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"OPTIMIZATION ON WEAR PERFORMANCE OF AA2014 COMPOSITES USING TAGUCHI METHODOLOGY"

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ABSTRACT

In the industrial products of aerospace, automobile, railway, structure, manufacturing, marine, Cell phone, defense have very general phenomenon occurring in the almost all the known materials metal, nonmetal, ceramic, composite components, which is known as Wear. It occurs due to the relative monition between the contact surfaces. The contact surfaces have have two region stick and slip region. The slip occurs at the trailing region of the contact zone causing rise on both longitudinal creep and tangential forces. Due to increases in the tangential force, the slip region advances resulting in the rolling and sliding contact. At the saturation value of tangential forces, the stick region disappears, resulting in a pure sliding contact such as ex-wheel rail contact. In this pin disc apparatus is used for wear test. For wear analysis of different specimen of AA2014 hybrid composite the pin on disc arrangement is used for analysis of essential features of materials measurement of load, measurement of friction coefficient, measurement of the surface roughness. The analysis is done with the help of Taguchi experimental design process for sliding contact surfaces.

Key Words: *Taguchi Method, Wear, Slip region*

I. INTRODUCTION

In the universe no any surface is perfectly smooth. Every surface have some irregularity. When the surface comes into the contact with the other surface there irregularities come into contact with each other. The surface irregularity entangle with each other then due to relative motion between the surfaces the peaks and crater of the irregularities break which causes the material removal from the surface. This phenomenon is called Abrasive wear. But At the elevated temperature the abrasive wear takes place along with along with another well known phenomenon adhesive wear. At high temperature, it depends upon the surfaces in contact. This happen because of the material at high temperature surface softening takes place. So not only abrasion but the surface stars adhesion on the mating surface [Selvakumar et al. (2017)]. Another very interesting phenomenon of wear occur when the surfaces have very slow relative motion or small vibration eg. the ground and the base of the machine, another wear phenomenon occurs called fretting wear [Fontalvo et al. (2006)] [Liskiewicz et al. (2017)]. Fretting wear plays so much significant role in the the long term observation. When the surface are kept in the such kind of environmental condition such that the material are reacting with the environment particle, in such a condition the material removal from the surface takes in the form of product formed after reaction between the surface material and environmental particle. This kind of erosion is called the corrosive wear. Wear is a generally observed problem it may in the form of mild wear or severe. It may be in the form two body wear or three body wear. So we have classified the wear process on the basis of different parameter. There are different types of wear mechanism occurring in the industry. Here we are going to describe the different type of

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wear along with their application. Abrasive wear is very much significant in specially the machining, some machining process like grinding, rubbing, lapping are very useful machining process by abrasion wear. In all material removal method the wear of material takes place by shearing. In industry specially where material like aluminum, Low carbon steel is used, wear should be strictly prohibited. [Buchely et al. (2005)] analyzed abrasive wear by hard facing the alloy which changed its micro structure. Hard-facing is among the most advantageous and commercially economic route to enhance the working of components submitted in the critical wear conditions. A study compared the micro structure and abrasive resistance of hard facing alloy having reinforcement of primary chromium carbides, complex carbides or tungsten carbide. The development in the resin composites in the form of dental restoration materials come through the need for the materials that make tooth structures. However, Wear of all these com-posites till now remains as a chief clinical issue. The wear resistance of such materials mainly depends on the size , distribution, mechanical properties and content of in-organic fillers [Souza et al. (2016)].

Pin on disc is the method Widely used in the field of wear test measurement. In this section we shall discuss some of pin on disc arrangement. Our focus will be constraint up to the experimentation part done with different material and hybrid composites. Wear test of AA7075 was investigated by the [Baradeswaran and Perumal (2014)]. A specimen of AA7075 Alumina hybrid composites having a diameter of 5mm and the height of 15mm was used as pin material whereas the OHNS (Oil Hardened Nickel steel) was used to make the disc of diameter 55mm. The test was conducted on the different load that were 10N, 20N, 30N. The sliding speed was also variable which had the value of 0.6m/s, 0.8m/s, 1m/s respectively. The sliding distance which he kept, was 2000 mm. The entire 2.1 test was conducted at the 30degC having the atmospheric condition of relative humidity of 60Pr-65Pr. The observation of the material removed was estimated by the electronic weighing machine with a least count of 0.0001g. the test of specimen was conducted for a short time after then the material was washed with the help of acetone solution. After then the weight was investigated.

