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EXPERIMENTAL INVESTIGATION OF LUBRICATION SYSTEM OF MILLING OPERATION ON ALUMINUM ALLOY 6060

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ABSTRACT: *In this project work an investigation into Minimum Quantity Lubricant (MQL) and wet machining in milling processes of AISI 6060 Aluminum work material has been carried out with the main objective is to determine the effect of lubrication conditions on the surface roughness. Three other parameters were also consider in this study; feed rate (FR), depth of cut (DOC) and cutting speed(CS).The levels each parameter had been selected is four levels. The ranges of feed rate 0.05mm/min,0.15mm/min,0.20mm/min and 0.25mm/min depth of cut used were 0.2mm, 0.4mm,0.6mm and 0.8mm whereby the cutting speed values were 600mm/min,800mm/min,100mm/min and 1200mm/min.*

I. INTRODUCTION

1.1 MACHINING ALUMINUM AND ALUMINUM ALLOYS

Traditional machining operations such as turning, milling, boring, tapping, sawing etc. are easily performed on aluminum and its alloys. The machines that are used can be the same as for use with steel, however optimum machining conditions such as rotational speeds and feed rates can ony be achieved on machines designed for machining aluminum alloys.

The specific properties of aluminum alloys must be considered:

a) Their density allows high speeds of rotation and translation as the inertia of aluminum alloy swarf is less than that of steel,
b) Their modulus of elasticity - one third that of steel - requires appropriate chucking and clamping arrangements that avoid deformation and distortion,
c) Their thermal conductivity assists heat dissipation. Given the high rate of chip removal, the heat generated by the machining process is taken away with the swarf without having the time to diffuse into the metal,
d) A coefficient of linear expansion that is twice that of steel makes heating undesirable if criteria of dimensional stability are to be satisfied.

Unlike steel, there is no need to provide heat treatment of the “stress-free annealing” type during machining.

1.2 CUTTING FORCE:

The specific cutting force needed to machine aluminum alloys is far less than is required for steel. For the same section of swarf, the force is one third of that required for aluminum than for low-carbon steel, so it follows for the same cutting force, chip removal is three times higher with aluminum alloys such as 2017A whose level of mechanical properties is on a par with that for low-carbon steel.

1.3 TOOLING:

The geometry of tools must be specially designed for use with aluminum alloys. Edges must be very keen and cutting tool faces must be highly polished so as to remove swarf efficiently and prevent it from bonding to the tool. Cutting angles will depend on the alloys. The rake angle of the cutting edge must be greater than 6^{o} and can attain 12^{o}.

The use of tools tipped with TiN or TiCN by PVD deposition only is highly advisable for machining alloys that contain no more than 7% silicon. (Angle of 15^{o} for diamond coated carbide (CVD Diamond) tools and polycrystalline diamond (PCD) tools.) Provided tooling is designed for aluminum alloys, tool life is much longer than for machining steels, all other factors being equal.

All wrought alloys can be machined very rapidly. With special machines (high speed spindles) the machining speed can attain (and exceed) 2 to 3000 m/min with 2000 and 7000 series alloys. Thus for a 12 mm diameter tool the cutting rate can be as high as 50,000 r.p.m. for a feed rate of 10 m/min. With very high cutting rates it is possible to obtain very thin sheet and much lighter components.

1.4 RATE OF ADVANCE AND DEPTH OF CUT:

Given the low modulus of aluminum alloys, high rates of advance are not advisable, even for rough machining. The feed rate should be limited to 0.3mm per revolution. For finishing operations the rate of advance will be determined by the specified surface roughness for the finished product. The depth of cut will depend on the specified accuracy.

1.5 MILLING:

1.5.1 Definition:

Milling is the process of machining the flat, curved or irregular surface by feeding the work piece against a rotating cutter containing a number of cutting edges. The milling machine consist of basically of a motor driven spindle which mounts and revolves the milling cutter and a reciprocating adjustable work table , which mount and feeds the work piece. Most of the milling machine haveself-contained electric drive motors, coolant systems, variable spindle speeds and power operated table feeds.

- Milling (grinding), the process of grinding grain or other materials in a mill
- Milling (machining), the process of machining metal via non-abrasive rotary cutting
- removing asphalt pavement with a milling machine
- Photochemical milling (disambiguation)
- a part of the leather crusting process
- a type of boxing session used in training by the British Army

Milling also refers to the process of breaking down, separating, sizing, or classifying aggregate material. For instance rock crushing or grinding to produce uniform aggregate size for construction purposes, or separation of rock, soil or aggregate material for the purposes of structural fill or land reclamation activities. Aggregate milling processes are also used to remove or separate contamination or moisture from aggregate or soil and to produce "dry fills" prior to transport or structural filling.

1.5.2 Types of milling machine:

Basically, Milling machines are classified as vertical and horizontal machines.
These machines also classified as

- Knee type machine
- Manufacturing or bed type machine
- Planner type machine

1.5.3 Milling cutters:

Milling cutters are usually made of high-speed steel available in a great variety of shapes and sizes for various purposes. You should know the names of the most common classifications of cutters, their uses, and, in a general way, the distance between like or sizes best suited to the work at hand
Classification of milling cutters:

- Helical milling cutter
- Metal slitting saw milling cutter
- Side milling cutter
- End milling cutter
- Angle milling cutter

- T-slot milling cutter
- Gear hob
- Woodruff key slot milling cutter
- Concave & convex milling cutter
- Corner rounding milling cutter
- Special shaped formed milling cutter

1.6 LUBRICATION:

1.6.1 Definition

Lubrication is the process, or technique employed to reduce wear of one or both surfaces in close proximity, and moving relative to each other, by interposing a substance called lubricant between the surfaces to carry or to help carry the load (pressure generated) between the opposing surfaces. The interposed lubricant film can be a solid, (e.g. graphite, MoS_2)[1] a solid/liquid dispersion, a liquid, a liquid-liquid dispersion (a grease) or, exceptionally, a gas.

Lubrication can also describe the phenomenon where such reduction of wear occurs without human intervention (hydroplaning on a road). As the load increases on the contacting surfaces three distinct situations can be observed with respect to the mode of lubrication, which are called regimes of lubrication. The science of friction, lubrication and wear is called tribology.

1.6.2 Function of lubrication

Lubrication is a very important factor in the machining of aluminum alloys, and has three main functions:

- cooling to dissipate the heat generated by cutting and friction,
- preventing swarf from bonding to the tools,
- removing swarf from the point of machining.

Although three types of lubrication are available- spray mists, full cutting oil, and oil emulsions- the latter option is the most common because this method dissipates more calories per kilo of lubricant, of the order of 200 kg/J. Cutting fluids reduce friction and aid tapping operations. Lubricant spray mists are not advisable where a lot of heat has to be dissipated.

The composition of cutting fluids must meet other requirements:

- they must be compatible with aluminum alloys, they must not cause stains or surface corrosion (no chlorine or sulfur compounds,
- they must have an anti-bacterial action to prevent fungal growth,
- they must be environmentally friendly.

