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Development of Friction Pad and Study for Its Wear Characteristics

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Abstract

This paper present a systematic approach to optimizing manufacturing methods of friction pad as well as wear characteristics. Friction Pads are most commonly used for stop the vehicle within smallest possible distance and this is done by converting the kinetic energy of the vehicle into heat energy which is dissipated into the atmosphere. The characteristics of metal powder such as Purity, Chemical Composition, Particle Size, Particle Shape, Size Distribution, Particle Micro Structure, Apparent Density, Flow Rate play a major role in deciding metal powder for manufacturing of friction pad. In the present study an attempt have been made to manufactured of friction pad by using sintering technique and pressure is apply by hydraulic mounting press. Friction pad manufactured by mixing of Copper Powder, Zinc Powder, and Lead Powder are used for experimental phenomenon. This study investigated the optimization of manufacturing parameter (molding temperature, molding pressure and molding time) for friction pads using Taguchi Method. Physical Properties (Hardness) and Tribological Properties (Wear) were selected as a quality target. Analysis of varience (ANOVA) is performed on experimental data. The signal to noice (S/N) ratio analysis is employed to find optimum condition for hardness and wear rate. The green compact was manufactured at different range of temperature and pressure with vering time for manufacturing of green. It was determine that moulding pressure has the strongest effect on hardness and wear properties. Density of green compact increase with increase load and also density increase with increasing temperature and increasing time at temperature. A laboratory-scale pad-on-disc brake testing machine was manufactured for measure the wear rate of brake friction pad material against the cast iron disc. While conducting these test 200 N force was applied with help of spring against the rotating disc. Due to this specimen weight changes caused by moisture adsorption were found to be similar in magnitude to the weight change caused by wear. These effect were studied using weight balanced equipment. Wear of friction pads were reduced with increase the sintering temperature and pressure. Lesser wear give higher life of friction pad.

Keywords: Powder Metallurgy, Sintering Process, Friction Pads, Taguchi method, Physical Properties, Tribological Properties.

Nomenclature

Nomenclature

u_θ	velocity in the direction of (m/s)
A	radius of (m)
B	position of
C	further nomenclature continues down the page inside the text box
Greek symbols	
γ	stoichiometric coefficient
δ	boundary layer thicknesses(m)
Subscripts	

r radial coordinate

1. Introduction

Brake Friction Materials is a heterogeneous materials that is diverse in the physical, mechanical, and chemical properties of the developed formulation. such materials are classified as binders, reinforcement, filler, friction modifiers. Friction and wear characteristics of the developed formulation cannot be predicted based on physical and mechanical properties. Selection of ingredient materials is the difficult task as it requires a great number of experiments to obtain the reliable brake performance. A variety of technique have been employed to investigate the development of ingredients for friction pads in order to provide stable friction, durability, adequate wear resistance and acceptable environmental condition [1,4].
In this paper attempt has been made to develop the friction pad using sintering techniques and experiments were carried out based on Taguchi approach. Also develop the unit for measurement of the wear rate of brake friction pad . From experiment it was observed Wear of friction pads were reduced with increase the sintering temperature and pressure.

2. Selection of Materials

Selection of metal powder are most commonly depend upon its characteristics, product application and manufacturing techniques. In this experiment copper metal powders are basic materials because of high Ductility,high Thermal Conductivity ,proper Melting Point (1083 degree C), low mohers Hardness and also play an important role as a solid lubricant at higher temperatute. Copper metal was mix with zinc and lead metal powder for improved it’s mechanical properties for manufacturing of friction brake pad [1]

Table 1. The ingredients of the friction brake pads materials

Sr No.	Metal Powders	Wt (%)	Mesh size (µm)
1	Copper Metal Powder	95	325
2	Zinc Metal Powder	3	300
3	Lead Metal Powder	2	2

3. Manufacturing of Friction Pads Specimens

In the present work friction pads manufactured contains three basic types of the metal powders used, as listed in the Table – 2.1. The friction pads are manufacturing by dry mixing, pre forming and hot press moulding at three different pressure (300 kg/cm^2 , 330 kg/cm^2 , and 355 kg/cm^2) , three different temperature (700^0C, 800^0C, 900^0C) and three different time (30 minute, 45 minute, 60 minute), post curing and heat treatment. To optimizing this parameters Taguchi approach is used. All the brake friction pads are cut into the size of (25 mm *12 mm * 12 mm).

