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Modelling of surface roughness in ball end magneto rheological fluid machine using artificial neural network.

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ABSTRACT
MRF is based on Magneto rheological (MR) fluids. These are special class of fluid called smart fluid. Some materials have the potential to change shape or size simply by adding a small amount of heat, or to change from a liquid to a solid almost instantly when close to magnet; these materials are called smart materials. Smart materials have several properties that can be rapidly altered. Magneto rheological (MR) materials (fluids) are a category of smart materials whose rheological properties (e.g. viscosity) may be quickly diverse by applying a magnetic field. Under influence of magnetic field the suspended magnetic particles interact to form a structure that resists shear deformation or flow. With the help of traditional finishing process, like grinding and lapping the surface finish on the component is achieved at micro level, with various surface defects. MRF has ability to improve micro-roughness, remove sub-surface damage, and reduce residual stresses, abrasive marks induced during lapping process. This study is divided in two phases. In first phase no. of experiment were conducted using Taguchi L9 orthogonal array and RSM experimental design. The results in terms of % improvement in surface roughness were analyzed to find the effect of process parameter by various approaches. With the help of RSM a regression model is developed and for various other set parameters the value of responses are predicted. In the second phase the result of the experiments from the RSM design are used to train feed forward back propagation neural network model. Similarly for the ANN model the same set of input parameters are predicted. At the end both of the models is validated through conducting the experiment and effectiveness of both model is compared.

Keywords:MRF, artificial neural network**,** ANN, taguchi parameter design, RSM model.

I. INTRODUCTION

As in normal MRF process the finishing tool used was a rotating wheel with MR polishing fluid ribbon which leads to restriction in finishing 3D intricate surfaces which are not manageable by wheel. A new process developed was MR jet finishing used to finish internal surfaces of steep concave and spherical shapes. In this process MRP-fluid jet is impinged on the work surface from the bottom and work surface rotates relative to the MR jet. Here also the relative movement of MR jet with respect to 3D complex work surfaces is a challenging task.

To overcome these challenges, a nanofinishing process for 3D surfaces using ball end magnetorheological (MR) finishing tool was developed by Anant Kumar Singh and Sunil Jha where there are comparatively fewer limitations on relative movement of finishing medium with respect to the work piece surface .

The vertical tapered tool tip portion with stiffened ball of MR polishing fluid has flexibility to move over different kinds of 3D surfaces such as in depth profiles or pockets in work piece, grove surfaces etc. through computer controlled programs. The innovated process can finish the work piece surfaces corresponding to the machining of 3D surfaces by CNC ball end milling process. In this process the tool is design in such a way that flow of pressurized MR fluid through center of the tool core and get stiffed controlled ball end shape of MR polishing at the tip surface of the tool. The stiffness of ball end shape was controlled by the magnetizing current. The complete setup and process can be visualized as similar to ball end milling cutter 3 axis vertical CNC machine. Innovated finishing process was beneficial to finish flat or 3D surfaces of

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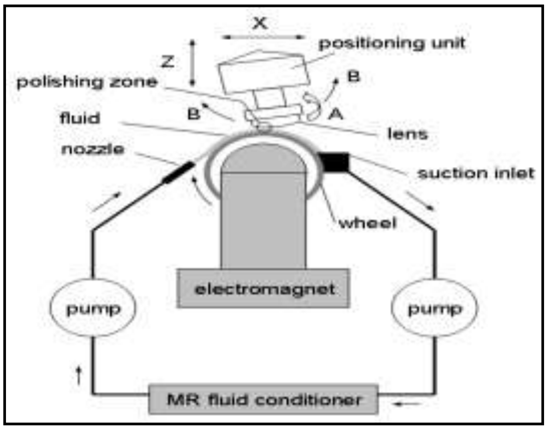
ferromagnetic as well as non-ferromagnetic materials using magnetorheological fluid

The development of the ball end magnenorehologiacal finishing process is very useful in the finishing process of ferromagnetic and nonmagnetic materials.



Artificial Neural Network

Artificial neural networks are nonlinear signal processing devices, which are developed from interconnected elementary processing devices called neurons. An ANN is an information-processing paradigm that is inspired by the way biological nervous systems, such as brain, process information. An ANN is confided for a specific application, such as pattern recognition or data classification, through a learning process.

