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OPTIMAL MACHINING CHARACTERISTICS OF METAL MATRIX COMPOSITES BY POWDER METALLURGY PROCESS

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ABSTRACT

Aluminum Metal Matrix composites founds several applications in automobile, aerospace and other engineering application due to its mechanical and tribological properties. To improve wear resistance and mechanical properties has led to design and selection of newer variants of the composite.The present investigation deal with the study of wear behaviour of Al-Sic-Gr MMCs for varying reinforcement content, applied load, sliding velocity. Aluminium MMCs reinforced with three different percentages of reinforcement 2, 4, 6,8% wt. Sic and 2% wt.gr prepared by stir casting method. Wear test was performed by using "pin on disk" apparatus. A plan of experiment based on L_9 Taguchi orthogonal array is used to acquire the wear data. An analysis of variance is employed to investigate the influence of three controlling parameters, Sic content, Normal load, sliding velocity on dry sliding wear of the composites. It is observed that Sic content, sliding velocity and normal load significantly affect the dry sliding wear. The optimal combination of the three controlling parameters is also obtained for minimum wear.

Keywords: Metal matrix composites; Al-Sic-Mg; Stir casting; Wear; Optimization

1.INTRODUCTION

Metals have much higher strength and stiffness in comparison to polymeric materials like Epoxy which is used as matrix in polymeric material. As we will show in the design of composite laminate, while reinforcements improve the mechanical properties along the longitudinal direction, the matrix mechanical properties contribute mainly in the transverse direction. Hence, better mechanical properties of metal matrix results in better mechanical properties along the transverse direction of a laminate. In PMCs, the same thing is achieved by using cross-ply laminate - this also sacrifices anisotropy in the laminate. MMCs also have higher service temperature. Though the density of metals are quite high but the modulus to density ratio is again significantly high for metals. The use of MMC is still restricted due to the expensive fabrication and processing technology. The table below shows some of the commonly used MMCs and their mechanical properties.

Metal Matrix Composite (MMC) is a material consisting of a metallic matrix combined with a ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) dispersed phase.

- Aluminum Matrix Composites (AMC)
- Magnesium Matrix Composite
- Titanium Matrix Composite
- Copper Matrix Composites
- Properties of some Metal Matrix Composites

The word ceramic is derived from the Greek word keramikos. Keramikos is used to refer to pottery. In general, ceramics may be defined as solid materials which exhibit very strong ionic bonding and in few cases covalent bonding. However, owing to their very low fracture toughness, ceramics are not appropriate for structural applications. When ceramic materials are subjected to mechanical or thermal loading, catastrophic failure takes place because ceramics do not exhibit plastic deformation as metals plastically deform due to their high mobility of dislocation. Even a minor crack can propagate so quickly or can grow to critical sizes that result in a sudden failure. Such type of failure in ceramic materials occurs because of one deadly characteristic, namely, lack of toughness. (CMCs) increases toughness of the composites. Ceramic matrix composites are becoming popular in material selection since 1980s. High modulus of elasticity of ceramics combined with superior toughness and strength contributed by the fibres have made CMCs a viable option in material selection. By definition ceramic matrix composites are materials in which one or more distinct ceramic phases are intentionally added to another, in order to enhance some property that is not possessed by the monolithic ceramic materials.. The basic reinforcements which are included in the ceramic matrices are carbon, glasses, glass-ceramics, oxides and non-oxides. The main function of the matrix is to keep the reinforcing phase in the desired orientation or location and act as a load transfer media as well as protect reinforcement from the environment. Whereas, the primary aim of the reinforcement is to provide toughness to an otherwise brittle matrix. Filler materials in particle form are also sometimes added to the matrix materials during the processing of CMCs to enhance the properties such as electrical conductivity, thermal conductivity, thermal expansion and hardness. Particles with different shapes such as spherical, irregular and faceted are commonly used during the processing of CMCs. Due to the brittleness and presence of flaws, ceramic materials are susceptible to damage due to shock and impact loading. It is observed that the reinforcement of fibre can increase the fracture energy by order of magnitude resulting in high fracture toughness (KIC from 2-3 to 30-40 Mpa- m1/2) . The table below. High performance/ composites are tailored to the mechanical properties requirement of the final structure. The types of carbon fibres commercially available are high – tensile , high modulus & intermediate modulus fibres. These fibres are prepared from pitch or polacrylanitrile (PAN) Compared of carbon atoms bonded together to from a long chain. A super strong material that's also extremely light weight. Five times stronger than steel , two times stiffer and about two third times less in weight.

