FABRICATION AND TESTING OF POWDER COMPACTION OF NiCr-B4N-Sic ANDTESTING OPTIMIZING WITH TAGUCHI METHOD

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ABSTRACT

Powder metallurgy products have found use in both conventional aerospace applications and in space vehicle systems components that have required extensive development programs to satisfy highly specialized purposes. This project reviews some powder metallurgy applications in space vehicles systems and discusses some examples of powder metallurgy parts and materials actually used in successfully orbited spacecraft. The aim of the project is preparing the new material using Nickel chromium, boron nitride , silica carbide powder different percentages .Taking nickel chromium 50microns and boron nitride nano size particle mixing in blender machine after adding the blender glycerin sintering with each specimen 26grms apply pressure 45 tons hardly holding time is 10sec maintain temperature is 200oc after heating process set temperature 1250 with gas treatment organ & hydrogen 2 bar after cooling process 1250oc to room temperature 5 hr's taking dimension of each specimen is 30x50x15mm thickness s. The wear and frictional properties of metal matrix hybrid composites were studied by performing dry sliding wear test using pin on disc wear test apparatus. Experiments were conducted based on the plan of experiments generated through Taguchi's technique. A L9 Orthogonal array was selected for analysis of data. Investigation to find the influence of applied load, sliding speed and track diameter on wear rate as well as coefficient of friction during wearing process was carried out using ANOVA. Objective of the model was chosen as smaller the better characteristics to analyze the dry sliding wear resistance. Results show that track diameter has highest influence followed by load and sliding speed.

INTRODUCTION

1.1 INTRODUCTION OF POWDER METALLUARGY:

Powder metallurgy is a manufacturing process that produces precision and highly accurate parts by pressing powdered metals and alloys into a rigid die under extreme pressure. With the development and implementation of technological advances, powder metallurgy has become the essential process for the production of bushings, bearings, gears, and an assortment of structural parts. Powder metallurgy is a metal-forming process performed by heating compacted metal powders to just below their melting points. Although the process has existed for more than 100 years, over the past quarter century it has become widely recognized as a superior way of producing high-quality parts for a variety of important applications. This success is due to the advantages the process offers over other metal forming technologies such as forging and metal casting, advantages in material utilization, shape complexity, near-net-shape dimensional control, among others. These, in turn, contribute to sustainability, making powder metallurgy a recognized green technology.

1.2 APPLICATIONS OF COMPOSITES

The following are the various applications of the composite materials in different fields like:

1. **Space craft:** Antenna structures, solar reflectors, Satellite structures, Radar, Rocket engines, etc.
2. **Aircraft:** Jet engines, Turbine blades, Turbine shafts, Compressor blades, Airfoil surfaces, Wing box structures, Fan blades, Flywheels, Engine bay doors, Rotor shafts in helicopters, Helicopter transmission structures etc.
3. **Marine:** shafts, hulls, spars (for racing boats).
4. **Communication antenna:** wireless communication, space communications, micro sensors
5. **Electronic circuit boards:** PCB, breadboard.
6. **Safety Equipment:** like ballistic protection and air bags of cars.

7. Automobile: Engines, bodies, Piston, cylinder, connecting rod, crankshafts, bearing materials

8. Miscellaneous: Bearing materials, Pressure vessels, Abrasive materials, Electrical machine Truss members, Cutting tools, Electrical brushes, etc..

1.3 POWDER METALLURGY TECHNOLOGIES

In reality, powder metallurgy comprises several different technologies for fabricating semi-dense and fully dense components. The conventional powder metallurgy process, referred to as press-and-sinter, was used to produce the planetary carrier shown here. The surgical scissor parts were formed through the metal injection molding (MIM) process, the manifold was manufactured through hot isostatic pressing (HIP), while the connecting rod was produced using powder forging (PF). Meanwhile, new to the scene, metal additive manufacturing (AM) is gaining popularity.

