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Research Article

Optimization Of Cold Rolling Lubricant By Grey Relation Method

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ARTICLE INFO	ABSTRACT

Cold Rolling may be defined as the reduction of cross- section area of the metal stock or general shaping of the metal product through the use of rotating rolls below recrystallization temperature. During the cold rolling in a rolling mill, lubricants are used for lubrication to provide the desired rolled surface. Lubricants consists mineral oils, chemical additives, synthetic oil, biodegradable oil etc. Within this study, the performance of synthetic lubricant has studied on rolling specimen in terms of surface roughness and chemical wear. On the basis of lubricating and rolling parameter Design of Experiment (DOE) approach has been applied to generate best combination of experimental variables or input variables to become desired response variable. DOE is a systematic approach for investigation of a system or process. Through the DOE approach obtain the responses in terms of surface roughness and chemical wear and optimized these responses by grey relation method to find out the effect of rolling parameters on specimen.

Keywords: Cold rolling, lubricant, Grey Relational analysis, Design of Experiment.

I.INTRODUCTION

Cold rolling operations related with the smooth processing of rolled products include the use of rolling lubricants. These materials, typically in the form of fatty or mineral oils, applied either neat or in emulsion form, greatly assist the reduction of the strip in that they significantly reduce the rolling force necessary for deformation. Without information of the efficiency of the rolling lubricants used, the adequate operation of commercial rolling services becomes more difficult to achieve. From an economic viewpoint, it is desired to use the economical material that will provide satisfactory lubrication in the roll bite. Although cold rolling lubricants have been widely used since the early 1930's, research into their performance was not commenced to any noteworthy extent until the late 1940's.

Base on analyzing the relationship among the main factors associated with roll-bending force in reversing multi-pass rolling, such as strip width and rolling force, a present mathematic model of bending force is developed by genetic algorithm [1]. Traditionally cold rolling work uses lubricant to predict adverse dynamic characteristics of rolling mills can prevent severe problems in dimensional quality in addition to expensive mill equipment damage [3]. The successful and efficient running of any system or any process largely depends on the fact that how it has been designed. Before a system or any process is developed it need to go through many experiments and a fruitful experiment helps the system or process to be designed successfully. So Design of Experiment (DOE) has a very important role in development of any system or a process [8]. It is very important to get the most information from each experiment performed. In addition, a well-designed experiment will ensure that the evaluation of the effects that had been identified as important. Experiment has been perform as per DOE to obtain the responses of surface roughness by surface profilometer and chemical wear by SEM analysis. To obtain the most effecting parameter on rolling process optimization technique applied on the responses.

II.REVIEW WORK

CAO Jian-guo, et al [1] they discuss the hydraulic roll-bending device, which is widely used in modern cold rolling mills to regulate the strip flatness. The simulation results show that, the quadratic component of strip crown decreases nearly linearly with the increase of the work roll bending force, when the shifting value of intermediate roll is determined by the rolling process. Guo then applied two-stage and single-stage transport matrix methods to solve a linear spring and beam model of 4high and 6-high mills, whereby contact between the individual rolls and between the strip and the work rolls was modeled by a finite number of discrete linear springs [2]. Malvezzi et al [4] has in his article proposed procedure that includes a mathematical model for lubricant flow based on Reynolds equation and a mathematical model for plastic deformation process based on Orowan approach.

Review of Surface defects in rolling

Shen et al [5] have shown the importance of rolling lubrication and coolant used in the process of Cold rolling. They have conducted their study on laboratory simulation and actual temper rolling process. Saboonchi & Aghili [6] have discussed about the role of temperature in rolling mill and on rolls. The temperature is one of the important parameter which is being constituted by various researchers for analyzing the performance of the roll. The study conducted on the headers having series of nozzles, which are responsible for the cooling and expansion of the work rolls. Wendt et al [7] have discussed about the sticking problem after annealing process in cold rolled steel. The coil of cold rolled steel when uncoiled after annealing face sticking. The sticking is termed as welding and the cause may be diffusion or sintering or other adhesion mechanism. Basically in sticking the role of roll and their attributes are having no significance but as the heat increases due to hard material and high speed rolling mills.

