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Testing of Fatigue for Coated and Uncoated on Aluminium Alloy 6063

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Abstract:
The purpose of this experiment was to observe fatigue failure using a rotating fatigue machine which applied a cyclical stress to sample of aluminium alloy 6063. In the current study it has been focused that the attention on the internal stress in a material. A stress applied to a specimen does not fully act to deform the material. The effective stress which actually acts on dislocations depends on the internal stress on the material. The origin of the internal stress is attribute here to the dislocation structure. From the view point, fatigue tests were carried out the origins of the internal stress and the effective stress were clarified by means of dislocation model. The behaviour of the internal stress during the fatigue process showed clear difference between over stress and under stress state. The concept of internal and effective stresses assists in our understanding of fatigue phenomena. The mechanism of fatigue failure in the under-stressed fatigue state was also studied and the concept of an internal stress was applied to instances of practical fatigue situations. The resulting numbers of cycles to failure were statistically analysed using chauvinist criterion and plotted as a stress vs cycles (s-n).The large change in N with small changes in neck radius indicates a high degree of uncertainty for data determined in this experiment.

Keywords: Aluminium Alloy 6063, ASTM standard E606, Machining process, uncoated materials, coated materials, Tensile strength, testing of fatigue, S-N curve, comparison of graphs.

I. INTRODUCTION

Fatigue may occur when a member is subjected to repeated cyclic loading s due to the action of fluctuating stress. The fatigue phenomenon shows itself in the form of cracks developing at particular locations in the structure. Cracks can appear in diverse type of structures such as planes, boats, bridges, frames, cranes, machine part, turbines, and transmission towers. Structures subjected to repeated cyclic loading can undergo progressive damage which shows itself by the propagation of cracks. This damage is called “Fatigue” and is represented by a loss of resistance with time. The physical effect of repeated load on a material is different from the static load and the failure always being brittle fracture regardless of whether the material is brittle or ductile. Mostly fatigue failure occur at stress well below the static elastic strength of the material. Fatigue failures in metallic structures are well known technical problem. Already in the 19th century several series fatigue failures were reported and the first laboratory investigation were carried out. Fatigue is the progressive, localized, permanent structural change that occurs in materials subjected to fluctuating stresses and strains that may result in cracks or fracture after a sufficient number of fluctuations. Fatigue fractures are caused by the simultaneous action of cyclic stress, tensile stress and plastic strain. If any one of these three is not present, fatigue cracking will not initiate and propagate. The cyclic stress starts the crack; the tensile stress produces crack growth (propagation). Although compressible stress will not cause fatigue, compression load may do so. The process of fatigue consists of three stages: Initial fatigue damage leading to crack nucleation and crack initiation Progressive cyclic growth of a crack (crack propagation) until the remaining uncracked cross section of a part becomes too weak to sustain the loads imposed Final, sudden fracture of the remaining cross section Fatigue cracking normally results from cyclic stresses that are well below the static yield strength of the material. (In low-cycle fatigue, however, or if the material has an appreciable work-hardening rate, the stresses also may be above the static yield strength.) Fatigue cracks initiate and propagate in regions where the strain is most severe. Because most engineering materials contain defects and thus regions of stress concentration that intensify strain, most fatigue cracks initiate and grow from structural defects. Under the action of cyclic loading, a plastic zone (or region of deformation) develops at the defect tip. This zone of high deformation becomes an initiation site for a fatigue crack. The crack propagates under the applied stress through the material until complete fracture results.

II. SCOPE AND OBJECTIVE

2.1 Scope of the Project

- In this module we will be discussing on design aspects related to fatigue failure.
- fatigue failure results mainly due to variable loading or more precisely due to cyclic variations in the applied loading or induced stresses
- we will be discussing how it leads to fatigue failure in components, what factor influence them, how to account them and finally how to design parts or components to resist failure by fatigue.

2.2 Objective of Project

- To determine fatigue life and the location of danger point that is location of failure of a specimen subjected to sequential stress.

- To demonstrate in an aluminum specimen to apply the S-N method to predict the No of cycles to failure.
- To determine the fatigue resistance of a part or component under loading and environmental condition akin to service condition.

III. METHODOLOGY

- Modelling
- Material Properties
- Loading (Fatigue)
  - Uncoated
    a) Fatigue Analysis
    b) Result
  - Coated
    1) Spray Coating With Sand Blasting
    a) Fatigue Analysis
    b) Result
    2) Anodizing Without Sand Blasting
    a) Fatigue Analysis
    b) Result
    3) Anodizing With Sand Blasting
    a) Fatigue Analysis
    b) Result

3.1 Modelling

The model chosen for the analysis is based on ASTM standards. ASTM stands for American Society for Testing and Materials. The standard took based for fatigue analysis which is a low cycle fatigue and the standard is E-606.

