A REVIEW ON VARIOUS STATISTICAL APPROACHES TO IMPROVE WELDING QUANTITY IN PLASMA TRANSFERRED ARC WELDING

N. Srimath[1], M. Manojkumar[2], P. Manjunath[3], P. Pravinth[4]

[1]Faculty, Department of Mechanical Engineering, Sri Ramakrishna Engineering College, Coimbatore- 641022,

[2,3,4]Scholars, Department of Mechanical Engineering, Sri Ramakrishna Engineering College, Coimbatore- 641022,

ABSTRACT

The widely used methods for experimental study of many manufacturing processes in engineering is Design of Experiment commonly referred to as DOE. The mathematical model in DOE is developed through experimental runs is a statistical approach. Based on the input parameters of the experimental setup it calculates possible output. In the below, study is made on Plasma Transferred Arc Welding using DOE techniques by other researchers which is used for various welding purposes. This article concentrates on the usage of Response Surface Method, Taguchi method and Factorial method in Plasma Transferred Arc Welding process.

Keywords: Plasma Transferred arc welding, Design of Experiments, Response Surface Method, Taguchi methodology and Factorial methodology.

INTRODUCTION

Design of Experiment (DOE) is an experimental or analytical method, which is commonly used to indicate the relationship between input parameters to output responses. Here a systematic way of execution is made on planning of experiments, collection and analysis of data. DOE has large applications particularly in the field of science and engineering for the purpose of process improvement and development, process management and validation tests. Avinash and Vinod (2007a) developed a mathematical model using analysis techniques such as ANOVA and regression analysis. The relationship between the input parameters and the output responses are showed by this mathematical model. This mathematical model shows (Montgomery, 1991). The most commonly used DOE techniques are Response Surface Methodology with Central Composite Design, Taguchi's method and Factorial Design. In DOE, interaction between mathematical and statistical techniques such as Regression, Analysis of Variance (ANOVA), Non-Linear Optimization and Desirability functions benefit to improve the quality features measured for a cost effective process. ANOVA helps to find each factor

Of effect versus the objective function, Wang et al. (2007b).

R. A. Fischer in 1920 introduced the first Experimental design. He developed the basic values of factorial design and the related data analysis known as ANOVA during research in improving the yield of agricultural crops, Alagumurthi et al. (2006a).

FACTORIAL METHOD

For conducting experiments as it allows study of interactions between factors factorial design is used. Interactions are the driving force in many methods. Vital interface may be ignored without factorial design of experiments. Responses are measured at combinations of the experimental level of factor in a full factorial experiment. The combinations of level of factor denote the conditions at which responses are measured. Each condition of experiment is called a "run" and measurement of response is called an "observation". Factorial design can be run on two-levels, three-levels and multi-level factorial. The complete set of runs is the "design". According to Myers and Montgomery (2002a), in Full Factorial Design all possible combinations of the factor levels are satisfied. The full factorial experiments would be more reliable, but conducting the experiments is costly and occasionally unaffordable.

RESPONSE SURFACE METHOD

Response Surface Method, which is commonly known as RSM, is a compilation of statistical and mathematical methods, which are supportive in creating improved methods and improving in a Plasma Transferred Arc Welding process. In 1951 G. E. P. Box and K. B. Wilson introduced RSM method. To use a set of designed experiments to get a best response is the main idea of RSM. Even when little information is known about the process, Box and Wilson used first-degree polynomial model to get DOE through RSM and recognized that the model is only an approximation and is easy to guess and apply. The assortment of mathematical and statistical techniques is Response Surface Regression method. For modeling and investigating experiments in which a response variable is influenced by several independent variables this method is used. It discovers the relationships between several independent variables and one or more response variables. The response variable can be clearly observed as a function of the process variables otherwise called as independent variables. In addition, this graphical view of the problem has directed to the Response Surface Method (Myers and Montgomery, 2002a). RSM is applied to fit the developed model to the desired model when arbitrary factors are present. It may suitable for linear or quadratic models to define the response in terms of the independent variables. By performing an optimization step, it is then search for the best settings for the independent variables. The RSM was created to check the model part accuracy that uses the physique time as function of the process variables and other parameters based on the view of Clurkin and Rosen (2002b). Asiabanpour et al. (2006b) developed the Regression model. It defines the relationship between the factors and the composite desirability. The analyst understands of the sensitivity between independent and dependent variables can be improved by RSM, Bauer et al. (1999a). The relationship between the independent variables and the responses can be measured with RSM (Kechagias, 2007c). The experimental approach is an RSM. With significant success in various situations to obtain solutions for complicated problems, it had been engaged by research and development personnel in the industry.