Using many of these PM processing techniques, as well as other processes such as spray forming, roll compaction, rapid solidification, and others, components are also produced today from particulate materials other than metal powders. Today's advanced materials are seldom made of metals and metallic alloys alone, often incorporating ceramics, ceramic fibers, and intermetallic compounds. These include:

- CERMETS
- INTERMETALLIC COMPOUNDS
- METAL MATRIX COMPOSITES
- NANOSTRUCTURED MATERIALS
- HIGH-SPEED STEELS

CHAPTER 2 LITERATURE REVIEW

[1] Boron carbide (B4C) is extreme hard reinforcement material component with significantly excellent hardness, Revised Manuscript Received on December 08, 2018. KATLA RAJENDAR, Department of mechanical engineering, Malla Reddy Engineering College, Secunderabad- 500100 Department of Mechanical Engineering, Kakatiya University, Warangal, Telangana- 506009, India Dr K. ESWARAIAH, Department of mechanical engineering, Malla Reddy Engineering College, Secunderabad-500100, India ANIL KUMAR BODUKURI, Department of Mechanical Engineering, Kakatiya University, Warangal, Telangana-506009, India SAMPATH.V, Department of Mechanical Engineering, Kakatiya University, Warangal, Telangana-506009,

[2] India impeccable corrosion resistance, numerous mechanical properties, which makes it is a desirable reinforcement material for enormous engineering requisite and its related applications. [1,2]. Hexagonally bonded boron nitride (hBN) particle also an effectual reinforcement for aluminum metal composites specially for TRIBOLOGICAL applications in automobiles and other because it makes the composites as the most toughest and self-lubricant in nature. The support provided by these h-BN particles improves the mach inability and wear resistance of Al-B4C composites when embeds into the base composite metal. The synthesized hybrid aluminum based composites encompassing B4C and h-BN particles having great benefit compared to other combination of reinforcements.

[3] A K BODUKURI et al, Investigated on hardness values of metal matrix composites by varying the compositions of B4C and Sic reinforcements in Aluminum metal matrix composites and conclude that hardness values are higher compared to the base metal aluminum and alloys. The effect of addition of molybdenum trioxide on strength coefficient, hardness, density and thermal conductivity was studied by B.STALIN et al, result reveals that addition of parentage of MoO3 increase the strength coefficient, hardness and density and decreases the strain hardening index during cold upset process.

[4] CUNGUANG CHEN et al observed that due to the distinct high relative density, more significantly distributed grain refinement and the presence of meagerly distributed hard particulates b4c and inter metallic phases sic in the matrix showed the best mechanical performance, including the BRINELL hardness, compressive strength and fracture strain.

[5] AMAR E NASSER et al investigated that Reinforcement of titanium dioxide with aluminum was effect on mechanical properties like tensile strength, hardness, density which were increased with increasing of NIcr with B4c. Also decreasing of ductility and enhancing of wear resistance of composite.

[6] K. KANTHAVEL, K.R. SUMESH, P. SARAVANAKUMAR proposed that the characteristic features of the combinations of Al+ 5% Al2O3, Al+ 5% Al2O3 + 5% MoS2 and Al +5% Al2O3 + 10% MoS2, reveals that further addition of 10% MoS2 in the hybrid composite does not help to improve the already existent *TRIBOLOGICAL* property.

[7] EHSAN GHASALI et al, says that Microwave sintering produce Nrcr /B4C metal matrix composite at a sintering temperature which is either at 850◦C or more. By increase the weight percentage of B4C micro hardness and compressive strength values increased. Use of Microwave heating produces Al/B4C composites and saves the energy proportions.

[8] MAHO YAMAGUCHI et al, Aluminum/boron nitride nano tube (BNNT) composites were prepared by the process of spark plasma sintering (SPS). The Boron nitride nano tubes were found in the grain boundaries in Plasma Sintering samples at room temperature containing about

3.0 wt% Boron nitride nano tubes (300MPa) became one and another half times higher than that of free High pressed torsion /Al compact (200MPa).

[9]MADHURI DESHPANDE et al studies on AL7075 alloy MMCs and discussed that there is good bonding exist between the reinforcement and alloys even high volume fractions of reinforcements also uniform distribution of the carbon fibers.

[10] S. OZKAYA, A. CANAKCI investigated the unreinforced Nicr alloy shows 15 wt% B4C composites produced with 25 hr milling time. The hardness of the hot pressed composites was higher than that of the hot pressed nano composites incurred by using the globally identified conventional powder metallurgy and 10 wt% of B4C nano composites produced with 6hr milling time gives the highest tensile strength.

[11] SENER KARABULUT et al, also proposed his theory on Nicr alloy reinforced with 5-20 wt% B4C produced using a powder metallurgy method. The highest tensile and transverse ruptures strengths are for Al6061/5 wt% B4C were estimated successfully.

