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Estimation of Wear and Friction Characteristics of Al Alloys for Cold Forging: Review

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Abstract : *Forging process is one of the most important metal forming processes. Wear in cold forging and hot forging has become wide considerable and research factor in industries to recognize it. Products made by hot forging are pinions, crankshafts, rolls etc. while smaller components usually less than 50 kg such as screws, nuts and small jut6;nction details etc are made by cold forging. So to understand tribological aspects in forging process such as wear, friction and lubrication is important. The rotation of punch on work-piece produces some amount of material wear in punch and work-piece. Wear properties of metal and alloy have significant effect on serviceability and durability on machine component. To understand material behaviour and effect of chemical composition and temperature during forging, numerical and experimental investigation is important for cold forging. This paper focuses on tribological investigation to estimate wear and friction characteristics of aluminium alloy during cold forging process.*

Keywords: *Cold forging,Coefficient of friction,Frictionalforce,Wear,Frictional stress*

I. Introduction

Cold forging process is onethe of most widely used forming processes, often requiring no machining other than drilling. This process produces greater dimensional accuracy than hot forming, and does not produce scale. However, the plastic flow characteristics of workpiece are not as good, so that higher forging pressures are required. From the smallest part to upto 50 kg billet metals can be cold forged. This process has vast use in mechanical industry. The information about tribilogy in forging and study on ring compression that is circular hollow billet, going into the various tribological changes such as wear, friction. Lubrication required for cold forging operation. In forging there is usually a temperature difference between the work piece and tooling and lubricant properties which are useful for cold and hot forging. Compression test shows temperature change because of massive force on workpiece which is at room temperature, grain structure change increases the workpiece temperature. Adhesive wear is a large concern because of aggressive and hot nascent material interacting with die materials. Forging tooling is usually restricted to highly alloyed steels, and chemically inert hard coatings are of continued interest [1]. Tribological conditions in bulk metal forming processes are characterized by high contact pressures and large relative movements at high velocities between the tool and the work piece. The significant surface expansion, exalted temperatures can occur [2]. The methodology and experimentation of helical gear, that wear and friction studied by using columb friction model and compare results with analysis software. The influence of the occurring friction conditions on selected component and process properties within cold forging of gears. Gears are made from cold extrusion process which [3].

The friction between die and work piece is a complex phenomenon and has a strong influence on the metal forming parameter sand the product quality. By using different friction models of cold forging complex shaped components friction calculated. The forging operations are simulate during the Coulomb and constant friction models, and the results are compared with the simulation results obtained by using the variable friction models developed by Wanheim–Bay general friction model and Levanov, which are integrated in the formulation procedure. The coefficient of friction may changes during the process and the constant coefficient of friction may not simulate the actual friction condition in the cold forging process [4].Erinosho et al. [5] gave the information about the effect of friction during forging operation must especially the double cup extrusion process. The metal forming process such as forging is one of the manufacturing processes where metal is pressed or forced under great pressure into high strength parts to form complicated shapes. Lubricant is applied to the dies in operation before the testing to promote the flow of metal, to reduce friction and wear, and to aid in the release of the finished part. Internal friction between the forgings dies and the work piece such as billet is having a significant effect on the forging applications, forming quality and deformation loads. The most common lubricants used are liquid based lubricants which are water based graphite, synthetic oils, liquid soap, shear butter etc. Under high pressure condition reductions of the lubricant film often breaks down the operation which causes poor metal flow and wears. High interfacial friction is a main of cause for adhesion pickups in cold forging. The spike forging test is still commonly used although there are some new tribology test methods but each designer would like to give their own parameters. The spike forging test gives results by using FEA

simulation by considering difference between low friction and high friction used as evaluation index. The result of spike forging test shows that geometrical parameter affects on the forging, wear and friction properties of spike forged component [6]. Clutch hub chosen as the object for numerical study investing the usefulness and effectiveness of employing numerical simulations in the design process of metal forming parts. Simulation for S10C steel using various die and work piece geometries were carried out and completeness of filling and road requirement were compared to determine the forming condition most suitable for production of clutch- hub. The effect of shear friction factor on forming process was examined using most suitable die and work piece geometries [7]. Also study on aluminium alloy Al1100-0, Al2024-T3, Al6061-T4, Al7075-T4 with respect to there to their defect factor of work hypothesis. The work piece material is of AISI Al6061 and die material is die steel D2.For front and back hub five cases of work piece with varying dimension are simulated to obtain the optimum work piece in terms of flash and without flash and optimization through verified through thermal analysis. How alloys react to same forging force and there temperature variation gives major feedback about flow stress and frictional stress [8].