[Bortoleto et al. (2013)] performed an ASTM G99 stranded Pin on Disc test. The pin specimen was AISI 4140 steel (430 HV hardness), and disc of another AISI H 13 material (430 HV hardness) tool steel material. The dimension of the pin was taken as the 5 mm diameter and the 22 mm height, Whereas the diameter of the disc is 60mm. The entire test was performed at the room temperature of 250C.

The rotational speed was 40rpm. The sliding distance was kept 25 mm, resulting the sliding speed 0.1m/s. The applied load varied from 5N to 140N at the 250 C temperature. The material removal rate was observed after weighing the specimen on the electronic weighing machine of precision 0.00001g, after each test the specimen was cleaned with the acetone solution. [Cui et al. (2018)] studied the wear behavior of different inorganic chemical compound which is useful for hot rolling. The oil was diluted with the distilled water. The compound was weighed previously on the weighing machine of accuracy upto ± .001g. The lubricant performance was evaluated on a pin on disc apparatus in which the pin specimen was made up of High speed steel of hardness 699 ± 33 Hv, and the disc specimen was made up of mild steel of hardness 190 ± 10 HV, respectively, but at a very high temperature of 9000C.

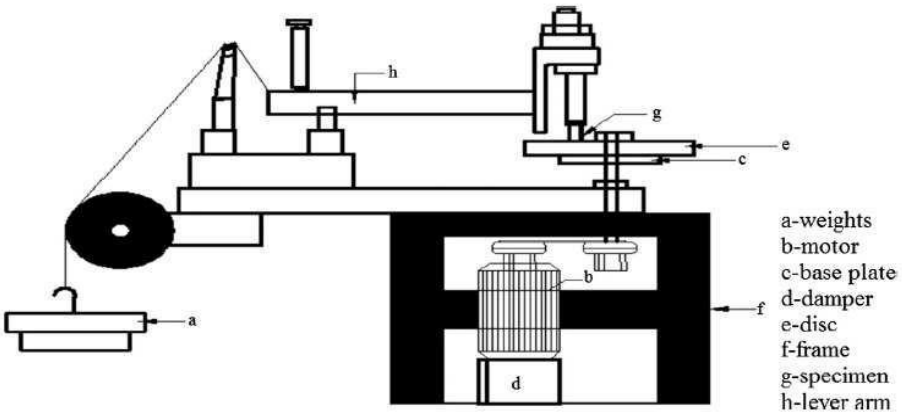

Fig. 1: Pin on disc arrangement Baradeswaran and Perumal (2014)

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[Cueva et al. (2003)] investigated wear resistance of cast iron. Which is used in brake disc rotates. The three type of grey cast iron was taken for the test. These three were named as one grade 250 (GI250), one high carbon (GIHC), One alloyed with Ti (GI250Ti) and a compact graphite iron. The all sample Michrostructure was identical consisting of basically pearlite and graphite flake form. The Content Of graphite was producing the basic Difference. The pin on disc wear test was performed in a PLINT TE67 wear testing machine, where the load applied pneumatically, because this is brake material test, the pin specimen were manufactured from brake pad that are used in Mercedes Benz sprite van. The specimen have square base area 144 mm2 and that were ground with sand paper grade 400. but disc specimen were manufactured having dia of 70 mm and thickness 7 mm having the surface finite. [Abbasi et al. (2012)] investigate the pin on disc wear measurement of airborne wear particle emission of railway breaking material. In the test the horizontal rotating disc was used and pin was dead loaded. Test apparatus was so much sophisticated. Except pin on disc arrangement the author have also used the supply air containing only wear particle. So to make air clean the whole setup is kept in the sealed box. The normal load of 100 N is exerted at the constant speed of 3000 rpm. [Federici et al. (2018)] investigated the pin on disc test to understand the behavior of brake friction. The cylindrical pin specimen was of diameter 30mm having height 15 mm. The test was performed to obtain coefficient of friction, by performing a dry sliding test, the disc material have hardness value of 209±3 HV 30 and dimensional specification of the disc 140mm in dia and thickness of 15mm. The average surface roughness of disc RA was equal to 2.2±.2micrometer as measure from the surface roughness tester. The material of disc and pin supposed to 15Kpa, 30 KPa, and 50KPa. The sliding velocity was 2.88m/s, which was kept constant.

