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Behavioral Examination of Wear and Corrosion Resistance for Hard Anodized Sprocket drive mechanism

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ABSTRACT
Aluminium alloy AL7075 chain sprocket is used in Racing motorbikes, Go cart vehicles and in All Terrain Vehicle. In this experimental work Al7075 is hard anodized through hard anodization process. Mechanical and wear behaviour of this hard-anodized composite material were investigated for tribological behaviour and morphology of the hard-anodized composite particle layer distribution were analysed by optical microscopy. Chemical corrosion test is performed to investigate the corrosion resistance, hardness test is performed to investigate the hardness range and effect of wear resistance were experimentally examined with different loads. Benchmarking of economical segment Hero splendour rear sprocket have taken and the stress deformation analysis done for the benchmarked chain sprocket with AL7075 material by using SOLIDWORKS and ANSYS. Experimental result of the mechanical properties, wear behaviour and stress deformation were obtained and the HARD ANODIZED AL7075 material for chain sprocket was investigated

Keywords- Anodization, wear, hardness, microstructure, Chain sprocket

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I. INTRODUCTION

Metal matrix composites are most promising materials in achieving enhanced mechanical properties such as hardness, Young's modulus, yield strength and ultimate tensile strength due to the presence of micro sized reinforcement particles into the matrix. Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement or reinforcing material, whereas the continuous phase is termed as the matrix. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them.

In this experimental work Al7075 is hard anodized through hard anodization process. Mechanical and wear behavior of this hard-anodized composite material were investigated for tribological behavior and morphology of the hard-anodized composite particle layer distribution were analyzed by optical microscopy. Chemical corrosion test is performed to investigate the corrosion resistance, hardness test is performed to investigate the hardness range and effect of wear resistance were experimentally examined with different loads.

Benchmarking of economical segment Hero splendor rear sprocket have taken and the stress deformation analysis done for the benchmarked chain sprocket with AL7075 material by using SOLIDWORKS and ANSYSAdditional inclusion of the reinforcement combination in the aluminium alloy leads to the corrosion which affects the material performance and the life time of the product.

It is predicted that anodizing electrolyte will result in anodized surface and the surface morphology will contribute to the interfacial interaction and the strength of the component.Higher porosity is beneficial to improve the lap-shear strength and also beneficial to form a composite intermediate layer that provides a much-increased area for psychochemical interactions and enhances the mechanical effect.

Optimum voltage and time is used to provide the better surface finish through anodization process.Hard anodization carried out for the rotating and the interlocking elements. Hard anodization provides better strength and the smooth surface which lead to the increased life time of the product and excellent corrosion resistance.Chain drive is much important in two-wheelersegment. Total deformation, Von mises stress, Von mises strain analysis of aluminium sprocket provides the strength of the material.

[1] It is predicted that different anodizing electrolytes will result in different anodized surface morphologies that will contribute to the interfacial interaction and the strength of FML systems. [2] Based on analysis and experimental test on Zinc coated Sprocket to find Wear rate and Hardness by using Tribometer and Vickers test. Both the results shows that the coated Sprocket has less wear rate, more hardness and fatigue limit the normal Sprocket.

[3] The electrolyte temperature and impurity type have slight effect on the volume expansion factor. The relation between the pore density of porous alumina and the anodizing voltage is found to follow the relation NP=9.4×1010exp(-0.042V). In addition, the current efficiency during the anodization was determined to be about 83%. [4]The investigation into the effect of time and voltage on anodization of aluminum using 0.1M concentration and 2.5 pH of H2SO4 electrolyte, under 35oC and 2.22amp/cm2 current density was carried out giving a much-desired product for industrial and domestic use. The optimum parameter for the coating was found to be 40minutes and 40volts for a thickness of 800μm.

[5] When compared with plain bath addition of gelatin along with SLS improves the finish of the anodic coating as well as coating ratio. In AC anodizing, gelatin slightly improves the finish of the anodic coating; moreover, due to its inhibiting action on the surface gelatin reduces the dissolution of anodic coating thereby slightly improves both thickness and coating ratio compared with plain bath.