3.1. Taguchi Experiment

Essentially, traditional experimental design procedures are too complicated and not easy to use. A large no of experimental work have to be carried out when the number of process parameters increases. To solve this problem, the Taguchi Method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments [5].

3.2. Experimental Procedure

In this research nine experiments were conducted at different parameters, for this Taguchi L_9 orthogonal array was used, which has nine rows corresponding to the number of tests, with three columns at three levels. Three levels are taken shown in Table 2.

Table :2 Friction Pad Process Parameters

Parameters	Code	Level – 1	Level - 2	Level - 3
Molding Temperature (^{0}C)	A	700	800	900
Molding Pressure (kg/cm^2)	B	300	330	355
Molding Time (minutes)	C	30	45	60

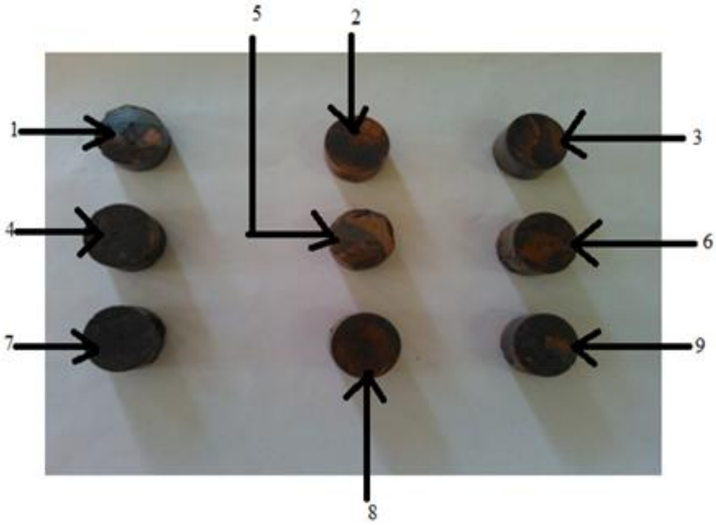

Figure : 1 Friction Pads Specimens

In Figure 1 :- 1,2,3...............9 represent the Friction Pads Sample number as per Taguchi Experiments

3.4 Measurement of tribological Properties

The friction and wear test were performed using a laboratory-scale pad-on-disc brake testing machine Which was developed in Lab shown in fig.2 In this test, each specimen was pressed against a cast iron disc rotating with a constant speed of 1120 rpm under a constant load of 200 N. The load is applied with help of spring.

The wear test was made by keeping the materials against the disc for ten minutes. The sample mass were measured before and after each test. So it was possible to evaluate the wear suffered by material. Wear was calculated using following formulas:-

$$W = \frac{(t0 - t1)}{t0} * 100 \% \quad (1)$$

Where, W = Wear Rate in %, t_0 = Weight loss of specimens before wear test, t_1 = Weight loss of specimens after wear test.

The Hardness and wear value corresponding to each experiment were shown in table 4.