3.1.1 Dimension of Specimen

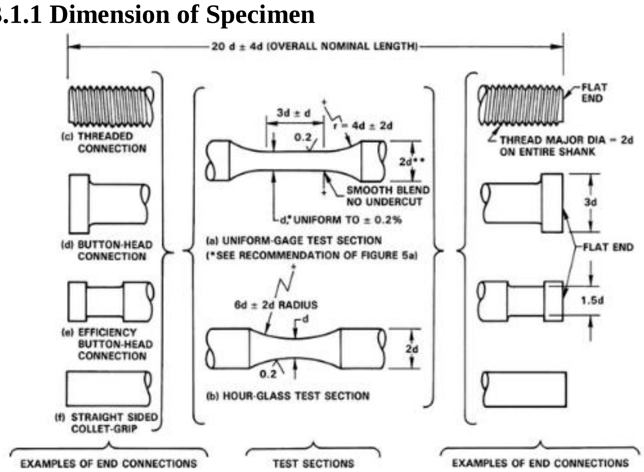


Figure.1. Standard Dimension of ASTM E – 606

3.1.2 Dimension of Specimen

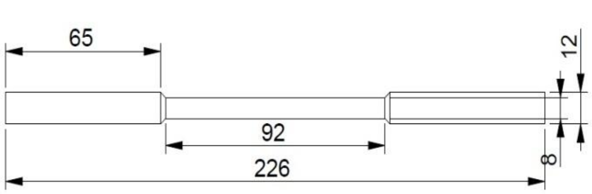


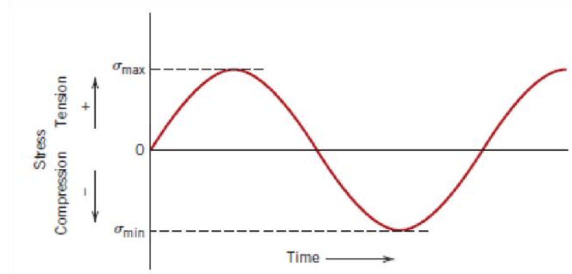
figure.2. All Dimensions are in mm

3.2 Material Properties

The material selected for the specimen is Aluminium Alloy, as it is one of the prominent materials used in manufacturing and fabrication of any structure in the engineering world.

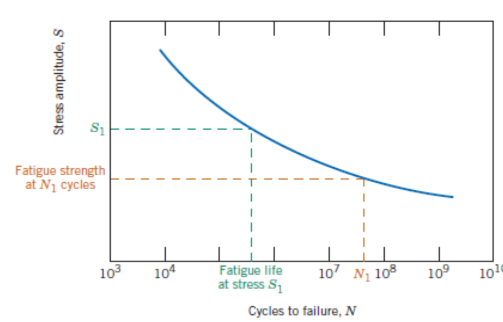
3.3 Fatigue

Fatigue is a form of failure that occurs in structures subjected to dynamic and fluctuating stresses. Under these circumstances it is possible for failure to occur at a stress level considerably lower than the tensile or yield strength for a static load. The term "fatigue" is used because this type of failure normally occurs after a lengthy period of repeated stress or strain cycling. Fatigue is important in as much it is the single largest cause of failure in metals, estimated approximately 90% of all metallic failures. Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. In fatigue testing, a specimen is subjected to periodically varying constant-amplitude stresses by means of mechanical or magnetic devices. The applied stress may alternate between equal positive and negative values, from zero to maximum positive or negative values .The most common loading is alternate tension and compression of equal numerical values obtained by rotating a smooth cylindrical specimen while under a bending load. A series of fatigue tests are made on a number of specimens of the material at different stresses level. The stress endured is then plotted against the number of cycles sustained. By choosing lower and lower stresses, a value may be found which will not produce failure, regardless of the number of applied cycles. This stress value is called the fatigue limit. The diagram is called the stress cycle diagram or S-N Diagram. The fatigue limit may be established for most steels between 2 and 10 million cycles.



3.4 S-N curve

S-N curve is a graph of the magnitude of a cyclical stress (S) against the logarithmic scale of cycles to failure (N). S-N curves are derived from tests on sample of the material to be characterized where a regular sinusoidal stress is applied by a testing machine which also counts the number of cycles to failure. This process is sometimes known as coupon testing. Each coupon tests generate a point on the plot, though in some cases there is a run out where the time to failure exceeds the time available for the test. Analysis of fatigue data requires techniques from statistics, especially survival analysis and linear regression.