The tribo-characteristics of metal forming at high temperatures which is been well understood due to the complex nature of thermal, micro structural, interaction, and process parameters. The scientist gives the information about effects of tribological characteristics such as lubrication, temperature in hot forming. Flow stress of aluminium alloy depends temperature of metal working condition. The tribobehaviour of oxides in hot forming like as rolling and stamping, were reviewed and presented [9].Andreas et al. [10] In forming industry the tool is fundamental for the profitability, as it determines efficiency of cold forging process.The tool surface has a distinctive influence on the tribological conditions and thus on the occurring tool stresses. Investigation shows that, the effect of different machining techniques on the tribological behavior of cold forging tools made offrom WC-Co cemented carbide, by implementing the double cup extrusion test. Ortiz et al. [11] suggested that Aluminum alloys 6061, 2024, and 7075 were heat treated to various tempers and then subjected to a range of plastic strain in order to determine their strain limits. The effects of the plastic strain on tribological properties are discussed and strain limits are decided. Salguero et al. [12] shows that wear is caused by different mechanisms so only one is considered as predominant or the controller of the process. The experimental research is focused on the application of Pin-on-Disc wear tests, in which the tribological involvementbetween UNS A92024-T3 Aluminium-Copper alloy and tungsten carbide (WC–Co) is studied. The main objective of this study is focused on the determination of the predominant wear mechanisms involved so in the process, the characterization of the sliding and friction effects. Study shows that having abrasive wear mechanisms related to adhesion. This fact gave clear idea about the adhesion mechanism to several stages because of the surface quality deterioration. Bay et al. [13] created a frictional stress model for aluminium, steel and stainless steel provided with useful lubricants for cold forging which has been determined for varying normal pressure and surface expansion and sliding length and tool/work piece interface temperature. The results show, that friction is strongly influenced by normal pressure and tool and work piece interface temperature, whereas the other process parameters studied shows minor influence on friction. Bay made experimental results and mathematical model established for friction with a function of normal pressure and tool work piece internal temperature. The friction models are verified by measuring friction at varying reduction in cold forward rod extrusion process.

Flow stress equation and behaviour of flow stress in metal forming process taken for calculation. The behavior of metal during compression and tensile test showed by friction. And total friction equation and how temperature effects the forming of metal or cold or hot working process. Materials differ according to their ability to undergo plastic deformation. Grain structure, nature of bonding are main factors considered while plastic deformation [14]. The mechanical and micro structural characteristics of optical and electron microscopy as well as micro hardness of Al 6063 alloy after mechanical and thermal treatment is given. Al-Mg based alloys have special importance due to the lightness of the material, other mechanical properties and recyclability. Cold rolling steps in Al 6063 alloy were employed for the recrystallization studies, followed by thermal treatment using four different isothermal heating conditions for four different timings. Non heat treatable alloys have high strength than heat treatable alloy. The formation of new grain structure it is non stable of new deformed microstructure, depending on sub grain size heterogeneities present as potential embryos in the deformed state adjacent to high local disorientation. The result shows effect of second phase particles on recrystallization and controlling the resulting microstructure and texture by the use of particles [15]. The information about different and modern manufacturing methods is given an idea. The forces required for manufacturing process during operation. Author gives the theory and mathematical equation about the cold forging process. During punch and die operation how much force is required during the operation and stress and strain equation for cold manufacturing process [16]. The basic mechanisms of tribological wear due to tribological processes that occur during cold and hot forging process. Forging dies surface wear has a large effect on the product surface quality so it is important to reduce the wear intensity. The tribological wear processes that occur on the forging die surfaces is important for analyses of wear in die.

Friction model based on ball on disc tribometer is developed. The friction model is verified by using double action extrusion test. The FE production and experiment have been obtained in terms of extrude length and steady state extrusion load having good agreement between them indicates ball on disc test is effective way of characterizing the friction for bearing channel for hot steel dies [18]. Forward and backward extrusionprocess are used in the forging industry and combination of forward and backward extrusion occurs during the forging of complicated shapes. Steady combined forward and backward extrusion test introduce to calculate friction factor in complicated parts. In this test, decreasing required ductility of the testing materials. Friction factors by this combined model were measured for five different lubricants and for dry friction in the cold extrusion of steel. The results of the conventional ring compression test were used in the extrusion analysis [19].