1.6.3 Types of lubrication

Fluid film lubrication

Fluid film lubrication is the lubrication regime in which through viscous forces the load is fully supported by the lubricant within the space or gap between the parts in motion relative to one another (the lubricated conjunction) and solid–solid contact is avoided.[2]

Hydrostatic lubrication

Hydrostatic lubrication is when an external pressure is applied to the lubricant in the bearing, to maintain the fluid lubricant film where it would otherwise be squeezed out.

Hydrodynamic lubrication

Hydrodynamic lubrication is where the motion of the contacting surfaces, and the exact design of the bearing is used to pump lubricant around the bearing to maintain the lubricating film. This design of bearing may wear when started, stopped or reversed, as the lubricant film breaks down.

Elasto hydrodynamic lubrication:

Elasto hydrodynamic lubrication, Mostly for nonconforming surfaces or higher load conditions, the bodies suffer elastic strains at the contact. Such strain creates a load-bearing area, which provides an almost parallel gap for the fluid to flow through. Much as in hydrodynamic lubrication, the motion of the contacting bodies generates a flow induced pressure, which acts as the bearing force over the contact area. In such high pressure regimes, the viscosity of the fluid may rise considerably. At full elastohydrodynamic lubrication the generated lubricant film completely separates the surfaces. Contact between raised solid features, or ***asperities***, can occur, leading to a mixed-lubrication or boundary lubrication regime.

Boundary lubrication

Boundary lubrication (also called boundary film lubrication),The bodies come into closer contact at their asperities; the heat developed by the local pressures causes a condition which is called stick-slip and some asperities break off. At the elevated temperature and pressure conditions chemically reactive constituents of the lubricant react with the contact surface forming a highly resistant tenacious layer, or film on the moving solid surfaces (boundary film) which is capable of supporting the load and major wear or breakdown is avoided. Boundary lubrication is also defined as that regime in which the load is carried by the surface asperities rather than by the lubricant.[3]

Besides supporting the load the lubricant may have to perform other functions as well, for instance it may cool the contact areas and remove wear products. While carrying out these functions the lubricant is constantly replaced from the contact areas either by the relative movement (hydrodynamics) or by externally induced forces.

Lubrication is required for correct operation of mechanical systems pistons, pumps, cams, bearings, turbines, cutting tools etc. where without lubrication the pressure between the surfaces in close proximity would generate enough heat for rapid surface damage which in a coarsened condition may literally weld the surfaces together, causing seizure.

1.6.4 Lubricants

A lubricant is a substance introduced to reduce friction between moving surfaces. It may also have the function of transporting foreign particles. The property of reducing friction is known aslubricity. (Slipperiness)
A good lubricant possesses the following characteristics:

- High boiling point
- Low freezing point
- High viscosity index
- Thermal stability
- Hydraulic Stability
- Demulsibility
- Corrosion prevention
- High resistance to oxidation

One of the single largest applications for lubricants, in the form of motor oil, is protecting the internal combustion engines in motor vehicles and powered equipment.

Typically lubricants contain 90% base oil (most often petroleum fractions, called mineral oils) and less than 10% additives. Vegetable oils or synthetic liquids such as hydrogenated polyolefins,esters, silicones, fluorocarbons and many others are sometimes used as base oils. Additives deliver reduced friction and wear, increased viscosity, improved viscosity index, resistance tocorrosion and oxidation, aging or contamination, etc.

Lubricants such as 2-cycle oil are added to fuels like gasoline which has low lubricity. Sulfur impurities in fuels also provide some lubrication properties, which has to be taken in account when switching to a low-sulfur diesel; biodiesel is a popular diesel fuel additive providing additional lubricity.

Non-liquid lubricants include grease, powders (dry graphite, PTFE, Molybdenum disulfide, tungsten disulfide, etc.), PTFE tape used in plumbing, air cushion and others. Dry lubricants such as graphite, molybdenum disulfide and tungsten disulfide also offer lubrication at temperatures (up to 350 °C) higher than liquid and oil-based lubricants are able to operate. Limited interest has been shown in low friction properties of compacted oxide glaze layers formed at several hundred degrees Celsius in metallic sliding systems, however, practical use is still many years away due to their physically unstable nature.
Lubricant manufacturers can supply products to match all types of machining.

Enormous efforts to reduce the use of lubricant in metal cutting are being made from the viewpoint of cost, ecological and human health issues. Minimal quantity lubrication (MQL) can be considered as one of the solutions to reduce the amount of lubricant and is being studied for practical applications, especially aluminum alloy cutting.

Its application scope is, however, uncertain because the MQL lubrication mechanism has not been sufficiently elucidated. Recently, by model experiments, Wakabayashi et al. suggested that ester supplied onto a rake face of a tool decomposes to carboxylic acid and alcohol and its carboxylic acid forms a chemisorbed film with lubricity . In actual conditions with high machining load, however, existence of this kind of boundary film is uncertain. Therefore an investigation into the lubrication mechanism of MQL in actual conditions must be essential. Recently two of the authors proposed a new type of MQL in which a minimal amount of oil is supplied into a cutting

II. LITERATURE SURVEY

2.1 RESEARCH WORKS ON ALUMINIUM ALLOY

Szablewsk et al (2000) investigated the high speed machining of aluminium silicon alloy castings has gained significant interest from automotive industry involved in the development of the new generation of lightweight vehicles. This paper investigates the influence of workpiece microstructure, namely the secondary dendritic arm spacing (SDAS), tool material and geometry on tool wear mechanisms, cutting forces and surface integrity when face milling at cutting speeds of 5,000 m min-'. It was found that the SDAS is the parameter with the main influence on tool wear rate; higher SDAS values require polycrystalline diamond (PCD) tooling due to the lower wear rates when compared with carbide tools. Finite Element Analysis (FEA) was employed to study the influence of tool wear on temperature and shear stress distribution in the workpiece material.

Balakrishna and yung (2001) hav done research and it is concerned with the analytical and experimental study on the high-speed face milling of 7075-T6 aluminum alloys with a single insert fly-cutter. The results are analyzed in terms of cutting forces, chip morphology, and surface integrity of the workpiece machined with carbide and diamond inserts. It is shown that a high cutting speed leads to a high chip flow angle, very low thrust forces and a high shear angle, while producing a thinner chip. Chip morphology studies indicate that shear localization can occur at higher feeds even for 7075-T6, which is known to produce continuous chips. The resultant compressive residual stresses are shown for the variation of cutting parameters and cutting tool material. The analysis of the high-speed cutting process mechanics is presented, based on the calculation results using extended oblique machining theory and finite element simulation.