The following two are designs, which are broadly used for fitting a quadratic model in RSM.

CENTRAL COMPOSITE DESIGNS

Central composite designs (CCDs), also known as Box-Wilson designs. It is suitable for standardizing the full quadratic models defined in Response Surface Models. There are three types of CCDs, namely, circumscribed, inscribed and faced. The geometry of CCDs is shown in Fig. 1.

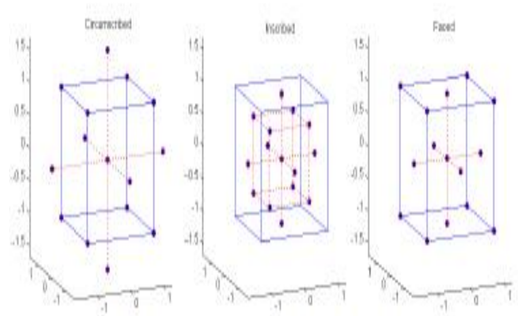


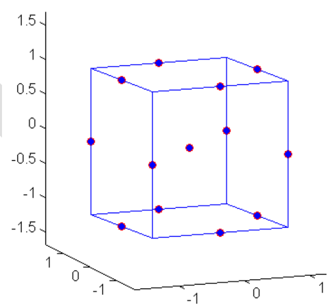
Figure 1. Circumscribed, inscribed and faced designs.

Each design contains of a factorial design i.e. in the corners of a cube. It is composed with *center* and *star* points, which allows the assessment of second order effects. CCDs have sufficient design points to evaluate the (n+2) (n+1)/2 coefficient in a full quadratic model with n factors.

By the number of factors and by the preferred properties of the design we can determine the type of CCD used. i.e. the position of the factorial and star points. Table 1 summarizes some important properties. If the calculation variance depends only on the distance of the design point from the center of the design, then the design is rotatable

BOX-BEHNKEN DESIGNS

To standardize full quadratic models Box-Behnken Designs are used. These are rotatable. It requires fewer runs than CCDs for a small number of factors (four or less). To avoid the corners of the design space, they allow experimenters to work around risky factor combinations. Like an inscribed CCD, extremes are then poorly valued.



The multiple response problem can be dealt by some extensions of RSM. Multiple response variables have created the difficulty, because what is good and possible for one response may not be very best for other responses. To reduce variability in a single response while aiming a specific value, or reaching a near maximum or minimum while avoiding variability in that response from receiving too large.

Important disapprovals of RSM include the fact that the improvement is nearly every time done with a model for which the coefficients are valued and not known. That is, a best value may only look ideal, but be distant from the truth because of changeability in the coefficients.

TAGUCHI METHOD

There were certain limitations when orthodox experimental design techniques were applied to industrial experimentation from last four decades. A Japanese engineer, Dr. Genichi Taguchi, developed a new method, which is known as orthogonal array design. It adds a new dimension to orthodox experimental design. Taguchi's DOE's are denoted by '$L_a b_c$', where 'La' be the orthogonal arrays of variables or design matrix, and 'b' be the levels of variables and 'c' be numbers of variables. Taguchi method is a mostly recognized method of DOE which has recognized to produce high quality products at subsequently low cost. This method is commonly used in automobile, electronics and other processing industries. The determination of the optimum settings of input parameters, ignoring the difference caused by uncontrollable factors or noise factors (Sivarao, 2010) is the objective of the Taguchi method. The Factor above indicate are represent to an input variable where the state can be organized during the experiment. A methodical application in design and analysis of experiments of Taguchi method (Juang et al. (2002c), Wu et al. (2004a)), is used for designing and improving product quality. Though, the new Taguchi method is deliberate to improve a single performance characteristic. Although improvisation of multiple performance characteristics is much more problematical than improvisation of a single performance characteristic (Lin. Z.C et al. (2003d), Fung et al. (2003b), Tarng et al. (2002d), Lin T.R. et al. (2004b), Huang et al. (2003c)). The Taguchi design only bears the stable orthogonal experimental combinations, that made the Taguchi design even more operative than a fractional factorial design. Industries were able to greatly decrease product development cycle time for both design and production and therefore reduce the costs and to increase profit (Julie Z. Zhang, 2007d) by using taguchi technique.