ANN's are a type of artificial intelligence that attempts to imitate the way a human brain works, rather than using a digital model ANN works by creating connections b/w processing elements, the computer equivalent of neurons. The organization and weights of the connections check the output.

Neural network known as parameterized computational nonlinear algorithms for (numerical) data/signal/image processing. These algorithms are either applied on a general-purpose computer or are built into a needed hardware.

ANN thus is an information-processing system. In this information-processing system, the elements called as neuron, process the information. The signals are conveyed by means of connection links. The links possess an attached weight, which is multiplied along with the net input for any typical neural net. The output signal is produce by applying activations to the net input.

Fig. Shows a simple ANN with two input neurons (X1, X2) and one output neuron (y). The interconnected weights are provided by W1 and W2. An artificial neuron is a p-input signal-processing element, which can be thought of as a simple model of a non-branching biological neuron. In Fig. various input to the network are represented by the mathematical symbol, X (n), weights are represented by W(n). In the basic case, these products are summed, fed through a transfer function to generate a outcome, and then delivered as output. This process lends itself to physical execution on a large scale in a small package. This electronic implementation is still possible with other network structures, which utilize different summing functions as well as different transfer functions.

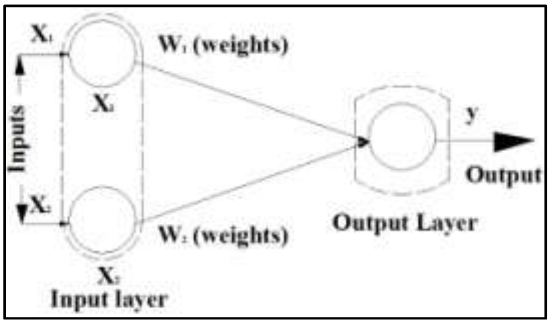


Fig. A simple Artificial Neural Net

An artificial neuron is characterized by:
1. Architecture (connection between neurons)
2. Training or learning (determining weights on the connections)
3. Activation function

ANN for Present study

In training of neural network the simulation data have been used. Input and output variables are normalized and input data is fitted to Neural Network for training. In the present study input data are process parameters (Magnetizing current, nozzle speed, working gap), while the output data is % change in surface roughness. The input data for training the neural network is taken and the data neural network has been trained with Feed Forward Back Propagation Method. FFBP method is based on iterative procedure. Initially random weight has been assigned on each neuron, and then network develops own input-output relation on the basis of their weight functions. Further difference in observed value and predicted value from model result into errors.

Need of Research

The development of new processes for the precision machining is the main requirement. The industrial applicability of the process can further be enhanced if the processing method is optimized and end user is provided with some predictive model, which can be used in the real production system. In this regard, it is good proposition to study holistically, the development of BEMRF process.In particular, following gaps were observed, which is turn generated opportunities for investigation into the process.

1. Although several authors contributed their work in magneto rheological finishing, but in case of ball end magneto rheological finishing process very few researches have been found out. Further no work has been reported to find optimal/near optimal solution with Taguchi Fractional Factorial experiments.
2. A need of generic predictive models with using soft computing techniques like ANN and mathematical model like RSM to find out surface quality in the set of input parameters has been observed.
3. Many researchers have compared the response surface model and artificial neural network model but in case of magneto rheological finishing no research has been found.

Tools

There are requirements of some equipment and machines are used for this research work. Some of them are listed below:

- Magneto rheological fluid finishing setup & Stirrer.
- Contact Mechanical Profiler PGI 120 (Taylor Hobson Make)
- Non-Contact – Optical Profiler CCI (Taylor Hobson Make)
- Minitab and Mat lab software

II. EXPERIMENT AND DESIGN

Taguchi Parameter Design

Taguchi developed a method for designing experiments to examine how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to settle the parameters affecting the process and the levels at which they should be varied. Instead of having to test all best combinations like the factorial design, the Taguchi method tests match of combinations. This allows for the collection of the necessary data to determine which factors affect quality with a minimum amount of experiment, thus saving risk, time and resources. The Taguchi method is best used when there are a between number of variables (3 to 50), few interactions between variables, and when only a few variables contribute significantly. The two major goals of the parameter design are (1) to minimize the process variation and (2) to design robust and flexible processes or products that are adaptable to environmental conditions.