Temperature, coating and lubrication are the main tribological characteristics in hot forming and the tribo meters for different metal in forming processes at elevated temperatures are mainly based on the experimental work [20]. Principle of the ring compression test, examples of practical applications and various methods for measuring the friction for use in subsequent analysis are shown. Sticking mechanism and how to avoid them by surface treatment of the dies is included in this paper [21]. Servo press is used to form holes in deep drawing operation. With high aspect ratio by using pulse punch ram motion is applied to form combined to form forward and extrusion test. The shear friction factor of aluminium is calculated by analyzing material flow. The suggested forming method with suitable pulse punch motion is confirmed to decrease the friction from the coefficient of shear friction of 0.4 to lower than 0.2 [22]. Reduction in areathe right lubrication selection methodology is exposing through a cold forward extrusion process. Friction test is performed according to physical and mechanical contact conditions. Three different criteria are proposed to characterize the performances, the friction coefficient, having the two types of surface defects and the result in roughness of the specimen. The forward extrusion test is selected by optimum presence of lubricating oil [23].Machining, drawing, rolling, extrusion, abrasive processes and processing at the micro and nano scales focuses on tribology in manufacturing processes. The view point of understanding the fundamentals of sliding friction in metal forming processes and the use of lubricants to study friction in manufacturing processes such as with the role of tribology to maximize productivity and reduces costs connected with manufacturing processes [24].Because of high frictional contact between the metals in break system shows the thermal changes. In Pin-on-disc tribometer is built to find the temperature rise during the sliding operation using experimental and numerical calculations [25]. The tribological behavior of different types of cold forging operation such as forging, rolling, drawing, extrusion studied and Friction factors such as stress, coefficient of friction are calculated by coloumb friction model. Definition and clear idea about how wear factor affect to operations through adhesive, abrasive and fatigue phenomenon in the operation.It shows characteristics behavior of hot rolling and wire drawing tribological aspects. It gives the clear idea about forging process and tribological condition of material. How material behave during metal forming process [26]. Steel can be cold forged but its recrystallization temperature difficult to maintain. Aluminium and brass alloys are easy to cold forged and its self heating temperature can be maintained. Most affecting chemical in aluminium alloy series 6xxx is magnesium and silicon. And in 7xxx series is Magnesium and zinc. Friction in cold forging is less than hot forging because of less material loss.

II. Forging Process

Forging is the controlled plastic deformation of materials through compressive stresses applied through dies. Tribology in forging is concerned with friction, wear, lubrication, and surface generation it is universal statement. It is carried out either hot or cold. Forging is usually classified as open die where flat or other simple tooling shapes are used and closed or impression die forging where quite intricate dies can be used. Open die forging is always performed hot, while closed die forging may occasionally be done on cold work pieces. Elevated temperatures are generally used in forging to reduce a materials elastic modulus and flow stress and increase its ductility. Hot forging is done at temperatures above recrystallization temperatures i.e. 0.6 Tm or above, where Tm is melting temperature. Warm forging is done in the temperature between 0.3 Tm to 0.5 Tm. Cold forging is done at below recrystallization temperature it has advantages such as good surface finish, high strength and greater accuracy. Hot forging needed lower load because of flow stress gets reduced at higher temperatures. The aim of this work is to simulate the cold forging process to estimate the tribological characteristic during the process. In open die forging the work piece is compressed between two plats. Upsetting is an open die forging in which the billet is subjected to lateral flow by the flat die and punch. Because of friction the material flow throughout the thickness is non uniform. Open die forging is mainly classified into three main types cogging, fullering and edging. Impression die forging is work like closed die forging. Impressions are made on a pair of dies.