IV. PROPERTIES OF MATERIAL

4.1 Aluminium Alloy 6063

An aluminium alloy, with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The aluminium association It has generally good mechanical properties and is heat treatable and weld able. It is similar to the British aluminium alloy HE9Alloy 6063, one of the most popular alloys in the 6000 series, provides good extrudability and a high quality surface finish. Produces 6063 for use in standard architectural shapes, custom solid shapes and heat-sinks, as well as seamless and structural tube and pipe. This alloy is often used for electrical applications in the -T5, -T52 and -T6 conditions due to its good electrical conductivity. In the heat-treated condition, alloy 6063 provides good resistance to general corrosion, including resistance to stress corrosion cracking. It is easily welded or brazed by various commercial methods (caution: direct contact by dissimilar metals can cause galvanic corrosion). Since 6063 is a heat-treatable alloy, strength in its -T6 condition can be reduced in the weld region. Selection of an appropriate filler alloy will depend on the desired weld characteristics. Consult the Material Safety Data Sheet (MSDS) for proper safety and handling precautions when using alloy 6063. Alloy 6063 offers excellent response for anodizing in its -T5, -T52 , -T53 ("matte finish"), -T54, -T6 tempers. The most common methods are clear, clear and colour dying, and bright dipping and hard coat. Bright dipping provides an economical alternative to mechanical polished finishes while offering improved surface durability. Since 6063 is the alloy of choice for aesthetic applications, special packaging may be required to protect critical exposed surfaces. Alloy 6063 is not typically ink-stenciled in order to preserve its surface finish quality.

Table.1. Chemical composition of Aluminium Alloy 6063

GRADE	**COMPOSITION**	
	MIN	MAX
Silicon	0.2	0.6
Iron	-	0.35
Copper	-	0.10
Mangansese	-	0.10
Chromium	-	0.10
Zink	-	0.10
Titanium	-	0.10
Magnesium	0.45	0.9
Other	0.05	0.15
Aluminium	Remain Balance	Remain Balance

V. AXIAL (DIRECT-STRESS) FATIGUE TESTING MACHINE

The direct-stress fatigue testing machine subjects a test specimen to a uniform stress or strain through its cross section. For the same cross section, an axial fatigue testing machine must be able to apply a greater force than a static bending machine to achieve the same stress. Elector-mechanical systems have been developed for axial fatigue studies. Generally, these are open-loop systems, but often have partial closed-loop features to continuously correct mean load. In crank and lever machines, a cyclic load is applied to one end of the test specimen through a deflection-calibrated lever that is driven by a variable-throw crank. The load is transmitted to the specimen through a flexure system, which provides straight-line motion to the specimen. The other end of the specimen is connected to a hydraulic piston that is part of an electro hydraulically controlled load-maintaining system that senses specimen yielding. This system automatically and steplessly restores the preset load through the hydraulic piston. Servo hydraulic closed-loop systems offer optimum control, monitoring, and versatility in fatigue testing systems. These can be obtained as component systems and can be upgraded as required. component systems and can be upgraded as required. A hydraulic actuator typically is used to apply the load in axial fatigue testing. Electromagnetic or electromagnetic excitation is used for axial fatigue testing machine drive systems, particularly when low-load amplitudes and high-cycle fatigue lives are desired in short test duration. The high cyclic frequency of operation of these types of machines enables testing to long fatigue lives (> 108 cycles) within weeks.

5.1 Direct Axial Fatigue Testing Machine Components

- Servo Valve
- Piston
- Hydraulic oil
- Chiller Unit
- Power Pack System
- Controller

Servo Valve - Is an electrically operated valve that controls how hydraulic fluid is send to an actuator. Servo valve are often used to control powerful hydraulic cylinders with a very small electrical signal. Servo valve can provide precise control of position, velocity, pressure and force with good post movement damping characteristics.

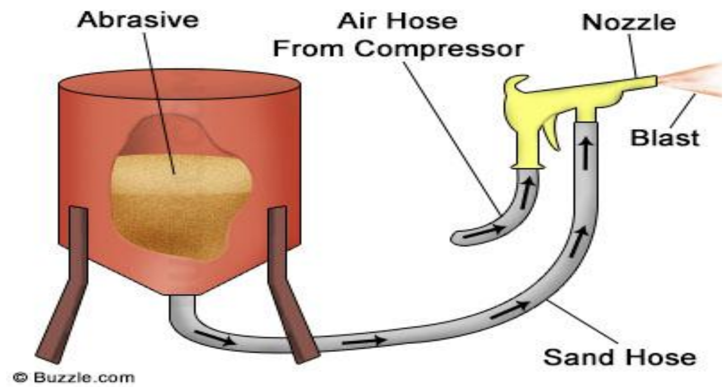
Power Pack System - Is the system used to generate electricity for locations where grid inaccessible or the access prohibitively expensive.