Optimize technique review

Sukhdev and Ganguly has projected grey relational analysis is implemented to optimize a set of operational parameters which are called as input variables of any process to achieve best result of any performance parameter, which is also known as response variable, of that process. Taguchi based DOE is important as a formal way of maximizing information gained while minimizing resources required. It has more to offer than 'one change at a time' experimental methods, because it allows a judgment on the significance to the output of input variables acting in combination with the other[8]. Sreenivasulu and Rao has optimize control factors for the hole quality were determined by using Taguchi - Gray relational analysis. Cutting speed, feed rate, drill diameter, point angle and cutting fluid mixture ratio were considered as control factors, and L18 (3*5) orthogonal array was determined for experimental trials. Gray relational analysis was employed to minimize the surface roughness and roundness error achieved via experimental design [9]. Suspicious planning helps to avoid problems that can occur during the execution of the experimental plan. The lubricant aspects of the system may affect the ability to complete the experiment. A well – defined objective will ensure that the experiment answers the gap of review literature informed.

Objective

There has been limited study done in the area of surface roughness of cold rolled product roller under the effects of different lubricants. This study examines the surface roughness and chemical wear that occur during the cold rolling of low carbon steel. The roller currently used in the industry is the steel alloy. Usually, higher roll hardness gives more thickness reduction to rolled low carbon steel and enhances metal working efficiency during cold rolling. The main objective is to find optimum cooling lubricants for the rolling mills to achieve desired surface roughness and reduce chemical wear.

III.METHODOLOGY

A simplified and precise framework is developed for optimization of synthetic lubricant. The flow chart of methodology is shown in Fig.1

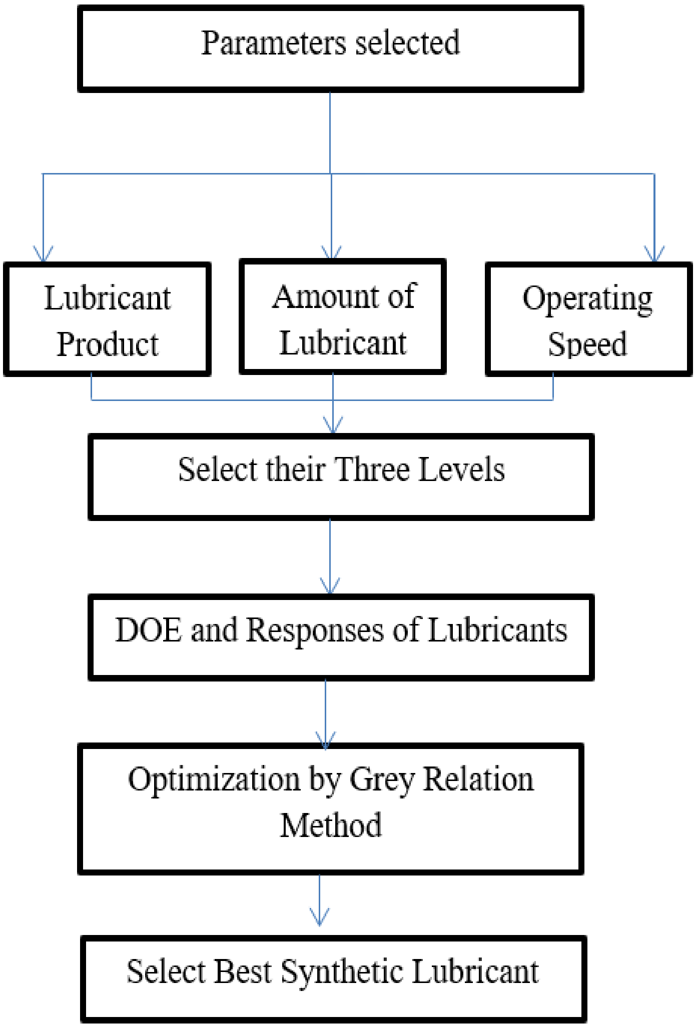

Fig. – 1 Flow Work

Design of Experiment

Classical experimental design methods are too complex and are not easy to use. A large number of experiments have to be carried out when the number of process parameters increase. 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. The DOE technique and the number of levels are to be selected according to the number of experiments which can be afforded. By the term levels we mean the number of different values a variable can assume according to its discretization. The number of levels for all variables are compatible as per their requirement i;e DOE techniques uses the differentiation of the number of levels for each variable as shown in table 1.

Table 1 Factor and level

Factor / Level	Product Name	Amount of lubricant (ml)	Operating Speed in RPM
1	Rhenus CGN 2	20	200
2	Rhenus NAN 02	25	300
3	Rhenus LMN 2	30	400

Orthogonal arrays are special standard experimental design that requires only a small number of experimental trials to find the main factors effects on output. On the basis of factors and their level L9 orthogonal array has to be design in Minitab software as shown in table 2, Where 1, 2 & 3 indicating the level of factors. Taguchi experimental design of experiments suggests L9 orthogonal array, where 9 experiments are sufficient to optimize the parameters. Based on main factor, the variables are assigned at columns, as stipulated by orthogonal array.