A plenty of authors have tested the wear property on the pin on disc wear measurement, Specially aluminum metal matrix which is drastically replacing the steel from so many industries that's why the wear test of all the machinery used material is important. For wear analysis of different specimen the pin on disc arrangement is essential to fabricate. our motto to design this wear machine is to develop such a machine which consist of all the measuring features like measurement of load, measurement of friction coefficient, measurement of the surface roughness. Both dry and wet sliding wear test may be performed. We decided to add a new function in this machine that is reciprocating wear measurement in the piston and cylindrical assembly.

II. Basic Mechanism

Mechanism is, an arrangement of the link mostly rigid sometime fluid, connected so that they are continuously transmitting the motion from the input end to the output end. Pin on disc apparatus is a system in which the pure rotation of disc is required. So the platform or the fixture on which the disc is fixed must have a rotational motion. The transmission of motion should be smooth as much as possible. We have changed the rotation motion in vertical plane to vertical motion in the horizontal plane. This conversion can be performed by the bevel gear assembly. Another mechanism or belt and pulley drive system has been used to transfer the motion from the electric motor shaft to the horizontal shaft. Gear assembly have 1:2 ratio for velocity reduction, we shall study the specification of gear assembly later. The basic formula for the velocity reduction is given below

$$\frac{V}{v} \equiv \frac{d}{D} \equiv \frac{t}{T} \qquad (1)$$

V = velocity of driven gear
v = velocity of driver gear
D = diameter of driven gear
d = diameter of driver gear
T = teeth of driven gear
t = teeth of driven gear

The belt and pulley drive also work on the above formula except the teeth ratio. So this is the basic arrangement done to get the required motion

III. Material and Dimension

In this section we shall describe the material along with there specification. The material to make any component have some special significance that's the reason behind the use of the any material. First of all we should formulate our need

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for material. It may be done when we have the right approach for the analysis of the force and the stress generated in the link or component which we are going to fabricate.

After estimation of the force generated the we should estimate the required working condition. On the basis of which we should search for the hardness of the surface. Then after we should search the availability of all the requirement fulfilling material. We should select all the material that are easily available .then the cheaper one should be selected. We have done the same procedure for the fabrication of the component or part of machine. We shall describe about the all the component dimension along with there material. In the case of material the hardness, strength, percentage elongation, yield strength. We shall start from the base material means frame.

Tab. 1: Mechanical property of Cast Iron

C in %	Designation	Hardness (HB)	Ultimate tensile Strength (MPa)	Elongation (in%)
0.15	SG900/2	280-360	900	2

3.1 Gear And Shaft

The miter bevel gear of pitch angle 45 deg is used for the conversion of horizontal motion of shaft to vertical motion of the shaft. A 17 inches Shaft of 35Ni5Cr2 material has the diameter of 38mm or 1.5 inch. The pulley attached to the horizontal shaft is of dia. 8 inch. The height of the pulley from the base or frame is 4.2 inch. The gear attached to this shaft is bevel gear of 40Cr4 having a pitch diameter of 2.5 inch having 20 teeth. It is connected to the mating vertical gear of same module having the diameter of 1.25 inch and 10 teeth making the velocity ratio 1:2. The vertical shaft is attached with the circular base on which the whole assembly of pin on disc is allocated. The mating gears are attached with the angle of 45degree making the whole assembly chatters less and smooth working. The horizontal circular shaft passes through the rectangular hollow bar made of medium carbon steel providing the housing to the circular shaft making it more reliable and effective working. The rectangular housing contains the ball bearing of modern Babbitt material having dimension of 52 mm outer diameter and the inner diameter is of 25 mm. The shoulder is provided to the shaft making the motion more effective. The vertical shaft is attached to the circular base housing.