2.PROCESS DETAILS :

Powder metallurgy (PM) is a metal working process for forming precision metal components from metal powders. The metal powder is first pressed into product shape at room temperature. This is followed by heating (sintering) that causes the powder particles to fuse together without melting. The parts produced by PM have adequate physical and mechanical properties while completely meeting the functional performance characteristics. The cost of producing a component of given shape and the required dimensional tolerances by PM is generally lower than the cost of casting or making it as a wrought product, because of extremely low scrap and the fewer processing steps. The cost advantage is the main reason for selecting PM as a process of production for high – volume component which needs to be produced exactly to, or close to, final dimensions. Parts can be produced which are impregnated with oil or plastic, or infiltrated with lower melting point metal. They can be electroplated, heat treated, and machined if necessary. The rate of production of parts is quite high, a few hundreds to several thousands per hour. Industrial applications of PM parts are several. These include self – lubricating bearings, porous metal filters and a wide range of engineered shapes, such as gears, cams, brackets, sprockets, etc.

2.1Process Details:

In the PM process the following three steps are followed in sequence: mixing (or blending), compacting, and sintering.

2.2Mixing: A homogeneous mixture of elemental metal powders or alloy powders is prepared. Depending upon the need, powders of other alloys or lubricants may be added.

2.3Compacting: A controlled amount of the mixed powder is introduced into a precision die and then it is pressed or compacted at a pressure in the range 100 MPa to 1000 MPa. The compacting pressure required depends on the characteristics and shape of the particles, the method of mixing, and on the lubricant used. This is generally done at room temperature. In doing so, the loose powder is consolidated and densified into a shaped model. The model is generally called "green compact." As is comes out of the die, the compact has the size and shape of the finished product. The strength of the compact is just sufficient for in – process handling and transportation to the sintering furnace.

1. With the upper punch in the withdrawn position, the empty die cavity is filled with mixed powder.

2. The metal powder in the die is pressed by simultaneous movement of upper and lower punches.

3. The upper punch is withdrawn, and the green compact is ejected from the die by the lower punch.

4. The green compact is pushed out of the pressing area so that the next operating cycle can start.

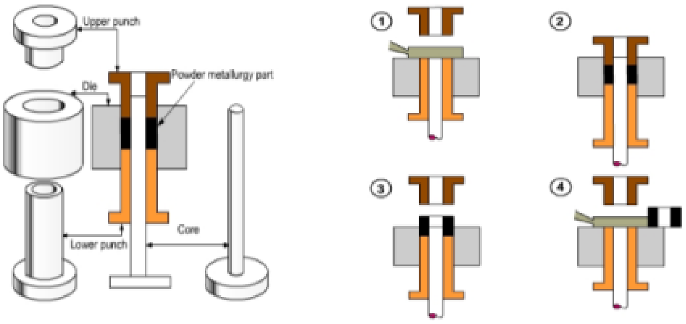


FIG.1 PROCESS FLOW CHART

2.4Sintering:

During this step, the green compact is heated in a protective atmosphere furnace to a suitable temperature, which is below the melting point of the metal. Typical sintering atmospheres are endothermic gas, exothermic gas, dissociated ammonia, hydrogen, and nitrogen. Sintering temperature varies from metal to metal; typically these are within 70 to 90% of the melting point of the metal or alloy. gives the sintering temperatures used for various metals. Sintering time varies with size and metal of part. also gives typical range of sintering time needed for various metals. Sintering temperature and time for various metal powders Sintering is a solid state process which is responsible for producing physical and mechanical properties in the PM part by developing metallurgical bond among the powder particles. It also serves to remove the lubricant from the powder, prevents oxidation, and controls carbon content in the part. The structure and porosity obtained in a sintered compact depend on the temperature, time, and processing details. It is not possible to completely eliminate the porosity because voids cannot be completely closed by compaction and because gases evolve during sintering. Porosity is an important characteristic for making PM bearings and filters.

