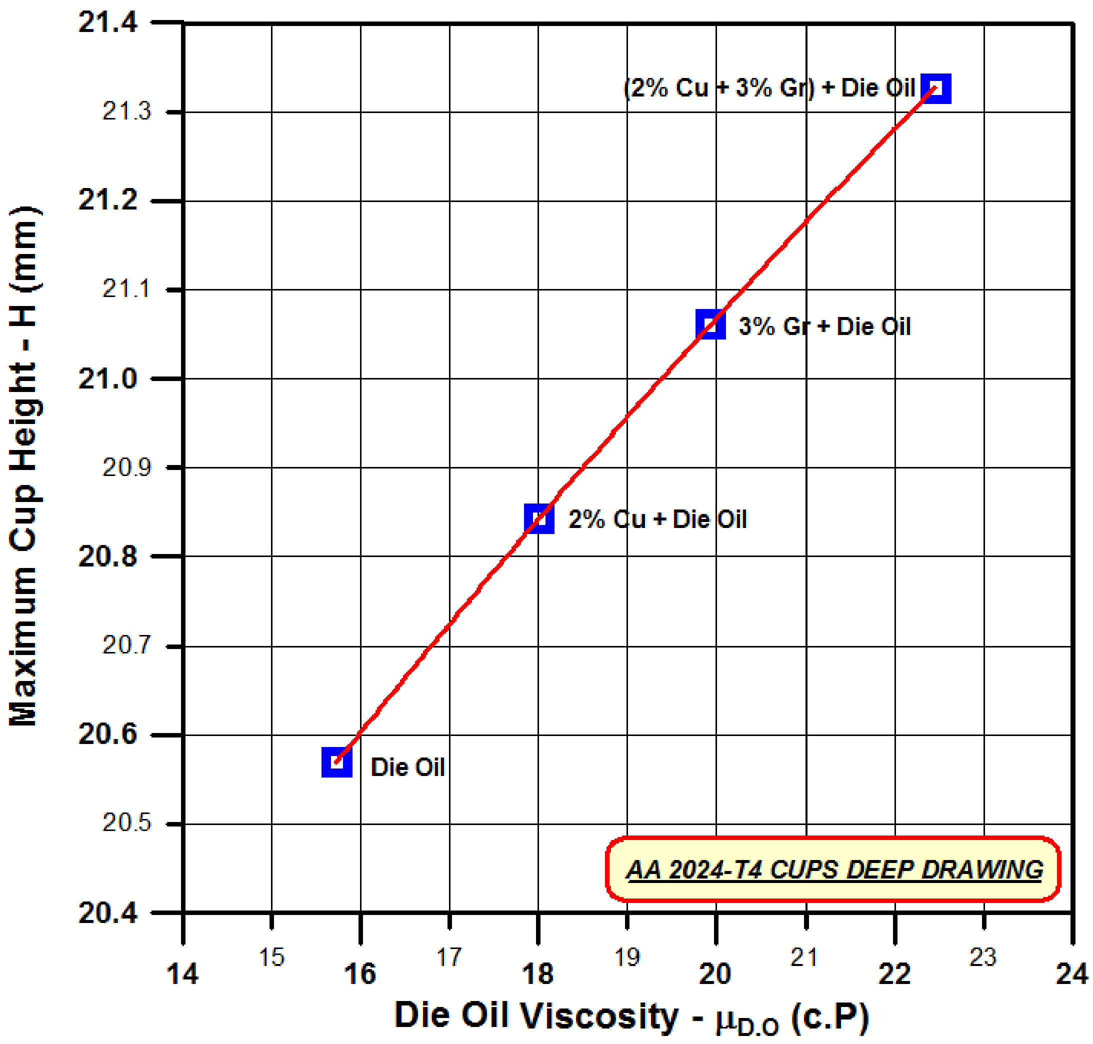


Figure (5.18) Viscosities of die oil lubricant with cup height

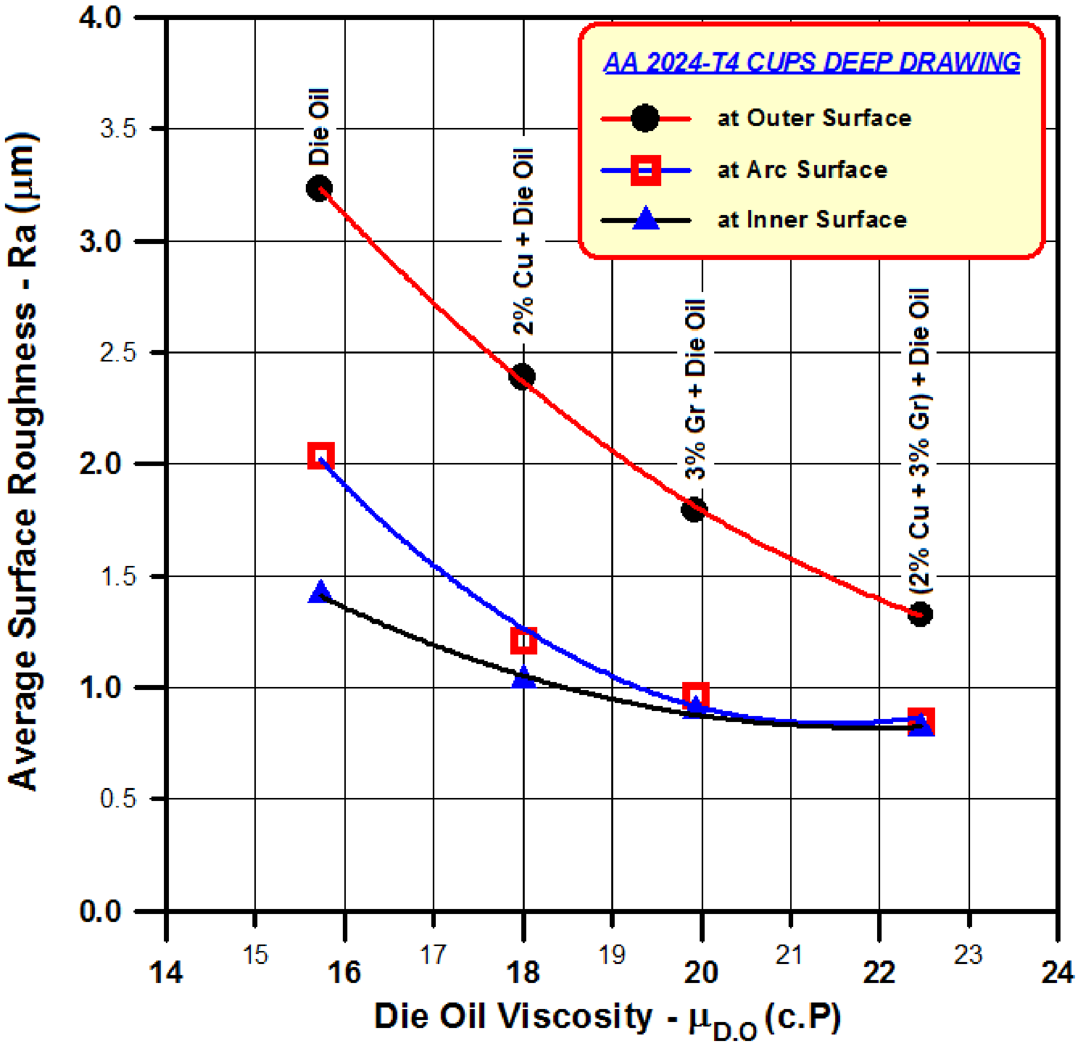


Figure (5.19) Viscosities of die oil lubricant with cup surface roughness

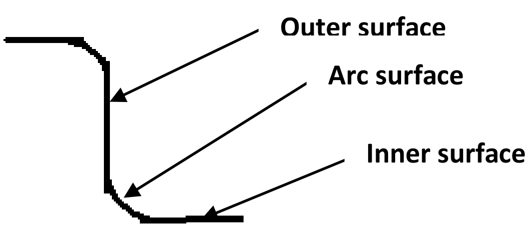


Figure (5.20) The point measure of outer, arc and inner surfaces

The effect of lubricant properties on the minimum cup thickness is seen in Figure (5.21), the minimum cup thickness can be calculated from equation (5-7), it can be gotten from the figure that the best cup thickness is for the best surface roughness, i. e., for the sample produced using die hybrid oil. Pure oil shows inhomogeneous thickness for the product, this because increasing in friction force cause unbalanced force distribution of the metal surface.