Table 2 DOE in Minitab

Product Name	Amount of lubricant (ml)	Operating Speed in RPM
1	1	1
1	2	2
1	3	3
2	1	2
2	2	3
2	3	1
3	1	3
3	2	1
3	3	2

Once the orthogonal array is selected, the experiments are selected as per the level combinations. It is important that all experiments are conducted. The performance parameter (output) is noted for each experimental run for analysis and the set of the nine experiments to be performed to obtain their responses as shown in table 3 respectively. The Specimen dimension before and after has shown in fig 2.surface roughness and chemical wear is measured of each specimen is tabulated in Table 3.

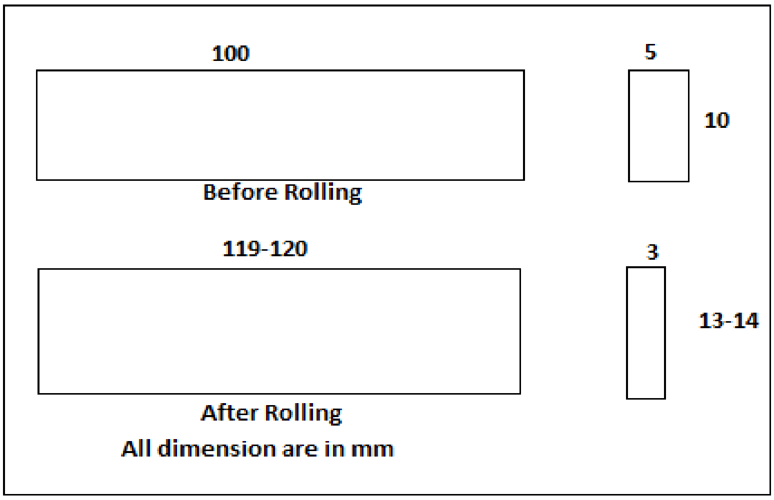

Fig. 2 Specimen dimension

Table 3 Response of L9 Orthogonal Array experiment of synthetic lubricant

Product Name	Amount of lubricant (ml)	Operating Speed in RPM	Suface Roughness Ra in µm	Chemical Wear in µm
Rhenus CGN 2	20	200	0.45	1.5
Rhenus CGN 2	25	300	0.47	1.4
Rhenus CGN 2	30	400	0.49	1.3
Rhenus NAN 02	20	300	0.56	1.2
Rhenus NAN 02	25	400	0.58	1.4
Rhenus NAN 02	30	200	0.62	1.6
Rhenus LMN 2	20	400	0.57	1.7
Rhenus LMN 2	25	200	0.49	1.6
Rhenus LMN 2	30	300	0.63	1.9

GREY RELATION ANALYSIS

The grey means the primitive data with incomplete and uncertain information in the grey systematic theory; the incomplete relation of information among these data is called the grey relation. First, the grey relation analysis was carried out to normalize the responses In reality, grey relational analysis compares relations of sequences in their appropriate metric spaces. If two systems agree at all points, then their grey relational coefficient is 1 everywhere, and therefore, their grey relational grade should be 1 or close to 1. In view of this, the relational grade of two comparing sequence can be quantified by the mean value of their grey relational coefficients;
For lower-the-better criterion, the normalized data can be expressed by equation (1)

$$X_i = \frac{max(y)_i - (y)_i}{\max(y)_i - \min(y)_i} \quad \ldots\ldots(1)$$
$$where\ i = 1,2 \ldots\ldots n$$

The calculation of the grey relational coefficient and the weight of each quality characteristic is determined by equation (2):

$$G_i = \frac{L_{min} + \varepsilon L_{max}}{L_i(k) + \varepsilon L_{max}} \quad \ldots\ldots\ldots(2)$$

Where, L_{min} is the global minimum, L_{max} is the global maximum and ε is distinguish coefficient which is taken in between 0 to 1 in this case 0.5 weight is taken. Grey relation grade can be calculated by equation (3)

$$Grg_i = \frac{1}{n}\sum_{j=1}^{n} G_i(j) \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where n is the number of process responses. The lower value of the grey relational grade represents the reference sequence Grg_i. As mentioned before, the reference sequence Grg_i is the best process response in the experimental layout is taken whose grey relation grade is maximum.

