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OPTIMIZATION OF DESIGN PARAMETER FOR COAL ASH AND PALM KENNEL SHELL BRAKE PAD USING TAGUCHI EXPERIMENT DESIGN METHOD

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ABSTRACT

Brake pad is a friction device created by mix of different materials equipped for holding the braking properties. This paper presents optimization of design parameters for coal powder and palm kernel shell brake pad. The disc brake lining was delivered in accordance with the geometrical particular of Peugeot 504 model utilizing coal fiery remains and palm kernel shell as base materials. Polyester resin was utilized as restricting material, fiber mesh as fortification, brass flex as abrasives and elastic residue from consumed tire as filler. The business brake pad gotten from the market was utilized as a control. Nine gatherings of test were delivered containing diverse rate arrangement of the materials. The examples were exposed to hardness, wear, particular gravity and oil/water ingestion tests. Result demonstrated that hardness, thermal resistance and specific gravity increases with increase in coal ash content while wear rate reduces with increase of coal ash. Taguchi method of design of experiment was used to determine the optimum design mix and optimum design parameter. Wear rate and hardness were used as response with molding temperature curing time and heat treatment time as control factors. Results showed that the optimum setting for wear rate is 175^{o}C molding temperature, 8mins curing time and 3hrs heat treatment time. For hardness the optimum settings is 175^{o}C molding temperature, 6mins curing time and 3hrs heat treatment time. Analysis of variance (ANOVA) was used to confirm the experiment that the most significant factor for wear rate is heat treatment time while the most significant factor for hardness is the molding temperature as depicted in their signal to noise ratio using minitab 2017 soft ware.

Keywords: Optimization, coal ash, Kernel shell, Brake pad.

1.0 INTRODUCTION

Brake instrument which is utilized for backing off or stopping a moving article or a machine at work and it is an imperative piece of a framework.

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Development turns out to be slower when the brake is locked in. Brake pads are critical segments of stopping mechanism for all classifications of vehicles outfitted with brake plates. Brake pads are segments of brake discs utilized in automobiles. Brake pads are utilized in the slowing mechanisms to control the speed of the automobile by changing over the kinetic energy of the automobile to thermal energy by friction and disseminating the heat created to the environment. Brake pads use as automobile brakes are of two sorts: drum brake and disc brake. The drum brake is situated inside a drum so that on utilization of the brakes, the brake lining is constrained outward and squeezed against the drum, while disc brakes work in comparative path with the exception of that they are presented to condition (Madu and Onwuamaeze, 2018).

Brake pads comprise of such a large number of materials in which asbestos grid are a piece of the part. Asbestos constituents in brake pad composites bestow wanted high grating property. The utilization of asbestos is avoided in developed countries and most developing countries as a result of its cancer-causing and destructive nature. Some others have restricted the utilization of asbestos as a rubbing material due to its danger of causing disease for generation laborers and the end clients. Historically, brake system can be followed back to the 1800s, where the first component to moderate a vehicle's energy was tried. Amid the use of brake, contact between brake pads and pivoting disc makes a stop the vehicle by changing kinetic energy of the vehicle into heat energy. Subsequently, the brake pads ought to rapidly ingest warm, withstand for higher temperatures and ought not to wear easily. For the most part brake pad comprises of an arrangement of strengthened strands, folio, fillers, and rubbing added substances. Every one of these constituents are blended or mixed in shifting creations and brake pad material is gotten utilizing distinctive manufacturing techniques as will be found in the later piece of this paper. A few looks into have been completed in the zone of advancement of asbestos free brake pad. Dagwa and Ibhadode in 2005, built up an asbestos free brake pad utilizing coconut and palm kernel shell. Dan-Asabe, Madakson and Manji (2012) enhanced the utilization of coconut shell to create brake pad and discovered that coconut shell incites fragility. Amaren, Yawas, and Aku (2013) created brake pad utilizing periwinkle shell with mesh result. Adeyemi, Ademoh and Okwu (2016) built up an asbestos free brake pad utilizing maize husk; the outcome demonstrated that maize husk particles could be adequately utilized as swap for asbestos. This paper explored the optimal design parameters of brake pad production using coal ash and palm kennel shell.

2. MATERIALS AND METHODS

The materials used for the experiment include: hand held XRF spectrometer, brake pad mold, coal ash, palm kennel shell, polyester resin, accelerator, burnt rubber dust, brass flex, rubber mesh, fiber mesh, and sieve.