3.1 PROJECT OVER VIEW

1) In this experimental work Powder metallurgy process was used to prepare the samples. This process consists of mainly four steps which were powder characterization, blending or mixing, compaction and sintering. A material used in the present nickel chromium and boron Carbide was used as reinforcement.

2) The aim of the project is preparing the new material using Nickel chromium, boron carbide, silica carbide powder different percentages.

3) Taking nickel chromium 50microns and boron nitride nano size particle mixing in blender machine after adding the blender glycerin sintering with each specimen 26grms apply pressure 45 tons.

4) Hardly holding time is 10sec maintain temperature is 200o c after hearing process set temperature 1250 with gas treatment organ & hydrogen 2 bar after cooling process 1250o c to room temperature 5 hr’s taking dimension of each specimen is 30x50x15mm thicknesses.

5) The wear and frictional properties of metal matrix hybrid composites were studied by performing dry sliding wear test using pin on disc wear test apparatus. Experiments were conducted based on the plan of experiments generated through Taguchi’s technique.

6) A L9 Orthogonal array was selected for analysis of data. Investigation to find the influence of applied load, sliding speed and track diameter on

wear rate as well as coefficient of friction during wearing process was carried out using ANOVA.

7) Objective of the model was chosen as smaller the better characteristics to analyze the dry sliding wear resistance. Results show that track diameter has highest influence followed by load and sliding speed.

8) Finally find out the which composition is the best compared to the Remaining materials

3.2 METHODOLOGY

1. Preparation of powders: very fine powders are obtained using various techniques.

2. Blending of powders: The fine powders are mixed along with a lubricant. The lubricant helps in imparting good fluidity to the powders.

3. Compacting: The blended powder is compacted in a mold or die.

4. Sintering: The compacted mass is sintered at a high temperature in a furnace in a controlled atmosphere

3.3 PROCESSING STAGES OF POWDER METALLURGY

1. First the primary material is powdered and divided into many small individual particles.
2. Two or more metal and or non metals are mixed or blended together to form a homogeneous mixture.
3. The blended mix is introduced into a mold cavity or a die and pressed to produce a weak cohesive mass called as green compact.
4. The green compact is then subjected to very high temperature and pressure for a known time to get a hardened mass.

Figure 1: Specimens prepared by using powder metallurgy

- ***JUST AS EARLIER STATED, POWER METALLURGY HAS BASIC FOUR PROCESSES WHICH INCLUDED***
  1) **POWDER PREPARATION**
  2) **MIXING AND BLENDING**
  3) **COMPACTING**
  4) **SINTERING**

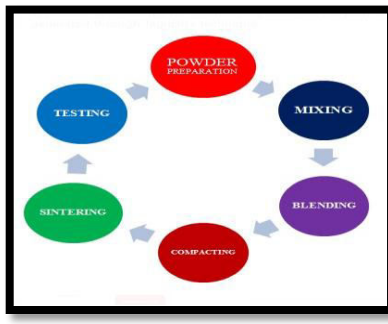

Figure 2: Stages of powder metallurgy

NICKEL CHROMIUM

The nickel-chromium system shows that chromium is quite soluble in nickel. This is a maximum at 47% at the eutectic temperature and drops off to about 30% at room temperature. A range of commercial nickel chromium alloys is based on this solid solution. Such nickel chromium alloys have excellent resistance to high temperature oxidation and corrosion and good wear resistance. The introduction of small amounts (<7%) of chromium to nickel increase the sensitivity of the nickel chromium alloy to oxidation. This is because the diffusion rate of oxygen in the scale is increased. This trend reverses after addition levels increase above 7% chromium and increases up to an addition level of approximately 30%. Above this level, there is little change.

Element	Intermittent	Continuous
Cr	20	20
Si	1.5	0.5
Ca	0.1	0.05
Ce	0.05	-
Ni	Balance	Balance

Table1: Composition of Ni Cr powder

Oxidation resistance can be attributed to the formation of a highly adherent protective scale. The adherence and coherence of the scale can be improved by the addition of small amounts of other reactive elements such as zirconium, silicon, cerium and calcium or similar. The scale thus formed is a mixture of nickel and chrome oxides (NiO and Cr2O3). These combine to form nickel chromate (NiCr2O4), which has a spinel-type structure.