IV.RESULT AND DISCUSSION

In this optimization, the synthetic lubricants are optimizing on the basis of Grey relation grade(GRG), which transforms the input values into suitable linguistic values; a rule base, which convert the input value in normalized form, then convert the multi-objective problem in single objective problem as per their weight in terms of GRG. The challenge of modern machining industries is generally focused on the attainment of high quality, in terms of work piece dimensional accuracy, surface roughness, high production rate, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact. The inputs for the normalized are the surface roughness and chemical wear data which is obtained from their lubricant property. The normalized value of lubricant response, grey relation coefficient and grey relation grade (GRG) is shown in Table 4.

Table 4 Optimize table of synthetic lubricante

N_{Ra}	N_{Cw}	L_{Ra}	L_{Cw}	Gi_{Ra}	Gi_{Cw}	GRG
1	**0.571429**	**0**	**0.428571**	**1**	**0.538462**	**0.769231**
0.888889	0.714286	0.111111	0.285714	0.818182	0.636364	0.727273
0.777778	0.857143	0.222222	0.142857	0.692308	0.777778	0.735043
0.388889	1	0.611111	0	0.45	1	0.725
0.277778	0.714286	0.722222	0.285714	0.409091	0.636364	0.522727
0.055556	0.428571	0.944444	0.571429	0.346154	0.466667	0.40641
0.333333	0.285714	0.666667	0.714286	0.428571	0.411765	0.420168
0.777778	0.428571	0.222222	0.571429	0.692308	0.466667	0.579487
0	0	1	1	0.333333	0.333333	0.333333

The leading step of Grey Relational analysis in which the output responses are first normalized, ranging from zero to one which is depict in fig 3. Based on this above obtained value grey relational coefficient is evaluated in next step in order to find out interaction between actual and desired experiment value whose graph is shown in fig 4.

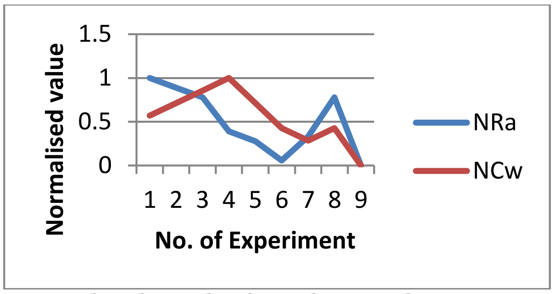

Fig 3 Normalized graph of Synthetic Lubricant Responses

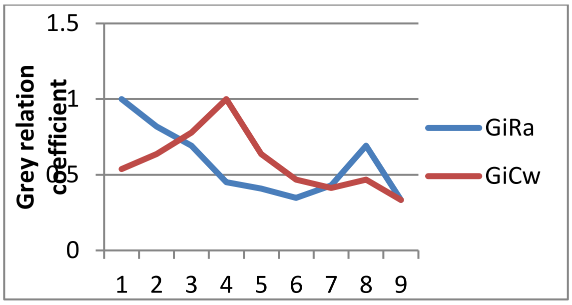

Fig 4 Grey Relation Coefficient graph of Synthetic Lubricant Responses

Third step is the averaging of grey relational coefficient which is designated as Grey relational Grade (GRG). The GRG calculation is the ultimate step of GRA which signifies its approach of converting a multiple response process optimization problem into a single response optimization problem and is used in determining the optimal combination of parameters which is generally the one with higher GRG value as shown in table 4 and their graph in fig 5.

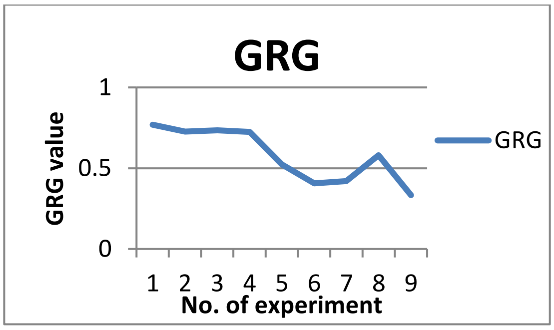

Fig 5 GRG graph of Synthetic Lubricant Responses

GRG and the Reference Sequence represent the best process sequence. Therefore the parameter combination having higher GRG value is closer to optimal. The process parameters are selected as optimized factors which are recommended for further process. The Fig 6 shows the higher values of each parameter is major factor. Out of these three parameter categories "A" denoted lubricants, "B" denotes amount of lubricant, "C" denotes Speed of rollers. In these factors category "A" showing higher value so the lubrication is the major factor in between all parameters.