Kelly and Coterbell (2001) discussed about the use of lubricants in machining. Industry and research institutions are looking for ways to reduce the use of lubricants because of ecological and economical reasons. While there are established applications of dry turning and milling, dry drilling presents special difficulties due to the problems of swarf clearance from the drill flutes and consequent heat buildup and clogging. The rising costs associated with the use and disposal of cutting fluid have forced engineers to concern themselves more intensively with questions of cooling technology. Included in these concerns are topics such as cooling lubricant monitoring, cleaning and disposal together with exploring the potential for cooling lubricant reduction and avoidance. This work presents an investigation into various methods of cutting fluid application with the objective of deriving the optimum cutting condition for the drilling of cast aluminium alloys. A series of tests were carried out using various methods of cutting fluid application, under varying conditions of cutting speed and feed

Itoigawa (2005) et al studied the effects and mechanisms in minimal quantity lubrication are investigated by use of an intermittent turning process. Especially a difference between minimal quantity lubrication (MQL) and MQL with water is inspected in detail to elucidate boundary film behaviour on the rake face. In order to obtain a good cutting performance by MQL it is considered that two things are needed: (1) an appropriate lubricant, such as a synthetic ester, to form a strong boundary film and (2) a chilling effect to sustain strength of the boundary film.

Gwo (2005) studied the burr formation mechanisms in face milling process, and to investigate the influence of cutting conditions on burr formation in face milling of aluminum alloys. The fly milling cutter is used to carry out single-tooth face milling tests. Three aluminum alloys were tested: Al 1100 (cold drawn), Al 2024-T4 and Al 6061-T6. It is found that the burr geometry is strongly dependent upon the in-plane exit angle. Five types of burrs were observed in the experiments: knife-type, wave-type burr, curl-type, edge breakout and secondary burr. Formation mechanisms of each type of these burrs are discussed in details. The relationship between their existence and the machining condition is indicated. The machining guideline in face milling is given at the end of the paper to reduce burr size effectively through the formation of secondary burr.

Tang et al (2008) dealt with milling of aluminum alloy .The machining processes could induce residual stresses that enhance or impair greatly the performance of the machined component. Machining residual stresses correlate very closely with the cutting parameters and the tool geometries. In this paper, the effect of the tool flank wear on residual stresses profiles in milling of aluminum alloy 7050-T7451 was investigated. In the experiments, the residual stresses on the surface of the workpiece and in-depth were measured by using X-ray diffraction technique in combination with electro-polishing technique. In order to correlate the residual stresses with the thermal and mechanical phenomena developed during milling, the orthogonal components of the cutting forces were measured using a Kistler 9257A type three-component piezoelectric dynamometer. The temperature field of the machined workpiece surface was obtained with the combination of infrared thermal imaging system and finite element method. The results show that the tool flank wear has a significant effect on residual stresses profiles, especially superficial residual stress. As the tool flank wear length increases, the residual stress on the machined surface shifts obviously to tensile range, the residual compressive stress beneath the machined surface increases and the thickness of the residual stresses layer also increases. The magnitude and distributions of the residual stresses are closely correlated with cutting forces and temperature field. The three orthogonal components of the peak cutting forces increase and the highest temperature of the machined workpiece surface also increases significantly with an increase in the flank wear. The results reveal that the thermal load plays a significant role in the formation of the superficial residual stress, while the dominative factor that affects thickness of residual stresses layer is the mechanical load in high-speed milling aluminum alloy using worn tool.

ImedZaghbani (2008)In this study, a new analytical cutting force model was developed for the Dry High Speed Milling of aluminium alloys. The proposed model requires only work-material properties and cutting conditions to estimate the cutting forces and the temperature during endmilling processes. The transformation from orthogonal-to-oblique cuttingwas used to study the end-milling operation. A new method, which includes a Needleman-Lemonds constitutive equation, was introduced to imultaneously determine the average shear stress and the cutting temperature in the primary and secondary shear zones. The model validation was performed by comparing the prediction for machining Al6061-T6 and Al7075-T6 aluminium to mechanistic model results and experimental results. The computed temperature resultswere compared to published data. A good agreementwas observed for both force and temperature results, for the investigated cutting conditions.

Dirk Biermann (2010) said that compliance with the quality requirements of components is essential for the functionality of the whole product. With respect to parts with face-milled faces, the surface quality and the shape of the workpiece edges are of great interest. Frequently, these faces take over the function of seal faces where high demands on the surface integrity and burr formation exist. To ensure the workpiece quality that is required, nowadays additional processes for deburring are often necessary. To avoid deburring, the modification of machining processes is a promising approach. In this study, the influence of process cooling on workpiece quality is investigated. Using this approach, two effects are expected. The cooling is used to minimize a reduction of flow stress generated from the process heat, which than leads to a lower formability. The second effect relates to the kinetic energy of the snow blast for deburring by deformation and breakage of the burrs. Using a process cooling with carbon dioxide, the surface quality is enhanced and the burr formation is minimized.

D. Apelian (2009)In modern manufacturing of metallic components, we must accept the premise that design dictates performance, and that the role of the designer is pivotal. Moreover, the designer must rely on databases and failure criteria that are robust and proven. However, as design dictates performance, performance itself is attained through alloy and process selection; both of which are quite interconnected and coupled with each other. Historically, new processes have been developed, but these have always been evaluated based on existing alloys rather than developing new alloys to take advantage of the processing attributes to optimize this coupling of alloy and process. During the last decade, we have witnessed the development of enabling tools that can be utilized to optimize alloy development, bring in measures to better control our processes and alloys, and in brief, tools that allow intelligent alloy development for specific performance metrics and processes.
In this World Wide Report, we first review the fundamentals of Al cast alloys as a primer, followed by a discussion of the various enabling tools available to the industry tools that were not available to the metal casting industry ten years ago or so. Specific case studies are presented and discussed to manifest the power of these enabling tools to improve and optimize alloy development.

VytautasOstasevicius et al (2013) discussed that ,this work studies the influence of high-frequency excitation of a cutting tool during end milling of workpieces made of difficult-to-cut metallic alloys. It is demonstrated that high-frequency vibrations superimposed onto the continuous movement of the tool lead to milling process stabilization with superior surface finish in comparison to conventional machining. A finite element model of the vibration milling tool was built and verified experimentally. The model treats the tool as an elastic pre-twisted structure (mill cutter) characterised by its natural vibration modes. The resonance frequencies of the axial vibration mode of cutters of two different lengths were predicted numerically and subsequently used for excitation of the vibration milling tool during cutting experiments. Qualitative and quantitative characterization of the surface quality of the machined stainless steel and titanium alloys was performed. Measurement results have confirmed that excitation of a specific tool mode is a prerequisite for achieving maximal efficiency of the vibration milling process. Statistical analysis of the collected roughness measurement data identified factors that most significantly contribute to the improved surface finish of the work pieces.
Keywords: vibration cutting, finite element model, pre-twisted cantilever, axial mode, roughness

Jurgita GRAŽEVIČIŪTĖ et al (2008) discussed taht,In many cases while treating low carbon, average carbon or alloyed steels and other hardly treated material, it is impossible to get particularly high-quality surface using finishing processing. In order to achieve this, vibration cutting is used, that is precise cutting technology, applied to get high quality ("specular") surfaces and it is characterized by high stability. Traditional cutting processes used for material treating sometimes are not attractive in such technological aspects as quality of finishing surface, cutting forces, wear of clearance surface of tool, tool durability, etc. For the latter technological purposes, particularly when treating workpieces with complicated profile, vibration cutting also may be used. To analyze the influence of the cutting modes to treatment process, first of all the theoretical methods are used, which allow describing physical process using computational methods and forecast it thus economizing human resources. The article presents experimental investigation which allows comparing classical milling process and milling process when tool is excited by high frequency vibrations. Also it presents FEM modelling of
milling process removing material chip (technological interaction of tool and work piece).