Figure 3: Nickel chromium powder

BORON CARBIDE

Boron Carbide (B4C) is one of the hardest materials known, ranking third behind diamond and cubic boron nitride. It is the hardest material produced in tonnage quantities. Originally discovered in mid 19th century as a by-product in the production of metal borides, boron carbide was only studied in detail since 1930.

Boron carbide powder is mainly produced by reacting carbon with B2O3 in an electric arc furnace, through carbothermal reduction or by gas phase reactions. For commercial use B4C powders usually need to be milled and purified to remove metallic impurities. In common with other non-oxide materials boron carbide is difficult to sinter to full density, with hot pressing or sinter HIP being required to achieve greater than 95% of theoretical density. Even using these techniques, in order to achieve sintering at realistic temperatures (e.g. 1900 - 2200°C), small quantities of do pants such as fine carbon, or silicon carbide are usually required. As an alternative, B4C can be formed as a coating on a suitable substrate by vapor phase reaction techniques e.g. using boron halides or di-borane with methane or another chemical carbon source.

Figure 4: Boron Carbide powder

SILICON CARBIDE

Silicon carbide (SiC) is a hard covalently bonded material predominantly produced by the carbothermal reduction of silica (typically using the Acheson process). Depending on the exact reaction conditions the resulting silicon carbide is either a fine powder or a bonded mass that requires crushing and milling to produce a usable feedstock.

Several hundred structures of silicon carbide (polytypes) have been identified which have different stacking arrangements for the silicon and carbon atoms. The simplest structure is a diamond structure which is designated β-SiC. Other structures are either hexagonal or rhombic and are referred to as α-SiC.

Figure 5: Silicon Carbide powder

EXPERIMENTAL WORK

The objective of the experiment was to develop a mathematical model to predict the influence of abrasive wear parameters on the weight loss of the experimental composites. The dry sliding wear experiments were conducted based on the plan generated by powder metallurgy analyzed with Taguchi method. The influence of various parameters on the wear rate was analyzed. The model was organized based on statistical approach by using Minitab package [15]. Regression equations were developed to correlate each response with the wear parameters. Validation tests were also conducted by using the parameters in between the low, medium and high levels to confirm the adequacy of the developed regression equation. Finally, multi-response optimization was done to optimize abrasive wear characteristics of the composites.

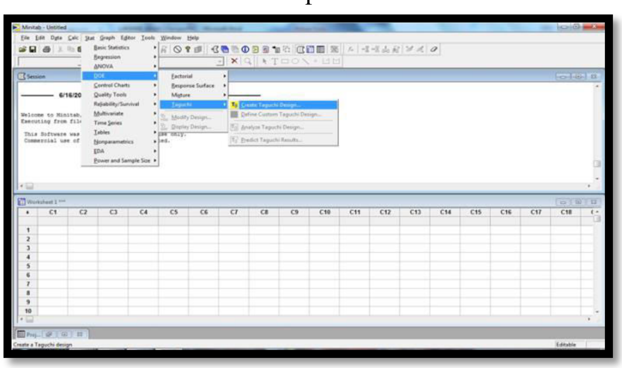

Figure 6: Taguchi on Minitab software

TAGUCHI TECHNIQUE

Taguchi technique is the statistical method developed by *GENICHI TAGUCHI* to improve the quality of manufactured goods, and more recently also applied to engineering, biotechnology. Taguchi proposes an "off-line" strategy for quality improvement as an alternative to an attempt to inspect quality into a product on the production line. He observes that poor quality cannot be improved by the process of inspection, screening and salvaging. No amount of inspection can put quality back into the product. Taguchi recommends a three- stage process: system design, parameter design and tolerance design.

An perimental design methodology that allows you to choose a product or process that performs more consistently in the operating environment. Taguchi designs recognize that not all factors that cause variability can be controlled in practice. These uncontrollable factors are called noise factors. Taguchi designs attempt to identify controllable factors (control factors) that minimize the effect of the noise factors. During experimentation, you manipulate noise factors to force variability to occur and then find optimal control factor settings that make the process or product robust, or resistant to variation from the noise factors. Taguchi designs use orthogonal arrays, which estimate the effects of factors on the response mean and variation. Orthogonal arrays allow you to investigate each effect independently from the others and may reduce the time and cost associated with the experiment when fractionated designed are used.

In classical designed experiments, the primary goal is to identify factors that affect the meant response and control them to desirable levels. Taguchi designs focus on reducing variability, as well as setting the mean to target.

