PREDICTION AND OPTIMIZATION OF GMAW PROCESS PARMAETERS ON STAINLESS STEEL CLADDING USING BACK PROPOGATION NEURAL NETWORK AND GENETIC ALGORITHM

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

Most Engineering applications require both high strength and corrosion resistant materials for long reliability and performance. Usually, the strength can be best achieved by the use of carbon steels. But these steels do not possess the required corrosion resistance. A possible materials solution is to provide these steels, a coating of a layer of corrosion resistant metal. Thereby, it has the combination of high strength as well as high corrosion resistance properties. The applying of this corrosion resistant layer is said to be cladding.

Weld cladding is a process of depositing a thick layer of a corrosion resistance material over carbon steel plate to improve corrosion resistance properties. In recent years, weld cladding processes have been developed rapidly and are now applied in numerous industries such as chemical, fertilizer, nuclear, petrochemical and steam power plants. The main problem faced in cladding is the selection of optimum combination of process parameters for achieving the required weld bead width.

This project highlights the effects of various input process parameters on weld bead width in stainless steel cladding of low carbon structural steel plates using gas metal arc welding. The experiments were conducted based on central composite rotatable design with full replications technique and mathematical model was developed using multiple regression method. The developed mathematical model has been checked for its adequacy and significance. This mathematical model is very useful for predicting the weld bead width.

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LIST OF ABBREVIATIONS

AWS	American Welding Society
CTWD	Contact Tip to Work piece Distance
DF	Degree of Freedom
DOE	Design of Experiments
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
IS	Indian Standards
MIG	Metal Inert Gas
N	Nozzle to Plate Distance
RSM	Response Surface Methodology
S	Welding Speed
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
SS	Sum of Squares
T	Welding gun angle
W	Clad Bead Width
M	Contact tip to Welding distance
R	Height of Reinforcement
P	Depth of Penetration
D	Dilution
ANN	Artificial Neural Network
AN	Artificial Neuron
GA	Genetic Algorithm

CHAPTER 1

INTRODUCTION

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INTRODUCTION

1.1 IMPORTANCE OF THE PROJECT

Most Engineering applications require both high strength and corrosion resistant materials for long reliability and performance. Usually, the strength can be best achieved by the use of carbon steels. But these steels do not possess the required corrosion resistance. A possible materials solution is to provide, a coating of a corrosion resistant metal. Thereby, it has the combination of high strength as well as high corrosion resistance properties. The application of this corrosion resistant layer by welding is said to be weld cladding.

Weld cladding is a process of depositing a relatively thick layer of corrosion resistance material over carbon steel plate to improve corrosion resistance properties. In recent years, weld cladding processes have been developed rapidly and are now applied in numerous industries such as chemical, fertilizer, nuclear, petrochemical and steam power plants. The main problem faced in cladding is dilution, it can be minimized by the selection of optimum combination of process parameters for achieving the required weld bead width.

1.2 PROJECT SEQUENCE

- Introduction about weld cladding.
- The gas metal arc welding process.
- An overview about the Design of Experiments.
- Explanation about the experimental set up.

- Explanation about the selection of process parameters.
- Description on the sequence of developing the mathematical model with the help of regression equation.
- The steps involved in finding the regression coefficients using Quality America software.
- Details on Prediction by using Neural Network.
- Optimization using Genetic Algorithm technique.
- Conclusions.

1.3 LITERATURE SURVEY

K. Manikya Kanti et al. predicted the bead geometry in pulsed GMA welding using back propagation neural network. They developed the model based on experimental data. The thickness of the plate, pulse frequency, wire feed rate, wire feed rate/travel speed ratio, and peak current have been considered as the input parameters and the bead penetration depth and the convexity index of the bead as output parameters to develop the model. The developed model is then compared with experimental results and it is found that the results obtained from neural network model are accurate in predicting the weld bead geometry.

D. S. Nagesh et al. have done modeling of fillet welded joint of GMAW process by integrated approach using DOE, ANN and GA. An integrated approach based on the use of Design of Experiment (DOE), Artificial Neural Networks (ANN), Genetic Algorithm (GA) for modeling of Gas Metal Arc Welding (GMAW) process has been explained in this paper. The effects on the five weld bead geometric descriptors by the five weld process variables has been initiated by means of 2^{n-1} fractional factorial experimental design technique. In this study, the 2^{n-1} fractional factorial experimental design method was applied on the data available.