In this process, the reinforcement particulates are introduced into a stream of molten alloy which is subsequently atomised by jets of inert gas. The sprayed mixture is collected on a substrate in the form of a reinforced metal matrix billet. Spray process in this process, droplets of molten metal are sprayed together with the reinforcing phase and collected on a substrate where metal solidification is completed. The critical parameters in spray processing are the initial temperature, size distribution and velocity of the metal drops, the velocity, temperature and feeding rate of the reinforcement and the nature and temperature of the substrate collecting the material. Most spray processes use gasses to atomize the molten metal into fine droplet stream. One advantage of the spray process is the fine grain size and low segregation of the resulting matrix microstructures. Spray deposition is not a powder metallurgical process within the strict definition of thatmterm since metal in actual powder form is not involved. It involves the atomisation of moltenmmetal, but instead of being allowed to solidify as powder, the spray is collected on a substrate to form billets for subsequent forging. The most common method of spray deposition is gas assisted spray forming. In gas assisted spray forming, high pressure high velocity inert gas jets are used to both atomise the melt stream and direct the resultant flow of semi-molten metal droplets onto the surface of a substrate or collector which is manipulated in order to allow the controlled build-up of deposit or preform shape. The range of materials that are being processed in this way is extremely wide and includes Al alloys, Cu alloys, stainless steels, high Cr alloy steels, and superalloys. The range of shapes is extensive also - round billets, tubes strip and sheet, and near-net shape pre-forms. Clad materials are also being produced, for example low alloy steel rolls clad with high speed steel. The sizes that can be produced are, naturally, a function of the available plant and they are continually rising. A recent installation will produce tube blanks weighing up to 4.5t.

2.5PRODUCT ADVANTAGES:

- Extreme speeds for particularly high fineness down to submicronrange.
- I grindingstation
- Grinding jars with the volumes from 12ml to 500ml, in 6materials
- Suitable for long-term trails and continuoususe
- Reproducible results due to energy and speedcontrol
- Directionreversal
- FFCS technology compensatesvibrations.
- Programmable startingtime.
- Power failure back up ensures storage of remaining grindingtime

- I-button operation with graphicdisplay
- 10 combination of grinding parameters can bestored
- Measurement of input energy helps to optimize grindingparameters
- Automatic grinding chamber ventilation for cooling the grindingjars
- CE-conforming

3.LITERATU REREVIW

The Al metal grid composites offer wide scope of properties reasonable for countless designing applications. Adequate written works are accessible on various parts of tribology and machining of regular metals and amalgams yet restricted writing are accessible for built up metal matrix composites. Aluminum-Silicon (Al- - Si) projecting amalgams are the most adaptable of all normal foundry cast combinations in the creation of cylinders for car motors. Contingent upon the Si fixation in weight percent, the Al- - Si combination frameworks fall into three significant classes: hypoeutectic (<12 wt % Si), eutectic (12-13 wt % Si) and hypereutectic (14-25 wt % Si). Nonetheless, business applications for hypereutectic combinations are generally restricted on the grounds that they are among the most troublesome Al composites to project and machine because of the great Si substance.

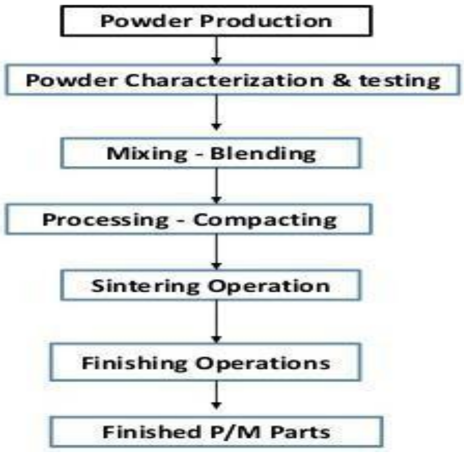
One methodology taken by the craftsmanship is to utilize fired strands or earthenware particulates to build the strength of hypoeutectic and eutectic Al- - Si amalgams. This methodology is known as the aluminum Metal Matrix Composites(MMC)technology. For instance, R. Bowles has utilized artistic filaments to work on elasticity of a hypoeutectic 332.0 combination, in a paper named, "Metal Matrix Composites Aid Piston Manufacture," Manufacturing Engineering, May1987. Moreover, A. Shakesheff has used ceramic particulate for reinforcing another type of hypoeutectic A359 alloy, as described in "Elevated Temperature Performance of Particulate Reinforced Aluminum Alloys," Materials Science Forum, Vol. 217-222, pp. 1133-1138 (1996).