M.Dhananchezian(2009)Cutting temperature is the determining factor for other machinability indices of material. The conventional cutting fluids are ineffective in controlling the cutting temperature in the cutting zone. Cryogenic cooling is environmental friendly new approach for desirable control of cutting temperature. Current work involved the experimental study of the effect of cryogenic cooling on cutting temperature, cutting force, chip thickness and shear angle in the orthogonal machining of AISI 1045 steel and Aluminium 6061-T6 alloy. It has been observed that in cryogenic cooling method, the temperature was reduced to 19–28% and the cutting force was increased to a maximum of 15% then dry machining of AISI 1045 steel. In machining of Aluminium 6061-T6 alloy, the temperature was reduced to 27–39% and the cutting force was increased to a maximum of 10%.

Marcel Mandel & Lutz Krüger(2013) had done research that, The galvanic corrosion of a rivet joint combining an EN AW-6060-T6 aluminium sheet and a CFRP (carbon fibre reinforced plastic) laminate by an Almac®-coated self-piercing rivet was investigated electrochemically in a 5 wt% NaCl solution. The corrosion parameters of the joint components were separately determined by potentiodynamicpolarisation and were used for finite-element-method (FEM) simulations to analyse the galvanic corrosion behaviour at joint conditions. A critical distance for galvanic induced pitting corrosion at the aluminium alloy surface was determined by FEM and confirmed by an immersion test in the same environment

BogusławaAdamczyk-Cieślak et al (2011)in this paper that the results concerning the microstructural refinement of the industrial 6060 aluminium alloy processed by severe plastic deformation (SPD). The high level of plastic deformation was achieved using the three methods: hydrostatic extrusion (HE), equal channel angular extrusion (ECAE) and extrusion torsion (ET), which differed in the dynamics of the loading, intensity and homogeneity of the plastic strain field. Microstructure analyses were performed before and after SPD deformation using a transmission (TEM) and a scanning electron microscope (SEM). The refined microstructures were examined qualitatively and quantitatively by the stereological methods and computer image analyses. The microstructure of the industrial 6060 aluminium alloy after deformation was characterized by an average grain size of about 0.4 μm. The results show that the precipitates strongly affect the degree of refinement and the mechanism of microstructural transformations. During the SPD, the second phase particles break apart and homogenize. The HE method generates the largest increase of the volume fraction of the small primary particles. Moreover, the HE process is most effective in reducing the primary particle size. During HE and ECAE processes the second phase precipitates dissolve partially and change their shape.

T. Kayser et al(2010) said that,The purpose of this work is the experimental investigation and statistical characterization of the grain microstructure and its development in aluminum alloys during hot extrusion. To this end, electron backscatter diffraction (EBSD) data are utilized. Based on this data, properties like the grain morphology, mean grain size, or mean grain misorientation, can be derived with the help of data analysis and processing methods. In the current work, these are applied to the investigation and quantitative determination of the microstructural development in the aluminum alloy EN AW-6060 along a path in the center of a partly extruded billet. With increasing deformation, it is observed that the mean grain size continually decreases due to dynamic recrystallization (CRX). As expected, grain alignment along the extrusion direction tends toward 〈1 1 1〉 with increasing deformation, and misorientation tends to decrease.

N. Coniglio et al (2009)discussed that, weld metal microstructure for alloy 6060 aluminum welds, made using the gas-tungsten arc process and alloy 4043 filler metal, has been characterized using optical metallography, EPMA microprobe analysis, SEM/EBSD and STEM/EDX electron microscopy, and single-sensor differential thermal analysis (SS-DTA). In addition, alloy 6060 castings were solidified at variable cooling rates approaching that of welding, to provide a reference for comparison with weld microstructure. It was found that a major change in cast microstructure occurs at cooling rates higher than 27 K/s resulting in a structure similar to that observed in weld metal. Rapid cooling is believed to favor low temperature solidification reactions that normally would be achieved only at higher silicon content. Accordingly, additions of 4043 filler metal that increase the weld metal silicon content have only limited affect on weld solidification range and microstructure. This has direct implications regarding how 4043 filler additions improve weldability and weld quality.

N. Tabrizian et al (2010) had a research that the,Influence of cold forging, and subsequent heat treatment and diamond turning on optical quality of anodized film on 6060 (AlMgSi) alloy was investigated and compared with microstructural changes. Heat treatment of the samples was carried out either prior to forging, post-forging, or both. The surface of the forged material was then diamond turned to a mirror like finish. The diamond turned samples were subsequently anodized in a sulphuric acid bath. The microstructure of the samples was analysed using optical microscopy (LOM), scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX). Colour/brightness measurements were carried out using CIE Lab system. An optical method was used to measure the thickness of the oxide film and roughness of the surface was measured before and after anodizing using stylus, a mechanical instrument, and bidirectional reflection distribution function (BRDF), an optical instrument. Results indicated that the post-forging heat treatment had a great influence on the appearance of the anodized layer, which was also a function of the deformation introduced prior to heat treatment. The effect was assumed to be attributed to the change in microstructure, especially the distribution and the amount of the intermetallic particles such as elemental Si and Mg_2Si. Roughness of the oxide film was also found to be a function of the heat treatment and deformation condition.

Mohamed Merzoug et al(2010)The friction stir welding is a process which made improvement in the light construction industries. The application of this new process lies in the capacity to assemble alloys of aluminium and more obviously with alloys which are not easily weldable alloys by the traditional processes. In our study, we centered the tests on the description of the significant parameters of process FSSW (friction stir spot welding) which will be at the origin of the realization of the weld bead. This experimental approach let us notice that the shape of the tool and in particular the pawn has a great influence on the mechanical resistance of the joint of welding. This is because of the heat gradients and mechanical undergone by material during welding. The importance of these phenomena depends on the same time on the nature of material and the choice on the parameters (geometry, positioning, tool rotating, penetration depth and the force applied of the pin and the shoulder).

J.H Nordlien et al(2002)Structure and chemistry of zirconium-titanium base conversion layers were characterised as a function of immersion time in the aqueous conversion bath to understand the mechanism of film formation. Characterisation was performed by glow discharge optical emission spectroscopy, scanning electron microscopy and transmission electron microscopy. Preferential nucleation of the zirconium-titanium oxide film and its growth occurred on and around intermetallic particles, resulting in reduced cathodic activity of the particles. Passivation of the cathodes in this manner constituted a limitation in the formation of a good quality conversion layer.