$$t_{min} = 0.8677 + 0.01115\ \mu_{D.O} - 0.0001466\ \mu_{D.O}^2 \ \dots\dots\dots (5-7)$$

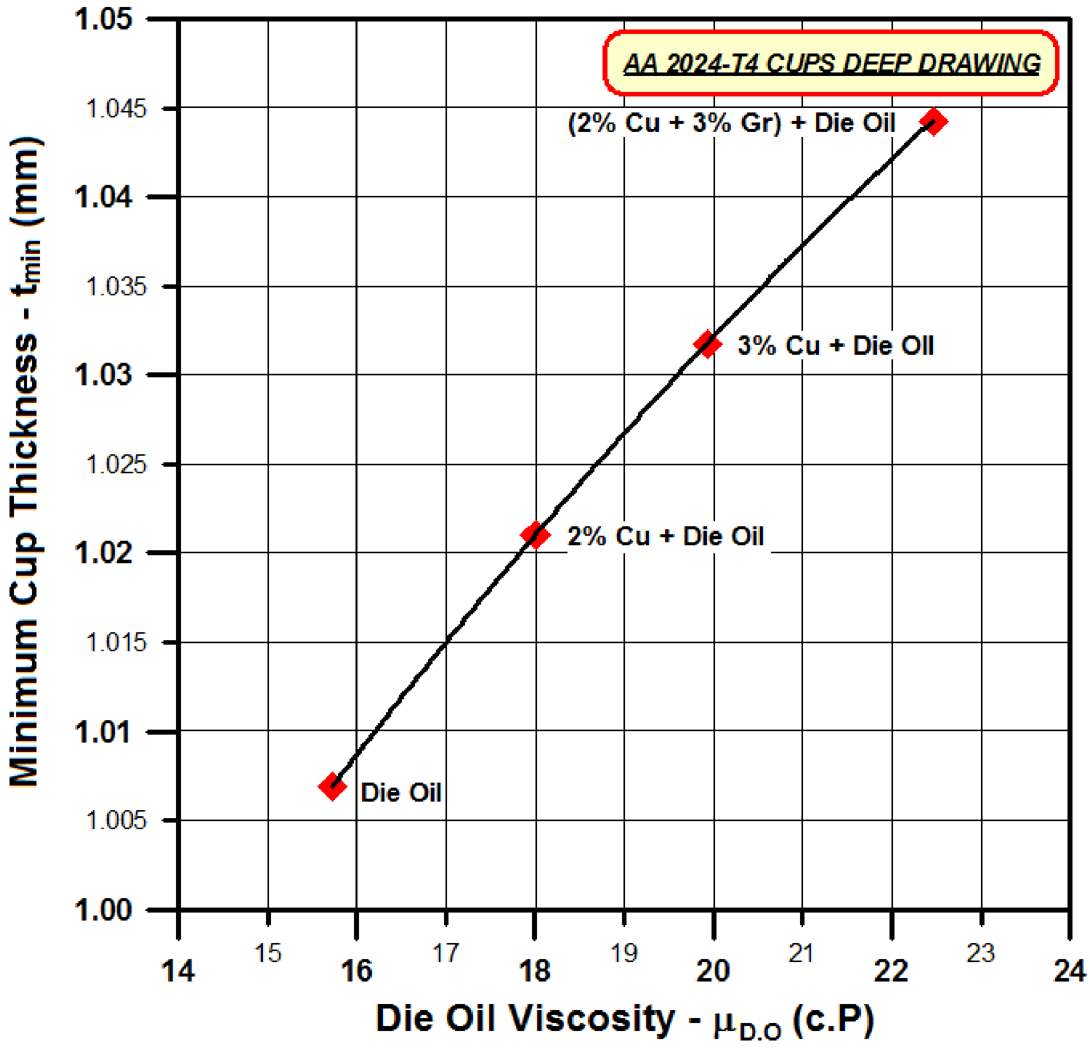


Figure (5.21) Viscosities of die oil lubricant with minimum cup thickness

5.5.2 *Drawn Cups by Castor Oil Lubricant and Their Additives*

Figure (5.22) shows the effect of castor oil lubricant with and without additives on the force required for deep drawing. The drawing force can be calculated from equation (5-8).

$$F_D = 83.915 - 0.2014\ \mu_{C.O} + 0.000276\ \mu_{C.O}^2 \ \dots\dots\dots (5-8)$$

It can be gotten from the figure that, the maximum force is for the pure castor oil, while the minimum work is from deep drawing with hybrid lubricant. The maximum reduction in force required for deep drawing was 6.5% for hybrid lubricant as compared with that for pure lubricant while there forces were consumed in both graphite and copper additives the same nearly.

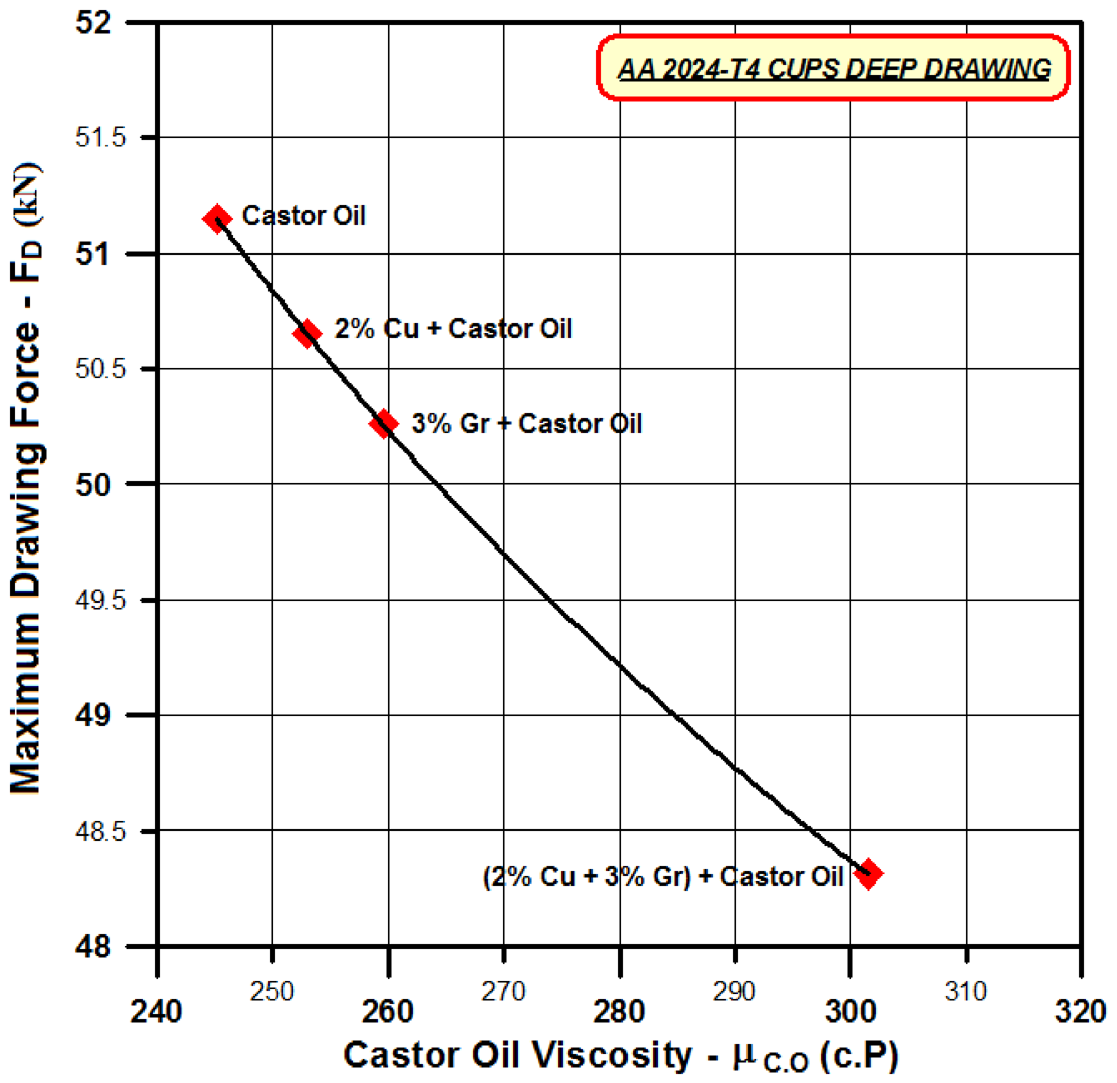


Figure (5.22) Viscosity of castor oil lubricant with drawing force

As mentioned previously, pure castor oil consumes more force to complete deep drawing process, as compared with the cup produced by lubricant with additives, as shown in Figure (5.23). This is because friction force appears when using pure lubricant. The cup height can be calculated from equation (5-9).

$$H = 9.3773 + 0.0746\,\mu_{C.O} - 0.000113\,\mu_{C.O}^{2} \;\ldots\ldots\ldots (5-9)$$

It was seen from that the figure that, there is 4% increase in the length of product when using hybrid lubricant as compared with using of pure castor oil. Although the difference between the forces required in deep drawing using lubricant with additives is very small, the length of product using lubricant of 3wt% graphite is more due to the reducing the friction force.