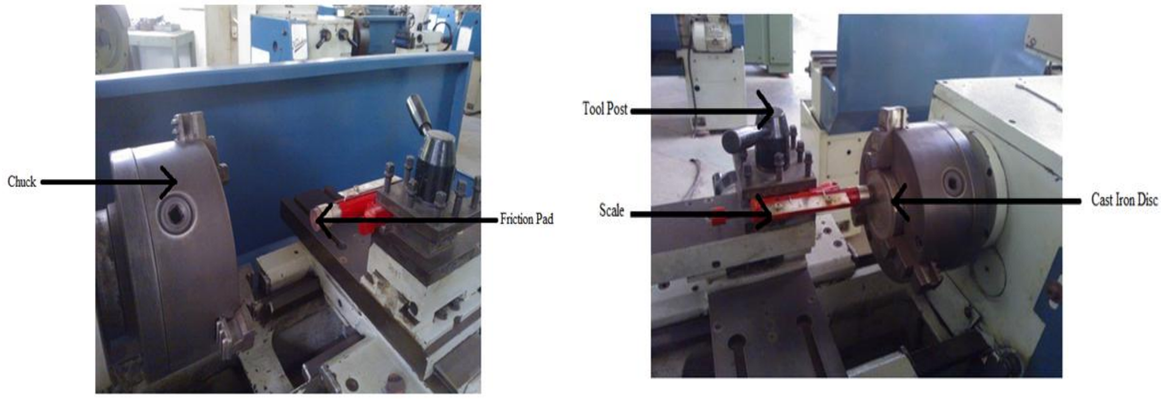

Figure 2: Experimental Set up for Wear Testing

Table 3. Taguchi L_9 OA for Hardness and Wear Rate

Exp.No.	A	B	C	Hardness (HRB)	Wear Rate(%)

1	1	1	1	19	4.69
2	1	2	2	19	3.89
3	1	3	3	15	3.37
4	2	1	2	30	5.17
5	2	2	3	40	3.91
6	2	3	1	26	1.99
7	3	1	3	24	3.55
8	3	2	1	18	2.34
9	3	3	2	12	6.55

Table 4. Experiments parameters and obtaining result

Exp.No.	A	B	C	Hardn-ess (HRB)	Wear Rate (%)
1	700	300	30	19	4.69
2	700	330	45	19	3.89
3	700	355	60	15	3.37
4	800	300	45	30	5.17
5	800	330	60	40	3.91
6	800	355	30	26	1.99
7	900	300	60	24	3.55
8	900	330	30	18	2.34
9	900	355	45	12	6.55

4. Result and Discussion

4.1 Analysis of the S/N Ratio

Taguchi method stresses the importance of studying the response variation using the signal to noise ratio (S/N) ratio, resulting in minimization of quality characteristics variation due to uncontrollable parameters. The hardness and wear rate was considered as quality characteristics with the concept of the " the larger the better", and the "smaller the better" respectively. The S/N ratio used for this type response is given by.

$$S / N = -10\log \sum ¿ \frac{1}{n} \;)$$

$$S / N = -10\log \frac{1}{n} (\sum y^2)$$

Where n is the number of measurement in a trial/row, in this case n = 1 and y is the measured value in a run/row.. The Hardness and wear rate value measured from the experiments and their corresponding S/N ratio values are listed in Table 5. The Hardness and Wear rate response table for the molding temperature, molding pressure, molding time concentration was created in the integrated manner and the results are given in Table 6 and 7 respectively.

Regardless of the category of the performance characteristics, a greater S/N ratio value corresponds to better performance for Hardness and a lower S/N ratio value corresponds to better performance for Wear rate. Therefore the optimum levels of the manufacturing parameters is the levels with the greatest S/N value for Hardness and lowest S/N value for wear rate. Based on the analysis of the S/N ratio the optimal manufacturing performance for the Hardness and wear rate was obtain at 800^0C molding temperature at (level 2), 330 kg/cm^2 molding pressure at (level 2), 45 minutes molding time at (level 2). Figure 3 and 4 shows the effect of manufacturing parameters on the Hardness and Wear Rate respectively.

Table 5. S/N ratio values for Hardness and Wear Rate by factor level

Exp No.	Hardness (HRB)	S/N ratio (db)	Wear Rate (%)	S/N ratio (db)
1	19	25.575	4.69	13.423
2	19	25.575	3.89	11.799
3	15	23.522	3.37	10.553

4	30	29.542	5.17	14.270
5	40	32.041	3.91	11.844
6	26	28.299	1.99	5.977
7	24	27.604	3.55	11.005
8	18	25.105	2.34	7.384
9	12	21.584	6.55	16.325