[6] The bare 7075-T73 alloy samples achieved fatigue strength of 225 MPa and the anodized/sealed samples enhanced their fatigue strength at 107 life cycles with 1020 μm film thickness. The fractured anodized/sealed sample showed fine striation spacing than bare sample after subjected to low stress amplitude.

[7] The results showed that anodizing time, temperature and concentration were the main variables that determined the surface acid properties of the samples, and to a lesser extent voltage. Acidity increased with increasing concentration of the electrolytic bath, whereas the rest of the variables had the opposite effect. [8] The investigations were performed using light and electron microscopy (AFM) for the microstructure determination. The morphology and size of the layer was also possible to determine. The anodizing conditions for surface hardening and its influence on properties were analysed.

[9] Black inorganic anodized aluminium alloys are used for managing passive thermal control on spacecraft and for avoiding stray light in optical equipment. Scratch-testing, used to evaluate coatingadhesion to its substrate, revealed the negative impact of thermal cycling. [10] In this study, chain sprocket is designed and analyzed using Finite Element Analysis for safety and reliability. ANSYS software is used for static and fatigue analysis of sprocket design. Using these results optimization of sprocket for weight reduction has been done. As sprocket undergo vibration, modal analysis is performed.

II. EXPERIMENTAL WORK

A. Material

Aluminium is selected as the base metal matrix it is relatively soft, durable, light weight, ductile, malleable metal and has high corrosion resistance, excellent heat conductivity. The selected aluminum alloy bears excellent characteristics for structural and automotive applications. It has major alloying elements Silicon, Copper which contributes for better strength, machinability and cast ability.

Hard anodization is a process that performed for the Aluminium 7075 alloys which are used for managing passive thermal control onspacecraft and for avoiding stray light in optical equipment. Spalling of these coatings has sometimes been observed after thermal cycling on 2XXX and 7XXX aluminium alloys. In this work, the influences of the four main steps of the process (pretreatments, sulphuric anodizing, coloring and sealing) on the coating characteristics have been studied for AL7075.

Table 1. Chemical composition of Al 7075 alloy

S.NO	Alloys	Composition %
1	Mg	2.1 – 2.5
2	Cr	0.05
3	Cu	1.2 – 1.6
4	Fe	0.05
5	Mn	0.05
6	Si	0.05
7	Zn	5.6 – 6.1
8	Ti	0.05
9	Others	0.05

Table 2. Al 7075 properties

PROPERTIES	VALUES
Density	2.81 g/cm^3
Elastic Modulus	71.7 Gpa
Melting Point	635 °C
Specific Heat Capacity	880 J/Kg-K
Tensile Strength: Ultimate (UTS)	572 Mpa
Rockwell Hardness	50,53 HRC
Thermal Conductivity	143 W/Mk
Elongation	11max

B. Hard Anodization

Aluminium 7075 was used as the template in the phosphoric acid electrolyte. The aluminium template was cut into pieces and was etched by HNO3 and water with a ratio of 1:3 to clean away dirt impurities and possible grease on its surface. The samples were later rinsed with distilled water. Anodization takes place in three different electrolytes as follows: 11% phosphoric acid (H3PO4), 11% sulphuric acid (H2SO4) and 11% nitric acid (HNO3).

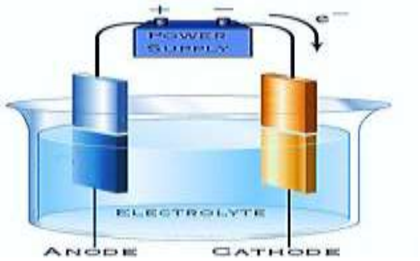


Figure1. Anodization electrolyte bath

The voltage was set up to be constant at 30V at ambient temperature. Samples were anodized for 30 minutes and 60 minutes at a constant current density of 1.5A/ft2. The weighed aluminum piece (anode) and the lead (cathode) were inserted into the bath solution and connected to the positive and negative terminal of the D.C. generator respectively. The anodized were rinsed thoroughly with distilled water and dried in the oven at the temperature of 60 deg C for 30 minutes, to ensure complete drying of the anodized aluminium.

