FRICTIONAL AND WEAR BEHAVIOUR OF CAST IRON IN LUBRICATED CONDITION

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Abstract - *The investigation pertains on frictional characteristics of the CI samples at variable time, different applied loads & different sliding velocity. This experiment shows the quality characteristics of samples deviating from standard value and the effects also undergo through the study of signal to noise ratio(Taguchi study) and study of varience(ANOVA) .To reduce the problem with S/N ratio we have used Grey study on test results to normalize the results. At various parameters and various conditions system response has changed. The wear response of the sample has been discussed at different study and conditions with a confirmation test. The microstructure of the sample surface (with 500X) has been tested and discussed after the investigation.*

1. INTRODUCTION:

CI tends to be brittle. With its relatively low mp, good fluidity, castability, excellent m/c ability, resistance to deformation and wear resistance, CIs have become an engineering material with a wide range of uses and are used in pipes, m/c and automotive industry parts, such as cylinder heads, cylinder blocks and gearbox cases .It is resistant to destruction and weakening by oxidation (rust). From commercially available specimens we developed the samples by machining, the process involves the maximization of different tribo testing parameters in order to obtain minimized friction and wear performance. Tribological experiments are carried out following Taguchi Method for different combinations of the tribo tester parameters – load, velocity and time. Taguchi's L27 orthogonal array is used depending upon the numbers and levels of design parameters in such a way that effects of the parameters both individual interaction effects can be studied. After developing it, the samples are tested in a MULTI TRIBOTESTER TR 25 apparatus. Here we use lubricant SERVO SUPER 20W-40MG.The study of the result data is carried out with the help of MINITAB software package.

2. LITERATURE REVIEW

Several wear failure mechanisms, such as plastic deformation, cracks, pits, debris, grooves & scratches, were identified after the experiments. In one study T. Miyauchi ,n, J.Nakayama , N.Fujiwara , K.Shimoda , S.Nakazawa , S.Fukagai are studied that the alloyed CI brake blocks were developed to reduce the braking distance and decrease the wear of brake blocks at high velocitys.K.Hirasata did an experiment for wear and frictional nature of various CI where the contact pressure P = 49.0MPa and the sliding velocity V = 8 m/s.In an experiment of Aravind Vadiraj, M.Kamaraj , V.S.Sreenivasan[4],they performed a Wear test at 100 N normal load for a fixed sliding distances of 6000 m. Wear loss is a measurement of difference in primary and final weights after sliding for a specific fixed distance. Wear loss was measured for four different sliding velocitys (1.0, 1.5, 2.0 and 2.5 m/s).In one study B.K.Prasad experiments the result of material and test parameters on the sliding wear characteristics of a CI. Increasing load and track dia caused the rate of wear, heating and frictional coefficient to increase. The author did an experiment conducted over a range of sliding velocity and applied load for affixed sliding distance in dry and oil lubricated conditions. The test parameters adopted were sliding velocity :500and1500rpm(corresponding linear velocitysbeing2.08and6.24m/s, respectively),(b)sliding distance: 500and2500m in dry and oil lubricated conditions ,respectively,and(c)load:1kg(correspondingtoapressureof0.196MPa)to up to seizure or operating load limit(20kg)of the m/c .The author also did an experiment where the sliding distance was fixed at 500 and 2500m in the dry and lubricated conditions, respectively with a view to attain measurable wear loss for the samples. O.jinno, M.R. Tyagi did an experiment with the velocity of 0.31 m/s. Initially the surfaces were run for 26 min under low load of 245 N. Then the load was increased in steps of 490 N.H.H.Masjuki, M.A.Maleque did another experiment on effect on oil diesel fuel contaminated lubricant on sliding wear response of CI against MS with pressure, 1 MPa; velocity of sliding, 0.3.

3. SIGNAL TO NOISE RATIO

Signal-to-noise ratio (often abbreviated SNR or S/N) is a measurement that compares the level of a desired signal to the level of background noise. It is defined by the ratio of signal power to the noise power, expressed in decibels. A ratio more than 1:1 (greater than 0 dB) indicates more signal than noise.