Powder metallurgy is one of the important tools based on performing evaluation or experiments to test the sensitivity of a set of response variables (independent or variables) by considering experiments in "orthogonal array" with the aim to attain the optimum setting of the control parameters. Orthogonal arrays provide a best set of well balanced (minimum) experiments. Array indicates the number of row and columns it has, and also the number of level in each of the columns.

The number of row of an orthogonal array represents the requisite number of experiments.

There are five basic phase, applied in Taguchi experiments design technique.

1. Phase 1- Experiment planning,
2. Phase 2- Design Experiment,
3. Phase 3- Conducting Experiments,
4. Phase 4- Analyzing Results, and
5. Phase 5- Confirming Prediction Results.

The Taguchi uses a statistical measure of performing called S/N ratio, which is logarithmic function of desired output to serve as objective function for optimization, help in data analysis and the prediction of the optimum results. There are three types of signal-to noise ratio of common interest for optimization of Static Problem; Smaller- the-better, Larger-the-better, nominal-the-best. They formulate for signal-to-noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. For the minimization of wear Larger the- Better needed to be used.

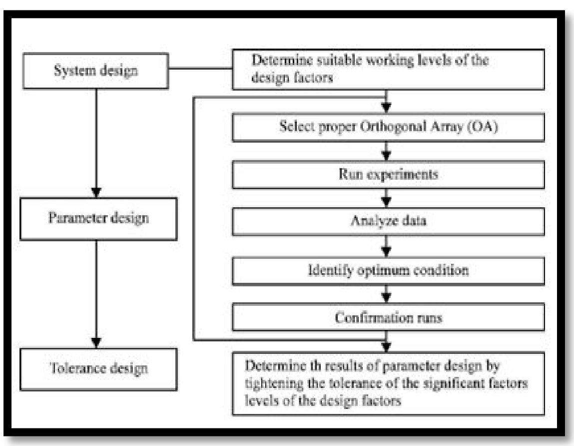

Figure 7: Different Phases of Taguchi method

In the present work Taguchi's parameter design approach is used to study the effect of operating parameters on the wear resisting behavior of NiCr+B_4C+SiC composite.

4.2 DESIGN OF EXPERIMENT:

Design of Experiments (DOE) was used for analyzing the impact of various input Parameters on a given output. DOE approach uses Taguchi technique to find the optimal combination of parameters for a given set of response. It provides an optimized picture to improve the performance, efficiency and cost. This technique was used for evaluating systems based on orthogonal arrays. The technique was widely used because of its ability to analyze and interpret data based on the responses. A standard orthogonal array was chosen based on the number of parameters, and the effect of parameters on the target value. Based on this, experiments were conducted to study the impact of various factors on the response. The variations were identified by means of a signal to noise ratio. This S/N ratio gives the effect of noise on various characteristics. ANOVA was used to determine the percentage of influence of various parameters on the response. It was a quantitative measurement to determine the contribution of each parameter on the response. The experiment was then conducted by varying the applied load, sliding velocity and % reinforcement for three levels as shown in Table .4. 1

Controllable factors	A :Load (N)	B:Sliding velocity (m/s)	C:%Reinforcement
1	10	1	5
2	20	2	10
3	30	3	15

Table 4: selected factor and level

WEAR TEST:

The dry sliding wear test was conducted on a pin on disc tester Shown in Figure. The dimension of each specimen is 30x50x15mm thickness. Before testing of the specimen they were machined and polished as per ASTM standards .The wear track, composite specimens were cleaned thoroughly with acetone before the test. The experiment was conducted by holding the pin against a rotating disc (EN32 steel) and by adding weights on the left arm of the apparatus. During the test condition the track diameter 100mm and the sliding distance 1500m was as kept constant.

A Linear Variable Differential Transformer monitors the motion of the left arm there by helping to determine wear at any given point of time. Once the surface in contact wears out, the load pushes out the arm to remain in contact with the disc. This generates a signal by means of which it monitors the maximum wear on a continuous scale. The weight loss was found by measuring the specimen before and after the experiment on an electronic weighing pan with accuracy of 0.0001g.