III. EXPERIMENTAL WORK

3.1 Methodology

The objective the experimental work is to investigate the Minimum Quantity Lubricant (MQL) and wet machining in milling processes of aluminum alloy 6060.Aluminum work material with the main objective is to determine the effect of lubrication conditions on the surface roughness. Three other parameters were also consider in this study are as follows:

- Feed rate (FR),
- Depth of cut (DOC)
- Cutting speed (CS).

3.2 EXPERIMENTAL SET UP

Based on observation, figure 3.1 shows the MQL machining using a very small amount compared to the wet lubricant using higher amount. Figure 2 shows the condition of wet machining. The ways to control the MQL and wet machining are adjust the valve to minimum.

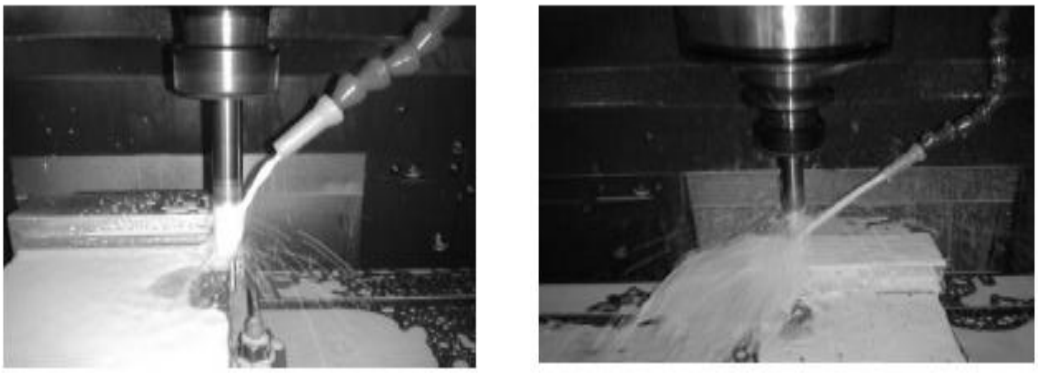

Figure 3.1 (a) MQL Machining **(b) Wet Machining**

MQL refers to the use of cutting fluids of only a minute amount typically of a flow rate of 50 500 ml/h which is about three to four orders of magnitude lower than the amount commonly used in flood cooling condition. (MQL) in machining is an alternative to completely dry or flood lubricating system, which has been considered as one of the solutions for reducing the amount of lubricant to address the environmental, economical and mechanical process performance concerns.

Wet machining refers use a large quantities of lubricants. The wet machining can reduce the heat between the material surface and tools surface. In wet machining, the role of cutting fluids is transports the chips away from the cutting zone, at the same time cooling the chips and keeping dust and small particulates in liquids rather than in the air .

3.3 DESIGN OF EXPERIMENTS

Taguchi Method was proposed by Genichi Taguchi, a Japanese quality management consultant. The method explores the concept of quadratic quality loss function and uses a statistical measure of performance called signal-to-noise (S/N) ratio, Antony, 2001). It is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized (Peace, 1993). The optimal setting is the parameter combination, which has the highest S/N ratio. Based on the signal-to-noise (S/N) analysis, the signal-to-noise (S/N) ratio for each level of process parameters are computed. Larger S/N ratio corresponds to better performance characteristics, regardless of their category of performance. It means that the level of process parameters with the highest S/N ratio corresponds to the optimum level of process parameters.

Taguchi method is usually used in an analysis that uses a lot of factor low than two will use the factorial design. When the total factors have been more than two, the number of experiment also will increase, and then the solution will be used

Taguchi method. The flow of process when analysis by using Taguchi method.

The first step before using the technique Design of Experiment (DOE) knew how many factors and level. Table 3.1 shown the factor and level had been decided. Actually, method of Taguchi has been be used if the factor has more than two to be
able to reduce the number of the experiment.

Table 3.1 Factors and Levels

FACTORS	**LEVELS**			
	1	2	3	4
CS	600	800	1000	1200
DOC	0.05	0.15	0.20	0.25
FR	0.1	0.2	0.3	0.4

After identifying the number of factors and level, orthogonal array of methods used for the experiment to knew the total of experiment. The total should be known in two ways, namely using a table or MINITAB software. In this experiment L16 has been used after recommended by orthogonal array based on the three factors and four levels. Table 3.2 shows the total number experiment has been conducted.

3.4 OPTIMIZATION

Process optimization is the discipline of adjusting a process so as to optimize some specified set of parameters without violating some constraint. The most common goals are minimizing cost, maximizing throughput, and/or efficiency. This is one of the major quantitative tools in industrial decision making.
When optimizing a process, the goal is to maximize one or more of the process specifications, while keeping all others within their constraints.
Fundamentally, there are three parameters that can be adjusted to affect optimal performance. They are:

- Equipment optimization

The first step is to verify that the existing equipment is being used to its fullest advantage by examining operating data to identify equipment bottlenecks.

- Control optimization

In a typical processing plant, such as a chemical plant or oil refinery, there are hundreds or even thousands of control loops. Each control loop is responsible for controlling one part of the process, such as maintaining a temperature, level, or flow.
Finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. In comparison, maximization means trying to attain the highest or maximum result or outcome without regard to cost or expense. Practice of optimization is restricted by the lack of full information, and the lack of time to evaluate what information is available (see bounded reality for details). In computer simulation (modeling) of business problems, optimization is achieved usually by using linear programming techniques of operations research. See also satisficing.

Table 3.2 Taguchi's L-16 series of Experiments

Sl.No	**CS**	**DOC**	**FR**
1	600	0.2	0.05
2	600	0.4	0.15
3	600	0.6	0.2
4	600	0.8	0.25
5	800	0.2	0.15
6	800	0.4	0.05
7	800	0.6	0.25

8	800	0.8	0.2
9	1000	0.2	0.2
10	1000	0.4	0.25
11	1000	0.6	0.05
12	1000	0.8	0.15
13	1200	0.2	0.25
14	1200	0.4	0.2
15	1200	0.6	0.15
16	1200	0.8	0.05

IV. SURFACE ANALYSIS

4.1 SURFACE FINISH DEFINITIONS

a) **Ra:** Ra is the arithmetic average of the absolute values of the roughness profile ordinates. Also known as Arithmetic Average (AA), Center Line Average (CLA). The average roughness is the area between the roughness profile and its mean line, or the integral of the absolute value of the roughness profile height over the evaluation length
b) **Rz:** is the arithmetic mean value of the single roughness depths of consecutive sampling lengths. Z is the sum of the height of the highest peaks and the lowest valley depth within a sampling length.
c) **Cutoff c:**of a profile filter determines which wavelengths belong to roughness and which ones to waviness.
d) Sampling Length: is the reference for roughness evaluation. Its length is equal to the cutoff wavelength.
e) TransversingLength : is the over all length travelled by the stylus when acquiring the traced profile. It is the total of Pre-travel, evaluation length and post travel
f) Evaluation Length: is the part of the traversing length from where the values of the surface parameters are determined.
g) Pre-Travel: the first part of the traversing length.
h) Post-Travel: The last part of the traversing length

4.2 TYPES OF SURFACE ANALYSIS

Contact angle analysis
Light microscopy
X-ray Photoelectron Spectroscopy(XPS)
Fourier-Transform Infrared Spectroscopy(FTIR)
Electron microscopy – TEM , SEM
Scanning probe/ Atomic force microscopy (SPM/AFM)

Contact angle methods.