A statistical analysis of variance (ANOVA) is then used to check the influences of the process parameters on the system response under different consideration. Taguchi method is employed with the following steps to maximise the tribo testing parameters so that the tribological performance of CI is improved:

4. CALCULATION OF GREY RELATION

In grey relational analysis the grey relational generation in which the results of the experiments are normalized in the range between zero and one. Then to calculate the grey relational coefficient from the normalized data to express the relationship between the desired and actual value.
They are described in the following:

1.If the expectancy is larger the better (e.g. the benefit) then it can be expressed by

$$x_i(k) = \frac{y_i(k) - min\ y_i(k)}{max\ y_i(k) - min y_i(k)}$$

2.If the expectancy is smaller the better (e.g. the cost and defects) then it can be expressed

$$x_i(k) = \frac{max y_i(k) - y_i(k)}{max\ y_i(k) - min y_i(k)}$$

3.If the expectancy is nominal the best (e.g. age) and when the targeted value is

$$x_i(k) = \frac{\| y_i(k) - y_o \|}{max\ y_i(k) - y_o}$$

Where xi (k) is the value after the grey relational generation, min yi (k) is the smallest value of yi (k) for the kth response, and the max yi (k) is the largest value of the yi (k) for the kth response. yo is the targeted value. An ideal sequence is x0 (k) (k=1, 2,..., 27). The definition of grey relational grade in the grey relational analysis is to show the relational degree between the twenty seven sequences [x0 (k) and i x (k) , i = 1,2,...,27; k = 1,2,...,27].

5. CALCULATION OF GREY RELATION GRADE

The grey relational coefficient ξi (k) can be calculated as:

$$\xi_i(k) = \frac{\Delta_{min} + \xi\Delta_{max}}{\Delta_{oi}(\kappa) + \xi\Delta_{max}}$$

Where Δoi = || xo (k) - xi (k) || = difference of the absolute value between xo (k) and xi (k);

ξ = distinguishing coefficient in between zero and one (0.5 in the present case). The maximum the value of grey relational grade considered as the stronger relational degree between the ideal sequence xo (k) and the given sequence xi (k) . As it has been mentioned, the ideal sequence xo (k) is the best process response in the experimental layout. Here, it may be concluded, the higher relational grade means that the corresponding parameter combination is closer to the optimal.

6. OPTIMIZATION OF TRIBO TESTING PARAMETERS OF CI

Accordingly the effect of the tribo testing conditions on the friction and wear behavior of CI is studied

Table -1:

Level	A	B	C
1	5.786	5.859	6.391
2	5.916	6.315	6.032
3	6.757	6.285	6.036
Delta	0.971	0.456	0.359

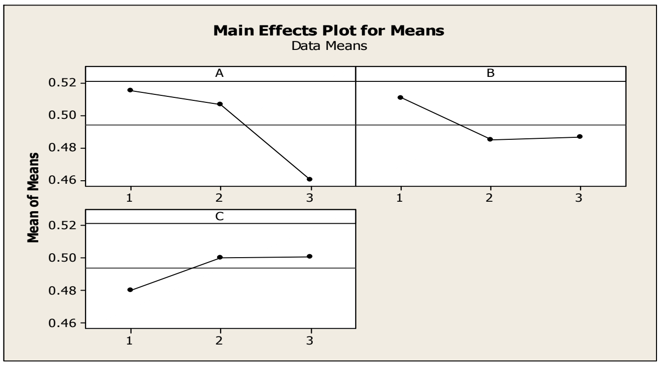


Fig-1.**Main effects plot for signal to noise ratio**

7. Analysis of signal-to-noise ratio

In Taguchi method, the term 'signal' expresses the expected value (mean) for the output characteristic and term 'noise' presents the undesirable value (SD) for the output characteristic. Therefore, S/N ratio is the ratio of the mean and the S.D. Taguchi method uses the S/N ratio to measure the quality characteristic deviating from the desired