In a similar approach, cast aluminum MMC for piston Susan eutectic alloy such as the 413.0 type, has been described by P. Rohatgi in a paper entitled, "Cast Aluminum Matrix Composites for Automotive Applications," Journal of Metals, April 1991.

Vikram Singh and R.C. Prasad has fabricated and analyzed the tensileand fracture behavior of 2024 Al-SiCp metal matrix Composite by reinforcing with 5%, 10%and15volume%SiCparticles.VidyaSaga Avadutalahasanalyzedthecracksin composite materials (aluminum and low carbon steel

4.POWDER METALLURGYTECHNIQUES:-

Process of Powder Metallurgy:



4.1MATERIALS

4.2ALUMINUM2024:

2024 aluminum compound (AL2024) is an aluminum composite, with zinc as the essential alloying component. It has superb mechanical properties, and displays great flexibility, high strength, sturdiness and great protection from weakness. It is more vulnerable to embrittlement than numerous other aluminum combinations on account of miniature isolation, however has altogether preferable erosion obstruction over the 2000 amalgams.

Physical properties

Density(**ṗ**) **-** 2.81G/CC

Mechanical properties

Young'smodulus(E) - 79.7 G Pa

Tensilestrength (σt) - 678M

PaElongation (ε)atbrake - 12%

Poisson'sratio(ν) - 0.37

Hardness - 83 HRB

FIG.2 AL2024 POWDER

4.3Sic(silicon carbide):

It is more defenseless to em brittlement than numerous other aluminum compounds in light of miniature isolation, yet has altogether preferred consumption obstruction over the 2000 combinations.

Fig-3 Sic POWDER

4.4Graphite properties:

Graphite is derived from a Greek word called graphene which means writing so it’s because graphite was primarily used initially for making pencils that’s how it got its name. is an aloe trope of carbon which is greyish in colour and opaque. It’s extracted from the ground, however, takes years to be formed.

4.5Reinforcement choice

S.No	Composition
1	AL 2024+2%Sic+2%Gr
2	Al 2024+4%Sic+2%Gr
3	Al 2024+6%Sic+2%Gr
4	Al 2024+8%Sic+2%Gr

TABLE 1 COMPOSITION

EXPERIMENTAL WORK

EXPERIMENTAL PROCEDURE ANDEQUIPMENT

FIG 4 AL2024POWDER

FIG.5 Sic POWDER

FIG.6 COMPERSION TESTING MACHINE

FIG 7 WORKING POSSITION

FIG.8 FINAL PRODUCT

- The pellets are then inserted in muffle furnace and temperature is gradually in steps until the temperature raise to 600˚C and pellets were maintained at this temperature for 4 hours approximately. The muffle furnace is switched off and pellets are allowed to cool in the furnace itself for 48hours.