The base raw materials, coal ash and palm kennel shell, were collected and cleaned thoroughly to remove impurities. They were crushed and ground to a fine powder and sieved using 125μm sieve. The weight of palm kernel shell powder and coal ash powder filler materials, matrix (polyester) was varied while that of the abrasives and reinforcement was kept constant. For each formulation quantities expressed in percentage weight presented in Table 2.3 for fillers, abrasives and reinforcement were approximately measured into mixing vessel and thoroughly mixed for 15 to 20 minutes to obtain homogenous mixture. The desired amounts of polyester resin was poured into a separate container and required quantity of hardener was added to form the matrix and thoroughly stirred for about 5 minutes to obtain uniform mixture. Thereafter, the matrix mixture was poured into the powdered friction material mixture and stirred further to obtain a paste-like homogenous mixture. The formed paste was poured into mold cavities that already had powdered talc applied for ease of component removal, the mixture was thereafter pressed with a hydraulic pressing machine at 100kN force for 2 minutes at room temperature and allowed to cure for 9 to 12 minutes and thereafter hardened by putting them under controlled temperature of 150^{o}C for 3hours in an oven to ensure a complete curing of the resin. About fifteen trial formulations were initially made for preliminary tests. After the trial formulations, a fairly good composition was arrived at, which was used for determining the manufacturing parameters: molding temperature, curing time and heat treatment time. Nine brake pads based on this formulation were made using nine different sets of manufacturing parameters derived by the Taguchi method.

3. RESULTS AND DISCUSSION

MIXTURE OPTIMIZATION

Analysis of Signal to Noise ratio

Tables 2 and 5 shows the computations for the quality characteristics (Wear rate and Hardness) with their respective signal-to-noise ratios which are targeted at reducing the variations due to uncontrollable parameters. The signal-to-noise ratios employed for the Wear rate and Hardness are THE LOWER THE BETTER and THE LARGER THE BETTER. They are expressed mathematically as:

LOWER THE BETTER

$$\frac{S}{N} = -10log_{10}y^2 \qquad 3.1$$

LARGER THE BETTER

$$\frac{S}{N} = -10log_{10}\frac{1}{n}\sum\frac{1}{y^2}(2) \qquad 3.2$$

The evaluation of the signal-to-noise ratios and mean responses for the wear rate and hardness are shown graphically in Figures 1 to 4, they indicate the factors that are statistically significant in the orthogonal array. Figure 1 indicates that wear rate under the S/N ratio of LOWER THE BETTER is best at the following settings: molding temperature of 175°C, cure time of 8 minutes and heat treatment time of 3 hours. Figure 2 clearly shows that the hardness under the S/N ratio of LARGER THE BETTER of the brake pad is best at the following settings: molding temperature of 175°C, cure time of 6 minutes and heat treatment time of 3 hours. The range (delta) is the difference between the high and low response. A high delta value signifies the strength of the parameter on the response factor while a low delta value signifies the least effect on the response factor. Therefore, Tables 3 and 7 show that the most significant factors responsible for wear rate for the brake pad investigated are ranked as follows: Heat treatment > Molding Temperature > Curing time while for the hardness as shown in Tables 6 and 7, the most significant factors are: Molding Temperature> Heat treatment> curing time.

Table 1: Experimental Outlay showing factors and levels

S/N	Parameters	Unit	Levels	Levels	Levels
1	A: Molding temp	°C	150	175	200
2	B: Curing time	Minute	6	8	10
3	C: Heat treatment time	Hour	1	2	3

Table 2: Experimental design matrix for Wear rate for the Brake pads developed

Experimental Number	A: Molding temperature	B:Curing time	C:Heat treatment	Wear rate(%)	S/N Ratio	Mean
1	1	1	1	0.740	2.6154	0.740
2	1	2	2	0.106	19.4939	0.106
3	1	3	3	0.107	19.4123	0.107
4	2	1	2	0.104	19.6593	0.104
5	2	2	3	0.100	20.0000	0.100
6	2	3	1	0.110	19.1721	0.110
7	3	1	3	0.103	19.7433	0.103
8	3	2	1	0.108	19.3315	0,108
9	3	3	2	0.400	7.9584	0.400

Table 3: Response Table for Signal to Noise Ratio Smaller is better for Wear rate

Level	A: Molding temperature	B:Curing Time	C:Heat Treatment time
1	13.84	14.01	13.71
2	19.61	19.61	15.70
3	15.68	15.51	19.72
Delta	5.77	5.60	6.01
Rank	2	3	1