The improvisation of a process or product should be conceded Taguchi proposed out in a three-step approach. They are system design, parameter design and tolerance design. The engineer smears scientific and engineering knowledge to yield a basic functional prototype design in system design.). To improve the settings of the process parameter values for enlightening performance characteristics and to recognize the product parameter values beneath the best process limitation values. Choosing the appropriate Orthogonal Array (OA) based on the number of manageable factors (parameters); runner experiments based on the OA; investigating data; finding the best condition; and directing confirmation runs with the ideal levels of all the parameters (Julie Z. Zhang, 2007d) are the steps included in taguchi parameter design. The general development of impact of each parameter is the main effects. Knowing the information of the role of specific parameters is the important to decide the nature of the control is to recognized on a production process. The statistical treatment is called ANOVA. It is most generally applied to the outcomes of the experiments to define the percentage influence of each parameter against a quantified level of confidence (Ross, 1988). Taguchi proposes two different routes for carrying out the whole analysis According to Roy (1990). In the typical approach, the outcomes of a single run or the middling of repetitive runs were managed through the main effect and ANOVA i.e. raw data analysis. The second approach, that Taguchi powerfully mentions for multiple runs was to practice the Signal-to-Noise (S/N) ratio for the similar steps in the analysis.

Deng (1989) proposed the Grey system theory have been proved to be useful for dealing with poor, imperfect and tentative information. The Grey relational analysis can be used to solve difficult interrelationships between multiple performance characteristics effectively (Lin, 2003d). Grey relational grade was attained to evaluate the multiple performance characteristics by this analysis. As a result, improvisation of the difficult multiple performance characteristics could be converted into improvisation of a single Grey relational grade.

To highlights a mean performance characteristic value close to the target value rather than a value within certain definite limits, thus enlightening the product quality is the advantage of the Taguchi method. Additionally, Taguchi's method for experimental design is forthright and easy to apply to many engineering situations, making it a controlling yet simple tool. It can be used to quickly narrow the scope of a research project or to recognize problems in a manufacturing process from data already in existence (Fraley, 2006c).

"Pure science struggles to learn the casual relationship and to understand the mechanics of how things happen. Engineering, however, strives to achieve the result needed to gratify the customer". In the same paper, Box among others, declared his thoughtful dissimilarity with this claim. Jeff Wu, one of the panelists, pointed out that the S/N ratio was an objective of the analysis.

The results obtained are only comparative and do not exactly indicate what parameter has the highest effect on the performance characteristic value is the main disadvantage of the Taguchi method. Since orthogonal arrays do not test all variable combinations. Taguchi method has been criticized in the literature for its trouble in accounting for interactions between parameters. Another limitation is that the Taguchi methods are offline, and therefore inappropriate for a dynamically changing process such as a simulation study. Furthermore, since the Taguchi methods deal with designing quality rather than modifying for poor quality, they are applied most effectively at early stages of process development (Unitek Miyachi Group, 1999b).

Advantages and Disadvantages of DOE

The most commonly used modeling technique was DOE prevalent its precursor one-factor-at-time (OFAT) technique. The main advantages of DOE are it displays the relationship between parameters and replies is one of in other words, DOE displays the interface between variables which in turn allows us to focus on controlling important parameters to get the best answers. DOE can afford us with the ideal setting of parametric values to discover the best possible output features. Further, the mathematical model created can be used to guess the possible output response, based on the input values. DOE can regulate the number of experiments or the number of runs before the actual experimentation is done. DOE is bright when it comes to calculation of linear behavior, however, when it comes to nonlinear behavior. DOE is particularly helpful in learning the key variables manipulating the quality features of interest in the process. A designed experiment is a test or arrangement of tests in which focused changes are made to the input variables of a process. The progress of various statistical methods is shown in Fig. 3.