Metrology equipment

Characterization is an integral part of precision surface generation in all the machining operations. Precise control of position, distance, and measuring speed is required for stable and repeatable results. Surface metrology is the measure of deviation of work piece from its intended shape (the shape specified on the drawing). It includes deviation from roundness, flatness and so on, measurement of surface texture. It ensures that all the aspects of the surface geometry are known & preferably controlled. It's important owing to its strong association with other disciplines such as Control of machine tools & manufacturing process, quality of optical components, tribology, surface engineering etc. For example, the control of surface texture allows engines to have reduced running in times and to be more fuel efficient with reduced emissions. It allows orthopedic implants to last longer through optimized surface topography. It enables bearings in machines such as hard disk drives to run more efficiently and wear less. In addition, when optical components have smoother surface, they scatter less light and have better optical qualities. The usefulness of surface metrology is not in doubt, it has been viewed as a means of obtaining fingerprint of surface to characterize and understand how the unique surface topography plays animportant role in the functional performance of a component in a system.

There are techniques for analysis and briefly of surface topographies. Among these methods the Scanning Electron Microscopy is widely used for surface imaging and characterization. Due to high depth of focus, SEM can provide detailed topographical information about the surface, but cannot provide quantitative topographical information. For that purpose mechanical stylus profilometer and optical profilometer are used.

Profilers are instrument's that are used to measure surface finish, surface roughness, and the geometry of small features on an object.

Design of MRF exercise

Hence, the objective of this effort is to study the behavioral aspects of MRF process parameters to obtain the optimum improvement in surface finish, ΔRa. Towards this objective and to analyze the surface quality of the surface profiles thus generated in terms of surface finish (Ra), a series of finishing exercises were planned and performed on a disc of 20 mm diameter and 15 mm thickness.

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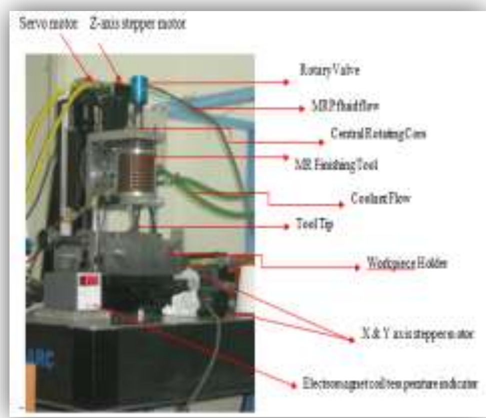

Experimentation for MRF

Experiments were performed on magneto rheological finishing set-up as shown in Fig. In the present work, experiments were conducted on EN-31workpiece of 20 mm diameter and 15 mm thickness. The work piece was kept in a rectangular slot of work piece holder and precision vice holds the work piece holder tightly along with the work piece. The reciprocating motion of the work piece was given by Y movement of linear slide which is driven by computer controlled stepper motor. The effect of parameters like current, nozzle speed and gap between the tool and work piece was studied. Fig. Showsstiffened MRP-fluid at the tip surface of MR finishing tool during finishing on work piece.

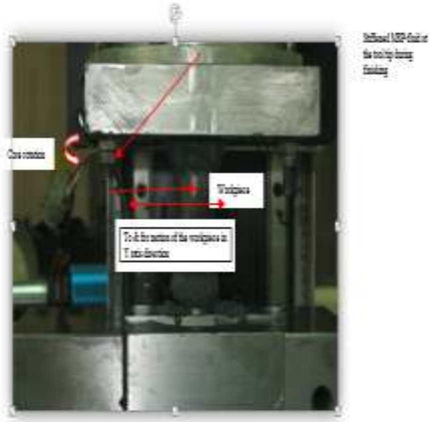

Fig Stiffened MR fluid at the tool tip is shown during Finishing on workpiece surface