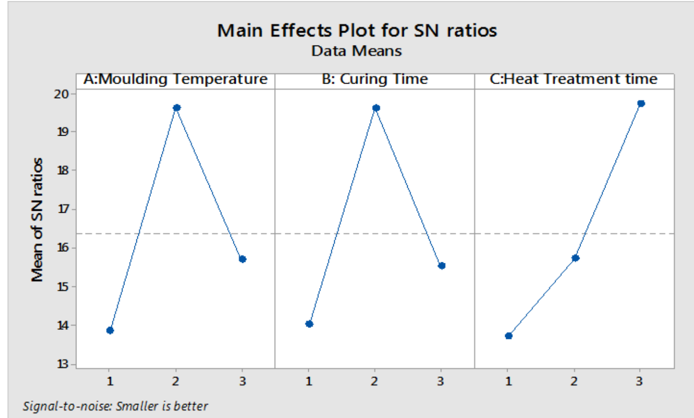

Figure 1: Main Effects plots for Signal-to-noise ratio of Wear rate

Table 4: Response Table for Means for the wear rate

Level	A:Moulding Temperature	B: Curing Time	C:Heat Treatment time
1	0.3177	0.3157	0.3193
2	0.1047	0.1047	0.2033
3	0.2037	0.2057	0.1033
Delta	0.2130	0.2110	0.2160
Rank	2	3	1

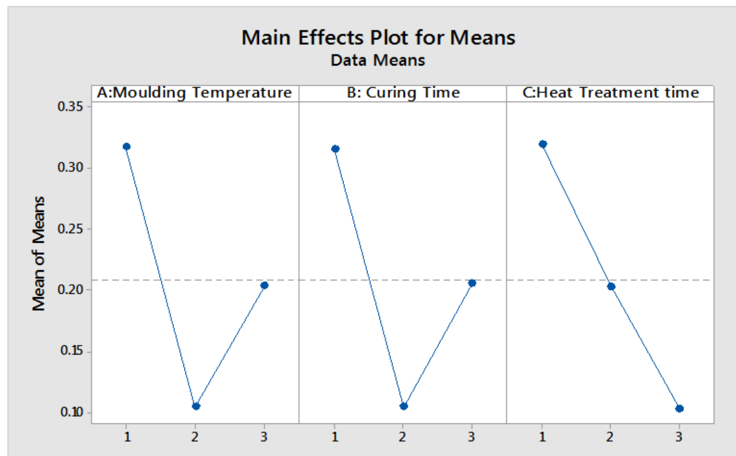

Figure 2: Main Effects plots for mean of means of Wear rate

Table 5: Experimental design matrix for Hardness for the Brake pads developed

Experiment number	A:Molding Temperature	B:Curing Time	C: Heat Treatment time	Hardness	S/N Ratio	Means
1	1	1	1	374	51.4574	374
2	1	2	2	379	51.5728	379
3	1	3	3	382	51.6413	382
4	2	1	2	395	51.9319	395
5	2	2	3	397	51.9758	397
6	2	3	1	394	51.9099	394
7	3	1	3	404	52.1276	404
8	3	2	1	378	51.5498	378
9	3	3	2	373	51.4342	373

Table 6: Response for Signal to Noise Ratios Larger is better for Hardness of the brake pad

Level	A:Molding Temperature	B:Curing Time	C:Heat Treatment time
1	51.56	51.84	51.64
2	51.94	51.70	51.65
3	51.70	51.66	51.91
Delta	0.38	0.18	0.28
Rank	1	3	2

Table 7: Response Table for Means for the Hardness

Level	A:Moulding Temperature	B:Curing Time	C:Heat Treatment time
1	378.3	391.0	382.0
2	395.3	384.7	382.3
3	385.0	383.0	394.3
Delta	17.0	8.0	12.3
Rank	1	3	2