Chiller Unit - chiller unit used to removes heat from one element and deposits into another element. In large data centers the chiller is used to cool the water .**Controller -** A controller, in a computing context is a hard were device or a software program that manages or directs the flow of data between two entities. In computing controllers may be cards, microchips or separate hardware device for the control of peripheral device. A controller can thought of something or someone that interfaces between two system and manages communications between them.

VI. COATINGS

6.1 SAND BLASTING

Sandblasters work on roughly the same principles: finely ground silica sand or glass beads are used to clean and abrade a surface, typically metal, of any rust, paint or other unwanted surface materials. This is done by means of an air-powered pressure gun that fires out the sand or glass beads at high velocity to impact with the intended surface. All sandblasters use said pressurized gun, which has a ceramic barrel or interior coating to prevent the sand from eroding it over time. The exact process by which the sand is introduced to the gun differs.



Blasting Variables

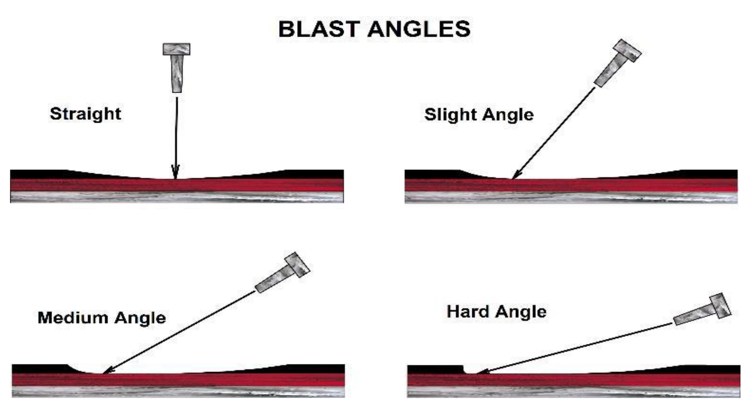
Air pressure – a higher pressure will make blasting faster. Lower pressure allows slower blasting for more control.

Nozzle size – a large nozzle sprays a wide pattern making it easier for uniform texture. A smaller nozzle blasts a fine pattern – better for fine detail control

Blast distance – blasting from farther away spreads over a wider area and is more likely to produce a more uniform pattern. Blasting closer allows for finer control.

Angle of blasting – will determine the angle the glass is etched. Varying the angle of blast will allow you to create variable contour shapes. Blasting on a tight angle is especially important for kiln-formed flashed glass.

Abrasive ratio can be controlled and varied with a pressure blaster. Higher ratio blasts faster and lower ratio slower – which may be desirable for fine control.



6.2Anodizing

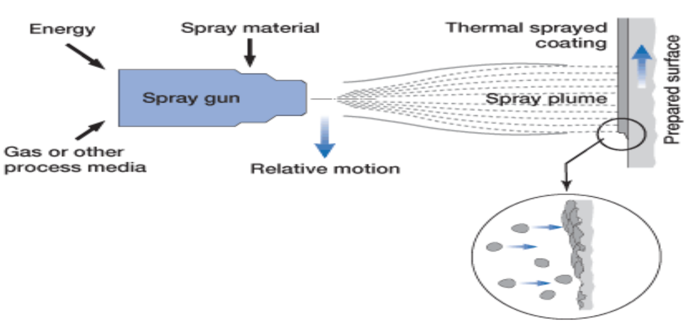
Anodizing refers to conversion coating of the surface of aluminum and its alloys to porous aluminium oxide. The process derives its name from the fact that aluminum part to be coated becomes the anode in an electrolytic cell. This differentiate it from electroplating, in which the part is made the cathode. Whereas anodizing is typically associated with aluminum, similar processes are used for other base metals including magnesium, titanium, and zinc. Anodizing aluminium can be accomplished in a with variety of electrolytes, employing varying operating conditions including concentration and composition of the electrolyte, presence of any additives temperature, voltage and amperage.

6.3Spray coating

Spray coating involves spray application of the solution to the wafer through a nozzle. The path travelled by the nozzle over the wafer is optimized to ensure that the coating is applied evenly to the substrate. The solutions used in spray coating usually feature a very low viscosity, which guarantees that fine droplets form. Spray coating ensures a uniform layer even with high topography substrates, making it the preferred technique for structures of this kind. Even square substrates can be easily coated using the spray technique.