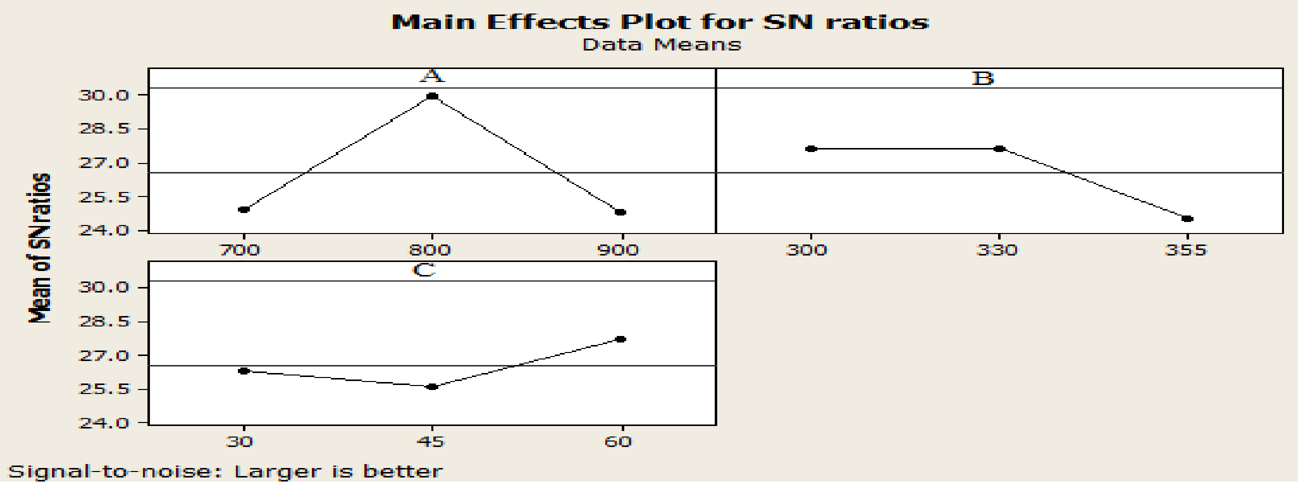

Figure 3. Effect of Manufacturing Parameters on Hardness

Table 6. Response table for Hardness

Level	Molding Temperature	Molding Pressure	Molding Time
1	24.89	27.57	26.33
2	29.96	27.57	25.57
3	24.76	24.47	27.72
Delta	5.20	3.11	2.16
Rank	1	2	3

Table 7. Response table for Wear Rate

Level	Molding Temperature	Molding Pressure	Molding Time
1	-11.925	-12.899	-8.928
2	-10.697	-10.342	-14.131
3	-11.571	-10.951	-11.134
Delta	1.228	2.557	5.203
Rank	3	2	1

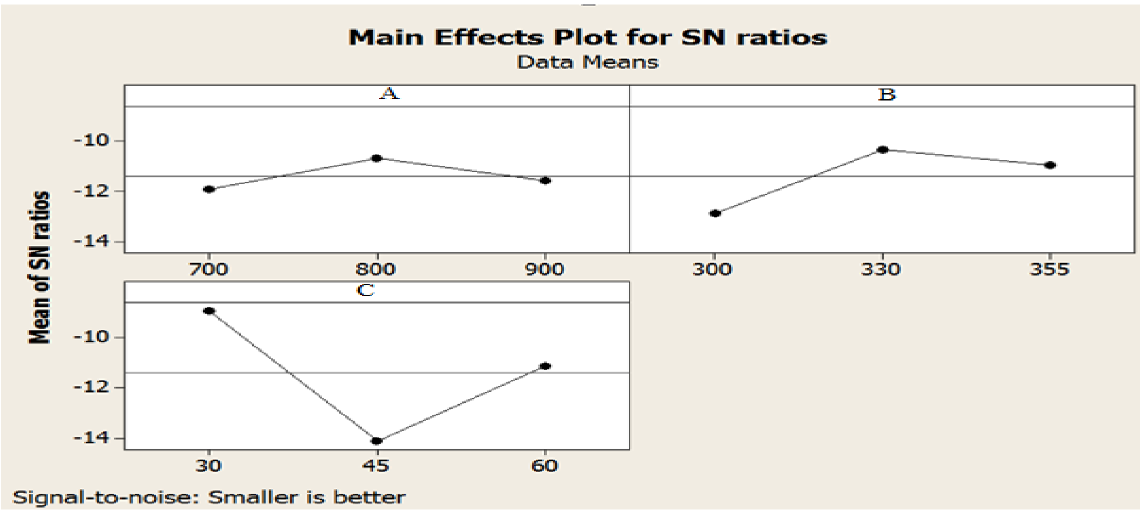

Figure 4. Effect of Manufacturing Parameters on Wear Rate

The hardness increase with increasing the moulding temperature. Hardness and Wear give best result at level 2. Higher pressure and temperature does not compulsorily produce a strong green part. Wear of friction materials should be minimized as much as possible. A higher wear rate means shorter friction materials life and thus, incurring more material cost and maintenance costs. A lower wear rate would increase the life of the brake pad and a higher friction co efficient would offer better performance.