Aman Aggarwal et al. In this paper optimization include geometric programming, geometric plus linear programming, goal programming, sequential unconstrained minimization technique, dynamic programming etc. The latest techniques for optimization include fuzzy logic, scatter search technique, genetic algorithm, Taguchi technique and response surface methodology.

D. S. Correia et al. They have given the possibility of using Genetic Algorithms (GAs) as a method to decide near-optimal settings of a GMAW welding process. The problem was to choose the near-best values of three control variables (welding voltage, wire feed rate and welding speed) based on four quality responses (deposition efficiency, bead width, depth of penetration and reinforcement), inside a previous delimited experimental region. The search for the near-optimal was carried out step by step, with the GA predicting the next experiment based on the previous, and without the knowledge of the modeling equations between the inputs and outputs of the GMAW process. However, the optimization by GA technique requires a good setting of its own parameters, such as population size, number of generations, etc. Otherwise, there is a risk of an insufficient sweeping of the search space.

George Y. Lai et al. They have done the cladding technology employing the automatic gas metal arc welding (GMAW) process

1.4 SUMMARY

Based on the literature survey made, it was found that the use of ER 308L grade stainless steel wire for the purpose of cladding Structural Steel to be very limited. The important property of ER 308L stainless steel wire is that, it is a highly corrosion resistance material. This has not been exploited in the previous study. Hence, in this project, weld cladding is made using the ER 308L grade Stainless Steel wire on IS 2062 carbon base plate in order to improve the corrosion resistance properties.

CHAPTER 2

WELD CLADDING

CHAPTER 2

WELD CLADDING

2.1 WELDING

The American Welding Society (AWS) defines welding process as "A localized coalescence of metals or nonmetals produced either by heating the materials to the required welding temperatures, with or without the application of pressure, or by the application of pressure alone, and with or without the use of filler materials".

Welding is a process of joining two metal pieces as a result of significant diffusion of the atoms of the welded pieces into the joint (weld) region. Welding is carried out by heating the joined pieces to melting point and fusing them together (with or without filler material) or by applying pressure to the pieces in cold or heated state.

2.2 APPLICATION OF WELDING

The welding technology is applied in various fields some of them where we mostly use the welding are

- Buildings and bridges structures.
- Automotive, ship and aircraft constructions.
- Pipe lines.
- Tanks and vessels.
- Machinery elements.

Role of welding process has now almost become inevitable. Recent developments in the area of welding are robotic welding, space welding, under water welding, etc. There are various methods of welding process

2.3 CLASSIFICATION OF WELDING

Welding is one of the metal joining processes which are used to produce welds. There are four major types of welding processes. They are:

1. Arc welding
2. Resistance welding
3. Gas welding
4. Solid state welding

Most of the welding processes utilize heat and / or pressure for making a weld joint. A weld is made when separate pieces of material to be joined combine and form one piece when heated to a temperature high enough to cause softening or melting and flow together. Based on the method of heat generation and its application, the four major welding processes can be divided into several classes.

ARC WELDING

- Carbon Arc Welding
- Shielded Metal Arc Welding (SMAW)
- Submerged Arc Welding (SAW)
- Metal Inert Gas Welding (MIG, GMAW)
- Tungsten Inert Gas Arc Welding (TIG, GTAW)
- Electroslag Welding (ESW)
- Plasma Arc Welding (PAW)

RESISTANCE WELDING

- Spot Welding (RSW)
- Flash Welding (FW)
- Resistance Butt Welding (UW)
- Seam Welding (RSEW)

GAS WELDING

- Oxyacetylene Welding (OAW)
- Oxyhydrogen Welding (OHW)
- Pressure Gas Welding (PGW)

SOLID STATE WELDING

- Friction Welding (FRW)
- Explosive Welding (EXW)
- Ultrasonic Welding (USW)

2.3.1 ARC WELDING

Arc welding is a welding process, in which heat is generated by an electric arc struck between an electrode and the work piece.Electric arc is luminous electrical discharge between two electrodes through ionized gas. The Arc welding are further classified into several classes.