Preparation of component for BEMRF process

BE MRF is a tiny finishing process which removes the material in the form of very small micro size of chips and can finish the components up to 15-20 nm so for better. For good performance of the process the initial surface roughness of the component should be as minimum as possible. In this study initially a rod of 20 mm diameter is taken and then it is cut down in to various disks of 15 mm thickness and 20 mm diameter by hand hexa. Then with the help of facing operation in the conventional lathe machine using carbide tool surface is improved. Then next the grinding process is applied on these work pieces. After the grinding process the surface finish is achieved up to 800 nm. Lapping operation is performed at component. Lapping is done by using alumina oxide as abrasive of size 303.5 (ma3) sizes 11µm and water as a base medium. After the lapping the surface finish was measured. After lapping the final surface roughness in all the components are around 210- 290 nm. The surface roughness of all the components is not same so % change in surface roughness is taken as output in this study.

III. RESULT AND DISCUSSION

It is noted during the experiment that though minimum working gap and higher current are good for highest % of improvement in surface finish but if we increase the value of current and decrease the value of working gap the magnetic field increases. More increment in the magnetic field result to increase the temperature of the magnetic coils and create problems in the functioning of machine. Also low working gap can damage the tool (nozzle) which results in the profile error of the component. The result shows that ball end magneto rheological finishing (BEMRF) machine is highly capable to improve the surface finish. In this study it is found that the process is strongly dependent on the process parameters. It is noted that in the near optimal parameters there is a larger change in surface roughness is 82.92% in just 30 minute of finishing. In this trial initially the average value of surface roughness is 256.4 nm and the surface roughness after finishing is 43.79 nm. The minimum surface roughness the minimum surface roughness achieved is 34.8 nm which is very good improvement in this short time by any conventional or modern manufacturing technique (finishing process) at present time.

Validation

Table 6.[illegible] Validation Table of RSM Model

Sr. No.	Parameters			Predicted value	Experimental value	Error %
	Current (A)	Gap (mm)	Nozzle speed (rpm)			
1	0.8	1	400	64.62434	68.1603	-5.18772
2	0.8	1.25	300	44.35936	52.0196	-14.7257
3	1.1	1	300	63.48171	66.89	-5.09537
4	1.4	1	300	79.67421	79.3133	0.455038
5	1.4	1.25	400	72.89673	66.6289	9.40706

It has been observed that the error percentage for improvement in average Ra is negligible for various parameters. It is also clear from the fig which shows the graph between the predicted value by RSM model by red line and experimental value by green line. These lines are very close to each other which indicate the effectiveness of the developed model. Main objective is to obtain the better surface roughness with low prediction error percentage during MRF. Therefore, the developed empirical model for the different MRF parameters well fit the experimental results, which have been duly verified from validation

Performance of the Model through Experimental Data and Simulated Data

With the help of neural network fitting tool performance of the neural network model is tested. For this purpose mat lab software is used. In this study 70% data is used for training, 15% for validation and 15% data is used for testing of fit, 19 experimental values for training, 3 for validation and 3 for testing of fit. The value of regression coefficient (R) at training stage is 0.97065, at validation is 0.99494, for test of fit is 0.99689 and value of overall regression coefficient is 0.95298. These values show the ANN model is very effective.