C. Experimental plan

The matrix material is aluminium alloy Al 7075. Samples are to be prepared usingAl 7075 reinforced with hard anodization process. Experiments were conducted using Taguchi L4 orthogonal design of experiments is shown in table 4.1 and figure 4.2 gives the various constituents levels of composite elements.

Table 3. Weight obtained before and after Anodization

Sample	Weight before anodization (gms)	Weight after anodization (gms)	Increased Thickness (mm)
plate1	46.236	47.916	1.68
plate2	47.390	49.090.	1.70
Rod1	8.148	8.405	0.257
Rod2	8.146	8.397	0.251

Table 4. Surface layer with respect to time, voltage

sample	Time (min)	Voltage (volt)	Thickness (mm)	Observed layer
plate1	50-60	40	40-50	Smooth surface
plate2				
Rod1				
Rod2				

D. Testing of composites

Microstructure of the anodized composite was tested with optical microscope.Hardness test of the samples are conducted as per ASTM-E-10 standards, test conducted with the Automated Hardness Tester. The hardness range was taken for each specimen at different locations to circumvent the possible effects of particle segregation and the average readings are noted.

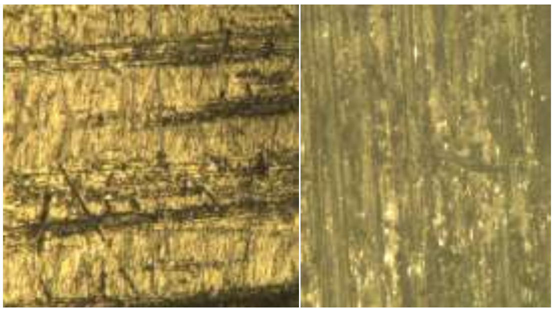
To investigate the tribological behavior of specimen Pin onDisktest was conducted with ASTM G99 standards sliding speed range 0.26-10metre/sec, disc rotation speed 100-600 rpm, maximumnormal load 200 N, frictional force 0-200 N, pin size 3-12 mm, disk size 160 mm and wear track diameter 10-140 mm are taken for wear measurement up to 4mm.

After Hard anodization process material weight calculated for both the unanodized and the anodized specimen then it is kept on the strong acid solution bath for 100 hours. As per the ASTM automobile standard both the plates immersed in the 0.1N HCL solution. It is kept about 100hours after that the pitting, corroded surfaces are observed visually. Modeling of chain sprocket was designed with solid works and the stress deformation of the chain sprocket was analyzed by ANSYS workbench with respect to the applied load on each consecutive tooth of the chain sprocket.

E. Results

1. Microstructure

The micrograph structure of the samples as shown in figure 2 clearly reveals the pores of the aluminium oxide layer over the surface of the AL7075.



Unanodized layer Anodized layer

Figure 2. Microstructure for Base & Anodized alloy

The coarse intermetallic compound particles apparently located at the grain boundaries were aligned along the longitudinal (extrusion) direction of the bar sample. Some sub grains are visible and likely formed due to thermal-activated recrystallization in the solution treatment, which was affected by soluble Mg and Zn atoms in the Al matrix. Overall analysis of structure indicates that the oxide layers are uniformly distributed in the alloy matrix.

2. Hardness test

Micro hardness test at various locations was carried out to know the effect of reinforced particulates on the alloy matrix as given in Table 5. Vickers hardness measurement has been carried out on the embedded reinforcement particles as well as in the locality of particles and matrix.

Table 5. Hardness range

Part1	VHN (HV)	BHN (HRC)	Part2	VHN (HV)	BHN (HRC)
Base	302.6	30.9	Anodized	650.8	56.5
	290.6	29.6		727.6	59.3

Figure.3. Hardness range for base and anodized alloy

3. Wear test

The wear rates were determined using the weight loss method. In the wear test the pin was pressed against the counterpart rotating against EN32 steel disc with hardness 65HRC by applying the load. An approximately strain-gauged friction detecting arm holds and loads the pin specimen vertically in to a rotating hardened steel disc. After running through a fixed sliding distance at specific time, the specimen was removed, cleaned and weighed to determine the weight loss due to wear. Table 6 shows the difference in weight measured before and after the test gives the wear of the specimen. The volume losses were determined using the weight loss method.