6.4Thermal coating

Thermal spraying, a group of coating processes in which finely divided metallic or non-metallic materials are deposited in a molten or semi molten condition to form a coating. The coating material may be in the form of powder, ceramic-rod, wire, or molten materials The resulting molten or nearly molten droplets of material are accelerated in a gas stream and projected against the surface to be coated on impact, the droplets flow into thin lamellar particles adhering to the surface, overlapping and interlocking as they solidify. The total coating thickness is usually generated in multiple passes of the coating device. A major advantage of the thermal spray processes is the extremely wide variety of materials that can be used to make a coating. Virtually any material that melts without decomposing can be used. A second major advantage is the ability of most of the thermal spray processes to apply a coating to a substrate without significantly heating it. Thus, materials with very high melting points can be applied to finally machined, fully heat-treated parts without changing the properties of the part and without thermal distortion of the part. A third advantage is the ability, in most cases, to strip and re coat worn or damaged coatings without changing the properties or dimensions of the part.



Spray Coating

VII. SPECIMENS

7.1Coated and Uncoated Specimens

The specimen is aluminium alloy 6063. It is then machined according to a ASTM E606 dimension. The figure shows below the specimen of uncoated material after machining.

Specimen of Uncoated Material

The specimen is of aluminium alloy 6063. It is then machined according to a ASTM E606 dimension. The figure shows below the specimen of sand blasting followed by spray coating.

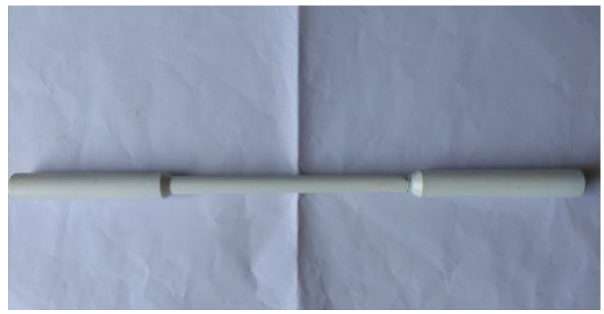


Figure.3. Specimen of coated (Spray Coating With Sand Blasting)

The specimen is of aluminium alloy 6063. It is then machined according to a ASTM E606 dimension. The figure shows below the specimen of anodizing followed by sand blasting coating.

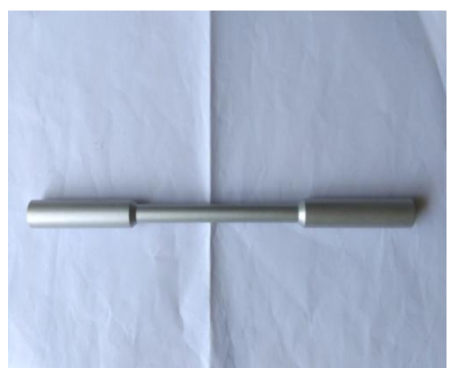


Figure.4.Specimen of Coated (Anodizing With Sand Blasting)

The specimen is of aluminium alloy 6063. It is then machined according to a ASTM E606 dimension. shows below the specimen of anodizing without sand blasting coating.

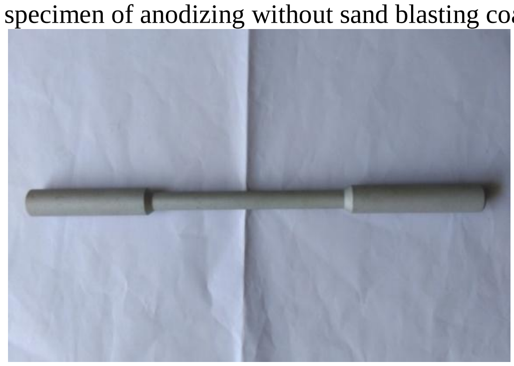


Figure.5. Specimen of Coated (Anodizing Without Sand Blasting)

VII. FATIGUE TEST RESULT

Fatigue test is done on Aluminium Alloy 6063 by applying a load of 9.34 KN. The testing is done on each specimen which as coated and uncoated. Testing is done by applying load which has two trails to find the mean value of no of cycles and the time. Coated materials are such as sand blasting, spray coating, and Anodizing.

Result at 9.34

Material (Aluminum Alloy 6063)	Load (KN)	No. of Cycles		Mean	Time (sec)		Mean
		Trial I	Trial II		Trial I	Trial II	
Uncoated	9.34	4182	5123	4652.5	837	1020.5	928.75
Spray Coating With Sand Blasting		5585	6013	5799	1138	1210	1174
Anodizing With Sand Blasting		4200	4731	4465.5	840	947	893.5
Anodizing Without Sand Blasting		3890	4037	3963.5	798	808	803

For Uncoated mean No of cycles is 4652.5 &Time taken 928.75 sec.For Spray Coating with Sand Blasting No of cycles is 5799 & Time taken 1174 secFor Anodizing with Sand Blasting No of cycles is 4465.5 & Time taken 893.5 secFor Anodizing without Sand Blasting No of cycles is 3963.5 & Time taken 803 sec

