REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 3 (2023)
http://www.veterinaria.org
Article Received: June 2023; Revised: July 2023; Accepted: August 2023

Optimization Of Natural Lubricant For Rolling Process By Grey Relation Method And Anova

Devesh Shrivastava[1*], Shubhlakshmi Tiwari[2], Rahul Gedam[3], Sharda Pratap Shrivas[4], Anand Kumar Shriwas[5]

[1*]Assistant Professor, Department of Mechanical Engineering, Bhilai Institute of Technology, Durg
[2]Professor and Head, Department of Civil Engineering, Chouksey Engineering College, Bilaspur
[3]Assistant Professor, Department of Electronics and Telecommunication Engineering, LCIT Bilaspur
[4,5]Assistant Professor, Department of Mechanical Engineering, Chouksey Engineering College, Bilaspur

***Corresponding Author:** Devesh Shrivastava
*E-mail: devesh.mech@gmail.com

Abstract
Ecologically approachable biodegradable lubricant has been synthesized through cold rolling processes. The lubricating oil should not be more viscous and should not contain any moisture content beyond its lubricating value. In this paper, attention is focused on recent research work on the optimization of biodegradable lubricant based on defects found on rolled strip. According to the Taguchi quality design concept, a L9 mixed-orthogonal-array table was chosen for the experiments. The anti-friction and anti-wear performance characteristics were evaluated in terms of surface roughness and chemical wear on rolled strip using standard test methods. Grey relational analysis applied to obtain significant influence on the rolling parameters i:e rolling lubrication, amount of lubricant used per rolled strip and roller speed. Moreover, the optimal rolling parameters for minimum surface roughness and chemical wear can be obtained and their significant parameter will show in result.

Keywords: Biodegradable lubricant, Grey Relational analysis, Design of Experiment.

INTRODUCTION

Biodegradation represents a major route for removal of oil from soil and water compartments. Hence, biodegradability studies are of significance for developing eco-friendly lubricants, devising corrective measures for clean-up in case of spillage and meeting the legislation governing the manufacture and use of lubricants in some countries. It is now a common practice in lubricant industry to assess the biodegradability of lubricants in the aquatic environment, and laboratory data are available for a wide range of products. Out of these ranges in this work select the best one for rolling process. Biodegradable lubricating oil that gives consideration to the environment in terms of manufacturing, distribution, and consumption was therefore included in this product category. 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 [2]. In the present paper, we have discussed the performance of biodegradable lubricants as base oils for synthesizing rolling lubricating. The performance of which is obtained low defect in their parameters will take as optimize lubrication. 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 performing 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.

I.REVIEW WORK

Saxena et al. [3] synthesize the biodegradable lubricant from the seeds of Indian origin. For our aim to be accomplished we have taken two oils (1).Mustard Seed Oil (2) Sal Seed Oil. Through various processes such as seed crushing, extraction and refining we obtain the pure form of oil and then lubricating oil. The lubricating oil should not be more viscous and should not contain any moisture content beyond its lubricating value. So the good lubricant should be ecofriendly in nature besides being biodegradable. We have gone through different oils of Indian origin rather than mineral oil.
Ojolo and Ohunakin [4] investigated the effect of cutting speed, feed rate, depth of cut and rake angle on cutting force when cylindrical turning mild steel, brass, and aluminum rods with high speed steel tool using palm-kernel oil as cutting

fluid. The impact of lubrication on the coefficient of friction between the chip and rake face during turning operation, assuming a negligible friction between the flank and cut surface was measured. The study established palm-kernel oil as a good metal cutting lubricant. It was observed that as turning parameters were varied, the performances of the lubricant were equally altered in term of the coefficient of friction. Sukirno et al. [5] studied an environmentally friendly palm-grease has been formulated from modified Refined Bleach Deodorized Palm Oil as base oil and lithium soap as thickener. Such palm-grease is dedicated for general application and or equipment working in areas where biodegradability is required such as in agriculture, forestry and coastal marine, recreation areas

Review of Surface defects in rolling

Shen et al [6] 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 [7] 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 [8] 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.