FIG 9 MUFFALE FURANCE


FIG 10 HEAT TREATMENT PROCESS


FIG 11 AFTER DISC POLISHING

5.Results and discussion

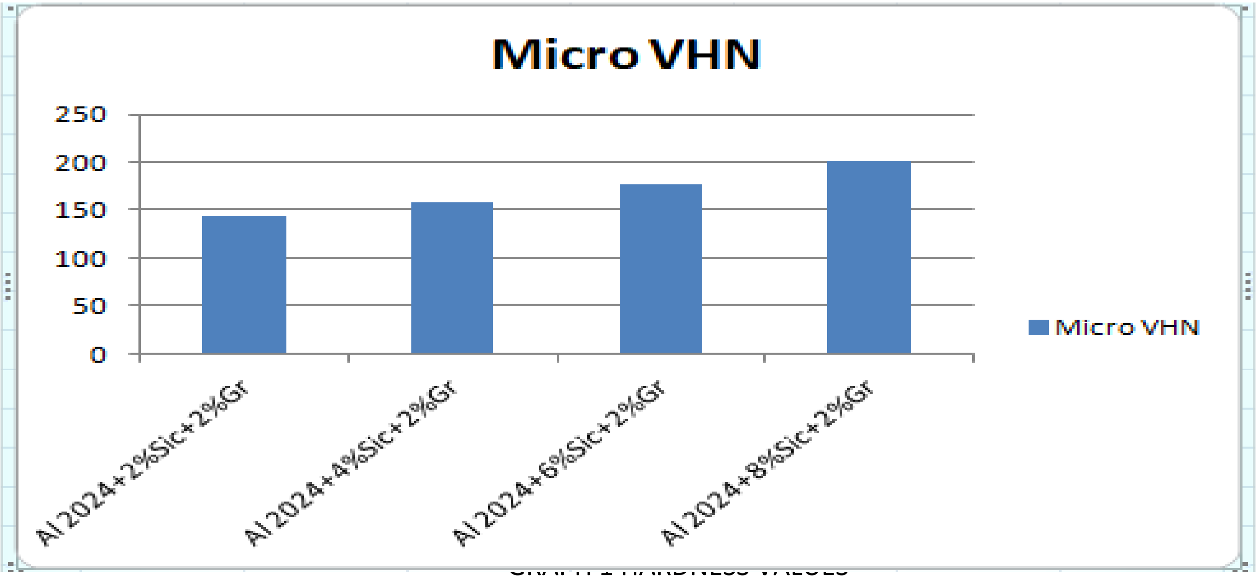
5.1Hardness:

Vickers hardness studies were carried out for the investigated materials using micro Vickers micro hardness tester (micro Vickers hardness tester, Model: LV 700) with 0.5kg load. The indentation time for the hardness measurement was 10 seconds. Averages of six readings were taken for each hardness value


FIG 11 MICRO VICKERS

composition	D1	D2	VHN	D1	D2	VHN	Micro VHN
Al 2024+2%Sic +2%Gr	94.32	94.25	111.09	82.68	111.09	137.50	144.507
Al 2024+4%Sic +2%Gr	80.15	80.06	157.750	80.71	80.01	159.950	158.850
Al 2024+6%Sic +2%Gr	75.96	76.20	174.069	79.71	161.60	176.089	175.679
Al 2024+8%Sic +2%Gr	73.84	78.06	199.438	79.09	153.00	201.638	200.538