Result at 11.8 KN

Material (Aluminium Alloy 6063)	Load (KN)	No. of Cycles		Mean	Time (sec)		Mean
		Trial I	Trial II		Trial I	Trial II	
Uncoated	11.8	1034	1043	1038.5	212	209	210.5
Spray Coating With Sand Blasting		1188	1391	1289.5	238	279	258.5
Anodizing With Sand Blasting		1290	1178	1234	240	260	250
Anodizing Without Sand Blasting		1146	1177	1161.5	229	236	232.5

Fatigue test is done on Aluminium Alloy 6063 by applying a load of 11.8 KN. The testing is done on each specimen which as coated and uncoated. Testing is done by applying load which has two trails to find the mean value of no of cycles and the time. Coated materials are such as sand blasting, spray coating, and anodizing.For Uncoated mean No of cycles is 1038.5 &Time taken 210.5 sec. For Spray Coating with Sand Blasting No of cycles is 1289.5 & Time taken 258.5secFor Anodizing with Sand Blasting No of cycles is 1234 & Time taken 250 sec
For Anodizing without Sand Blasting No of cycles is 1161.5 & Time taken 232.5 sec

IX. GRAPHS

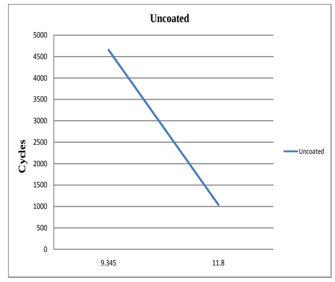


Figure.6.Uncoated Material (Cycle vs Load)

The graph is plotted based on the no of cycles and load. This graph is represent on uncoated aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. In 9.34 KN the point is marked on 4652.5 and in 11.8 KN marked as 1038.5. Increase in load may decreases the no of cycles.

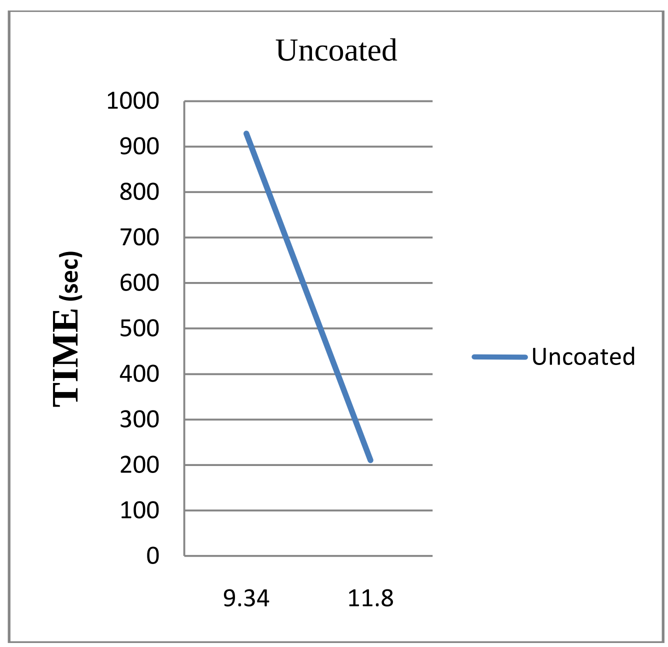


Figure.7. Uncoated Material (Time vs Load)

The graph is plotted based on the time and the load. This graph is represent on uncoated aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. In 9.34 KN the point of time is marked on 928.75 sec and in 11.8 KN marked as 210.5 sec. Increase in load may decreases the time.

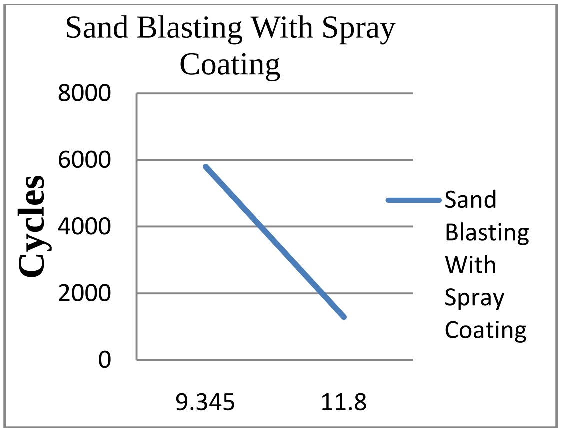


Figure.8. Sand Blast with Spray Coating (Cycle vs Load)

The graph is plotted based on the no of cycles and load. This graph is represent on sand blasting with spray coating aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. In 9.34 KN the point is marked on 5799 and in 11.8 KN marked as 1289.5. Increase in load may decreases the no of cycles.