3.2 Disc

The circular plate made of mild steel is attached to the vertical shaft having M24 threaded joint. The disc is of the circular shape of diameter 10.6 inch and the thickness

Tab. 2: Material Specification Of Shaft, Gear, Bearing Material

Component	Material	Hardness(HB)	Ultimate Tensile strength (MPa)
Shaft	35Ni5Cr2	201-248	490
Gear	40Cr4	201-248	490
Bearing	Babbit	240-245HB	146MPa

Tab. 3: Typical Mechanical Properties of Martenstic Stainless Steel

Component	Material	Hardness	Ultimate Tensile Strength	Elongation
Disc	Martensitic FeCrNiC grade	550 HB	340 MPa	1 percent

is 0.6 inch. The circular base is super finished. On its surface the cylindrical chamber is attached. The disc type specimen will be used when having the diameter of 10 cm and the thickness is of 5mm.

3.3Lubrication Chamber

The whole pin and disc experiment are kept in the lubrication chamber made of cast iron which have dimension as the diameter is 4 inch. one important noticeable point about the chamber is that its base is made in the form of tapered surface. Which have an important significance that is described below. The chamber contains disc element which is

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threaded to the base of lubrication chamber with M8 thread joint. The lubrication chamber is welded to the circular base. The different lubrication fluid can be filled into the chamber in case of testing the wet sliding wear behavior of the specimen. When rotation is given to the circular which may cause a splashing of fluid at the disc surface. This makes a difference in the height of liquid level in both the surfaces. This splashing effect makes the testing inaccurate and inconvenient in thermocouple reading. So, a tapered is made in one side that makes the testing very accurate. The surface plates are provided at the base of lubrication chamber to fix the particular disc specimen making it more reliable. The disc can be dismantled also. The pin is kept at a particular sliding distance which is fixed to remove the oil from the chamber a gate is provided below on the decreased height of taper. This makes the fluid excretion easy.

3.4Pin Arrangement

The pin made of aluminum 2014 is threaded of M20 joint at the end of the lever which is hinged at one end. The pin can be dismantled easily . At the pin end the load is kept by fixing it through a threaded joint by M12 joint. So the load can also be changed for different load condition. Load can be varying as 10N, 20N, 50N so for. values of the load that can be applied on it have a maximum value of 100N. This much amount of force leads to the accurate result so for. Length of the lever made of WM 350 is 8 inches from the hinge. Flexibility in pin engagement and ejection in the test is provided appropriately. It simply makes the uplifting and dismantling of the pin by giving it a simple torque about the hinge. The maximum height that a pin can take from the frame is 5 inches. One special dimensional feature is added to the pin is making it in a taper profile which affect the material removal because of having less area in contact with the disc. Then two special kind of wear or material removal measurement can be obtained.

3.5Sensor Designation

The Sensor Used in this machine are Thermocouple and variable frequency drive. The thermocouple is used for temperature measurement. The Variable frequency drive is used for the variation in the rotational speed of motor. The description about all the component is given below. We shall describe all about their description and specification.

IV. EXPERIMENTATION

4.1 Machine used

To perform the Wear test On AA2014 a typical arrangement is required. The accuracy and precision is an important factor to design any test. The all apparatus and devices used in this application are discussed below. Every device or Apparatus have special significance to conduct the experiment. Some apparatus are performing, some are sensing. The pin on disc apparatus is used for the abrasion or wear performance. The Wear is measured by weighing machine in the form of weight reduction. The thermocouple is used for the temperature measurement in the form of increment in the temperature or the decrement in the temperature. A variable frequency drive is used to control the rotation speed. The specification of all the component required have been discussed earlier in the design section.