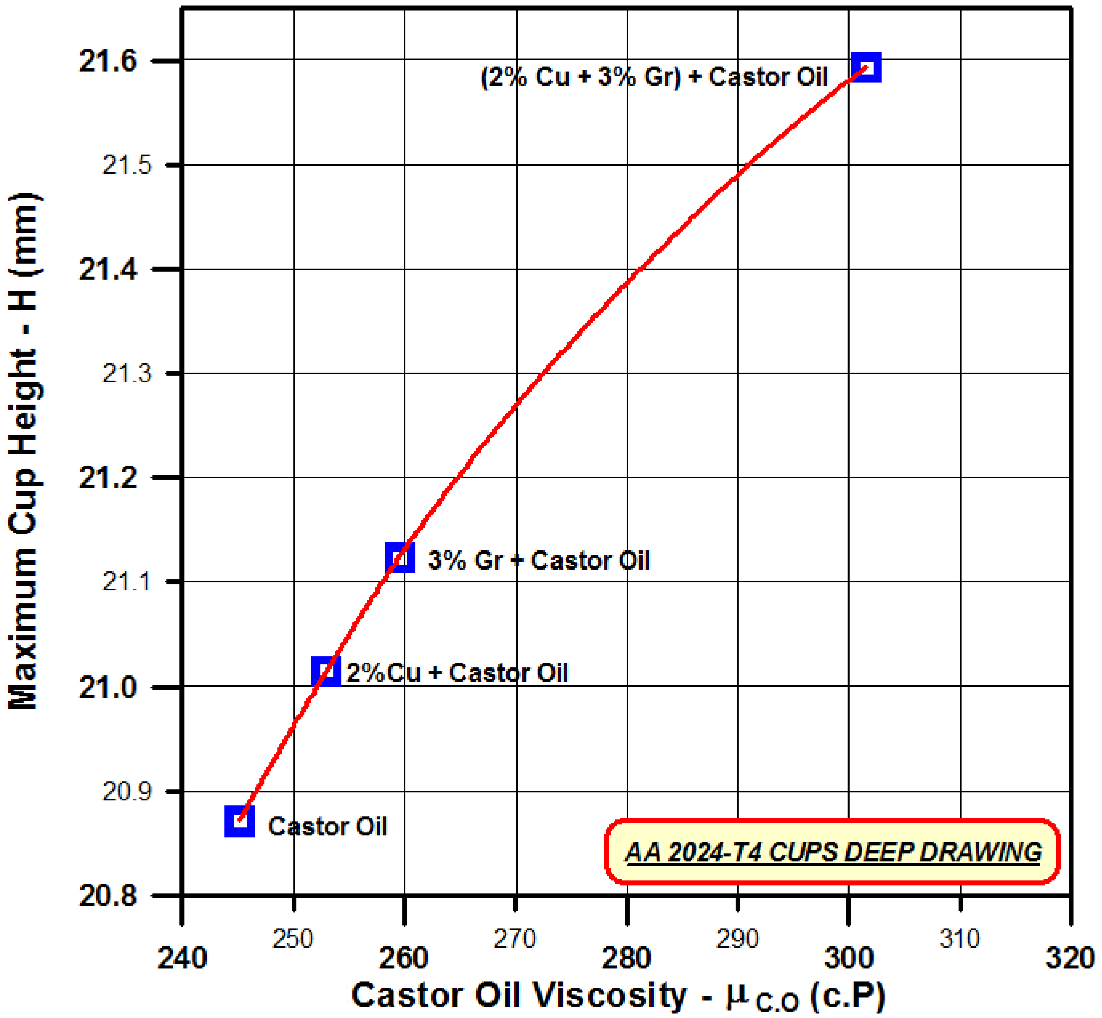


Figure (5.23) Viscosity of castor oil with cup height

Figure (5.24) shows that using pure lubricant causes rough surface, as compared with lubricant with additives. The cup surface roughness can be calculated from equation (5-10), (5-11) and (5-12).

$$(R_a)_{Outer\ Surface} = 29.177 - 0.180\,\mu_{C.O} + 0.000285\,\mu_{C.O}^2 \ldots\ldots\ldots (5-10)$$

$$(R_a)_{Arc\ Surface} = 33.7533 - 0.2194\,\mu_{c.o} + 0.0003597\,\mu_{c.o}^2 \ldots\ldots\ldots (5-11)$$

$$(R_a)_{Inner\ Surface} = 22.1519 - 0.1421\,\mu_{c.o} + 0.0002305\,\mu_{c.o}^2 \ldots\ldots\ldots (5-12)$$

It can be gotten from the figure that the best surface properties is for the cup produced by deep drawing using hybrid castor oil. The increase in friction between die and metal sample, not only distorts sample surface, but also gives the product irregular thickness, as shown in Figure (5.25), the minimum cup thickness can be calculated from equation (5-13), it can be gotten from the figure that using pure castor oil gives high cup thickness for the product, while the most regular thickness is for the cup produced using hybrid castor oil.