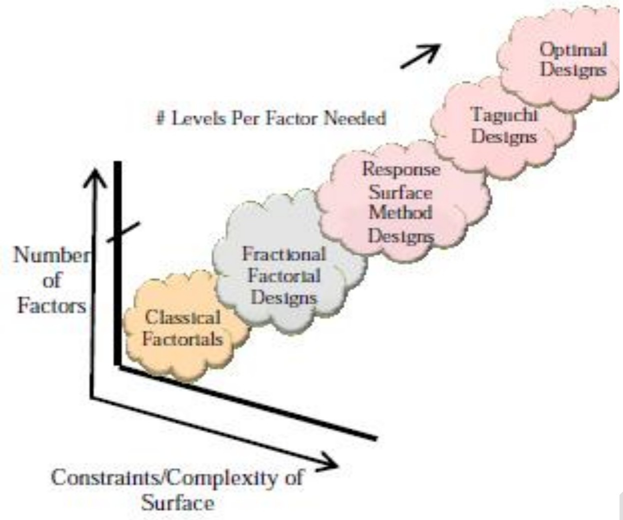


Figure 3. Progress of various statistical methods.

APPLICATION OF DESIGN OF EXPERIMENTS TO PLASMA TRANSFERRED ARC WELDING

In the modern days of fabrication industry, welding has one of the larger manufacturing process almost used in all types of works. The weld joint quality based on input parameters of welding which is control to found a proper weld. The selection of input parameters vary with the welding process type, thickness and base material type used. In order to create the accurate grouping of input weld parameters demo experiments are to be made which takes more time and manufacturing cost. Therefore, geometric techniques were applied to avoid demo experiments and decrease the cost for manufacturing. The purpose experiments were to be conduct in a successive manner based on the type of selection of geometric technique. Geometric techniques like Factorial Method, Response Surface Method and Taguchi Method were to be adopt in Design of Experiments to improve the required output parameters.

Marimuthtu and Murugan (2003e) use five-factor, five-level factorial method to calculate the geometry of the weld in the deposition of Stellite 6 (Co -Cr -A) alloy into carbon steel valve seat rings using plasma transferred arc welding process. They stated that improving the process parameters decrease the amount of metal deposited and greater the mechanical and metallurgical properties of the hard-faced layers. The application of an artificial neural network to a Taguchi experiment to improve a strong and effective method of depositing alloys with a satisfactory surface morphology by an exact micro welding hard facing process was proposed by Ming-Der Jean et al. (2005). The investigational results expose that the hard facing roughness act of the product of plasma-transferred arc coating was improved to improving the condition for coating and is exactly find by the artificial neural network (ANN) model. The combined model of of the neural network with Taguchi-based experiments were establish to an actual and smart method for developing a strong, effective, high-quality coating process.

Balasubramanian et al. (2009a) used RSM to forecast and improve the percentage of dilution of iron-based hard-faced surface produced by the PTA (Plasma Transferred Arc Welding) process. The experiments are to conduct based on five-factor five-level CCD with full repetition technique and a using RSM a mathematical model was developed. Further, the RSM were used to develop the process parameters, which yield the less percentage of dilution. Ramachandran et al. (2009b) considered the effects of many investigational conditions on the dry slipping wear behavior of stainless steel surface created by PTA hard facing process. Mathematical models were to establish guess wear rate integrating with speed of rotation, applied load and hardness of roller using statistical tools such as DOE, reversion analysis and analysis of variance. It was establishing that the wear resistance of the PTA hard-faced stainless steel surface was better than carbon steel substrate. Siva et al. (2009c) described the modeling, analysis and improvisation of weld droplet parameters of nickel-based overlay was deposit by plasma transferred arc surfacing. The experiment is to conduct based on a five-factor, five-level central composite rotatable design and a measured model was to establish using multiple regression method. The direct and collaboration effects of input process parameters of PTA Hard facing on weld geometry are to discuss. Siva et al. (2009d) using multiple regression analysis he creates mathematical equations, comparing various process parameters to weld geometry in PTA hard facing of Commonly 5, a nickel-based alloy over stainless steel 316 L plates. A hereditary algorithm has developed to improve the process parameters for attaining the favorite bead geometry variables. Mohan and Murugan (2009e) examined the result of various parameters such as welding current, open circuit voltage, travel speed, nozzle to work distance, shielding gas flow rate and welding position on bead width, height of reinforcement, penetration depth and percentage of dilution of plasma transferred arc welding tungsten carbide hard facing of 316 stainless steel plates. The experiments were lead based on five-factor, five-level CCD design matrix.