Measurement of the contact angle of a liquid test droplet on a solid surface is a straightforward technique revealing surface energetic information inaccessible by the surface spectroscopy. Although, this method represents perhaps one of the earliest methods used to investigate surface structure, it still yields very useful information . Contact angle measurements at biomaterials surfaces can be carried out by several different methods including:
The Wilhelmy plate method.
The sessile drop method .
The captive bubble method.

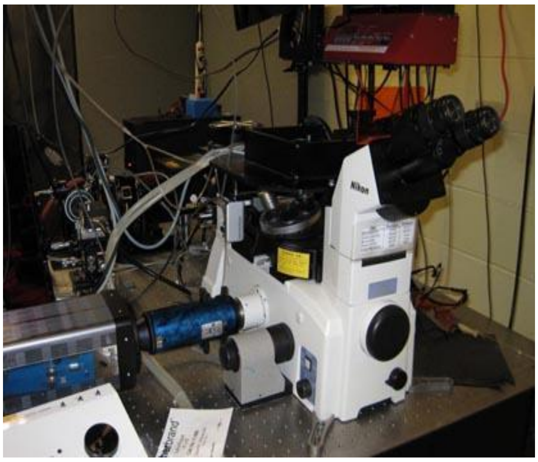

Figure 4.1 Contact angle analysis microscopy

A drop of fluid is placed on the biomaterial surface of interest, an equilibrium position is achieved, and the contact angle determined from the tangent associated with the drop/polymer surface. Contact angles, for immobile surfaces, are believed to be sensitive to the outermost 3–10 Angstroms of a surface [7]. Typically, in the biomaterials literature, contact angles are measured in air, utilizing a goniometer, using the sessile drop method with water as the test fluid. Contact angle analysis of control and modified polymeric materials can quickly provide valuable information about the relative hydrophilicity/ hydrophobicity of the surfaces. In addition, information about the hysteresis can be obtained when comparing contact angles obtained during increase, referred to as the advancing contact angle, and decrease, referred to as the receding contact angle, in the test droplet volume [74]. Figure 4.1 is contact angle analysis microscope.

X-ray Photoelectron Spectroscopy

X-ray Photoelectron Spectroscopy (XPS), also known as Electron Spectroscopy for Chemical Analysis (ESCA) is a widely used technique to investigate the chemical composition of surfaces. Fig 4.1 explain the spectrum of polydimethylsiloxane. Fig explains the electron emitted as a result of x-ray bombardment are separated by kinetic energy and counted by the detector.

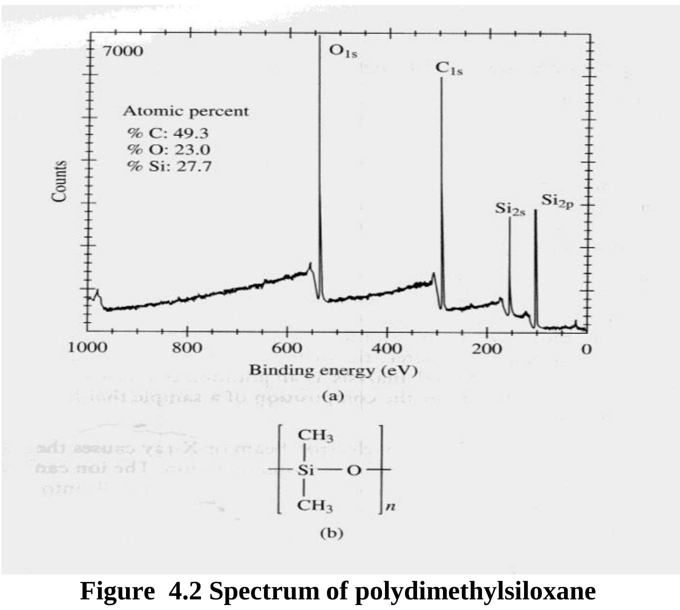

Figure 4.2 Spectrum of polydimethylsiloxane

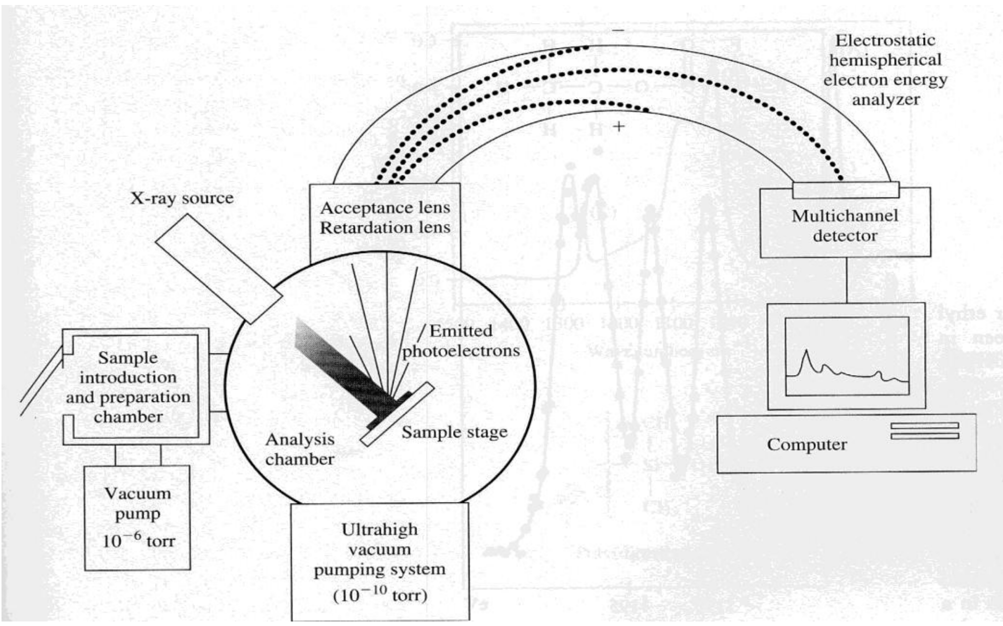

Figure 4.3 Electron emission

XPS can determine the types of carbon present by shifts in the binding energy of the C(1s) peak. These data show three primary types of carbon present in PET. These are (fig)CC, C-O, and O-C=O (Figure 4.4)