Optimize technique review

Sukhdev and Ganguly [9] 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. Sreenivasulu and Rao [10] 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. 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

As observed from past literature, no systematic study has been reported so far to analyze the interaction effects of process parameters on rolling process with biodegradable lubricant used. The study is necessary to investigate the performance in different variation, and to find the global optimum parameters. It is necessary to find out single optimum parameters setting to satisfy the requirements of excellent strip surface quality as per the application. In this paper attempt is made to finalize optimum parameters grey relational analysis. The main objective is to find optimum biodegradable lubricants for the rolling mills to achieve desired surface roughness and reduce chemical wear.

II.Design of Experiment

In this study, experiments were designed on the basis of the experimental design technique which refers to the planning of experiments, collection and analysis of data. It is an experimental method designed and developed for evaluating the effects of process parameters on enactment characteristics. During experimentation, a large number of experiments have to be carried out as the number of machining parameters increases. Design of experiments involves proper selection of variables (input factors) and their interactions. The centre composite design consists of all combinations of the input parameters taking on three levels. Accordingly to L9 orthogonal array mixed design experiments were planned as per the selected design. The present investigation studied the results of the effects of lubrication, amount of lubrication and rolling speed. 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	BD68	20	200
2	BD100	25	300
3	BD150	30	400

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 3 (2023)
http://www.veterinaria.org
Article Received: June 2023; Revised: July 2023; Accepted: August 2023

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 shows experimental design matrix with coded and un-coded values of nine experimental designs.

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.

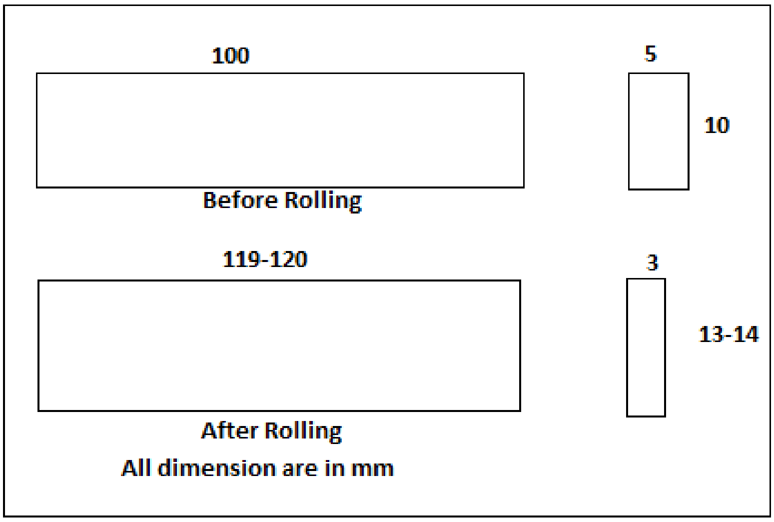

Fig. 2 Specimen dimension

Table 3 Response of L9 Orthogonal Array experiment of biodegradable lubricant

Product Name	Amount of lubricant (ml)	Operating Speed in RPM	Suface Roughness Ra in µm	Chemical Wear in µm
BD68	20	200	0.46	1.8
BD68	25	300	0.52	1.7
BD68	30	400	0.63	1.6
BD100	20	300	0.47	1.2
BD100	25	400	0.44	1.6
BD100	30	200	0.41	1.4
BD150	20	400	0.68	1.9
BD150	25	200	0.63	1.6
BD150	30	300	0.59	1.3

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 3 (2023)
http://www.veterinaria.org
Article Received: June 2023; Revised: July 2023; Accepted: August 2023

GREY RELATION ANALYSIS

In grey relational analysis, the data pre-processing is the first step performed to normalize the random grey data with different measurement units to transform them to dimensionless parameters. Experimental data i.e. measured features of quality characteristics of the product are first normalized ranging from zero to one by lower the better relation because in this work need to reduce surface roughness and chemical wear, so the responses value should be low to reducing the defects. This process is known as grey relational generation. For lower-the-better criterion, the normalized data can be expressed by equation (1)

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

Based on normalized responses data, grey relational coefficient is calculated to signify the correlation between the desired and actual experimental data. Then overall grey relational grade is determined by averaging the grey relational coefficient corresponding to selected responses. The overall performance distinctive of the multiple response process depends on the calculated grey relational grade. This approach converts a multiple-response process optimization problem into a single response optimization situation; the single objective function is the overall grey relational grade. The optimal parametric combination is then evaluated by maximizing the overall grey relational grade.