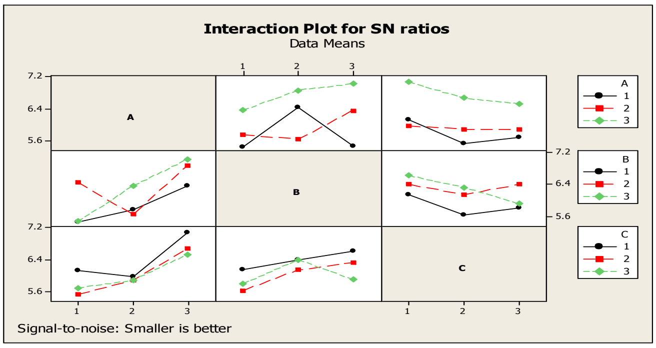


Fig-2

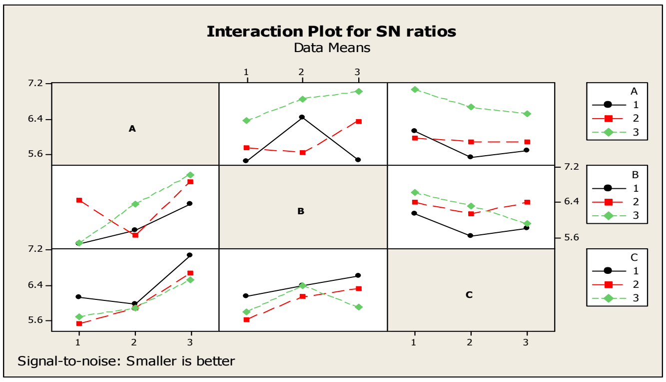


Fig-3

8. Analysis of variance (ANOVA)

The total sum of square deviations SST from the total mean of the S/N ratio (η_n) can be evaluated as follows:

SST=SSd+ SSe

$$SS_T = \sum_{i=1}^{m} (\eta_i - \eta_n)^2$$

$$\sum_{i=1}^{m} \eta_i^2 - \frac{1}{m}[\sum_{i=1}^{m} \eta_i]^2$$

Where, m is the number of experiments in the orthogonal array and η_i is the mean S/N ratio for the ith experiments. The percentage of contributions ρ can be calculated as follows:

$$\rho = \frac{SS_d}{SS_T}$$

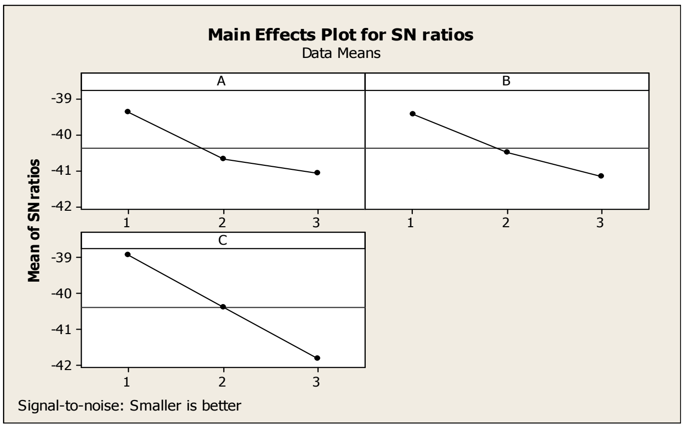
Where, SSd is the sum of the square deviations and SSe is the sum of squared error. In the statistical analysis, F - tests are carried out to see which design parameters have a significant effect on the response characteristics. To conduct the F – test, the mean of the square deviations SSm due to each design parameter need to be calculated.

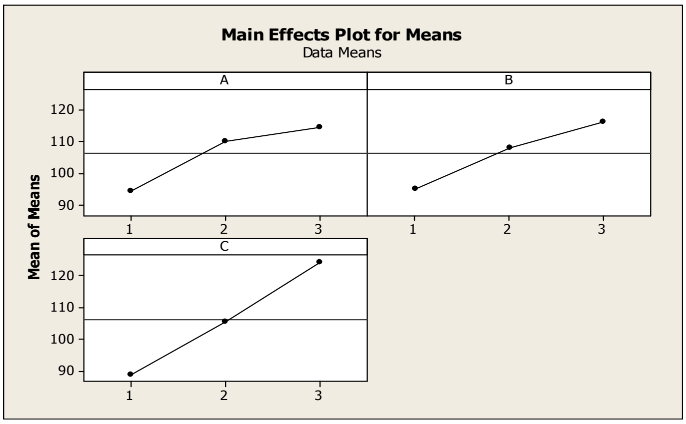
$$SS_m = \frac{\text{Sum of squared deviation } (SS_d)}{\text{Number of degrees of freedom of each parameters}}$$