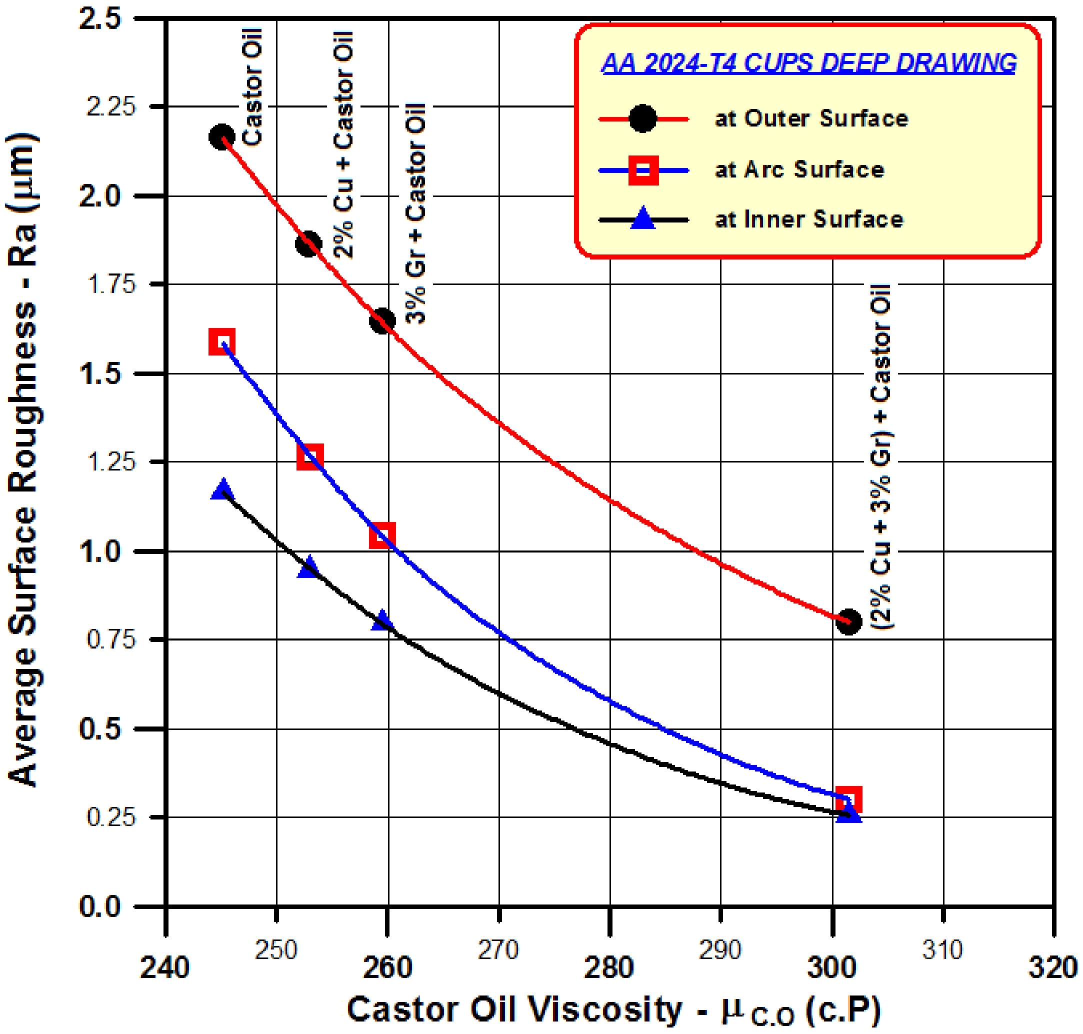


Figure (5.24) Viscosity of castor oil with cup surface roughness

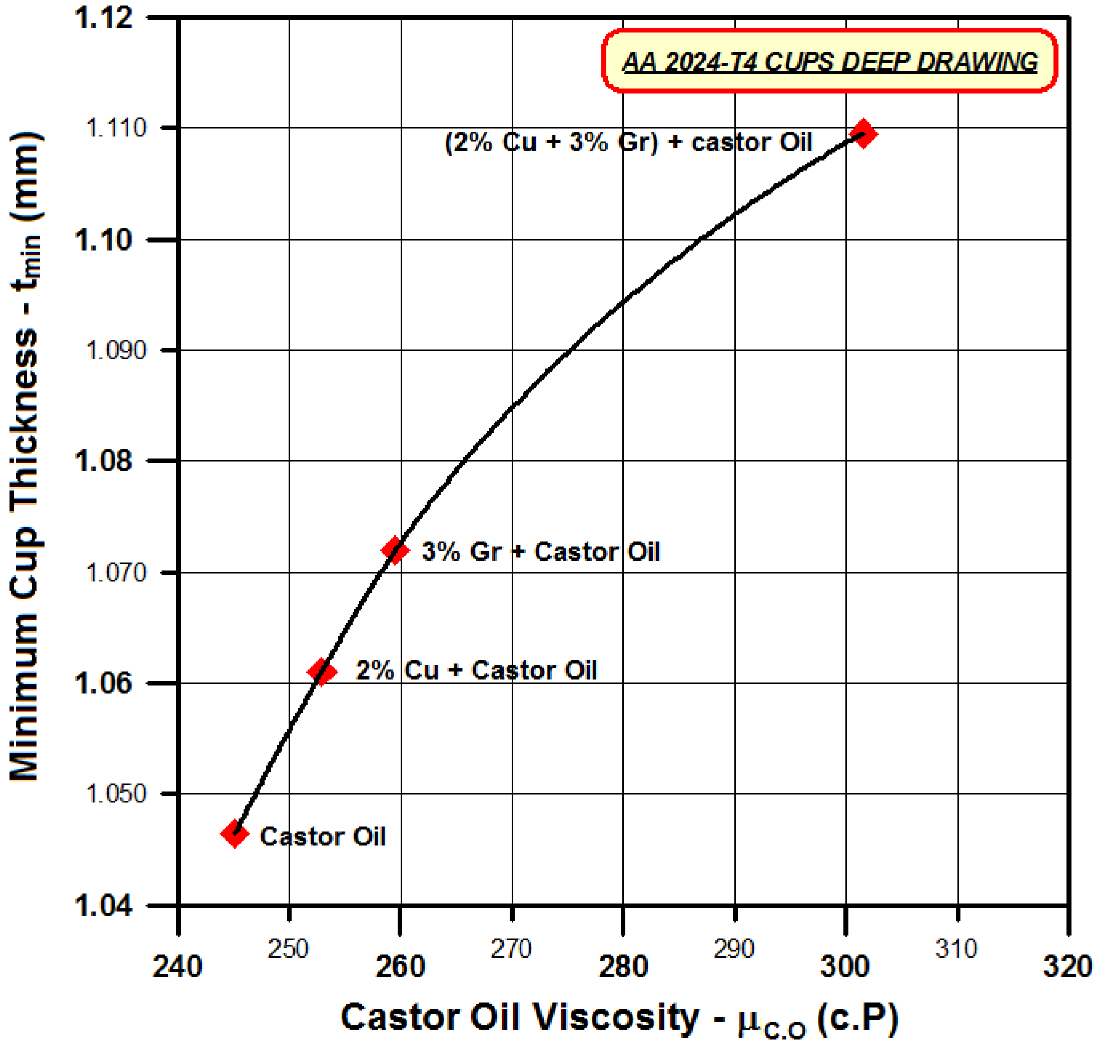


Figure (5.25) Viscosity of castor oil with minimum cup thickness

$$t_{min} = -0.3737 + 0.00959\,\mu_{C.O} - 1.5505E-5\,\mu_{C.O}^2 \;\dots\dots\dots (5-14)$$

5.5.3 *Comparison between Hybrid Oils Additives:*

As mentioned above, it can be concluded that hybrid oil of both types, namely die and castor oil, give always the best mechanical properties for the product, as well as saving in the power consumed for achieving deep drawing processes. in this section, a comparison between the both types of hybrid oils is discussed. Figure (5.26) shows that there is completely insignificant difference between the forces used to deform the products by the two hybrid oil, also, this can be said for product height, as shown in figure (5.27). The most parameter effect in type of lubricant is the product quality; castor hybrid oil gives always high quality products. Figure (5.28) shows that the improvement in surface roughness is 51% when using castor hybrid oil instead of hybrid die oil. Also Figure (5.29) shows the thickness profile is improved clearly when using hybrid castor oil, compared with that when using hybrid die oil. This means that hybrid castor forms a tight thin layer between the die and metal that can reduce the distortion of sample surface.