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

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

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)

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

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.

III.RESULT AND DISCUSSION

It can be seen clearly that biodegradable lubricant BD100 is directly proportional to the responses as shown in Fig 6. In other words, there is a direct effect of changing lubricant, on the responses. 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 biodegradable lubricant

N_{Ra}	N_{Cw}	L_{Ra}	L_{Cw}	Gi_{Ra}	Gi_{Cw}	GRG
0.814815	0.142857	0.185185	0.857143	0.72973	0.368421	0.549075
0.592593	0.285714	0.407407	0.714286	0.55102	0.411765	0.481393
0.185185	0.428571	0.814815	0.571429	0.380282	0.466667	0.423474
0.777778	1	0.222222	0	0.692308	1	0.846154
0.888889	0.428571	0.111111	0.571429	0.818182	0.466667	0.642424
1	0.714286	0	0.285714	1	0.636364	0.818182
0	0	1	1	0.333333	0.333333	0.333333
0.185185	0.428571	0.814815	0.571429	0.380282	0.466667	0.423474
0.333333	0.857143	0.666667	0.142857	0.428571	0.777778	0.603175

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.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 3 (2023)
http://www.veterinaria.org
Article Received: June 2023; Revised: July 2023; Accepted: August 2023

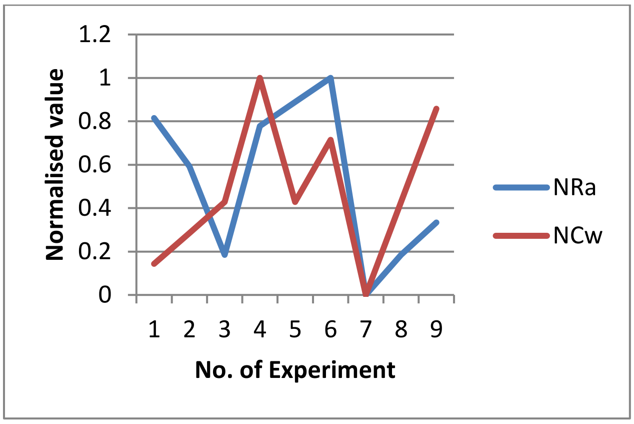

Fig 3 Normalized graph of Biodegradable Lubricant Responses

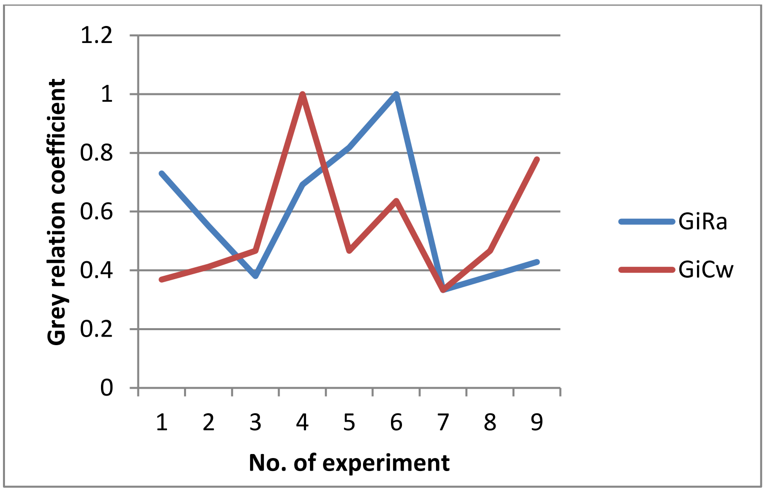

Fig 4 Grey Relation Coefficient graph of Biodegradable Lubricant Responses

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.