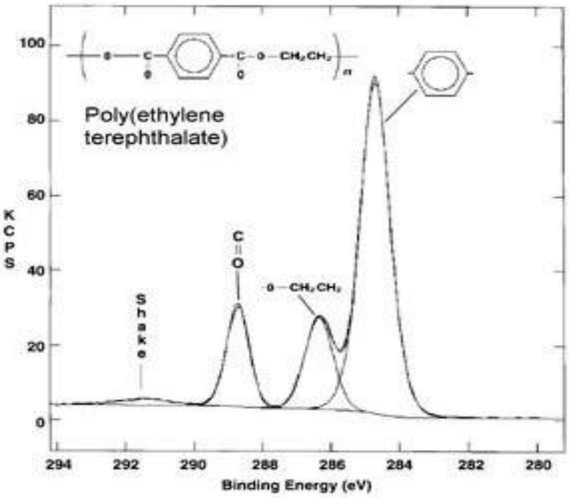

Figure 4.4 Spectrum of carbon

Fourier transform infrared spectroscopy

Infrared spectroscopy (IR) and attenuated total reflection Fourier transform infrared spectroscopy (ATR-FTIR). Infrared spectroscopy is used to obtain information about molecular structure by measuring the frequency of IR radiation needed to excite vibrations in molecular bonds Sample preparation is minimal involving application of the polymeric material of interest, in .lm form, onto a crystal element. Instrumentation is relatively inexpensive, and the resulting spectra provide chemical bonding information . Infrared spectroscopy in attenuated total reflection (ATR-FTIR) couples the analytical method of infrared spectroscopy with the physical phenomena of total internal reflection (i.e. reflection and refraction of electromagnetic radiation at an interface of two media having different indices of refraction) to restrict the analyzed volume on the surface region of the sample For this technique, the incident electromagnetic waves are entirely reflected back into the initial medium. The electromagnetic field is established in the second medium as represented by an evanescent wave due to diffraction at the edges of the incident radiation at the interface [73]. In attenuated total reflectance (ATR) sampling mode the second medium is the material to be studied, with the medium acting as the internal reflection element [24, 73]. Information about the molecular structure of the material, inter- and intra-molecular interactions, crystallinity , conformation (e.g. proteins) and orientation of molecules can be obtained through analysis of the infrared spectra [74, 75]. Although depth pro. les can be obtained using this technique, the XPS and SIMS techniques discussed earlier are considered much more surface sensitive.

Scanning electron microscopy and transmission electron microscopy

Scanning electron microscopy and transmission electron microscopy.Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) are commonly used for studying both the surface morphology of and the cellular response to biomaterials [11, 22]. These techniques make use of a primary beam of electrons that interact with the specimen of interest, in a vacuum environment, resulting in different types of electrons and electromagnetic waves being emitted. The secondary electrons ejected from the specimen surface are collected and displayed to provide a high-resolution micrograph.

SEM sample preparation involves (if proteins, cells, or tissue are present), followed by drying, attachment to a metallic stub, and then coating with a metal prior to data collection. The thin metallic coating, usually applied by sputter coating, is typically 20 to 30 nm in thickness. Common conductive metals used include gold, platinum, or gold/palladium alloy. It should be noted that the drying and metal coating processes used in the preparation of some polymeric materials might alter surface morphology, particularly those surfaces that may undergo changes in a hydrated environment. Upon insertion of the sample into the SEM, acquisition of the micrographs can usually be done fairly quickly allowing for a large number of images to be obtained with varying magnifications. Newer SEM models are reported to resolve in the nm range with magnifications in excess of 200 000£. Photographic prints, or computerized image acquisition, provide a permanent record. Micrographs typically included in the biomaterial literature depict images of 10 to 300 ¹m in length (see Fig. 4.5). In addition to imaging the surface morphology of polymeric biomaterials, the SEM can be combined with other analysis methods such as energy dispersive X-ray analysis (EDX) to determine elemental distribution (11) and IR and Raman spectroscopy to monitor surface modification procedures [23]. EDX results are typically obtained from a sampling depth on the order of micrometers, thus are more representative of the bulk material rather than the surface . TEM sample preparation involves xation (if proteins, cells, or tissue are present), processing, embedding and sectioning. Embedding media can include methacrylates, polyester and acrylic resins, although epoxy resins are now commonly used.

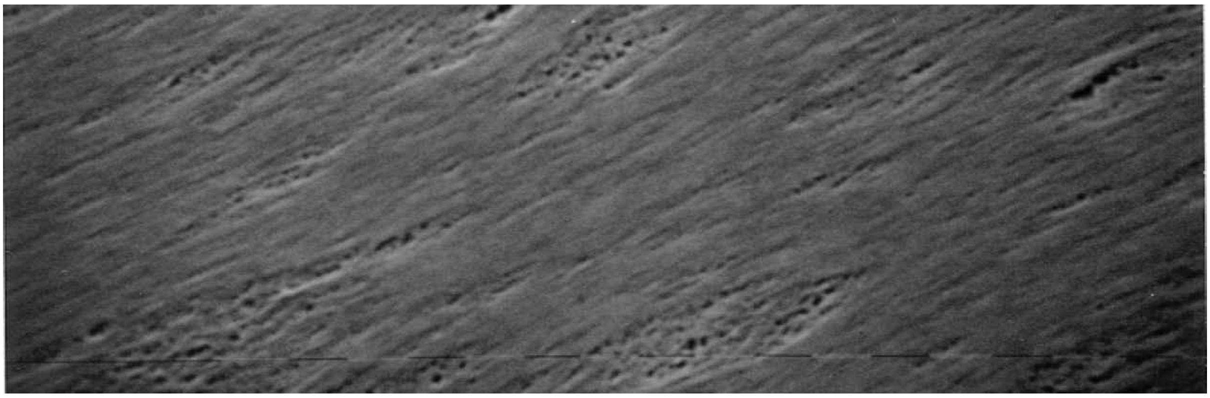

Figure 4.5 SEM image of bio material

Specimens are typically sectioned using a microtome and need to be very thin since electrons with an accelerating voltage of 100 kV will not penetrate specimens more than 1 ¹m thick. Good resolution and clarity of detail can normally be obtained with sample thicknesses on the order of 50–90 nm. A modest TEM can resolve in the sub nm range with magnifications considerably higher than 200 000£. It should however be noted that the embedding and sectioning processes used in the preparation of some polymeric materials may alter the polymeric material itself or the quality of the image obtained due to factors such as drying, thickness variations, wrinkling or compression. Micrographs typically included in the biomaterial literature depict images of 5 to 300 ^{1}m in length (see Fig. 4.6).