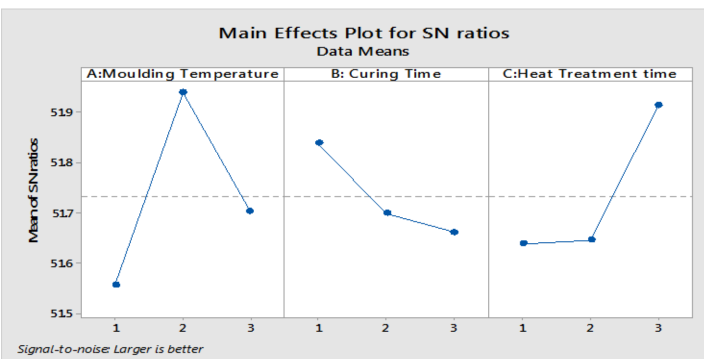

Figure 3: Main Effects plots for Signal-to-noise ratio of Hardness

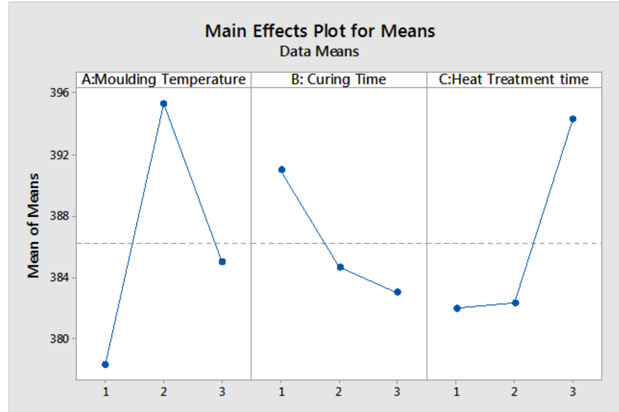

Figure 4: Main Effects plots for mean of means of Hardness

3.1: Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) is conducted to examine the factors that significantly affect the responses (Wear rates and Hardness). The percentage contribution, P reports the significance level. The Fisher test (F-Test) is used to determine statistically, the parameters that have significant effect on the quality characteristics. The lower the percentage value (P value), the more significant is the factor. Tables 8-10 shows the one-way ANOVA results for wear rate response. The most significant factor for the wear rate is heat treatment as depicted in Table 10. Tables 11- 13 show the one-way ANOVA result for hardness response. The most significant factor for hardness is molding temperature as shown in Table 11. The result obtained from the ANOVA is in agreement with the analysis of the signal-to-noise ratios obtained in Tables 3-4 and 6 -7.

Table 8: One-way ANOVA results for wear rate using the factor molding temp.

Factor	DOF	Adj SS	Adj MS	F-value	P-value	Status
A:MouldingTemperature	2	0.06817	0.03408	0.63	0.565	Insignificant
Error	6	0.32543	0.05424			
Total	8	0.39360				

S=0.232892; RSq=17.32%; RSq (adj)=0%;RSq (Pred)=0.0%

Table 9: One-way ANOVA results for wear rate using the factor curing time

Factor	DOF	Adj SS	Adj MS	F-value	P-value	Status
B: Curing time	2	0.6682	0.03341	0.61	0.572	Insignificant
Error	6	0.32678	0.05446			

Total	8	0.39360

S=0.233372; RSq=16.98%; RSq (adj)=0%;RSq (Pred)=0.0%

Table 10: One-way ANOVA results for wear rate using the factor Heat treatment

Factor	DOF	Adj SS	Adj MS	F-value	P-value	Status
C:Heat treatment	2	0.07011	0.03506	0.65	0.555	Significant
Error	6	0.32349	0.05391			
Total	8	0.39360				

S=0.232195; RSq=17.81%; RSq (adj)=0%;RSq (Pred)=0.0%

Table 11: One-way ANOVA results for Hardness using the factor molding temp.

Factor	DOF	Adj SS	Adj MS	F-value	p-value	Status
A:Molding Temperature	2	440.2	220.11	2.23	0.188	Significant
Error	6	591.3	98.56			
Total	8	1031.6				

S=9.92752; RSq=42.68%; RSq (adj)=23.57%;RSq (Pred)=0.0%

Table 12: One-way ANOVA results for Hardness using the factor curing time

Factor	DOF	Adj SS	Adj MS	F-value	P-value	Status
B: Curing Time	2	106.9	53.44	0.35	0.720	Insignificant
Error	6	924.7	154.11			
Total	8	1031.6				

S=12.414; RSq=10.36%; RSq (adj)=0%;RSq (Pred)=0.0%

Table 13: One-way ANOVA results for Hardness using the factor heat treatment

Factor	DOF	Adj SS	Adj MS	F-value	P-value	Status
C: Heat treatment	2	296.2	148.1	1.21	0.362	Insignificant
Error	6	735.3	122.6			
Total	8	1031.6				

S=11.070; RSq=28.72%; RSq (adj)=4.95%;RSq (Pred)=0.0%

Table 14: Optimum settings of Control factors and expected optimum values for responses

Response	Control factor	Optimum Settings
Wear Rate:	A: Molding Temperature	175
	B: Curing Time	8
	C: Heat treatment	3
Hardness	A: Molding Temperature	175
	B: Curing Time	6
	C: Heat treatment	3

4.0 CONCLUSION

The thermo-physical properties of coal powder and palm kernel shell that made them appropriate for brake pad creation were set up. This test was the thermal resistance test, water absorption test and particular gravity.

Moreover, an asbestos free brake pad was delivered utilizing coal gotten from Enugu State, palm kernel shell and different materials sourced locally. The samples of brake pad delivered were tried for oil and water retention, thermal resistance, hardness, resistance to wear and specific gravity. The outcomes acquired from the samples produces were contrasted with the traditional brake pad and the standard set by the Standards Organizations of Nigeria (SON). These outcomes are in concurrence with those of asbestos friction materials delivered. It is consequently deducible that this material can be utilized on peogout 504 model. At long last, this paper can be viewed as the initials preparation required for ensuing enhancements and improvement. Though more research is as yet required, the destinations which were set out toward the start of the work have to a substantial degree been accomplished.

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