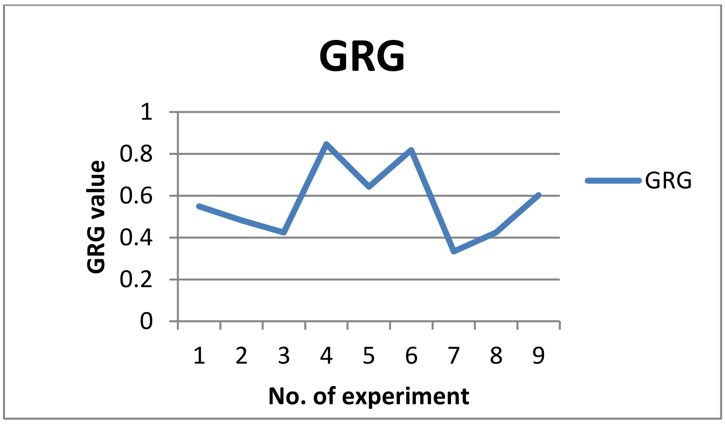

Fig 5 GRG graph of Biodegradable Lubricant Responses

It is to emphasize here that the GRG value reflects the multi optimisation value of the multiple experimental output or performance. It is also to note here that higher value of GRG, the closer the parameter to its optimum value. 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.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 3 (2023)
http://www.veterinaria.org
Article Received: June 2023; Revised: July 2023; Accepted: August 2023

Table 5 Rank of biodegradable lubricant

Product Name	Amount of fluid in ml applied on roller	Operating Speed in RPM	GRG
BD68	20	200	0.549075
BD68	25	300	0.481393
BD68	30	400	0.423474
BD100	**20**	**300**	**0.846154**
BD100	25	400	0.642424
BD100	30	200	0.818182
BD150	20	400	0.333333
BD150	25	200	0.423474
BD150	30	300	0.603175

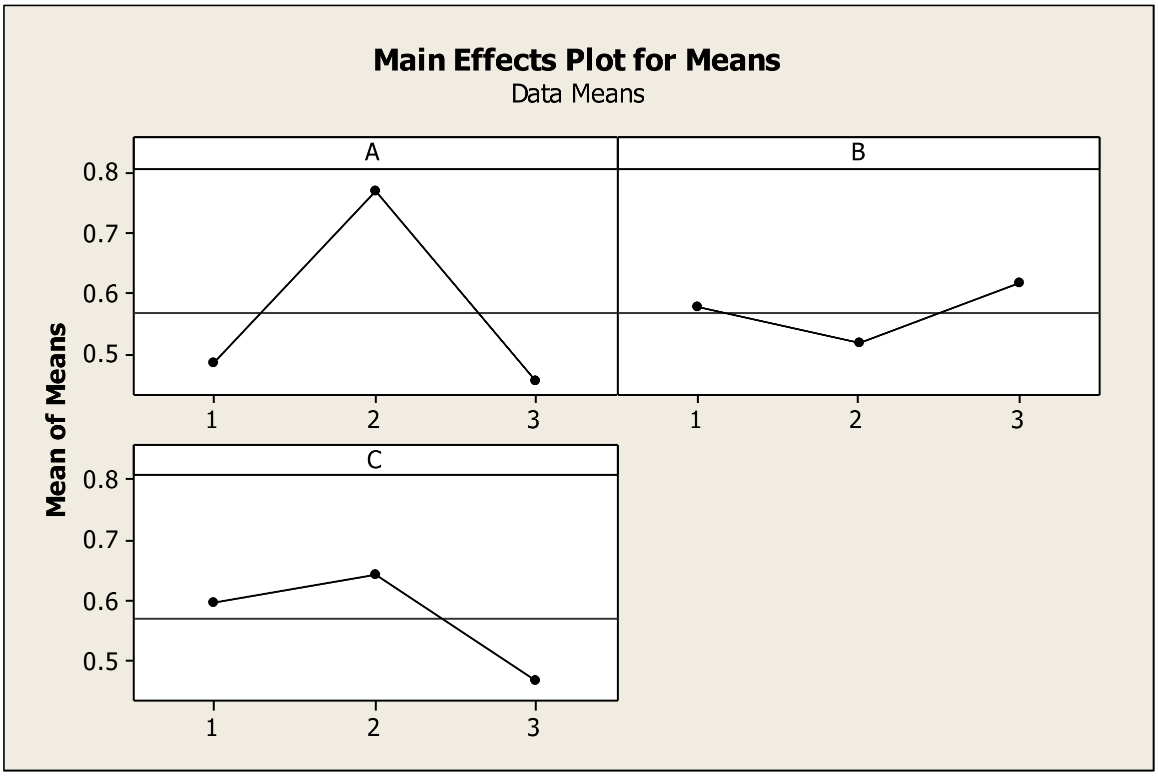

Fig 6 Effect Plot of Parameters

Study of the ANOVA table for a given analysis determines, whether a factor requires control or not. Once the optimum condition is determined, it is usually a good practice to run a confirmation experiment. The analysis of variance (ANOVA) test establishes the relative significance of the individual factors and their interaction effects. The P values which are less than 0.05 are considered significant and the models are adequate to represent the relationship between response and the parameters [9]. 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	0.181391	0.181391	0.090695	40.70	0.024
B	2	0.014990	0.014990	0.007495	3.36	0.229
C	2	0.050595	0.050595	0.025297	11.35	0.081
Residual Error	2	0.004456	0.004456	0.002228		
Total	8	0.251432				