Table 6. Wear resistance for 3kg applied load

Sample	Base	Anodized
Load (kg)	3	3
Speed (rpm)	500	500
Time(min)	5	5
Initial weight (gms)	8.148	8.148
Final weight (gms)	8.141	8.145
Changed weight (gms)	0.007	0.003
Wear (µm)	129	113

It has been shown that the wear rate of the hard-anodized specimen is less compared to the Aluminium base alloy. Hence wear rate of the chain sprocket gets improved by hard anodization process

4. Corrosion Resistance Test

After Hard anodization process material weight calculated for both the unanodized and the anodized specimen then it is kept on the strong acid solution bath for 100 hours. As per the ASTM automobile standard both the plates immersed in the 0.1N HCL solution (i.e. for 1 litre of water solution 10ml of HCL acid is added).It is kept about 100hours after that the pitting, corroded surfaces are observed visually.

Start time after 50 hours

After completing 100 hours

Figure 3. Corrosion resistance test

The figure 3 shows the corrosion resistance testing for the specimen at the time of start, during test and after the completion of 100 hours in 0.1 N HCL solutions. Here the hard-anodized specimen corrosion resistance is much higher than the base alloy.

5. Design and Analysis

As per von-mises stress theory:
Von-mises stress <= UTS/ F.O.S
Ultimate tensile stress of Aluminium 7075 = 570Mpa.
Obtained von-mises stress in ANSYS workbench
=21.885Mpa (HERO), 14.889Mpa (modified).
Fixed Factor of safety = 2.
Obtained:162 <= (570/2) = 285Mpa.
Obtained value ≤ calculated value, therefore design is safe.

Force for consecutive tooth calculated
$T_k = T0 * (\sin \varphi / \sin (\varphi + 2)$ ^k-1
Where:
T_k= Back tension at tooth k,
T0 = Chain tension = 487.69 N
Φ = Sprocket minimum pressure angle (17 – 64/N)
= 16.86 degree
N = Number of teeth on driven sprocket = 43,
2β = Sprocket tooth angle (360/N) = 8
K = the number of engaged teeth= (ϴ *N/360)
= 14,
ϴ =Angle of wrap of chain oversprocket = 120

Table 7. Force for the sprocket tooth

TOOTH	FORCE (Newton)
T1	131.67
T2	95.54
T3	80.30
T4	72.28
T5	60.50
T6	53.20
T7	45.15
T8	39.20
T9	33.10
T10	25.70

Here from the Figures 5 to 10 the total deformation, stress analysis and the strain distribution for the benchmarked chain sprocket has been calculated and the modified design has been modeled through solid works and the analysis has been done with AL7075 material .Material selection done for the chain sprocket in solid works before applying the analysis in ANSYS.