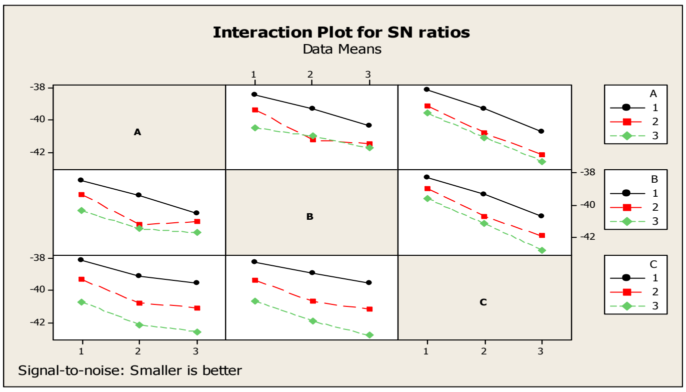
F-value can be found out with following equation:
F-value=
(Mean squared deviation(SS_d))/(Mean squared error(SS_e))

Table -2: Response table of mean S/N ratio for wear

Level	A	B	C
1	-39.38	-39.44	-38.94
2	-40.69	-40.52	-40.40
3	-41.07	-41.18	-41.80
Delta	1.69	1.74	2.87
Rank	3	2	1







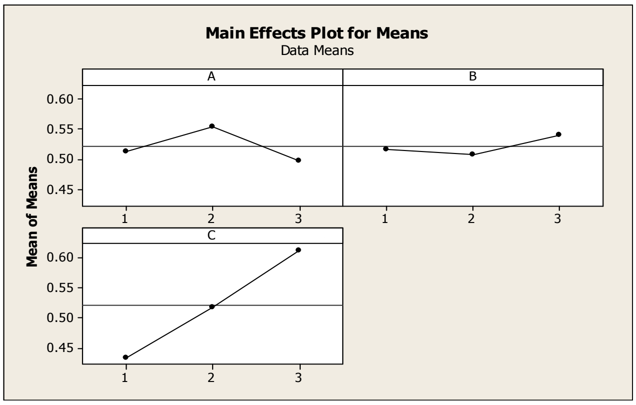


Table -3: Response table for grey grade

	Initial Parameter	Optimal Parameter	Experimental Parameter
LEVEL	A2 B2 C2		A1 B1 C1
Wear Depth	121.12		75.15
S/N ratio(dB)	-41.6643	-39.4427	-37.5187

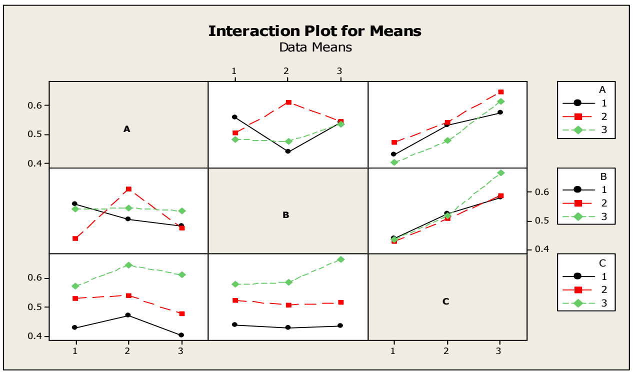


Table -4: Confirmation Tests

	Initial Parameter	Optimal Parameter	Experimental Parameter
Level	A2 B2 C2		A2 B3 C3
COF	0.513		0.491
Wear Depth	121.12		140.37
Grade	0.5811	0.6344	0.6795