CONCLUSIONS

The study work described so far reveals the following inferences in establishing DOE to plasma transferred arc welding.

• Taguchi was interest to find a "strong" answer to the investigational problem. It tells the answer, which is unresponsive to factor differences and noise. It did not guess the better grouping of factors to attain preferred goals.

• The first method applied with design of experiments were "Factorial” or "Traditional DOE”. It permits the user to saw which factors were more significant and supports to find main relations between the factors. It did not guess the good factor levels to achieve the preferred goals.

• Response Surface Methodology (RSM) used model to made line plots of expected behavior. With the use of these plots, the better grouping of factors to achieve the preferred goals.

• RSM had an advantage over the Taguchi method in terms of worth of relations and square terms of parameters.

• Taguchi analysis provided the ultimate information though there was only one reply, but it did not deal with conditions where large amounts of responses is to improve. With the use of RSM, there was only two control factors to get at a time on a single line plot even though more than four reply on one graph becomes very tough to infer. Moreover, if a response surface was available, an automatic improver is used to help in defining the improved setting for each response. DOE used all the above strategies. The technique of DOE applied would differ based on the goals of the approach, but the DOE technique did not vary.

• Implementation of RSM and ANNs to find and improve the plasma transferred arc welding processes were choosing over implementation of Taguchi method and ANN's. Because in RSM interface, the multiple variables are available, where in Taguchi method it is not available.

• The time essential to conduct experiments using RSM is nearly twice which needed for the Taguchi method. However, one may use any type of improvisation methods such as Artificial Neural Networks (ANN), Particle Swarm Optimization (PSO), Genetic Algorithms (GA), Fuzzy, etc. After choosing suitable DOE for the method of plasma transferred arc welding phenomena.

• From the above literature study it is understanding that most of the works described was relate to Plasma transferred arc welding. Many of the investigators argued about effect of weld input factors on weld pool geometry. Very few works were stated relate to weld quality features like tensile properties, hardness etc. Another interest thing was that very few works were state on practice of DOE techniques in lesser current series and low thickness applications of plasma transferred arc welding.

Thus, the product of plasma-transferred coating was greatly increase by improving the condition of coating and is exactly find by artificial neural network model (ANN).