TABLE 2 HARDNESS VALUES



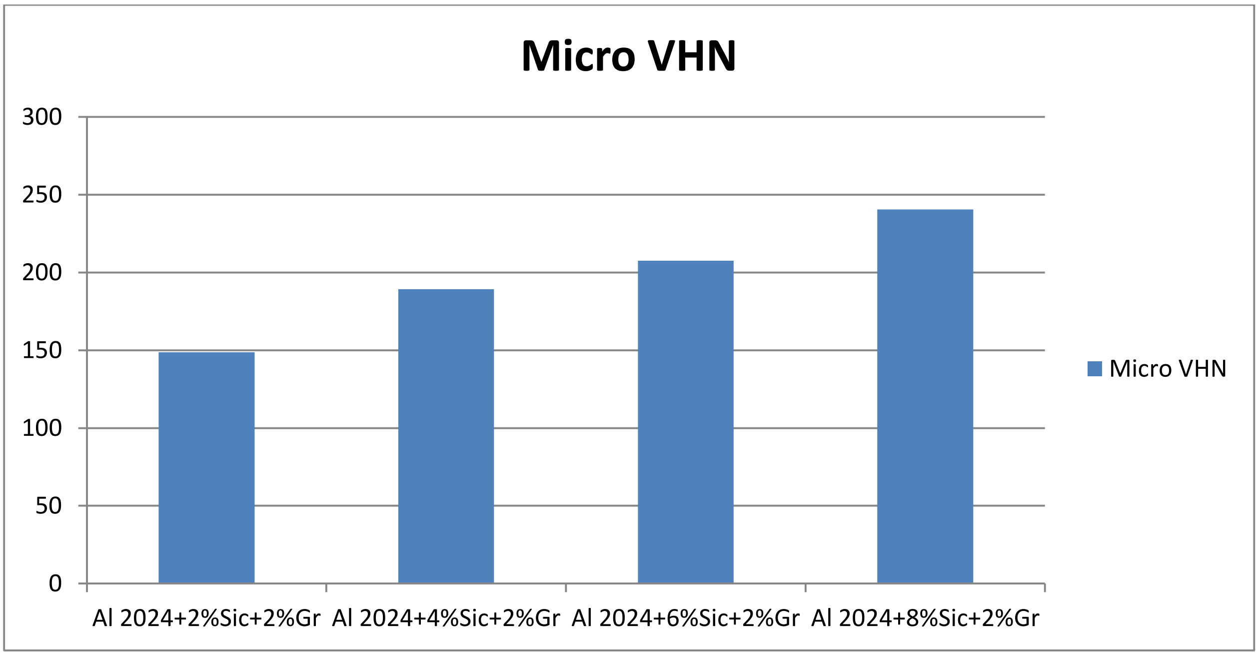
GRAPH 1 HARDNESS VALUES

5.2 HEAT TREATMENT

Heat treatment hardness@ 2 hours

composition	D1	D2	VHN	D1	D2	VHN	Micro VHN
Al 2024+2%Sic +2%Gr	94.32	94.25	133.09	82.68	111.09	164.50	148.795
Al 2024+4%Sic +2%Gr	80.15	80.06	187.750	80.71	80.01	190.950	189.35
Al 2024+6%Sic +2%Gr	75.96	76.20	204.069	79.71	161.60	211.089	207.579
Al 2024+8%Sic +2%Gr	73.84	78.06	239.438	79.09	153.00	241.638	240.538

TABLE 3 HEAT TREATED HARDNESS



GRAPH 2 HEAT TREATED HARDNESS

5.3TAGUCHI DESIGN

The target of the analysis was to foster a numerical model to foresee the impact of grating wear boundaries on the weight reduction of the test composites. The dry sliding wear tests were led dependent on the arrangement produced by Taguchi procedure. The impact of different boundaries on the wear rate was examined utilizing Signal-to-Noise (S/N) proportion and Analysis of Variance (ANOVA). The model was coordinated dependent on factual methodology by utilizing Minitab bundle [15] . Relapse conditions were created to associate every reaction with the wear boundaries. Approval tests were additionally led by utilizing the boundaries in the middle of the low, medium and significant levels to affirm the ampleness of the created relapse condition. At last, multi-reaction streamlining was done to improve grating wear attributes of the composites.

Start → DOE → Taguchi → Create Taguchi Design

Controllable factors	A :Load(N)	B:Sliding velocity (m/s)	C:distance
1	15	1.5	5
2	25	2.5	10
3	35	3.5	15

TABLE 4 L9 Orthogonal Array

Exp.No	Load(N)	Sliding Velocity(m/s)	Distance
1	**1**	**1**	**1**
2	**1**	**2**	**2**
3	**1**	**3**	**3**
4	**2**	**1**	**2**
5	**2**	**2**	**3**
6	**2**	**3**	**1**
7	**3**	**1**	**3**
8	**3**	**2**	**1**
9	**3**	**3**	**2**

TABLE 4 **L9 orthogonal array for experiment**

Exp. No	Load(N)	Sliding velocity(m/s)	Distance
1	15	1.5	5
2	15	2.5	10
3	15	3.5	15
4	25	1.5	10
5	25	2.5	15
6	25	3.5	5
7	35	1.5	15
8	35	2.5	5
9	35	3.5	10

TABLE 5 WAR

Exp.no	Initial weight of specimen (grams)	Final weight of specimen (grams)	Weight loss
1	8.76	8.9839	0.09841
2	8.45	8.9832	0.008625
3	8.78	8.5432	0.00533
4	8.45	8.8718	0.008435
5	8.58	8.9544	0.00961
6	8.43	8.9858	0.007325
7	8.78	8.9621	0.0978375
8	8.43	8.9866	0.0843454
9	8.34	8.7642	0.07525