4.2Analysis of Variance (ANOVA)

ANOVA is a statistically based objectives decision making tool for detecting any differences in the average performance of groups of items tested. ANOVA helps in formally testing the significance of all main factors and their intersections by comparing the mean square against an estimate of the experimental errors at specific confidence levels. First the total sum of squared deviation SS_T from the total mean S/N ratio n_m can be calculated as,

$$SS_T = \sum_{i-1}^{n} \left(-nm \right) 2$$

Where, n is the number of experiments in the orthogonal array and n_i is the mean S/N ratio for the experiments.
The percentage contribution P can be calculated as,

$$P = \frac{ssd}{ssT}$$

Where, SS_d is the sum of the square deviations. The ANOVA results are illustrated in table 8.

Table 8 ANOVA results for Wear Rate of Friction Pads

Source of Variation	D O F	Sum of Squares (SS)	F-Ratio (F)	P - Value (P)	Percentage (%)
A	2	401.6	6.45	0.032	68.27
B	2	110.2	0.69	0.537	18.74
C	2	64.9	0.37	0.704	11.03
Error	2	11.5			1.96
Total	8	588.2			100

Statistically there is a tool called an F test named after Fisher, to see which design parameters have a significant effect on the quality characteristics. In the analysis, the F-ratio is a ratio of the mean square error to the residual error, and is traditionally used to determine the significance of factor.

The P-value reports the significance level (suitable and unsuitable) in table. 8 Percent is defined as the significance rate of the manufacturing parameters on the Hardness and Wear rate. The percentage numbers depict that the molding temperature, molding pressure, molding time have significant effects on the hardness and wear rate. It can observed from table 8.4 and 8 that the molding temperature (A), molding pressure (B), molding time (C) affect the hardness and wear rate by 68.27 percentage, 18.74 percentage and 11.03 percentage and wear rate by 2.04 percentage, 11.36 percentage and 49.13 percentage respectively in the manufacturing process of friction pads respectively.

5. Conclusion

This study has discussed an application of Taguchi methods for investigating the effect of manufacturing parameters on the hardness and wear rate of friction pads. The parameters were selected taking into consideration of manufacturing and industrial requirement of friction pads. From the analysis of the results in the friction pads using the conceptual signal to noice ratio (S/N) ratio approch, analysis of variance and Taguchi optimization methods the following can be conclued from the present study,

- **In the present study quentity of copper metal powders are selected at maximum amount at least 95 percentage. because copper metal powder have a high ductility, high thermal conductivity and highre melting point. for these properties copper metal powder are selected as a parent material for manufacturing friction pads.**
- statistically designed experiments based on Taguchi methods were performed

using orthogonal arrays to analyzed the hardness and wear rate as per response variables. conceptual S/N ratio and ANOVA approches for data analysis drew similer conclusions.

- statistical results (at a 98 percentage confidence level temperature (A), molding pressure (B), molding time (C) affect the hardness rate by 68.27 percentage, 18.74 percentage and 11.03 percentage in friction pads manufacturing.
- The maximum hardness rate measured as 40 HRB and minimum wear rate measured as 1.99 percentage at level - 2 .
- In this study, the analysis of the confirmation experiment for hardness has shown that Taguchi parameters design can successfully verify the optimum hardness and wear paramaters which are molding temperature = 800 (A2), molding pressure = 330 kg/cm sq. (B2), molding time = 30 minutes (C1).
- Hardness increases with molding temperature, molding pressure and molding time at optimum level after then hardness decrease with increasing amount of molding temperature, molding pressure and molding time.
- Higher temperature and pressure do not compulsorily produce strong green parts.

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