The Pin on Disc wear measuring instrument has the following main components:

1. Rotating Disc
2. Pin Holder
3. Load Pan

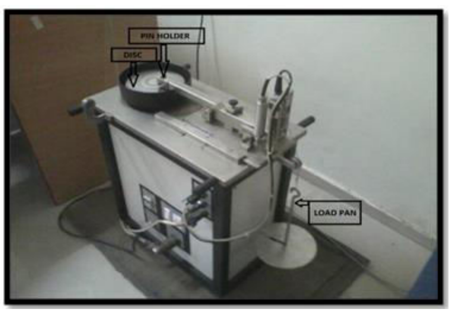

Figure 8: Friction wear testing machine

SELECTION OF AN ORTHOGONAL ARRAY (OA):

The selection for the array depends on the number of factors involved, the number of levels and the desired experimental resolution or cost limitations. A total of 9 experiments were performed based on the run order generated by the *TAGUCHI* model. The response for the model is wear rate. The general layout of L_9 orthogonal array is shown in Table.4.2**.**experimental design with a L_9 orthogonal array as suggested by *TAGUCHI* has been used to carry out experiments with three inputs parameters and for three levels of individual parameters. The inputs parameters used are load (N), sliding velocity (v) and %Reinforcement (%R).as per *TAGUCHI* experimental design philosophy a set of three levels assigned to each process parameter has two degrees of freedom (DOF). This gives a total of six DOF for three process parameters selected in this work. The nearest three level orthogonal array available satisfying the criterion of selecting the OA is L_9 having 26 DOF. The details of experiments with parameters and levels are given in Table.4.3.The first column was taken as the load Applied, the second taken as the Sliding velocity and third as the % Reinforcement

Exp. No	Load(N)	Sliding velocity(m/s)	% Reinforcement
1	10	1	5
2	10	2	10
3	10	3	15
4	20	1	15
5	20	2	10
6	20	3	5
7	30	1	10
8	30	2	5
9	30	3	15

Table 5: L9 orthogonal array for experiment

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The wear behavior of the work pieces obtained by the testing from pin on disc wear measuring instrument. Three responses were taken from each experiment e.g. R1, R2 and R3 responses for each experiment. For the wear resisting feature, the signal-to-noise ratio should be small e.g. smaller the S/N ratio, better will be the wear resisting feature. The response tables for signal to noise ratios show the average of selected characteristics for each level of the factor .The result of L9 orthogonal array from Table .4.3 is shown in Table.4.5 .ANOVA was performed to determine the percentage effect of each parameter

Exp. no	Initial weight of specimen (grams)	Final weight of specimen (grams)	Weight loss
1	26.77	26.7115	0.05841
2	26.85	26.8422	0.007725
3	26.90	26.8916	0.00833
4	26.85	26.8393	0.010658
5	26.90	26.89	0.00991
6	26.77	26.7624	0.007525
7	26.90	26.701	0.0198375
8	26.77	26.7595	0.010454
9	26.85	26.8387	0.01125

Table 6: wear test

Exp. No	Load (N)	Sliding Velocity (m/s)	% Reinforcement	Wear Rate (mm^3/m)	S/N Ratio (db)
1	10	1	5	0.001402	57.0618
2	10	2	10	0.001854	54.6437
3	10	3	15	0.0020	53.5555
4	20	1	15	0.002558	51.8458
5	20	2	10	0.002380	52.4648
6	20	3	5	0.001806	54.8706
7	30	1	10	0.004761	46.4441
8	30	2	5	0.002509	52.0149
9	30	3	15	0.0027	51.0567

CHAPTER 5

RESULTS AND DISCUSSION

The aim of this project is to achieve the minimum wear rate for NiCr+B_4C+SiC metal matrix composite using Taguchi method prepared by powder metallurgy. The Investigation is carried out using three control parameters weight % of reinforcement, applied load, sliding speed. Wear depth is taken as system response parameter.

5.1 S/N RATIO

In Taguchi designs, signal-to-noise ratio is a measure of robustness Used to identify control factors that reduce variability in a product or process by minimizing the effects of uncontrollable factors (**noise** factors).Control factors are those design and process parameters that can be controlled. Noise factors can be controlled during production or product use, but can be controlled during factor during experimentation, you manipulate noise factors to force variability to occur and from the results identify optimal control factor settings that make the process or product robust, or resistant to variation from the noise factors.

The signal to noise ratios is derived from the Taguchi loss function. **Taguchi's Signal-to-Noise Ratios** are in Log form. Taguchi experiments often use a2-step optimization process. In step1 use the signal- to – noise ratio to identify those control factors that reduce variability. In step-2, identify control factors that move the mean to target value and have small or no effect on the signal- to – noise ratio. The signal- to- noise ratio measures how the response varies relative to the nominal or target value under different noise conditions. You can choose from different signal-to-noise ratios, depending on the goal of your experiment. For static designs, Minitab offers four signal –to – noise ratios.