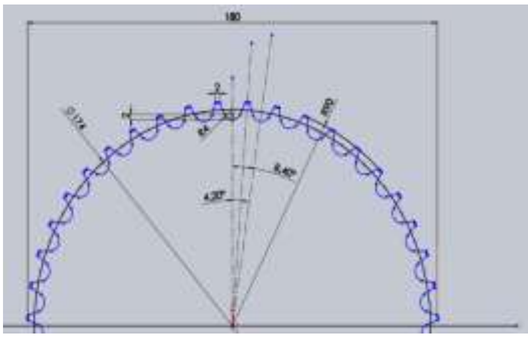


Fig 4.Benchmarked design of HERO chain sprocket

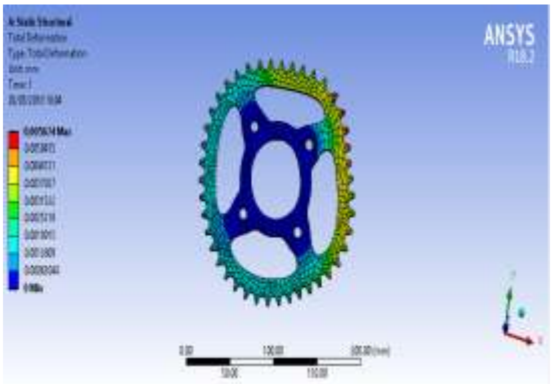


Fig 5.Total deformation of Hero Sprocket

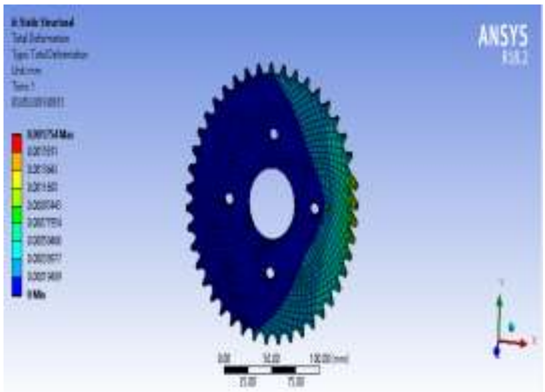


Fig 6. Total deformation of modified sprocket

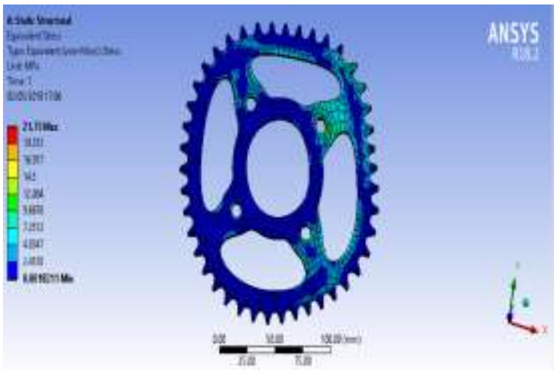


Fig 7. Equivalent von mises stress of Hero sprocket

Fig 8. Equivalent von mises stress of modified sprocket

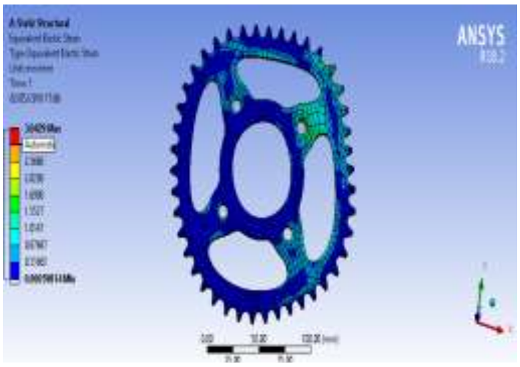


Fig 9. Equivalent von mises strain of Hero sprocket

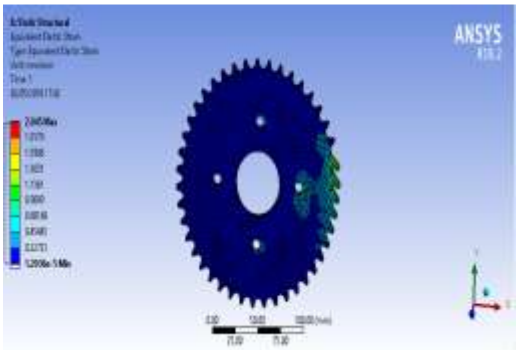


Fig 10. Equivalent von mises stress of modified sprocket

The chain sprocket design was modeled by using Solid works, force for the consecutive teeth calculated by the back-tension formula which is applied to the chain sprocket and analyzed by ANSYS workbench. Von mises stress is less than the preliminary design hence the design is safe where the modified design change provides less deformation compared to the existing design.

III. CONCLUSION

The composite samples of Al7075 anodized through HARD ANODIZED process. The mechanical properties such as hardness, wear, corrosion and microstructure were investigated from the fabricated samples.Anodized material provides better corrosion resistance by the anodization process and also, it'simproving hardness range over the surface layer. Through hard anodizing lifetime exceeds than the existing chain sprocket, corrosion resistance and the hardness range of the surface layer gets increased. Composite of AL7075 with HARD ANODIZATION provides better corrosion resistance, lifetime and then the base aluminium alloy. Experimental result of the mechanical properties, wear behavior and stress deformation were obtained and the HARD ANODIZED AL7075 material for chain sprocket was investigated.

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