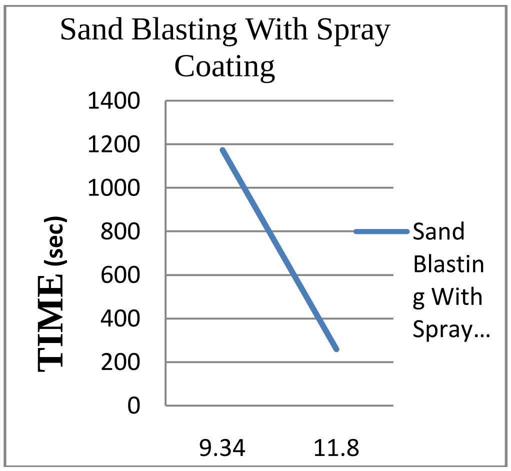


Figure.9. Sand Blast with Spray Coating (Time vs Load)

The graph is plotted based on the time and the load. This graph is represent on sand blasting with spray coating aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. In 9.34 KN the point of time is marked on 1174 sec and in 11.8 KN marked as 258.5 sec. Increase in load may decreases the time.

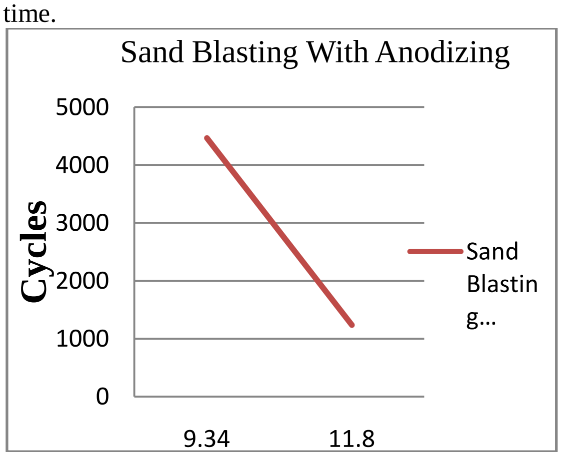


Figure.10. Sand Blast with Anodizing (Cycle vs Load)

The graph is plotted based on the no of cycles and load. This graph is represent on sand blasting with anodizing aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. In 9.34 KN the point is marked on 4465.5 and in 11.8 KN marked as 1234. Increase in load may decreases the no of cycles.

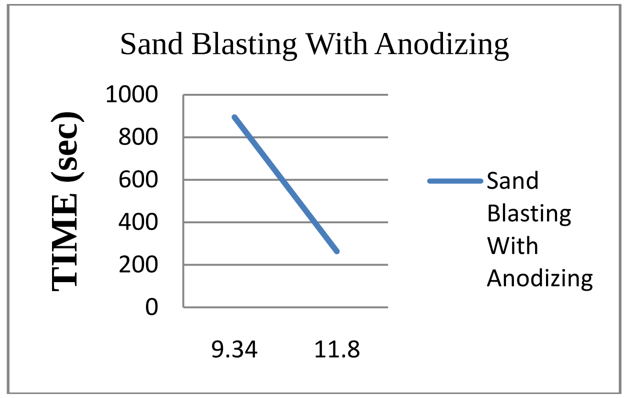


Figure.11. Sand Blast with Anodizing (Time vs Load)

The graph is plotted based on the time and the load. This graph is represent on sand blasting with anodizing aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. In 9.34 KN the point of time is marked on 893.5 sec and in 11.8 KN marked as 250 sec. Increase in load may decreases the time.

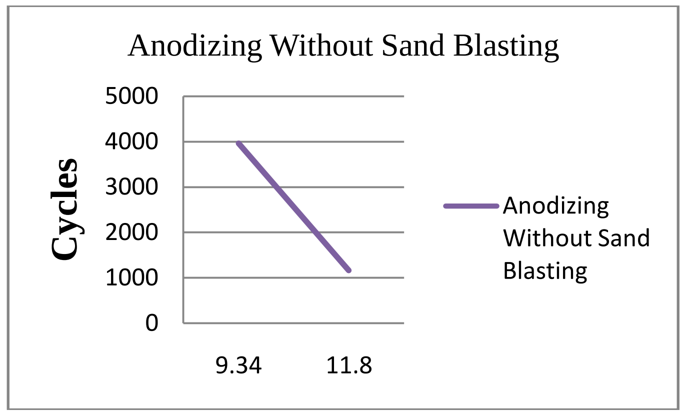


Figure.12. Anodizing without Sand Blasting (Cycle vs Load)

The graph is plotted based on the no of cycles and load. This graph is represent on anodizing without sand blasting aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. In 9.34 KN the point is marked on 3963.5 and in 11.8 KN marked as 1161.5. Increase in load may decreases the no of cycles.