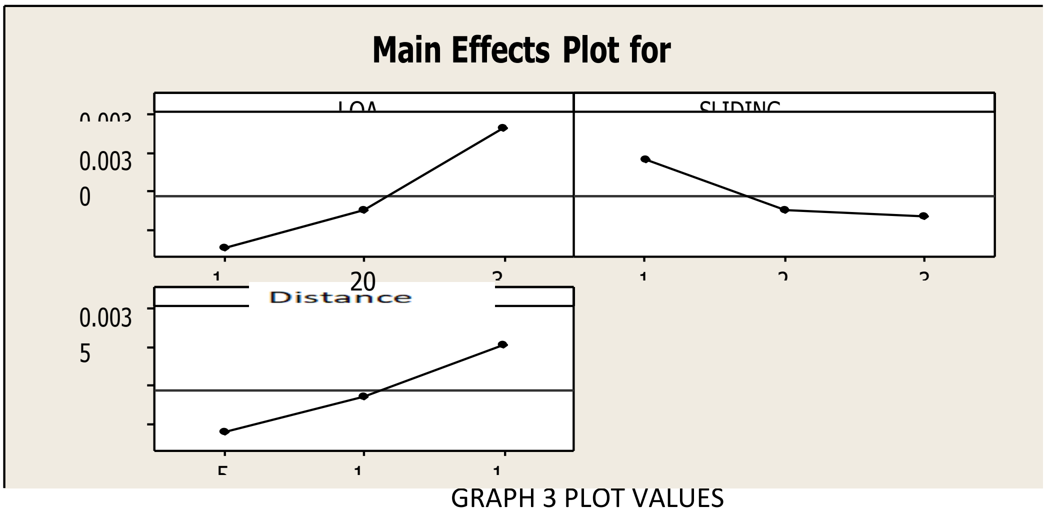
TABLE 6 WEAT TEST VALUES

Exp. No	Load (N)	Sliding Velocity (m/s)	Distance	Wear Rate (mm^3/m)	S/N Ratio (db)
1	15	1.5	5	0.004602	67.083
2	15	2.5	10	0.002654	64.367
3	15	3.5	15	0.0060	63.3789
4	25	1.5	10	0.004628	61.3789
5	25	2.5	15	0.005780	62.25797
6	25	3.5	5	0.009366	64.2678
7	35	1.5	15	0.003781	66.2679
8	35	2.5	5	0.003899	62.2357
9	35	3.5	10	0.0037	61.3678

TABLE 7Results of L9 orthogonal array.

Level	Load (N)	Sliding velocity(m/s)	distance
1	76.23	65.78	65.65
2	76.06	67.04	45.62
3	76.94	58.41	55.96
DELTA	6.34	2.98	5.68
RANK	1	3	2

TABLE 8 Response table for S/N ratio - Wear Rate



GRAPH 3 PLOT VALUES

SOURCE	DF	SEQ SS	ADJ SS	ADJ MS	F	P	P%
L	1	0.0000045	0.0000005	0.0000007	4.78	0.363	36.32
V	1	0.0000008	0.0000007	0.0000007	3.56	0.363	3.32
%R	1	0.0000043	0.0000003	0.0000007	5.08	0.363	36.0
L*V	1	0.0000007	0.0000007	0.0000005	5.75	0.363	3.00
L*%R	1	0.0000009	0.0000005	0.0000003	5.79	0.363	3.32
V*%R	1	0.0000003	0.0000007	0.0000007	0.67	0.363	7.32
ERROR	2	0.0000009	0.0000005	0.0000007			
TOTAL	8	0.0000089					

TABLE 9ANALYSIS OF VARIANCE

6.CONCLUSION

By using powder metallurgy technique hybrid composites were fabricated successfully. All the composites were exhibits higher hardness than base material.

Hybrid composites the preference of graphite in hybrid composites will lose the strength because of soft and having much inability.

Micro structure of all composites were shown.

FESEM for the hybrid composites were shown.

By using software based electro chemical weld tester system was used to carry out potential dynamic polarization tests conducted.

All the composites were shown better corrosive resistive than the base material.

All the hybrid composites were good corrosive resistive than non-hybrid composites because of AL2024 and SIC were forums a layer of protection to oxygen reaction.

Taguchi parameter design can provide a systematic procedure that can effectively and efficiently identify the optimum wear rate of the composite. This research demonstrates How to use Taguchi parameter design for optimizing wear rate with Minimum cost.

Incorporation of silicon carbide as primary reinforcement with increasing composition increases the wear resistance of composite.

Optimal conditions for minimum wear rate were obtained using S/N ratio analysis and ANOVA .The analysis shows that wear rate increases with increase in applied load and % reinforcement and decrease in sliding velocity. From the Main effects plot for means and S/N ratio, it was found that L=10 N, V=3 m/s and %R=5 gives minimum wear rate. The ANOVA shows the percentage contribution of each control parameter on wear rate. From the S/N ratio and ANOVA analysis, it was found that applied load has the highest significance on wear rate followed

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