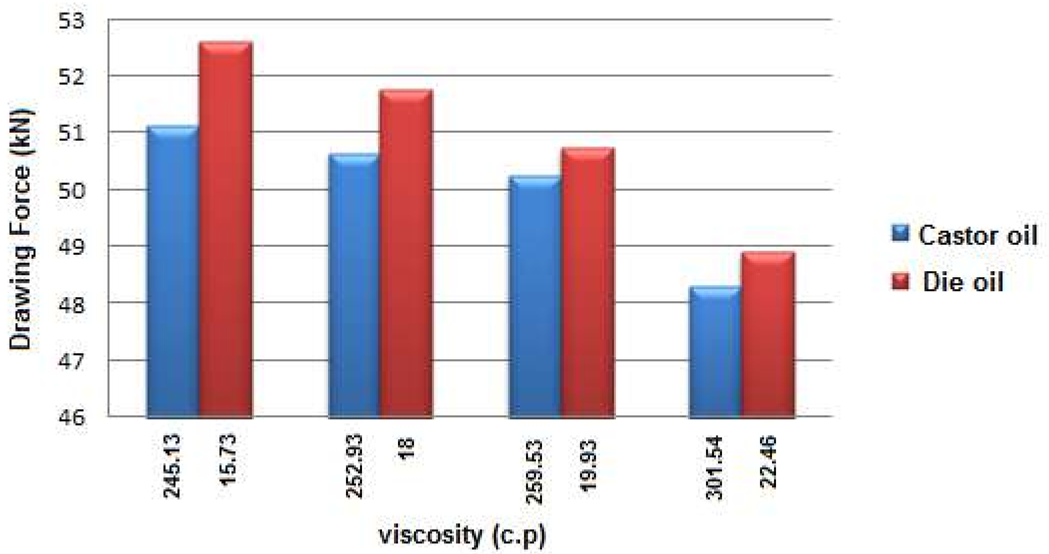


Figure (5.26) Improvement in drawing force

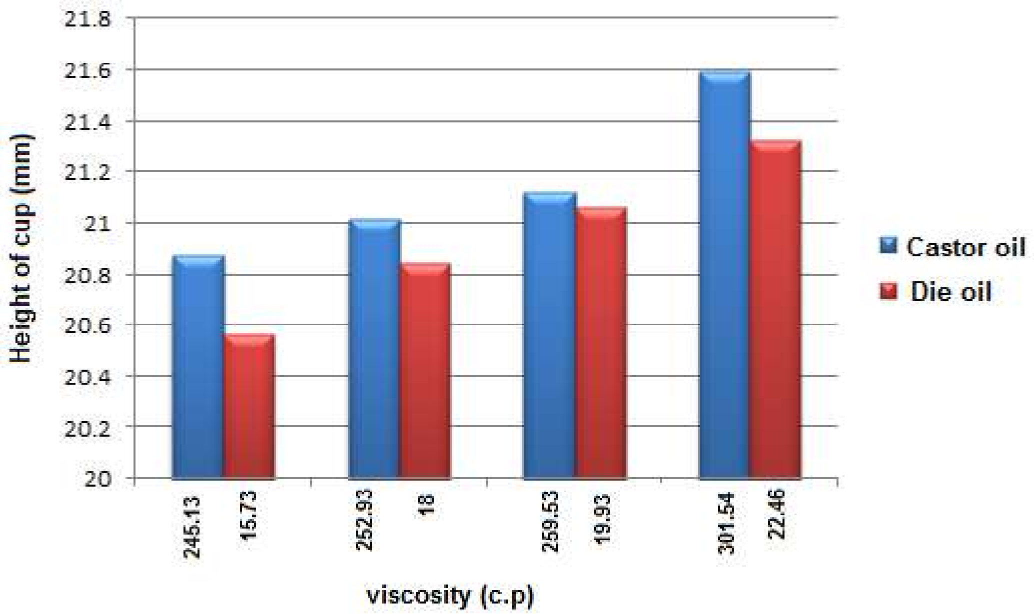


Figure (5.27) Improvement in height of cup

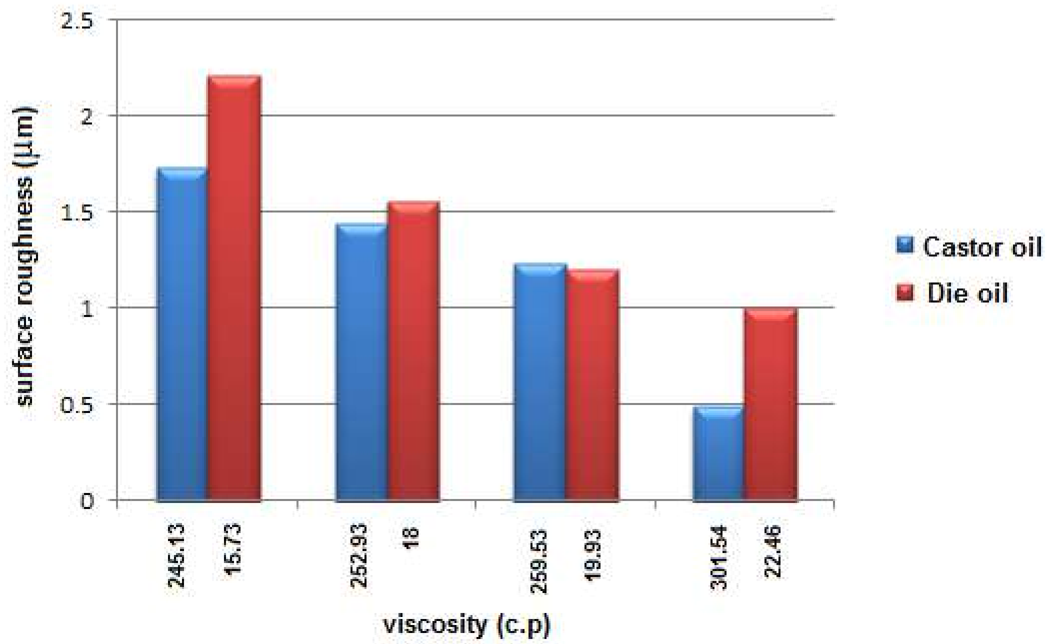


Figure (5.28) Improvement in surface roughness

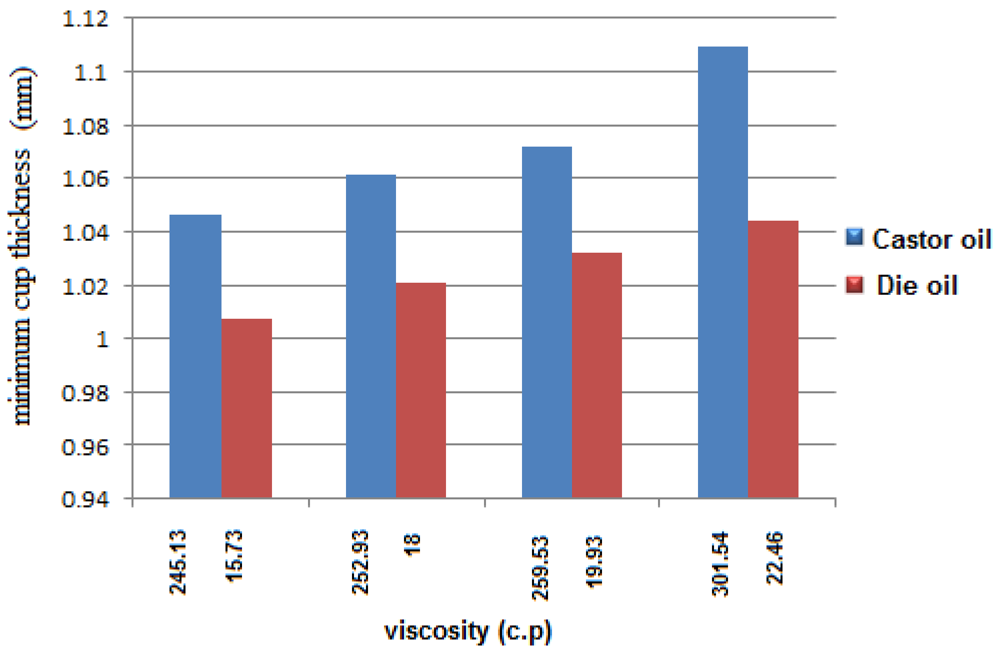


Figure (5.29) Improvement in cup thickness

5.6 *Forming Limit Diagram*

Forming limit shows the amount of deformation which occurs during drawing operation and it is used to evaluate the maximum amount of deformation that can be exerted to the material before it fails. [18]

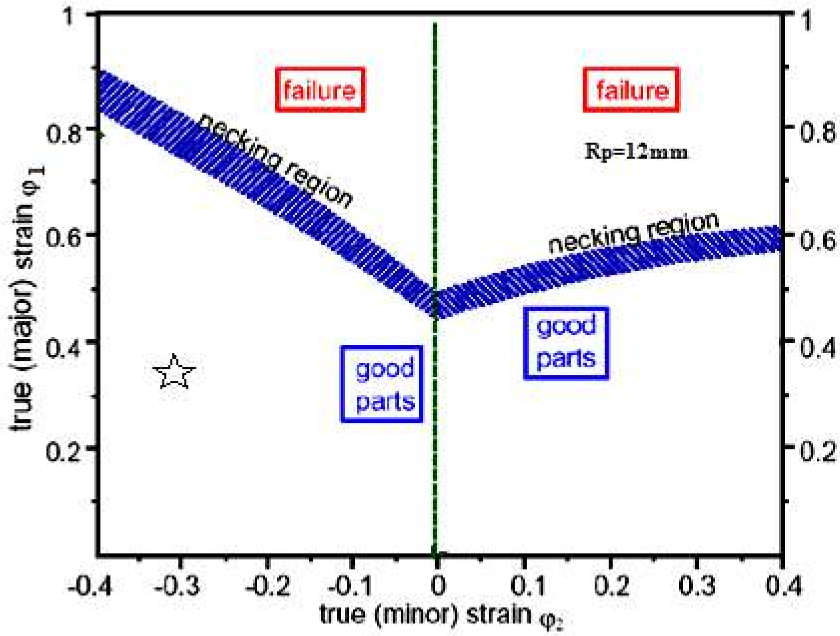


Figure (5.30) Forming limit diagram

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 *Conclusions:*

From the present work it can be concluded that:

6.1.1 *Using lubricant with and without additives gives the following improvements in the wear test:*

1. The experiments show an increase in the efficiency of the lubricating medium in sliding steel-aluminum pair with the addition of additives to the lubricant oils (dies and castor oils) i.e. addition of graphite – copper powder (mixed) in comparison with the case of administration of the same amounts of graphite and copper powders, entered separately.
2. A theoretical concept is put forward that the introduction of a lubricating base medium of graphite – copper powder (mixed) should lead to an increase in anti-friction efficiency and anti-wear performance in comparison with the case of administration of the same amounts of graphite and copper powders, entered separately.
3. Tribological characteristics of composite graphite – copper additives are obtained from the lubricant oils with a thin protected layer on the contacting surfaces. It was shown that the wear rate may drop about (1.5-2) times and about (3-3.5) times for dies oil and castor oil respectively in comparison with the case of administration of the same amounts of graphite and copper powders, entered separately.
4. Established from the friction pair steel-steel that the introduction of graphite – copper powder (mixed) additive powders shows optimum lubricating effect on the level of concentration of these additives of (5) wt. %.