1. Larger is best
2. Nominal is best
3. Nominal is best (Default)
4. Smaller Is Better

5.2 Analysis Using S/N Ratio:

Experiments were conducted accordance to the orthogonal array and the corresponding values of wear rate were shown in Table.4.5 .The influence of input process parameters on wear rate were determined using S/N ratio. The parameter with the highest S/Nratio gives minimum wear rate. The response table for S/N ratio was shown in Table .5.1. The difference between the maximum and minimum values of S/N ratio gives delta. Ranking of parameter were done according to the delta value. The parameter with the highest value of delta has the greatest influence on wear rate. From Table 4.5, it was found that load has the significant impact on wear rate followed by sliding distance and sliding velocity.

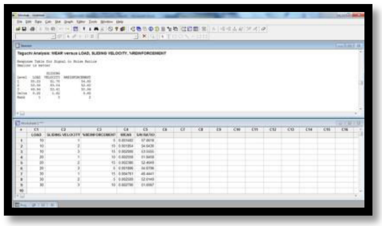

Figure 9: Response table for S/N ratio - Wear Rate

Level	Load (N)	Sliding velocity(m/s)	%Reinforcement
1	55.23	51.78	54.65
2	53.06	53.04	52.62
3	49.94	53.41	50.96
DELTA	5.28	1.62	3.68
RANK	1	3	2

Table 7: Response table for S/N ratio -Wear Rate

5.3 REGRESSION ANALYSIS AND CONFIRMATION TEST:

Regression analysis generates an equation to describe the statistical relationship between one or more predictors and the response variable and to predict new observations.

Regression generally uses the ordinary least squares method which derives theequation by minimizing the sum of the squared residuals.

Regression results indicate the direction, size, and statistical significance of the relationship between a predictor and response.

- Sign of each coefficient indicates the direction of the relationship.
- Coefficients represent the mean change in the response for one unit of change in the predictor while holding other predictors in the model constant.
- P-value for each coefficient tests the null hypothesis that the coefficient is equal to zero (no effect). Therefore, low p-values suggest the predictor is a meaningful addition to your model.
- The equation predicts new observations given specified predictor values.

A regression model was developed based on the experimental results and this establishes a correlation between the significant parameters. The regression equation developed for wear rate was:

Wear rate = 0.000386 + 0.00008 L - 0.000338v+ 0.000014%R

From the above relation, it was observed that the coefficient associated withload and %reinforcement was positive. This clearly reveals that as load and %reinforcementincreases, wear rate of the hybrid composite also increases. The negative coefficient of sliding speed reveals that increase in speed decreases the wear rate. To validate theconclusions obtained from the analysis, confirmation experiment was conducted and comparison was made between experimental values and computed values developed fromregression model. Table 5.3 and Table 5.4 show the confirmation experiment and its results. Based on the confirmation experiment, it was observed that the error associated with experimental values and computed values was minimal and hence this regression modelobtained from L_9 array can be used effectively to predict the wear rate of the composites withgood accuracy.

Exp. no	Load (N)	Sliding velocity(m/s)	%Reinforcement
1	15	1.5	7
2	22	1.8	9
3	25	2.5	13

Table 8: Confirmation Experiment.

Exp .No	Exp. Wear Rate(mm^3/m)	Reg. Model Wear Rate (mm^3/m)	%Error
1	0.00 1991	0.001913	4.01
2	0.002452	0.002602	5.75
3	0.003153	0.003101	1.92

Table 9: Results of Confirmation Experiment.

CONCLUSION

Following are the conclusions drawn from the study on dry sliding wear test using Taguchi's technique specimens prepared by powder metallurgy:

1) 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.

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

3) 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 by %reinforcement and sliding velocity. The regression model generated was effectively used to predict the wear rate. Thus the optimized condition can be well utilized to improve the wear resistance of the components and these components can be used in automotive and aerospace industry for wear resistance applications.

4) Confirmation experiment was carried out and made a comparison between experimental values and computed values showing a change associated with dry sliding wear of composites,

Thus, Design of experiments by Powder metallurgy was successfully used to predict the tribological behavior of composites.

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