2.3.2 SUBMERGED ARC WELDING

In this welding, an electric arc is produced between the electrode and the work plate. But the arc is completely submerged (hidden) under the flux powder. The arc is not visible outside. The electrode is a continuous bare wire electrode. When the arc is produced in the welding zone, the end of electrode and the arc are completely covered by flux powder. So there will not be any defect in the weld due to atmospheric effects. The electrode is contained in a hopper. The flux powder is supplied over the work in front of the welding area continuously. The flux covers the arc and molten metal. Some of the flux melts and forms slag on the weld. The unused flux is sucked by a pipe. The electrode is fed down automatically. The welder need not wear the protective glass. SAW is specially used for welding carbon steels and alloys steels.

2.3.3 GAS METAL ARC WELDING

In this welding, the electric arc is produced between a consumable metal electrode and the work. During welding, the arc and welding zone are surrounded by an inert gas. This inert gas covers and protects the weld from atmospheric effects. Argon or helium is used as inert gas. This welding can be done manually or automatically. MIG welding is used for welding aluminium, stainless steel and magnesium without weld defects.

2.3.4 TUNGSTEN INERT GAS ARC WELDING

Tungsten Inert Gas Arc Welding (Gas Tungsten Arc Welding) is a welding process, in which heat is generated by an electric arc struck between a tungsten non-consumable electrode and the work piece. The weld pool is shielded by an inert gas (Argon, helium, Nitrogen) protecting the molten metal from atmospheric contamination. The heat produced by the arc melts the work pieces edges and joins them. Filler rod may be used, if required. Tungsten Inert Gas Arc Welding produces a high quality weld of most of metals. Flux is not used in the process.

2.3.5 GAS WELDING

Gas Welding is a welding process utilizing heat of the flame from a welding torch. The torch mixes a fuel gas with Oxygen in the proper ratio and flow rate providing combustion process at a required temperature. The hot flame fuses the edges of the welded parts, which are joined together forming a weld after Solidification.

The flame temperature is determined by a type of the fuel gas and proportion of oxygen in the combustion mixture: 4500°F - 6300°F (2500°C - 3500°C). Depending on the proportion of the fuel gas and oxygen in the combustion mixture, the flame may be chemically neutral (stoichiometric content of the gases), oxidizing (excess of oxygen), and carburizing (excess of fuel gas). Filler rod is used when an additional supply of metal to weld is required. Shielding flux may be used if protection of weld pool is necessary.

2.3.6 EXPLOSIVE WELDING

In this process, two metal surfaces are brought together with high relative velocity under a heavy pressure. The pressure and velocity are developed by igniting an explosive. The explosion causes very high impact and forces the metal surfaces to join at a high velocity. Metallurgical bond takes place between the surfaces. The strength of the weld increases due to interlocking action.

2.4 CLADDING

Weld cladding is a means of depositing a metallic layer onto a substrate to enhance the properties. The most common purpose is to enhance corrosion resistance and is commonly applied to boiler walls and roofs in utility boilers and energy-from-waste boilers. Cladding has been successfully deposited over large surface areas and in intricate, hard-to reach places in high value plant items. Additional applications include deposition of weld metal buttering to reinstate minimum design thickness requirements on vessels and tanks. The benefit of weld cladding is that it is a fused bond onto the substrate creating an integral layer with the component, eliminating the risk of the layer spalling or detaching during service and aiding volumetric inspection. This is shown in fig. 2.1

FIG. 2.1 CLADDED MATERIAL

2.4.1 CLADDING TO PROVIDE A CORROSION RESISTANCE LAYER

The application of stainless material to a lower alloy steel is an economic method of producing reactor pressure vessels or pressure vessels for such applications as the chemical industry, where a thick-walled vessel is needed with internal corrosion protection. There are several different welding methods that can be used:

1. Submerged arc welding using a solid wire electrode.
2. Twin Arc double wire, or using a flux cored wire.
3. Submerged arc welding using a broad but thin strip electrode.
4. Strip electrode welding with a flux that enables the process to be carried out using the electroslag principle,
5. Plasma cladding.
6. Thermal spraying.

The aim is to achieve a sound weld, but with little melting of the underlying material. In this respect, the electroslag method is preferable to ordinary submerged arc welding, as it penetrates less into the substrate material and so results in less mixing of the weld metal.