4.1.1 Pin on Disc Wear Testing Machine

To estimate the wear behavior of AA2014 hybrid composite it is essential to perform a wear test. So the Wear test is performed on a designed Wear testing machine. All the specification have been discussed earlier in the design section. As per Fig.2.1 the Pin on Disc wear machine we used in the test.

4.1.2 Weighing Machine

To measure the weight loss the weighing machine have been used. The weighing machine have capacity to measure the weight up to 400gm. The figure below shows the schematic diagram of the weighing machine used for the application.

4.1.3 Thermocouple

Thermocouple is used for the temperature measurement of the surface. A brief discussion on the thermocouple have been discussed earlier. The temperature measurement is very essential in wear testing. Figure below shows the temperature measurement device or the thermocouple used in the application

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4.1.4 Variable Frequency Drive

A variable frequency drive is a instrument used for the control of the speed of the Electric motor. This is done because we have tested the wear of the material at the different rotational speed. Below figure showed the figure of variable frequency drive used for the application.

4.2 Design of experiment

The AA2014 hybrid composite made by stir casting method. we have discussed briefly about the stir casting method. The input variables are in our test are the Load , speed, composition of the hybrid. whereas the output are the Material removal rate and the temperature increment. Below table shows the input and output variable.

Table 4. The input process factors and their levels

Sr. No.	Input process factors	level 1	level 2	level 3
1	Load	10N	20N	30N
2	rotational speed(rpm)	30rpm	40rpm	50rpm
3	composition (Sic wt per)	A1	A2	A3

4.2.1 Taguchi's Method

On putting the data of experimental design on the Taguchi a statistical analysis method the obtained table is given below in Table 4.2.

Tab. 5: Taguchi L9orthogonal array and values of different response characteristics

S. no.	Cond	Compo	Load(N)	Speed	Wt Loss(gm)	Temp(deg C)
1	D	A1	10	30	0.021	2degC
2	D	A1	20	40	0.034	9deg C
3	D	A1	30	50	0.065	11deg C
4	D	A2	10	30	0.045	4deg C
5	D	A2	20	40	0.016	6deg C
6	D	A2	30	50	0.270	21 deg C
7	D	A3	10	40	0.079	13deg C
8	D	A3	20	50	0.119	18 deg C
9	D	A3	30	30	0.471	21 deg C

4.2.2 Experimental Procedure

The AA2014 hybrid composite specimen of 3 different composition were made by stir casting process. The Specimen have 5mm diameter and 140 mm height. The Specimen have the 95 mm threaded length along with the 35 mm well finished cylindrical length. The specimen is first cleaned and washed with Acetone The After it is fixed with the lever Attached to the Pin. The Pin specimen was kept at the rest on the stainless steel disc surface at the sliding distance of 5.5cm from the center of the disc. The Load Holder is attached on the top of the Pin. The Load is settled into the housing. Then the temperature is measured with the help of Thermocouple. The variable frequency drive is fixed at a specific speed. Then the rotation is given to the chamber. Test is conducted for 20 min. the stopwatch is set at 20 min as we start rotation. After every test the specimen is washed with the abrasive paper and the acetone.

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V. RESULT AND DISCUSSION

5.1 Measurement of Responses:

At the end of every test session of 20 min the temperature rise is measured instantaneously by thermocouple. Then the specimen is removed from the Lever and tested on the wear testing machine having the capacity to measure the weight decrement of the specimen. The weight measurement is given by the formula (W1-W2). Thermocouple measures the temperature on the concept of phenomenon in which the resistance of thhe material changes with the change with the change in temperature.

5.2Experimental Data

The test have been observed with the help of sensing device gives some data. The data are shown in below table. Below bar diagram shows the dependency of Weight Loss on the load.