5. Using filler, graphite – copper additive powders leads to the formation of copper films on the contacting friction surfaces able to express anti-friction and wear effects.

6.1.2 ***Using lubricants with and without additives gives the following improvements in the deep drawing processes:***

1.The experiments show an increase in the efficiency of the drawing parameters lubricating medium in sliding steel-aluminum pair with the addition of additives to the lubricant oils (dies and castor oils) i.e. addition of graphite – copper powder (mixing) in comparison with the case of administration of the same amounts of graphite and copper powders, entered separately.

2. Optimum results obtained from drawing force, cup height, thickness distribution and surface roughness in the formability of AA2024 – T4 under experiment conditions for dies oil were(7.2%), (1%), (3.5 %) and (55%) respectively by using the composite (hybrid) graphite – copper powder compared with the case of administration of the same amounts of graphite and copper powders, entered separately.

3. Optimum results obtained from drawing force, cup height, thickness distribution and surface roughness in the formability of AA2024 – T4 under experiment conditions for castor oil were(6.5%), (1%), (6 %) and (70.5%) respectively by using the composite (hybrid) graphite – copper powder compared with the case of administration of the same amounts of graphite and copper powders, entered separately.

6.2 ***Recommendations For Future Work***

It is recommended that future work should study the effect of:

1. Study the effect of nano particle lubricant additives on wear test and product of deep drawing process.
2. Study the effect of additives particle lubricant on deep drawing process of metal samples combined by friction stir welding.
3. Study the effect of different additives powders such as Ni, Mos_2, Serpentine, etc. on deep drawing lubricants.

References

References

[1] Muhammad Safwan, Ismail. “Experimental study of formability of sheet metal in deep drawing process”. Diss. Universiti Malaysia Pahang, 2011.

[2] Mohd Naeemil Mahmudi, Mahmud.” Reducing wrinkling and tearing of deep draw part”. Diss. Universiti Malaysia Pahang, 2012.

[3] Zhang, Wenfeng, and Rajiv Shivpuri. "Probabilistic design of aluminum sheet drawing for reduced risk of wrinkling and fracture." Reliability Engineering & System Safety 94.2 (2009): 152-161.

[4]Available at http://www.google .iq/url?url=http://cuiet.info/notes /chemistry/Lubricants.pdf&rct.

[5] Ahmed, Nehal S., and Amal M. Nassar. “Lubricating Oil Additives. Intech Open Access Publisher, 2011.

[6] Soelch, Richard, Thomas Auletto, and Grant Drew. "Novel self-lubricating surface coating composition." U.S. Patent Application 13/108,677.2011.

[7] Rizvi, Syed QA. Lubricant Chemistry, Technology, Selection, and Design. ASTM International: West Conshohocken, PA, USA, 2009.

[8] Available at http://www.makeitfrom.com/material-properties/2024-T4-Aluminum/.

[9] Siegert, K., Dannenmann, E., Wagner, S., & Galaiko, A. (1995). Closed-loop control system for blank holder forces in deep drawing. CIRP Annals-Manufacturing Technology, 44(1), 251-254.

[10] DIN standard 8584: Fabricating process tensile-compressive forming.

[11] Jaisingh Amit, Narasimhan K., Date P.P., Maiti S.K., Singh U.P. “Sensitivity Analysis of a Deep Drawing Process for Miniaturised Products”, Journal of Material Processing Technology, vol. 147, pp 321-327, 2004.

[12] Chandra Pal Singh and Geeta Agnihotri “Study of Deep Drawing Process Parameters : A Review ” Mechanical Engineering , MANIT

BHOPAL , International Journal of Scientific and Research Publications , Volume 5 , 2015

[13] Zhao S.D., Zhang Z.Y., Zhang Y., Yuan J.H. , “The Study on Forming Principle in the Process of Hydro-Mechanical Reverse Deep Drawing with Axial Pushing Force for Cylindrical Cups”, Journal of Materials Processing Technology, vol. 187-188, pp 300-303 2007.

[14] Wilson WRD, Hsu TC, Huang XB. “A realistic friction model for computer simulation of sheet metal forming processes”. ASME Journal of Engineering for Industry 1995;117:202–9.

[15] E. Rajesh and M. Siva Prakash, 2013, "Analysis of friction factor by employing the ring compression test under different lubricants," International Journal of Scientific & Engineering Research, Vol. 4, Issue 5, pp.1163-1170.

[16] Murat Baspinar, “Modelling and simulation of friction in deep” drawing , a thesis submitted to the graduate school of natural and applied sciences of middle east technical university 2015.

[17] Karupannasamy, D. K., et al. "Modelling mixed lubrication for deep drawing processes." *Wear* 294 (2012): 296-304.

[18] Metal Forming Handbook /Schuler (c) Springer-Verlag Berlin Heidelberg 1998 .

[19] Lovell, M. ,Higgs, C. F. and Mobley, A. J. “A Novel Particulate-Fluid Lubrication For Environmentally Benign Forming Processes ” World Tribology Congress, Washington , D.C., USA , 2005 .

[20] Chandra Pal Singh and Geeta Agnihotri “Study of Deep Drawing Process Parameters : A Review “Mechanical Engineering” , MANIT BHOPAL , International Journal of Scientific and Research Publications , Volume 5 , 2015 .

[21] Sokolova O.A., Kuhn M., Palkowski H., “Deep Drawing Properties of Lightweight Steel/Polymer/Steel Sandwich Composites”, Archive of Civil and Mechanical Engineering, vol. 12, pp 105-112, 2012.

[22] Signorelli J.W., Serenelli M.J., Bertinetti M.A., "Experimental and Numerical Study of the Role of Crystallographic Texture on the Formability of an Electro-Galvanized Steel Sheet", Journal of Materials Processing Technology, vol. 212 ,pp 1367– 1376, 2012.

[23] Natarajan S., Venkataswamy S., Bagavathiperumal P. "A Note on Deep Drawing Process: Numerical Simulation and Experimental Validation" Journal of Materials Processing Technology, vol. 127, pp 64-67, 2002.

[24] Peled A., Rubin M.B., Tirosh J. "Analysis of Blank Thickening in Deep Drawing Processes Using the Theory of a Cosserat Generalized Membrane", Journal of the Mechanics and Physics of Solids, vol.52, pp 317-340, 2004.

[25] I., Suchy, Hand Book of Die Design, 2nd ed., McGraw-Hill, USA, Chap.9,pp 367-450, 1998.

[26] ASM handbook Volume 14 "Forming and forging".

[27] Trivedi Nirav R. "Effects of Various Parameters in Deep Drawing Process Over Sheet Metal to Get Optimum Result." (2014).

[28] Feng Gong . Bin Guo . Chun Ju Wang and De Bin Shan " Effects of lubrication conditions on micro deep drawing " TECHNICAL PAPER Springer-Verlag , 2010 .

[29] Turkoz, Mevlut, Murat Dilmec, and Huseyin Selcuk Halkaci. "Investigation on Earing Behavior of AA 2024-T4 and AA 5754-O Aluminum Alloys." *Advanced Materials Research*. Vol. 264. 2011.

[30] Milan Jurkovic , Muslic Merima , Irfana Liubijankice , Bihac Bosnia and Herzegovina "Mathematical Modeling of Friction Force and Friction Coefficient at Deep Drawing Process" 15th International Research /Expert Conference ,Trends in the Development of Machinery and Associated Technology ,Prague , Czech Republic, 2011 .