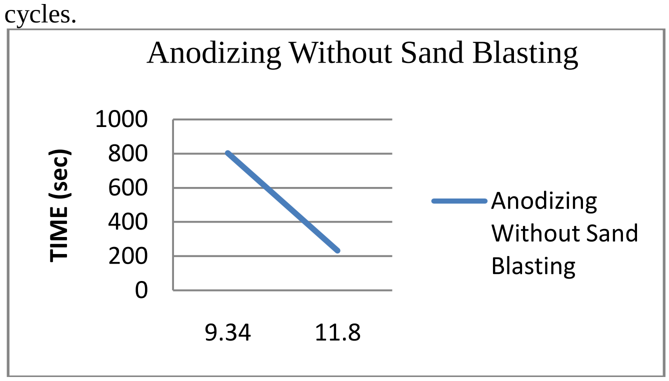


Figure.13. Anodizing without Sand Blasting (Time vs Load)

The graph is plotted based on the time and the load. This graph is represent on anodizing without sand blasting aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. In 9.34 KN the point of time is marked on 803 sec and in 11.8 KN marked as 232.5 sec. Increase in load may decreases the time.

Comparison of Results

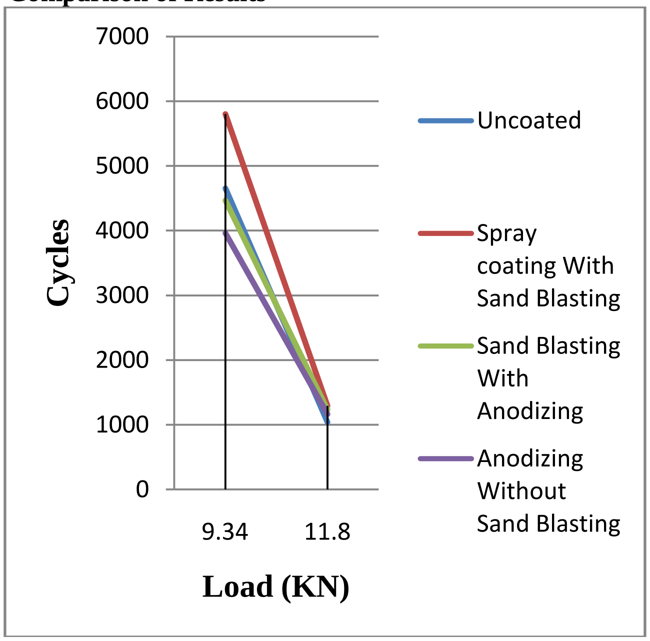
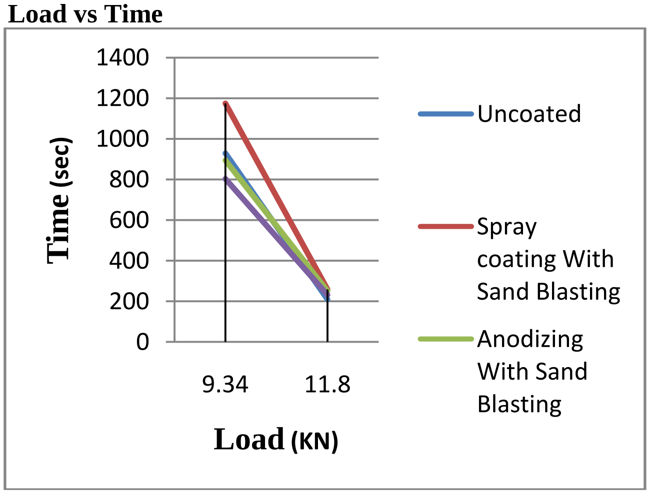


Figure.14. Load vs Cycles

The graph is plotted based on the no of cycles and load. This graph is represent on uncoated, spray coating with sand blasting, anodizing with sand blasting, anodizing without sand blasting, aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. Increase in load may decreases the no of cycles.

Load vs Time



The graph is plotted based on the time and load. This graph is represent on uncoated, spray coating with sand blasting, anodizing with sand blasting, anodizing without sand blasting, aluminium alloy 6063 specimen. The load is taken as 9.34 and 11.8 KN. The value should be taken as per the mean value of two set of trials. Increase in load may decreases the time

X. CONCLUSION

The comparison of uncoated and coated aluminium alloy 6063 is done successfully. For these material loads is applied and noted that at what cycle the material breaks, and also what time to be taken. The specimens which used are uncoated aluminium alloy 6063, coated with sand blasting and spray coating, anodizing with sand blasting, and anodizing without sand blasting. Compare the coated and uncoated aluminium alloy 6063 specimens. While compare to uncoated, coated with anodizing with or without sand blasting, spray coating with sand blasting is much more life. And also increase in load may decrease the time and no of cycles

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