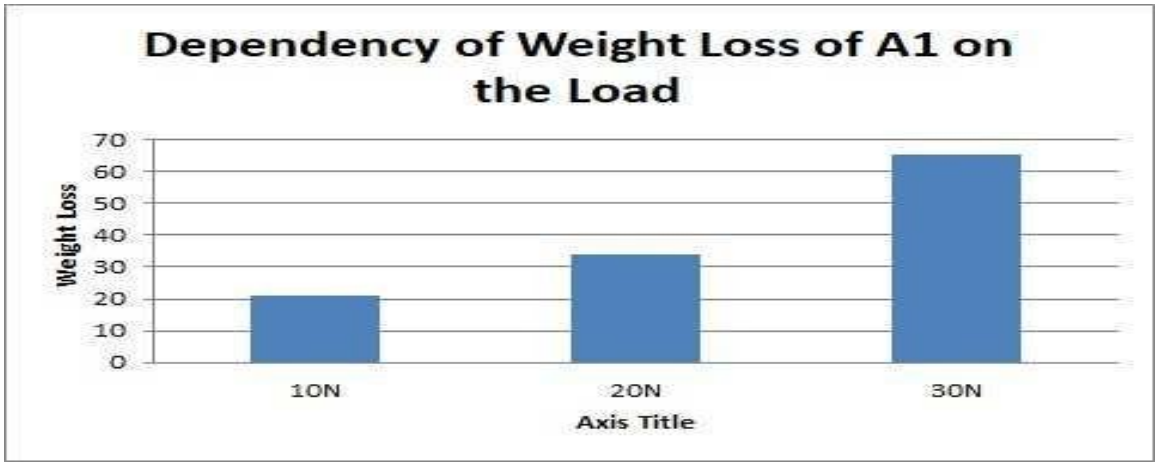

Fig.2 Dependency of Weight Loss on A1 on Load

The Fig.2 represents the bar chart of weight loss versus Force. Here we can found from the graph that intensity of force is increasing weight loss of A1 material composition is increasing.

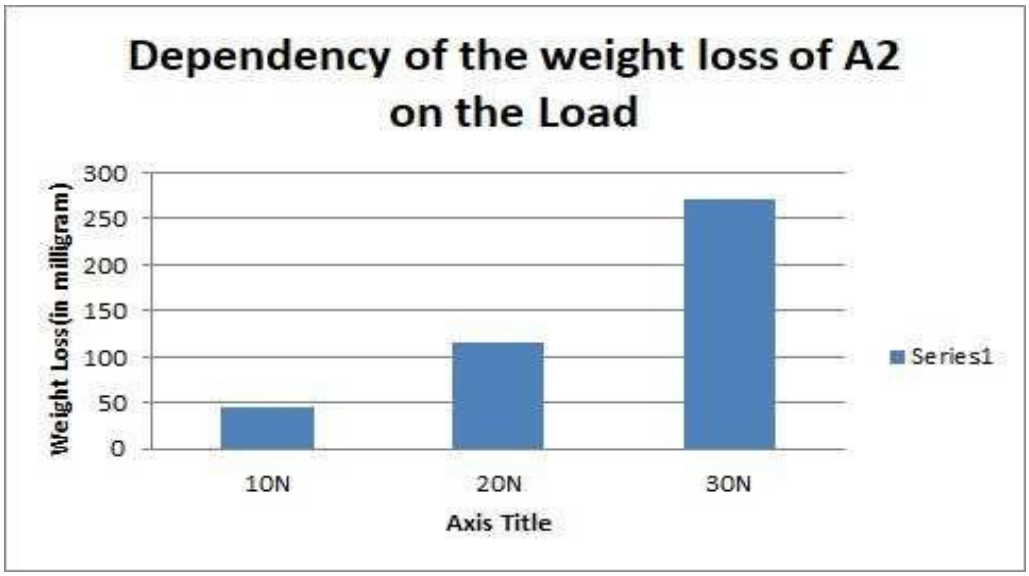

Fig.3 Dependency of Weight Loss on A2 on Load

The Fig.3 represents the bar chart of weight loss versus Force. Here we can also found from the graph that as the intensity of force is increasing weight loss of A2 material composition is

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VI. CONCLUSION

From the graph we can conclude following remarks

1. As the sped intensity is increasing the weight loss of material is increasing.
2. As the load is increasing temperature increment of alloying element is also increasing.
3. We can not clearly estimate the temperature loss versus speed balance.

But we can control weight loss at definite speed and low temperature increment.

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