These impressions are moved to the work piece during deformation. Flash has got a very important role during deformation of the work piece inside the die cavity. Because of high length to thickness ratio of the flash gutter and friction in the die and flash is very high. The material in the flash gap is subjected to high pressure,

that there is high resistance to flow. Another benefit of cold forging is the lack of grain growth and therefore perfectly aligned to the shape of the part metal grains with an exceptionally strong and resistant surface. There are a number of friction sources, namely adhesion, abrasion, lubricant shear, hysteresis, etc. Adhesive friction arises due to the shearing of micro welds at contacting asperities between tooling and workpiece. It can be best understood by noting that even in elastically loaded machinery elements, the pressure at contacting asperities is very large and is sufficient to cause cold welding. With metal forming, the pressures are sufficient to cause plastic deformation and nascent surface generation and are often at elevated temperatures, so adhesion between workpiece and tooling asperities is unavoidable if the lubrication system is not properly designed.

III. Result and Discussion

Forging pressure for cold forging operations studied from various formulas and used to calculate cold forging force. We can apply the von Mises yield criterion for the compression. Assuming that all the three stresses are principal stresses, we find thatfor sliding Phenomenon

$\tau = \mu \times \sigma flow$ ……(1)

$p = \sigma flow\ (1 + \frac{2\mu R}{3h})$ ……..(2)

μ = coefficient of friction

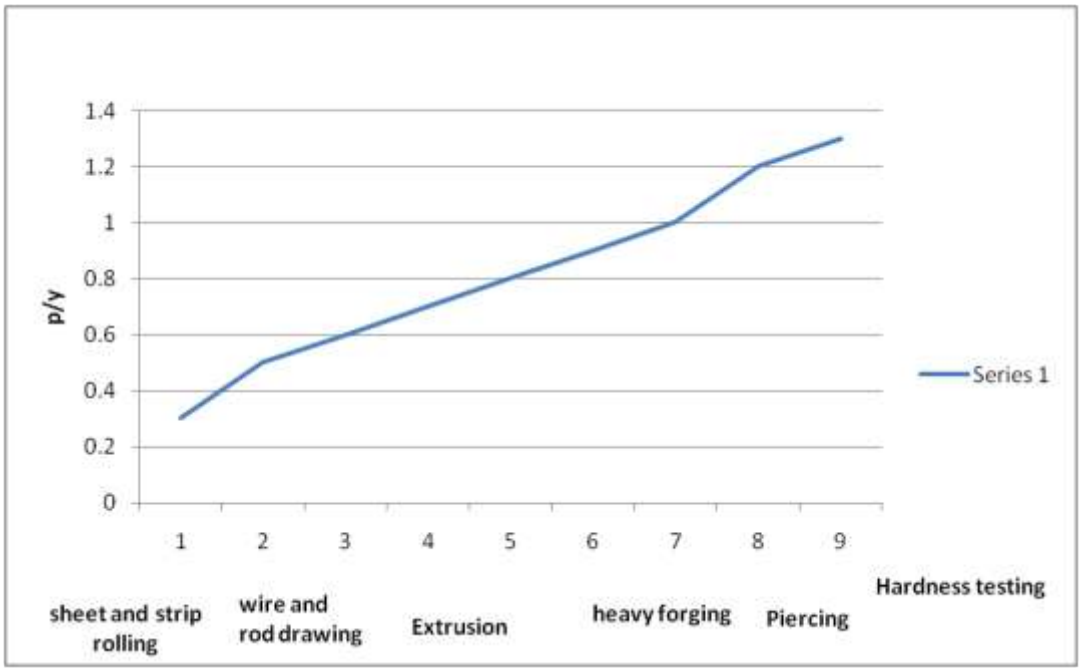

Fig: 1- Coefficient of friction range for cold forging process

Table:1- Coefficient of friction values for various forming operations

Process	μ = Cold forming	μ = Hot forming
Forging	0.05 to 0.1	0.2 to 0.7
Drawing	0.05 to 0.1	0.1 to 0.2
Rolling	0.03 to 0.1	0.1 to 0.2
Sheet metal forming	0.05 to 0.1	

Fig:1 shows the coefficient of friction value for different cold forging operations. As above diagram shows the deformation pressure increases with increase in deformation zone geometry, due to increases in redundant work. Table: 1 shows the coefficient of friction values for cold and hot forming operations.

IV. Conclusion

In this paper show the wear and friction factor affects on cold forging process simulated by different methods. To calculate the values such as coefficient of friction, frictional shear stress by numerical and experimental calculations done by mathematical model. Different cold forging process behaves with different load conditions and shows tribological properties. Al6082 have frictional stress value calculated from friction model by considering flow stress at different temperature range.

Conflict of interestthe authors declare that there is no conflict of interests regarding the publication of this paper.

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