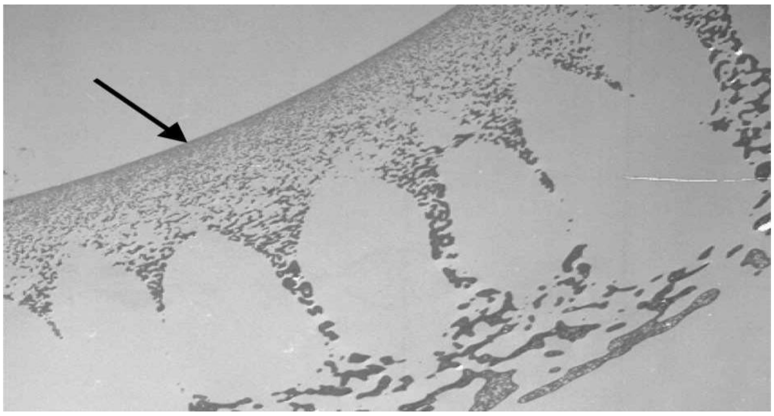

Figure 4.6 Microscopic image of bio-material

ATOMIC FORCE MICROSCOPY

AFM — contact mode. In contact mode, the AFM tip scans across a surface at very low force and is deflected by repulsive forces acting between the tip and the surface atoms. A photodiode detector monitors the deflections of a laser light reflected from the tip of a cantilever. A feedback loop maintains constant deflection of the cantilever, by vertically moving the scanner as it scans laterally across the surface. A computer stores the information and a topographic image with potentially atomic-scale resolution is generated. The forces at the tip are very small (0.01 to 1.0 N/m in air) and metal or hard polymeric surfaces are not generally damaged [7]. However, the lateral shear forces caused by the scanning motion may alter soft materials, thus distorting measurement data and causing damage to the sample [29]. Obtaining images of hydrated polymeric materials in fluid may be further hampered by the fact that some hydrated polymers are softer than dried samples leading to an increase in sample deformation and damage and a reduced image quality resulting from the dragging motion of the tip.

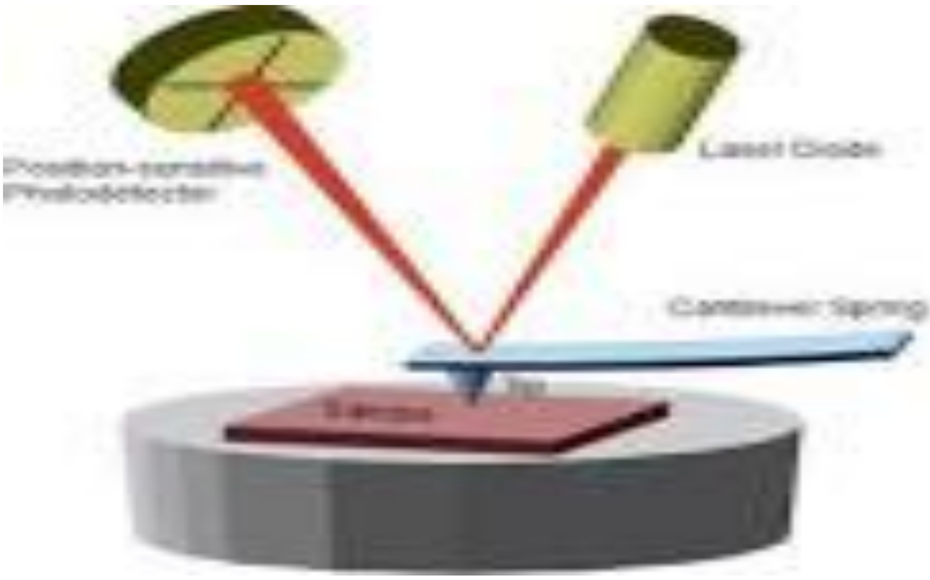

Figure 4.7 ATOMIC FORCE MICROSCOPY

AFM— non contact mode. In non-contact mode, attractive rather than repulsive forces are measured. The scanning tip is oscillated perpendicular to, and just above the sample surface with an amplitude typically less than 10 nm. As with contact mode, a photodiode detector monitors the deflections of the laser light reflected from the tip of a cantilever. A feedback loop maintains constant oscillation amplitude or frequency, as the scanner moves laterally. A computer stores the information and a topographic image, with a lower resolution than in contact mode, is generated. Noncontact mode may work well with hydrophobic polymers.

The AFM consists of a cantilever with a sharp tip (probe) at its end that is used to scan the pecimen surface. The cantilever is typically silicon or silicon nitride with a tip radius of curvature on the order of nanometers. When the tip is brought into proximity of a sample surface, forces between the tip and the sample lead to a deflection of the cantilever according to Hooke's law.[2] Depending on the situation, forces that are measured in AFM include mechanical contact force, van der Waals forces, capillary forces, chemical bonding, electrostatic forces, magnetic forces (see magnetic force microscope, MFM),Casimir forces, solvation forces, etc. Along with force, additional quantities may simultaneously be measured through the use of specialized types of probes (see scanning thermal microscopy, scanning joule expansion microscopy, photothermalmicrospectroscopy, etc.). Typically, the deflection is measured using a laser spot reflected from the top surface of the cantilever into an array of photodiodes. Other methods that are used include optical interferometry,capacitive sensing or piezoresistive AFM cantilevers. These cantilevers are fabricated with piezoresistive elements that act as a strain gauge. Using aWheatstone bridge, strain in the AFM cantilever due to deflection can be measured, but this method is not as sensitive as laser deflection or interferometry[*citation needed*].

Atomic force microscope topographical scan of a glass surface. The micro and nano-scale features of the glass can be observed, portraying the roughness of the material. The image space is (x,y,z) = (20 µm × 20 µm × 420 nm).

If the tip was scanned at a constant height, a risk would exist that the tip collides with the surface, causing damage. Hence, in most cases a feedbackmechanism is employed to adjust the tip-to-sample distance to maintain a constant force between the tip and the sample. Traditionally the tip or sample mounted on a 'tripod' of three piezo crystals, with each responsible for scanning in the *x*,*y* and *z* directions.[3] In 1986, the same year as the AFM was invented, a new piezoelectric scanner, the tube scanner, was developed for use in STM.[4] Later tube scanners were implemented in to AFMs. The tube scanner can move the sample in the *x*, *y*, and *z* directions using a single tube piezo with a single interior contact and four external contacts. An advantage of the tube scanner is that being composed of a single crystal it has a higher resonant frequency, (which, in combination with a low resonant frequency isolation stage, provides better vibrational isolation). A disadvantage is that the *x*-*y* motion can cause unwanted *z* motion resulting in distortion.

The AFM can be operated in a number of modes, depending on the application. In general, possible imaging modes are divided into static (also called*contact*) modes and a variety of dynamic (non-contact or "tapping") modes where the cantilever is vibrated.[3]

V. CONCLUSION

In previous works the various combination of material was done to achieve various property enhancements. The proposed works in phase II are as follow :

(i) Purchasing of aluminium alloy 6060
(ii) Machining of aluminium alloy by milling machine
(iii) Optimization using taguchi’s method
(iv) Report preparation

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