[31] Taylan Altan , Milan Jurich , Soumya Subramonian , Nimet Kardes and Yurdaer Demiralp "Evaluation of Stamping Lubricants in Forming

Galvannealed Steels for Industrial Application" Journal of Manufacturing Science and Engineering by ASME, 2011 .

[32] Y. M .Shashidhara and S.R. Jayaram "Deep drawing of 304 L Steel Sheet using Vegetable oils as Forming Lubricants " International Journal of Advancements in Research and Technology , Volume 1 , 2012 .

[33] A. Vadiraj , G. Manivasagam , K. Kamani and V.S. Sreenivasan " Effect of Nano Oil Additive Proportions on Friction and Wear Performance of Automotive Materials " School of Mechanical and Building Science ,VIT University ,Tamil Nadu , India .Vol.34 . 2012.

[34] Dilmec, M., Halkaci, H. S., Ozturk, F., Livatyali, H., & Yigit, O. (2013). Effects of sheet thickness and anisotropy on forming limit curves of AA2024-T4. The International Journal of Advanced Manufacturing Technology, 67(9-12), 2689-2700.

[35] Obasi A.U, Udeagbara ,S.G , Anusiobi, O.J "Effect of Additives on the Performance of Engine Oil " International Journal of Engineering and Technology Research Vol. 2, Available online at www.ijeatr.org , 2014 .

[36] Carlton J . Reeves , Pradeep L. Menezes, Michael R. Lovell and Tien-Chien Jen "The Effect of Particulate Additives on the Tribological Performance of Bio-based and Ionic Liquid-based Lubricants for Energy Conservation and Sustainability " Proceedings of the STLE Annual Meeting and Exhibition, Lake Buena Vista, Florida , USA , 2014 .

[37] U. Pranavi , P. Venkateshwar Reddy and Perumalla Janaki Ramulu " Formability Studies on Aluminum Alloy Sheets through Deep Drawing Process " 5th International and 26th All India Manufacturing , Design and Research Conference , 2014 .

[38] Sivarajan, S., and R. Padmanabhan. "Green Machining and Forming by the use of Surface coated tools." *Procedia Engineering* 97 (2014): 15-21.

[39] Zareh-Desari, Behrooz, Mohammad Abaszadeh-Yakhforvazani, and Saman Khalilpourazary. "The effect of nanoparticle additives on

lubrication performance in deep drawing process: Evaluation of forming load, friction coefficient and surface quality." International Journal of Precision Engineering and Manufacturing 16.5 (2015): 929-936.

[40] Chandra Pal Singh and Geeta Agnihotri "Study of Deep Drawing Process Parameters : A Review " Mechanical Engineering , MANIT BHOPAL , International Journal of Scientific and Research Publications , Volume 5 , 2015 .

[41] Tingting Mao , Xiaoqiang Li , Taylan Altan and Julio Malpica "Evaluation of optimum lubrication condition for Stamping of Al 5182-O Aluminum Sheet using Cup Drawing Test " Center for Precision Forming (CPF) , The Ohio State University ,USA , www.cpforming.org , 2015 .

[42] Freiße, Hannes, et al. "Dry metal forming of high alloy steel using laser generated aluminum bronze tools." MATEC Web of Conferences. Vol. 21. EDP Sciences, 2015.

[43] Namer, Nasri SM, Sami Ali Nama, and Jumana Wassfee Thabit. "Numerical and Experimental Study on Deep Drawing Process for AA2024-T4 Sheet." *Journal of Applied and Experimental Mechanics* 1.1 (2015): 1-9.

[44] Khan, Mohd Shadab, Zahir Hasan, and Yaqoob Ali Ansari. "Statistical Analysis for the Abrasive Wear Behavior of Al 6061." Journal of Minerals and Materials Characterization and Engineering 2.04 (2014): 292.

Appendixes

Appendix A

Appendix A

Wear resistance test results for all samples

	Types of Lubricant	Additives	Ratio of Additives	Load (N)	Wear Rate (gm/cm)
1	Castor oil	Graphite	2%	2.5	0.5001E-7
2		Graphite		5	0.5379E-7
3		Graphite		7.5	1.0946E-7
4		Graphite		10	1.5617E-7
5		Graphite		12.5	2.1043E-7
6	Castor oil	Graphite	2.5%	2.5	0.3727E-7
7		Graphite		5	0.519E-7
8		Graphite		7.5	0.9814E-7
9		Graphite		10	1.4154E-7
10		Graphite		12.5	1.9344E-7
11	Castor oil	Graphite	3%	2.5	0.0942E-7
12		Graphite		5	0.401E-7
13		Graphite		7.5	0.7077E-7
14		Graphite		10	0.8493E-7
15		Graphite		12.5	1.0852E-7
16	Castor oil	Graphite	4%	2.5	0.302E-7
17		Graphite		5	0.4671E-7
18		Graphite		7.5	0.8068E-7
19		Graphite		10	1.288E-7
20		Graphite		12.5	1.4768E-7
21	Castor oil	Graphite	5%	2.5	0.486E-7
22		Graphite		5	0.5662E-7
23		Graphite		7.5	1.2833E-7
24		Graphite		10	1.5617E-7
25		Graphite		12.5	1.8023E-7
26	Die oil	Graphite	2%	2.5	1.1748E-7
27		Graphite		5	1.9108E-7
28		Graphite		7.5	2.779E-7
29		Graphite		10	3.3121E-7
30		Graphite		12.5	3.9774E-7
31	Die oil	Graphite	2.5%	2.5	1.0852E-7
32		Graphite		5	1.8401E-7
33		Graphite		7.5	2.359E-7
34		Graphite		10	3.2885E-7
35		Graphite		12.5	3.8217E-7
36	Die oil	Graphite	3%	2.5	0.6191E-7
37		Graphite		5	1.0268E-7
38		Graphite		7.5	1.2175E-7
39		Graphite		10	2.0573E-7
40		Graphite		12.5	3.0329E-7

Appendix A

	Types of Lubricant	Additives	Ratio of Additives	Load (N)	Wear Rate (gm/cm)
41	Die oil	Graphite	4%	2.5	1.1654E-7
42		Graphite		5	1.8872E-7
43		Graphite		7.5	2.7035E-7
44		Graphite		10	3.3074E-7
45		Graphite		12.5	3.8075E-7
46	Die oil	Graphite	5%	2.5	1.1795E-7
47		Graphite		5	2.1562E-7
48		Graphite		7.5	2.9252E-7
49		Graphite		10	3.6518E-7
50		Graphite		12.5	3.916E-7
51	Castor oil	Copper	1%	2.5	0.8776E-7
52		Copper		5	1.4107E-7
53		Copper		7.5	1.5287E-7
54		Copper		10	2.3543E-7
55		Copper		12.5	2.5336E-7
56	Castor oil	Copper	1.5%	2.5	0.302E-7
57		Copper		5	0.9106E-7
58		Copper		7.5	1.4673E-7
59		Copper		10	2.109E-7
60		Copper		12.5	2.5006E-7
61	Castor oil	Copper	2%	2.5	0.1236E-7
62		Copper		5	0.6228E-7
63		Copper		7.5	0.9389E-7
64		Copper		10	1.6183E-7
65		Copper		12.5	2.1939E-7
66	Castor oil	Copper	2.5%	2.5	0.1708E-7
67		Copper		5	0.7266E-7
68		Copper		7.5	1.2503E-7
69		Copper		10	1.896E-7
70		Copper		12.5	2.3449E-7
71	Castor oil	Copper	3%	2.5	0.2453E-7
72		Copper		5	1.1465E-7
73		Copper		7.5	1.4768E-7
74		Copper		10	2E-7
75		Copper		12.5	2.4345E-7
76	Die oil	Copper	1%	2.5	0.9342E-7
77		Copper		5	1.8495E-7
78		Copper		7.5	2.7601E-7
79		Copper		10	3.2602E-7
80		Copper		12.5	4.1944E-7