Several of the ordinary submerged arc welding methods can of course be used, but it may be necessary to apply two or more layers until a sufficiently pure layer of weld metal is produced.

2.4.2 ADVANTAGES OF WELD CLADDING

Weld cladding has several advantages while manufacturing a product. Some of its advantages are discussed below:

1. Corrosion resistance is improved by means of cladding a layer of corrosion resistant material over a base carbon metal.
2. Permanent control of the heat input.
3. The cost of the product when made entirely of a single corrosion resistance material (like, stainless steel) becomes very high. So, in order to reduce the cost of the material, cladding is preferred.
4. The strength of a material cannot be compromised for the purpose of corrosion resistance, pitting resistance, etc. But, cladding helps in providing strength to a material as well as improves the corrosion resistance properties.
5. Laser cladding can be used to repair a component that has suffered damage by rebuilding the entire area.

2.4.3 APPLICATIONS OF WELD CLADDING

Some of the applications of weld cladding are in the industries such as chemical and fertilizer plants, nuclear and steam power plants, food processing and petrochemical industries and many others.

2.4.3.1 BOILER TUBES

Heat exchanger tubes in power boilers and waste recovery systems are typically made up of ferritic steels. Ferritic steels provide strength and structural integrity for the system as well as excellent resistance to high temperature, pressure water or steam. However, the fireside of the ferritic steel tube components in these systems can suffer significantly higher metal wastage rates on the tube wall due to high temperature corrosion and corrosion attack from the hot flue gas stream. Without adequate protection, the plant may experience frequent shutdowns and excessive maintenance costs. Hence a bimetallic approach using the cladding technology employing GMAW process can reduce corrosion. A typical example of water wall boiler tube is shown in fig. 2.2

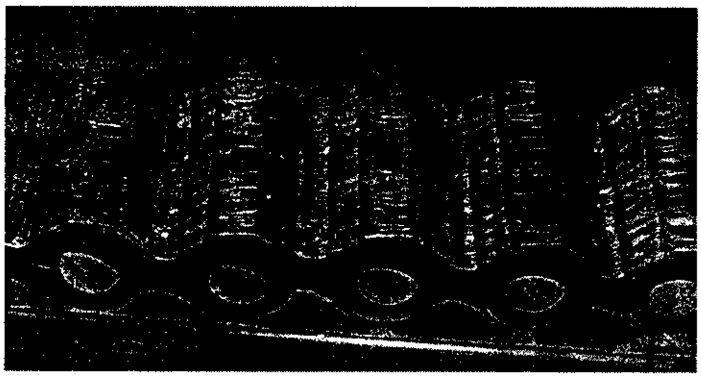


FIG. 2.2 WATER WALL BOILER TUBES

2.4.3.2 SPENT NUCLEAR FUEL SHIPPING FLASKS

Spent Nuclear Fuel Shipping Flasks are used for shipping Spent Nuclear Fuel from various Atomic Power Plants to recharging plants. The equipments are manufactured from 45 mm thick IS: 2062 Grade plates and S.S. 304L plates of various thickness. The equipment is shielded by lead. The entire equipment is cladded with 6 mm thick Stainless Steel 304L plates.

2.5 DIFFERENCES BETWEEN WELDING AND CLADDING

Basically, cladding is the applying of a thick layer of weld metal (filler) over the base metal to improve corrosion resistance properties. But, in welding, the filler material is used for the purpose of joining two different work pieces.

The primary difference between welding and cladding is the dilution. Dilution is defined as the amount of base metal melted (B) divided by the sum of the filler metal added and base metal melted (A + B). In cladding, the dilution percentage should be very low in order to retain the characteristics of the clad metal in the final composite material. This is shown in fig. 2.3.