IV.CONCLUSION

Grey Relational Analysis is especially suitable for industrial use, but it can also be used for scientific research purposes and it emphasizes a mean performance characteristic value close to the target value rather than a value within certain specified limits, thus improving the product quality. Different lubricant materials do affect the morphology of the mating steel surface with apparent surface defects. DOE was performed by L9 orthogonal array was chosen by considering three factors and three levels were employed to analyze the influence of process parameters by using grey relation analysis and analysis of variance to get the optimal conditions and performances that means the best parameters is lubricant BD100 is obtain within the experimental results. The results show importance of influential factors based on lubricant BD100 will give highest value of GRG, ANOVA also indicated that lubricant is major factor in three parameters so it will take as optimize lubricant.

REFERENCES

[1]. CAO Jian-guo ,XU Xiao-zhao, SONG Mu-qing , ZHANG Jie, GONG Gui-liang, ZENG Wei (2011) Preset Model of bending force or 6-high reversing cold rolling mill based on genetic algorithm J. Cent. South Univ. Technol. 18: 1487− 1492 DOI: 10.1007/s11771−011−0864−6.
[2]. Guo, R. M., “Development of a single-stage transport matrix method using the beam on elastic foundation theory,” 19th Southeastern Conference on Theoretical and Applied Mechanics, May 2-5, 1998, Ft. Lauderdale, USA.
[3]. Saxena S. K., Chhibber V. K., Joshi H. C., O.N. Anand (2012), “Derivatives of seed oil as a biodegradable lubricants”, Advances in Pure and Applied Chemistry (APAC) 18 Vol. 1, No. 1, pp. 18- 19, ISSN 2167-0854
[4]. Ojolo, S.J., Ohunakin, O.S., Study of rake face action on cutting using palm-kernel oil as lubricant, Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2 (1): 30-35 © Scholarlink Research Institute Journals, 2011 (ISSN: 2141-7016), jeteas.scholarlinkresearch.org.
[5]. Sukirno, R.F.; Bismo, S.; Nasikin, M. Biogrease based on palm oil and lithium soap thickener: Evaluation of antiwear property. World Appl. Sci. J. 2009, 3, 401–407.
[6]. Shen et. al.,(2008), Influence of Rolling Chemicals on temper rolling process and anti rust performance of cold rolled steels, China Technical Report, No. 21, pp. 45-51.
[7]. Ahmad Saboonchi , Sayyed Majid Aghili (2006), The effect of Header Geometry on Temperature Distribution in Cold Rolling, International Journal of ISSI, Vol 2, No.2, pp. 24-29
[8]. Guo, R. M. and Malik, A. S., “Development of a New Crown/Shape Control Model for Cluster Mills,” Iron and Steel Technology, Vol. 2, No.8, August 2005, pp. 31-40.
[9]. Wendt, Winfried and Leifgen (2007), Cold Rolling defects, “Stickers” and countermeasures, Heat Processing – International magazine for industrial furnaces, Heat treatment plant and equipments, ISSN 1611-616X, Vol 2.
[10]. Vikas Sukhdeve, Dr. S.K.Ganguly, UTILITY OF TAGUCHI BASED GREY RELATIONAL ANALYSIS TO OPTIMIZE ANY PROCESS OR SYSTEM International Journal of Advanced Engineering Research and Studies, vol. IV, issue II (2015), pp. 242-250, ISSN2249–8974.
[11]. Reddy Sreenivasulu and Dr.Ch.Srinivasa Rao, APPLICATION OF GRAY RELATIONAL ANALYSIS FOR SURFACE ROUGHNESS AND ROUNDNESS ERROR IN DRILLING OF AL 6061 ALLOY, International Journal of Lean Thinking Volume 3, Issue 2 (December 2012)