Table 5 Rank of synthetic lubricant

Product Name	**Amount of fluid in ml applied on roller**	**Operating Speed in RPM**	**GRG**
Rhenus CGN 2	20	200	**0.769231**
Rhenus CGN 2	25	300	0.727273
Rhenus CGN 2	30	400	0.735043
Rhenus NAN 02	20	300	0.725
Rhenus NAN 02	25	400	0.522727
Rhenus NAN 02	30	200	0.40641
Rhenus LMN 2	20	400	0.420168
Rhenus LMN 2	25	200	0.579487
Rhenus LMN 2	30	300	0.333333

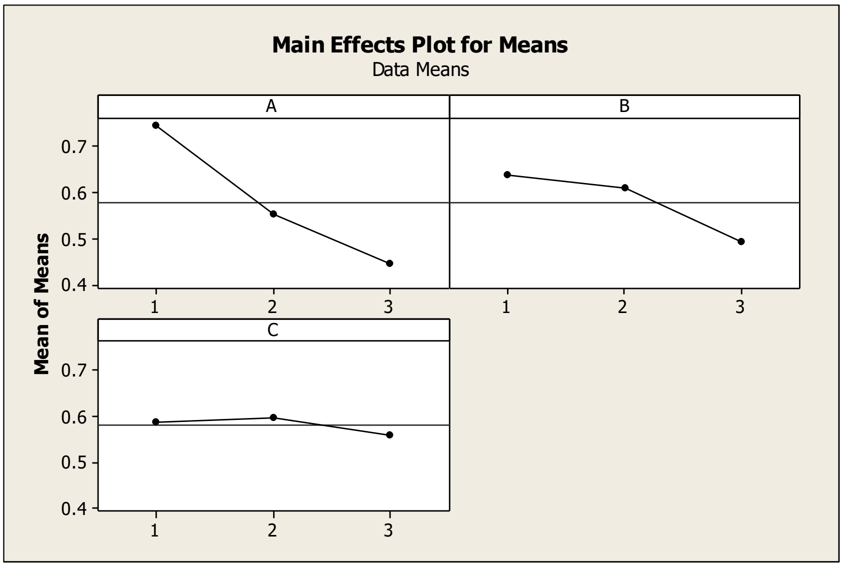

Fig 6 Effect Plot of Parameters

The P values which are less are considered significant and the models are adequate to represent the relationship between response and the parameters. The analysis of variance can be used as an exploratory tool to explain observations of experiment in multiple parameters. In this machining work ANOVA result has shown in Table 6, lower P (probability) value indicating more effective parameter is lubricant in all groups. It is observed from the adequacy test by ANOVA lubricant is significant. To analyse the data, checking of goodness of fit of the model is very much required. The model adequacy checking includes the test for significance of the regression model, test for significance on model coefficients, and test for lack of fit. For this purpose, analysis of variance (ANOVA) is performed.

Table 6 Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	0.138216	0.138216	0.069108	3.02	0.249
B	2	0.036254	0.036254	0.018127	0.79	0.558
C	2	0.002053	0.002053	0.001027	0.04	0.957
Residual Error	2	0.045842	0.045842	0.022921		
Total	8	0.222366				

V.CONCLUSION

Cold rolling simulation experiments were conducted using the steel alloy rollers in order to study the surface roughness and chemical wear occurring during standard operations and to study the lubricant that influence them. Different lubricant materials do affect the morphology of the mating steel surface with apparent surface defects. The Grey relational analysis based on an orthogonal array of the DOE methods was a way of optimizing the process parameters in lubricants. The analytical results summarized as follows:

1. From the response table of the average grey relational grade, it is found that the largest value of the GRG for the Lubricating is Rhenus CGN 2, the amount of lubricant is obtain 20ml, the speed of rollers is 200 rpm from all three categories of lubricant and their other level. It is the recommended levels of the controllable parameters for the process of rolling as the minimization of average surface roughness and chemical wear.
2. The results show importance of influential factors based on lubricant Rhenus CGN 2 will give highest value of GRG and ANOVA also indicated that lubricant is major factor in three parameters so it will take as optimize lubricant.

According to the confirmation test the developed model seems to be satisfactory because the predicted result is in an acceptable zone with respect to the experimental result, optimize lubricant is used for further work with hybrid type of optimization.

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