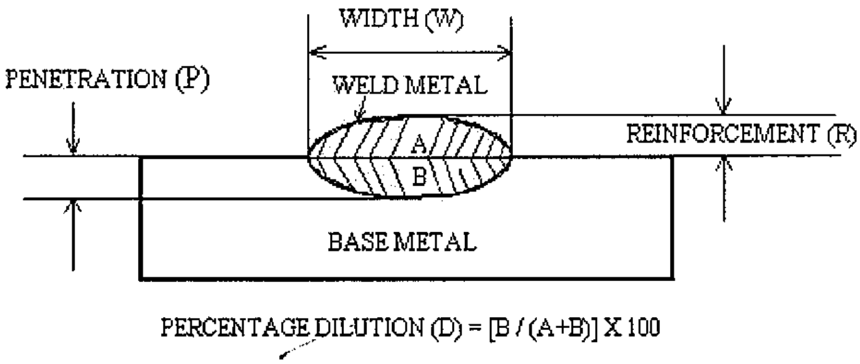


FIG. 2.3 CLAD BEAD GEOMETRY

CHAPTER 3

GAS METAL ARC WELDING

CHAPTER 3

GAS METAL ARC WELDING

3.1 GMAW PROCESS

Gas metal arc welding (GMAW), sometimes referred as Metal inert gas (MIG) welding , is a semi-automatic or automatic arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. There are four primary methods of metal transfer in GMAW, called globular, short-circuiting, spray, and pulsed-spray, each of which has distinct properties and corresponding advantages and limitations.

Today, GMAW is the most common industrial welding process, preferred for its versatility, speed and the relative ease of adapting the process to robotic automation. The automobile industry in particular uses GMAW welding almost exclusively. Unlike welding processes that do not employ a shielding gas, such as shielded metal arc welding, it is rarely used outdoors or in other areas of air volatility. A related process, flux cored arc welding, often does not utilize a shielding gas, instead employing a hollow electrode wire that is filled with flux on the inside.

3.1.2 ADVANTAGES OF GMAW

The GMAW process enjoys widespread use because of its ability to provide high quality welds, for a wide range of ferrous and non-ferrous alloys, at a low price.

GMAW has the following important advantages:

- The ability to join a wide range of material types and thicknesses.
- Simple equipment components are readily available and affordable.
- GMAW has higher electrode efficiencies, usually between 93% and 98%, when compared to other welding processes.
- Higher welder efficiencies and operator factor, when compared to other open arc welding processes.
- GMAW is easily adapted for high-speed robotic, hard automation and semiautomatic welding applications.
- All-position welding capability.
- Lower heat input when compared to other welding processes.
- A minimum of weld spatter and slag makes weld clean up fast and easy.
- Less welding fumes when compared to SMAW (Shielded Metal Arc Welding) and FCAW (Flux-Cored Arc Welding) processes.
- Generally, lower cost per length of weld metal deposited when compared to other open arc welding processes.
- Reduced welding fume generation.

3.1.3 LIMITATIONS OF GMAW

- The lower heat input characteristic of the short-circuiting mode of metal transfer restricts its use to thin materials.
- The higher heat input axial spray transfer generally restricts its use to thicker base materials.
- The higher heat input mode of axial spray is restricted to flat or horizontal welding positions.

- The use of argon based shielding gas for axial spray and pulsed spray transfer modes is more expensive than 100% carbon dioxide (CO_2).

3.2 WELDING PROCEDURE

1. The welding procedures for MIG welding are similar to those for other arc welding processes. Adequate fixturing and clamping of the work are required with adequate accessibility for the welding gun. Fixturing must hold the work rigid to minimize distortion from welding. It should be designed for easy loading and unloading. Good connection of the work lead (ground) to the workpiece or fixturing is required. Location of the connection is important, particularly when welding ferromagnetic materials such as steel. The best direction of welding is away from the work lead connection. The position of the electrode with respect to the weld joint is important in order to obtain the desired joint penetration, fusion, and weld bead geometry. Electrode positions for automatic MIG welding are similar to those used with submerged arc welding.

2. When complete joint penetration is required, some method of weld backing will help to control it. A backing strip, backing weld, or copper backing bar can be used. Backing strips and backing welds usually are left in place. Copper backing bars are removable.

3. The assembly of the welding equipment should be done according to the manufacturer's directions. All gas and water connections should be tight; there should be no leaks. Aspiration of water or air into the shielding gas will result in erractic arc operation and contamination of the weld. Porosity may also occur.

4. The gun nozzle size and the shielding gas flow rate should be set according to the recommended welding procedure for the material and joint design to be welded. Joint designs that require long nozzle-to-work distances will need higher gas flow rates than those used with normal nozzle-to-work distances. The gas nozzle should be of adequate size to provide good gas coverage of the weld area. When welding is done in confined areas or in the root of thick weld joints, small size nozzles are used.