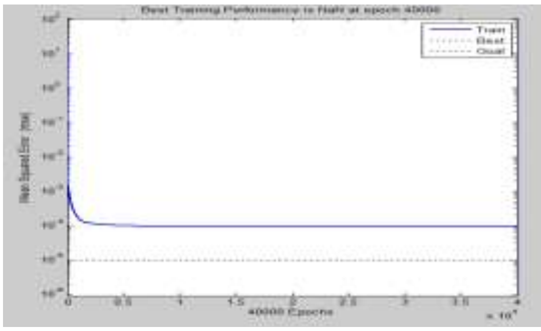

Fig A: Mean square error during and after training

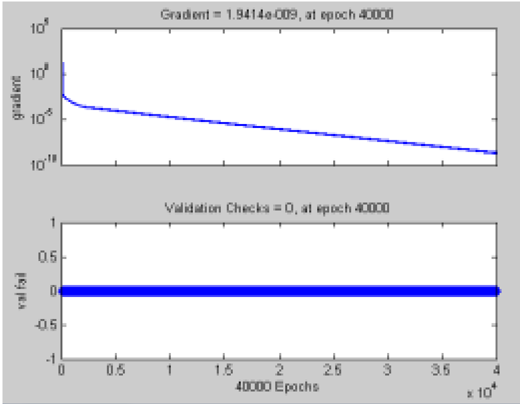

Fig.C : Gradient of ANN training curve

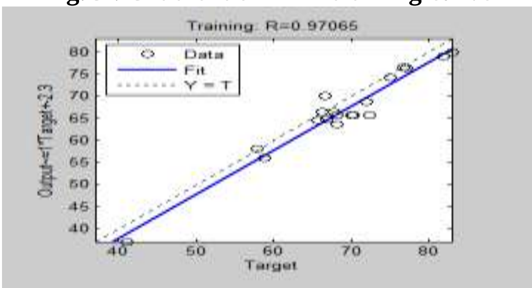

Fig.E: Regression coefficients of training neural network model

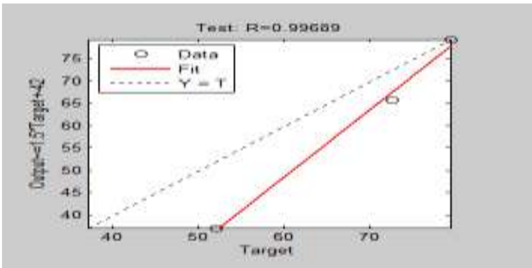

Fig.B : Regression coefficients of Fit of neural network model

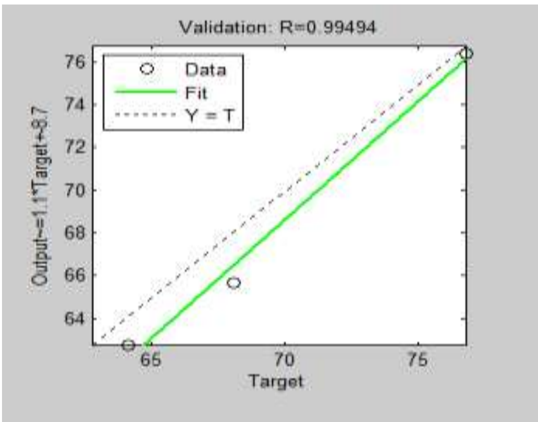

Fig.D : Regression coefficients of validation of neural network model

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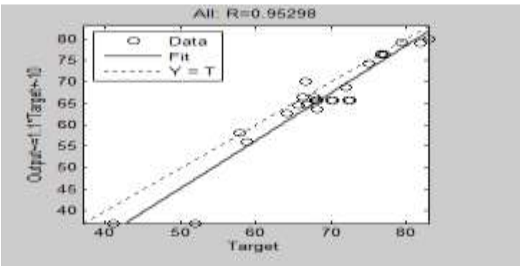

Fig.F : Regression coefficients of overall neural network mode

IV. CONCLUSION

The aim of this study was to identify the effect of process parameters of the magneto rheological fluid for surface finish. This exercise helps in identifying the optimum MRF conditions and thereby helps in improving the performance of product. In this study two models are developed for prediction of the improvement of the surface roughness in terms of percentage. One is on the basis of RSM design and other is on the basis of ANN. From this study, main conclusions are:-

- It was found that working gap is a one of the important parameter in the finishing of EN-31 steel having contribution 66.59%.
- Magnetizing current and nozzle speed are found significant factors for surface roughness with their contribution to surface roughness as 22.65% and 3.61% respectively.
- In the best set of parameters the maximum improvement in the surface roughness of the EN-31 steel sample is 82.92% from initial 245 nm to final 43.79 nm and minimum change is 44.16 %.
- The MRF process was able to remove the abrasive marks left over from lapping process.
- A second order mathematical equation is generated based on bases of RSM experimental design and confirmation tests are performed for validation of empirical equation. It is found from the conformation test that minimum error in case of mathematical model developed by RSM is 0.455% and maximum error is -14.72%.
- Confirmation test shows that the predicted values from both the model are very close to the actual experimental values. But in case of artificial neural network it is more accurate than RSM model. The value of regression coefficient in case of ANN model is 0.97 and in case of RSM model is 0.95 which shows the effectiveness of the models.

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