Appendix A

	Types of Lubricant	Additives	Ratio of Additives	Load (N)	Wear Rate (gm/cm)
81	Die oil	Copper	1.5%	2.5	0.8728E-7
82		Copper		5	1.6089E-7
83		Copper		7.5	2.4817E-7
84		Copper		10	3.2083E-7
85		Copper		12.5	4.0151E-7
86	Die oil	Copper	2%	2.5	0.7549E-7
87		Copper		5	1.2503E-7
88		Copper		7.5	1.991E-7
89		Copper		10	2.76E-7
90		Copper		12.5	3.3027E-7
91	Die oil	Copper	2.5%	2.5	0.92E-7
92		Copper		5	1.7551E-7
93		Copper		7.5	2.8025E-7
94		Copper		10	3.3498E-7
95		Copper		12.5	4.1991E-7
96	Die oil	Copper	3%	2.5	1.1135E-7
97		Copper		5	2.0524E-7
98		Copper		7.5	2.8544E-7
99		Copper		10	3.5103E-7
100		Copper		12.5	4.2416E-7
101	Hybrid castor oil	Graphite + Copper	3%+2%	2.5	0.006605E-7
102		Graphite + Copper		5	0.033027E-7
103		Graphite + Copper		7.5	0.062279E-7
104		Graphite + Copper		10	0.103798E-7
105		Graphite + Copper		12.5	0.158528E-7
106	Hybrid die oil	Graphite + Copper	3%+2%	2.5	0.13824E-7
107		Graphite + Copper		5	0.35197E-7
108		Graphite + Copper		7.5	0.380278E-7
109		Graphite + Copper		10	0.447747E-7
110		Graphite + Copper		12.5	0.533616E-7

Appendix A

	Types of Lubricant	Additives	Load (N)	Wear Rate (gm/cm)
111	Castor oil	Without additives	2.5	1.0238E-7
112		Without additives	5	1.4532E-7
113		Without additives	7.5	1.9816E-7
114		Without additives	10	2.2552E-7
115		Without additives	12.5	2.7129E-7
116	Die oil	Without additives	2.5	1.2126E-7
117		Without additives	5	2.293E-7
118		Without additives	7.5	3.114E-7
119		Without additives	10	3.7273E-7
120		Without additives	12.5	4.2935E-7

	Dry test	Load (N)	Wear Rate (gm/cm)
121	Without oil	2.5	1.4768E-7
122		5	2.4062E-7
123		7.5	3.4159E-7
124		10	4.0104E-7
125		12.5	4.5766E-7

Appendix B

بسم الله الرحمن الرحيم

جمهورية العراق
وزارة النفـــط
شـركة مصــافي الوســط /شـركة عامــة
بغــداد

REPUBLIC OF IRAQ
MINISTRY OF OIL
MIDLAND REFINERIES COMPANY
(GENERAL COMPANY) MRC
BAGHDAD

العدد: ١ / ٧ / RQD/ ٦٥٤/ ٢٣٣٤٨
التاريخ: ١٩/ ١١/ ٢٠١٤/ م
الموافق: / /١٤٣٣/ هـ

REF:
DATE:

وزارة التعليم العالي والبحث العلمي
هيئة التعليم التقني
الكلية التقنيه - بغداد

م/ **ابداء مساعدة**

أشـــــــارة الى كتابكم المرقم (٢٩٩٦) فـــــــي ٢٠١٤/١١/٥ ٠
نــــــدرج لكم نتائج الفحوصات المختبريـــــة التي اجريت على نمـــوذجي الـــزيتين المرسلين من قبلكم مع مواصفات لبعض منتجاتنا وبناءا" لطلبكم ٠

Lab. Insp. Data	زيت نباتي	زيت عضوي	7701	144.MG	شحم الليثيوم
Vis. C.st @ 40 °C	245.13	70.18	15.73	124.35	–
Vis. C.st @ 100 °C	19.12	12.08	3.56	15.88	–
VI	88	170	106	135	–
SP. Gravity @ 15.6 °C	0.9739	0.8524	0.850	0.8902	–
COC Flash	310	224	198	220	–
Penetration @ 25°C	-	-	-	-	280
Dropping point °C	-	-	-	-	204

٠٠٠ **مع التقديــــــر** ٠٠٠

ســـعد نـــوري محمـــد
المدير العام
أيـــاد أحمـــد محمـــد
مدير قسم البحوث والسيطرة النوعيـــة

صــــورة منه إلى :/
- مكتب السيد المدير العام / للتفضل بالاطلاع ٠٠ مع التقدير
- قسم الحسابات: بلغت كلفة الفحوصات (٢٢٠ ٠٠٠) مائتان وعشرون ألف دينار فقط(مجانا" حسب موافقة السيد معاون مدير العام لشؤون الانتاج).
- قسم البحوث والسيطرة النوعية /- شعبة الدهون والمنتجات الثقيلة
/- الشعبة الإدارية/ - نظام الأرشيف الإلكتروني
- الأضبارة ( )
- الدوار

يوسف / رشـــــا ٢٠١٤/١١/١٦

الخلاصة

يتناول هذا البحث دراسة تاثير اضافة كل من مسحوق كرافايت- نحاس عالي النعومة الى الزيوت المستخدمة في عمليات السحب العميق لصفائح الالمنيوم بشكل عام ولسبيكة الالمنيوم نوع (AA2024-T4) بشكل خاص لمدى من التراكيز يتراوح بين (5-2)% نسب وزنية لمسحوق الكرافايت و (3-1)% نسب وزنية لمسحوق النحاس . ان تحسين خصائص مزيتات السحب العميق الترايبولجية باضافة مزيج مركب من هذه المساحيق بات جليا عما هو عليه عند اضافة كل مسحوق من هذه المواد بشكل منفصل تحت نفس الضروف التشغيلية وباستخدام نفس النسب الوزنية .

ان المادة المركبة المتكونة من مزيج هذه المساحيق تم دراسة تاثير اضافتها الى نوعين من المزيتات المستخدمة في عملية السحب العميق وهي زيت القوالب وزيت الخروع واثر ذلك على تحسين قابلية هذه المزيتات في تقليل البلى والاحتكاك بين السطوح المتلامسة باستخدام جهاز فحص البلى من خلال دراسة تاثير الاحمال المسلطة والسرعة النسبية بين السطحين المتلامسين اوضحت النتائج ان افضل النتائج كانت عند تراكيز للمواد المضافة لكل من الكرافايت والنحاس بحدود 3% و 2% على التوالي وذلك من خلال تكوين طبقة قوية واقية بين الاسطح المنزلقة تعمل على تقليل البلى كما بين النتائج تحسن واضح للخصائص الترايبولجية باستخدام هذه المادة المركبة المضافة حيث انخفض معدل الاستهلاك بنسبة 89% و99.7% عند استخدام كل من زيت القوالب وزيت الخروع على التوالي بالمقارنة عند استخدام (زيت القوالب وزيت الخروع) بدون اضافات.

ان تأثير الحمل المطبق مقابل معدل التآكل لجميع اختبارات البليان مع وبدون المزيتات وعلى جميع النسب الوزنية ٪ من الاضافات المقدمة إلى نموذج المعادلة متعدد الحدود من الدرجة الثانية مع ارتباط ارتفاع المعامل أكثر من 97٪ وأدنى انحراف معياري ≤ 0.1.

ان المادة المركبة الجديدة تم تطبيقها في عملية السحب العميق لصفائح الالمنيوم نوع (AA2024-T4) باستخدام عينات دائرية بسمك (1.2 ملم) في قالب سحب بنصف قطر مخرم وزاوية حامل العينة (12 ملم) (0°) على التوالي اوضحت نتائج عمليات السحب العميق امكانية عالية في تحسين نتائج المتغيرات لعملية التشكيل فقد تحسنت كل من قوة السحب وخشونة السطح للمنتج وتوزيع السمك بنسب (7.2 % و 70.5 % و 6%) على التوالي مقارنة مع استخدام المزيتات بدون اضافات .

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
الجامعة التقنية الوسطى
الكلية التقنية الهندسية / بغداد

دراسة تأثير المواد المضافة الى مزيتات قوالب السحب العميق في تشكيل صفائح الالمنيوم

رسالة مقدمة
إلى مجلس الكلية التقنية الهندسية / بغداد وهي جزء من
متطلبات نيل شهادة الماجستير التقني في
هندسة تقنيات القوالب

من قبل الطالب
مناف هاشم رضا
بكلوريوس هندسة تقنيات القوالب والعدد

بأشراف

د.نصري صالح محمد
أستاذ مساعد

د .حيدر اكرم السبتي
أستاذ مساعد

أب 2015

ذو القعدة 1436