5. The gun contact tube and electrode feed drive rolls are selected for the particular electrode composition and diameter, as specified by the equipment manufacturer. The contact tube will wear with usage, and must be replaced periodically if good electrical contact with electrode is to be maintained and heating of the gun is to be minimized.

6. Electrode extension is set by the distance between the tip of the contact tube and the gas nozzle opening. The extension used is related to the type of MIG welding, short circuiting or spray type transfer. It is important to keep the electrode extension (nozzle-to-work distance) as uniform as possible during welding. Therefore, depending on the application, the contact tube may be inside, flush with, or extending beyond the gas nozzle.

7. The electrode feed rate and welding voltage are set to the recommended values for the electrode size and material. With a constant voltage power source, the welding current will be establish by the electrode feed rate. A trial bead weld should be made to establish proper voltage (arc length) and feed rate values. Other variables, such as slope control, inductance, or both, should be

adjusted to give good arc starting and smooth arc operation with minimum spatter.

The optimum settings will depend on the equipment design and controls, electrode material and size, shielding gas, weld joint design, base metal composition and thickness, welding position, and welding speed

CHAPTER 4

EXPERIMENTAL DESIGN PROCEDURE

CHAPTER 4

EXPERIMENTAL DESIGN PROCEDURE

4.1 STEPS IN EXPERIMENTAL DESIGN PROCEDURE

The various steps in the experimental design procedure are as follows:

a. Identification of factors and responses
b. Finding the limits of process variables
c. Development of design matrix
d. Conducting experiments as per the design matrix
e. Recording the response
f. Development of mathematical models
g. Checking adequacy of the developed models
h. Conducting conformity tests

4.1.1 IDENTIFICATION OF FACTORS AND RESPONSES

The input parameters were identified based on the literature survey. Wire feed rate (W), Welding speed (S), Welding gun angle (T), Contact tip to plate distance (M) and Pinch (P) were found to be the vital independently controllable process parameters affecting the output parameters. The responses chosen were clad bead width (W), Height of reinforcement (R), depth of penetration (P) and Percent dilution (D). The responses were chosen based on the impact these parameters are having on the final composition and properties of the composite material.

4.1.2 FINDING THE LIMITS OF THE PROCESS VARIABLES

The working ranges of all selected factors are fixed by conducting trial runs. This was carried out by varying one of the factors while keeping the rest of them as constant values. The working range of each process parameters was decided upon by inspecting the bead for a smooth appearance without any visible defects such as surface porosity, undercut, etc. The upper limit of a given factor was coded as +2 and the lower limit was coded as –2. The coded values for intermediate values were calculated using the equation (5.1):

$$X_i = 2\,[2X - (X_{max} + X_{min})] / [(X_{max} - X_{min})] \quad \text{--- (5.1)}$$

where X_i is the required coded value of a parameter X; X is any value of the parameter from X_{min} to X_{max}; X_{min} is the lower limit of the parameter and X_{max} is the upper limit of the parameter. The chosen levels of the selected process parameters with their units and notations are given in Table 4.1.

TABLE 4.1 WELDING PARAMETERS AND THEIR LEVELS

PARAMETER	UNIT	NOTATION	LEVELS				
			-2	-1	0	1	2
Wire feed rate	In/min	W	275	295	315	325	355
Welding speed	mm/min	S	150	158	166	174	182
Contact tip to Plate Distance	mm	M	10	14	18	22	26
Welding gun Angle	Degree	T	70	80	90	100	110
Pinch	Nil	P	-10	-5	0	5	10

4.1.3 DEVELOPMENT OF DESIGN MATRIX

The design matrix chosen to conduct the experiments was a central composite rotatable design. This design matrix comprises a full replication of 2^5 = 32 factorial design is shown in Table 4.2. All welding parameters in the intermediate levels (0) constitute the center points and the combination of each welding parameters at either its highest value (+2) or lowest value (-2) with other three parameters of the intermediate levels (0) constitute the star points.