REFERENCES

- Avanish, K.D. and Vinod, Y., 2007a "Laser Beam Machining - A Review", International Journal of Machine Tools & Manufacture, 48, pp. 609-628.
- Wang, C.C, Lin. T.W & Hu, S.S, 2007b, Optimizing the rapid prototyping process by integrating the taguchi method with the Gray relational analysis, Rapid Prototyping Journal, 13(5), pp: 304-315.
- Alagumurthi, N., Palaniradja, K. and Soundararajan, V., 2006a, "Optimization of Grinding Process Through Design of Experiment (DOE) - A Comparative Study", Materials and Manufacturing Processes, 21(1), pp. 19-21.
- Myers, R. and Montgomery, D., 2002a, "Response Surface Methodology", 2nd ed. Wiley: New York.
- Mc Clurkin, J.E. and Rosen, D.W., 2002b, "Computer-aided build style decision support for stereo lithography", Rapid Prototyping Journal, 4(1), pp. 4-9.
- Asiabanpour, B., Khoshnevis, B. and Palmer, K., 2006b, "Development of a rapid prototyping system using response surface methodology", Journal of Quality and Reliability Engineering International, 22(8), pp. 919-937.
- Bauer, W.K., Parnell, S.G. and Meyers, A.D., 1999a, "Response Surface Methodology as a Sensitivity Analysis Tool in Decision Analysis", Journal of Multi-Criteria Decision Analysis, 8, pp. 162-168.
- Kechagias, J., 2007c, "An experiment investigation of the surface roughness of parts produced by LOM process", Rapid Prototyping Journal, 13(1), pp. 17-22.
- Juang, S.C., Tarng, Y.S., 2002c, "Process parameter selection for optimizing the weld pool geometry in the tungsten inert gas welding of stainless steel", J. Materials Processing Technology, 122, pp. 33-37.
- Wu, D.H., Chang, M.S., 2004a, "Use of Taguchi method to develop a robust design for the magnesium alloy die casting process", Materials Science and Engineering, 379, pp. 366-371.
- Lin, C.L, 2003d, "Use of the taguchi method and grey relational analysis

to optimize turning operations with multiple performance characteristics", Materials and Manufacturing Processes, 19, pp. 209-220.

- Fung, C.P., 2003b, "Manufacturing process optimization for wear property of fiber-reinforced polybutylene terephthalate composites with grey relational analysis", Science direct, Wear, 254, pp. 298-306.
- Tarng, Y.S., Juang, S.C., Chang, C.H., 2002d, "The use of grey-base Taguchi methods to determine submerged arc welding process parameters in hard facing", J. Materials Processing Technology, 128, pp. 1-6.
- Lin, T.R., Chiu, H.C., Huang, M.F., 2004b, "Optimizing removal rate and reliability of polishing of ceramic blocks using a combination of Taguchi and grey methods", Materials Science and Technology, 20(12), pp. 1649-1654.
- Huang, J.T., Liao, Y.S., 2003c, "Optimization of machining parameters of Wire-EDM based on grey relational and statistical analyses", International J. Production Research, 41(8), pp. 1707-1720
- Julie Z. Zhang, Joseph C. Chen, E. Daniel Kirby, 2007d, "Surface roughness optimization in an end-milling operation using the Taguchi design method", Journal of Materials Processing Technology, 184, pp. 233-239.
- Fraley, S., Oom, M., Terrien, B. and Date, J.Z., 2006c, Design of Experiments via Taguchi Methods: Orthogonal Arrays, The Michigan Chemical Process Dynamic and Controls Open Text Book, USA.
- Unitek Miyachi Group, 1999b, "Welding Material Control", Technical Application Brief, 2, pp. 1-5.
- Balasubramanian, V., Lakshminarayanan, A.K., Varahamoorthy, R. and Babu, S., 2009a, "Application of Response Surface Methodology to Prediction of Dilution in Plasma Transferred Arc Hard facing of Stainless Steel on Carbon Steel", Science Direct, 16(1), pp. 44-53.
- Ramachandran, C.S., Balasubràmanian, V., Varahamoorthy, R., 2009b, "Evaluation of Dry Sliding Wear Behavior of Plasma Transferred Arc Hard faced Stainless Steel", Journal of Iron and Steel Research, International, 16(4), pp. 49-54.
- Siva, K., Murugan, N. and Logesh, R., 2009c, "Optimization of weld bead geometry in plasma transferred arc hard faced austenitic stainless steel plates using genetic algorithm", Int. J. Adv. Manuf. Technol., 41, pp. 24-30.
- Siva, K., Murugan, N. and Raghupathy, V.P., 2009d, "Modelling, analysis and optimisation of weld bead parameters of nickel based overlay deposited by plasma transferred arc surfacing", Archives of Computational Materials Science and Surface Engineering, 1(3), pp. 174-182.
- Mohan, K. and Murugan, N., 2009e, "Effects of Plasma Transferred Arc Welding Parameters on Bead Geometry in Tungsten Carbide hard facing", Journal for Manufacturing Science and Production, Vol. 10, No. 3-4, pp. 155-168.