After the optimal level of testing parameters have been found, it is necessary that verification tests are carried out for evaluate the accuracy of the analysis and to validate the experimental results. The estimated S/N ratio $\hat{\eta}$ using the optimal level of the testing parameters can be calculated as:

$$\hat{\eta} = \eta_m + \sum_{i=1}^{o} (\overline{\eta_i} - \eta_m)$$

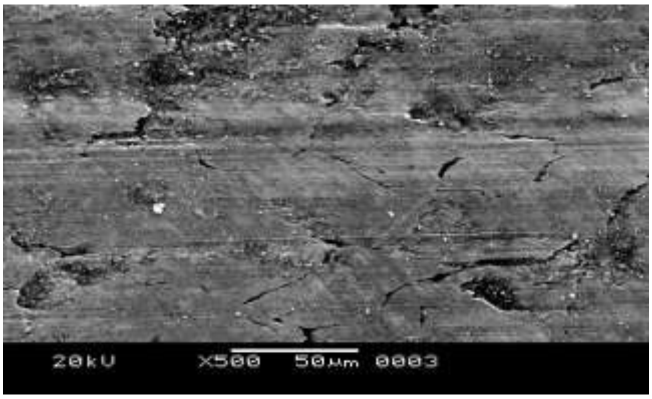
Where, η_m is the total mean S/N ratio, $\overline{\eta_i}$ is the mean S/N ratio at the optimal testing parameter level and o is the number of main design process parameters that significantly affect the friction and wear performance of cast iron. The confirmation tests for all the experiments are presented in the following section:

9. STUDY OF MICROSTRUCTURE

The present study to analyze the microstructure of the blank and worn surface to see the surface morphology and the pattern of the wear tracks respectively.

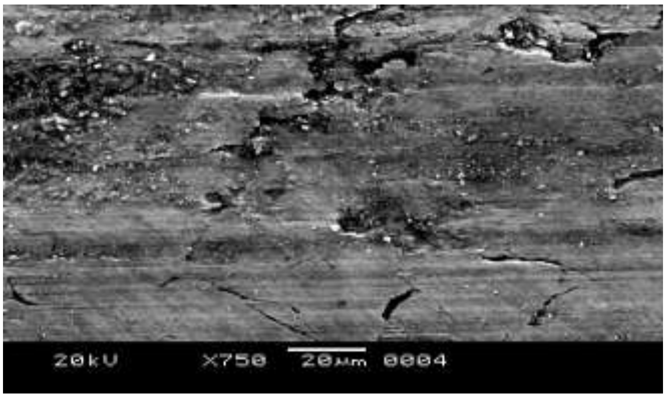
10. ANALYSIS OF MICROSTRUCTURE

The SEM micrographs of the blank surface of the CI. The blank surface appears shining grey to the naked eye. The SEM micrograph of the blank surface reveals that the surface is almost smooth. From the SEM micrograph it is observed that the worn surface is mainly composed of partial irregular pits along the sliding direction. The presence of pits or rows are indicative of adhesive wear failure of CI.



microstructure with magnification 500x of cast iron specimen

Level	**A**	**B**	**C**
1	0.5123	0.5150	0.4343
2	0.5533	0.5081	0.5173
3	0.4976	0.5402	0.6117
Delta	0.0557	0.0321	0.1773
Rank	2	3	1



With magnification of 750x, magnification of cast iron sample in SEM

	Initial Parameter	Optimal Parameter	Experimental Parameter
LEVEL	A2 B2 C2		A3 B2 C1
COF	0.513		0.447
S/N ratio(dB)	5.79765	6.13563	6.99385

11. CONCLUSION:

In the present thesis the tribological performance of CI is studied. Taguchi's L27 helps to test Optimization of the tribological orthogonal array design. Study has been done on both the main effects as well as interaction effect of the parameters. Also ANOVA helps to study about the significance of the design parameters and their interactions. The optimization of the multiple performance characteristics are also studied from the grey relational analysis. From the present study the following conclusions are drawn:

The optimal tribological testing parameter combination for friction for CI is found to be A3B2C1. The B and C are found to affect friction significantly. The B is the most important factor with a contribution. The interaction between A&B is found to be the most significant interaction.

The optimal tribological testing parameters combination for wear for MS is found to be A1B1C1. All the factors i.e. A, B and C are significant parameters affecting the wear behaviour, the factor A is most affective with a contribution. The interaction between A and B is the significant interactions.

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