TABLE 4.2 DESIGN MATRIX

TRIAL NUMBER	DESIGN MATRIX				
	W	S	M	T	P
1	-1	-1	-1	-1	1
2	1	-1	-1	-1	-1
3	-1	1	-1	-1	-1
4	1	1	-1	-1	1
5	-1	-1	1	-1	-1
6	1	-1	1	-1	1
7	-1	1	1	-1	1
8	1	1	1	-1	-1
9	-1	-1	-1	1	-1
10	1	-1	-1	1	1
11	-1	1	-1	1	1
12	1	1	-1	1	-1
13	-1	-1	1	1	1
14	1	-1	1	1	-1
15	-1	1	1	1	-1
16	1	1	1	1	1
17	-2	0	0	0	0
18	2	0	0	0	0
19	0	-2	0	0	0
20	0	2	0	0	0
21	0	0	-2	0	0
22	0	0	2	0	0
23	0	0	0	-2	0
24	0	0	0	2	0
25	0	0	0	0	-2
26	0	0	0	0	2
27	0	0	0	0	0
28	0	0	0	0	0
29	0	0	0	0	0
30	0	0	0	0	0
31	0	0	0	0	0
32	0	0	0	0	0

4.1.4 CONDUCTING THE EXPERIMENTS AS PER DESIGN MATRIX

The experiments were conducted at Kumaraguru College of Technology, Coimbatore. In this work, thirty two experimental runs were allowed for the estimation of the linear, quadratic and two – way interactive effects of the process parameters on the bead geometry corresponding to each treatment combination of parameters as shown in Table 4.2 at random. At the end of each run, settings for all parameters were disturbed and reset for the next deposit. This is essential to introduce variability caused by errors in experimental settings.

4.1.4.1 EXPERIMENTAL SET UP

The following machines and consumables were used for the purpose of conducting the experiments:

1. A constant voltage gas metal arc welding machine (Invertec V350-PRO Advanced Process with 5-425 amp output range) (Fig. 4.1).
2. Welding manipulator (Fig. 4.2).
3. ER 308L stainless steel welding wire (Fig. 4.3).
4. Gas cylinder consisting a mixture of 98% argon and 2% oxygen (fig. 4.4).
5. Mild steel plate of grade IS 2062 GRB AlSiKUnTr

The main experimental set up used consists of a traveling carriage with a table for supporting the specimens. A power source is present The welding gun is held stationary in a frame above the table, and it is provided with an attachment for setting the required nozzle to plate distance and welding gun angle respectively.

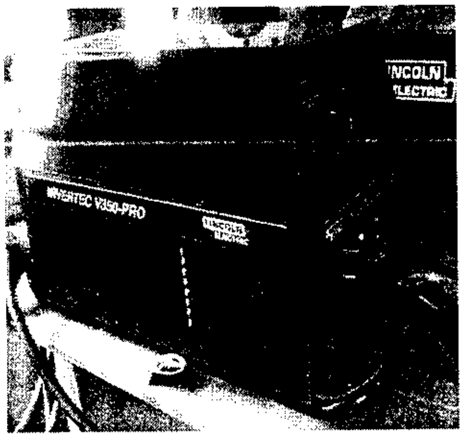
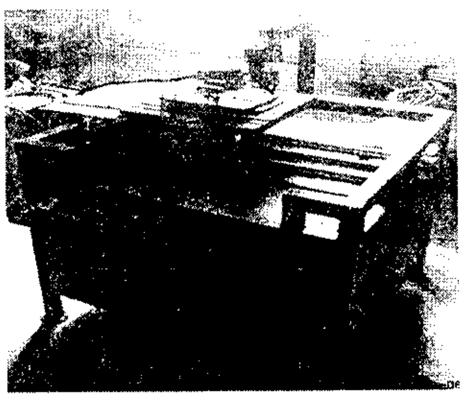


FIG 4.1 INVERTER

FIG 4.2 WIRE FEEDER



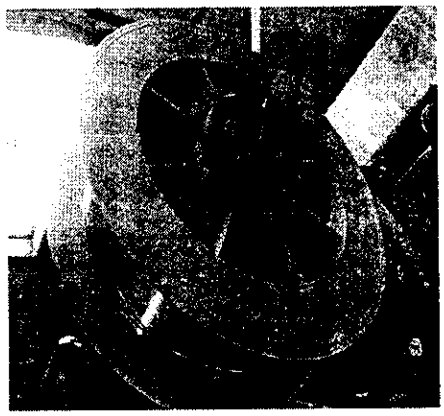


FIG. 4.3 MANIPULATOR

FIG. 4.4 FILLER ROD

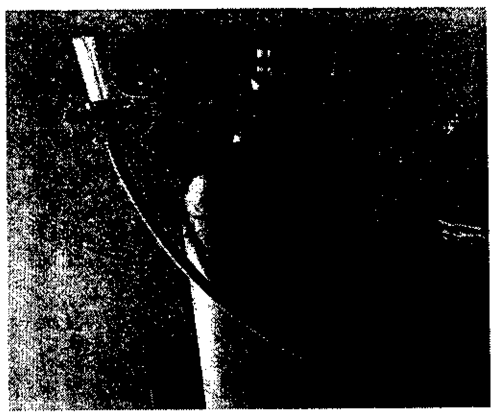


FIG. 4.5 ARGON GAS CYLINDER WITH REGULATOR

The experiments were conducted using the constant voltage welding machine Test plates of size 300 × 200 × 20mm were cut from low carbon structural steel plate (IS 2062) and one surface was cleaned to remove oxide scale and dirt before cladding. ER 308L stainless steel welding wire of 1.2 mm diameter was used for depositing the weld beads through the wire feeder. Argon gas at a constant flow rate of 16.5 liters per minute was used for shielding.

FIG. 4.6 WELD CLADDING

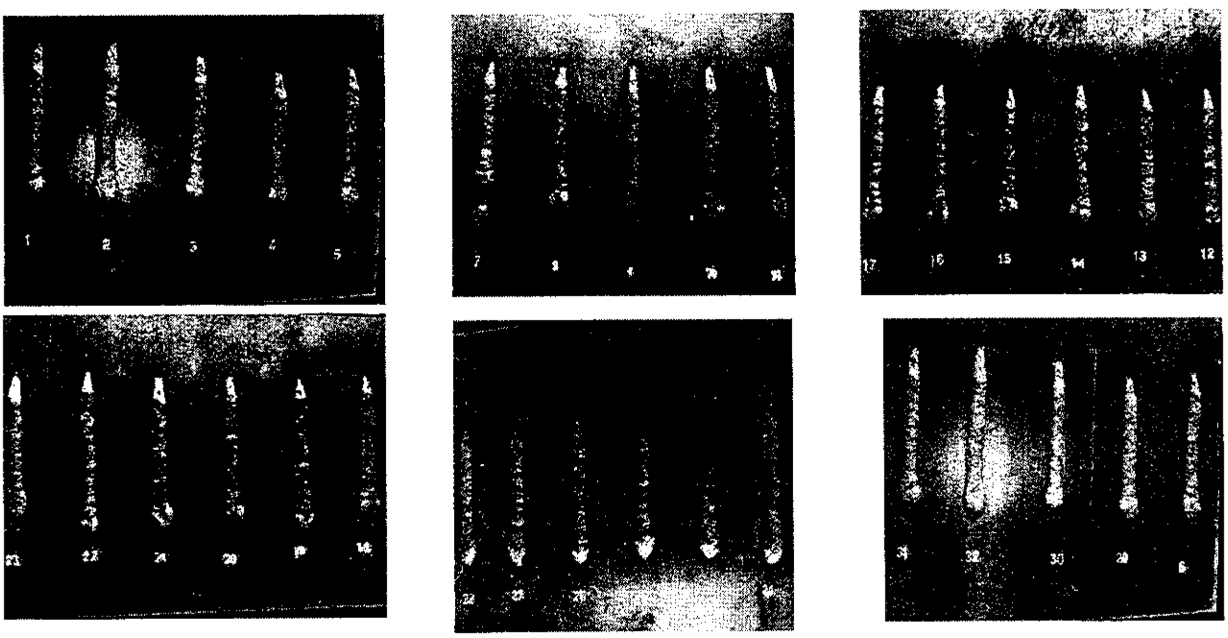


FIG. 4.7 WELD CLADDED PLATES

WELD CLADDED PLATES

4.1.5 RECORDING THE RESPONSES

To measure the clad bead geometry, transverse sections of each weld overlays (fig. 4.6) were cut using band saw (fig. 4.7) from the mid-length position of the welds, and the end faces were machined. Specimen end faces were polished and etched using a 5% nital solution to display bead dimensions.

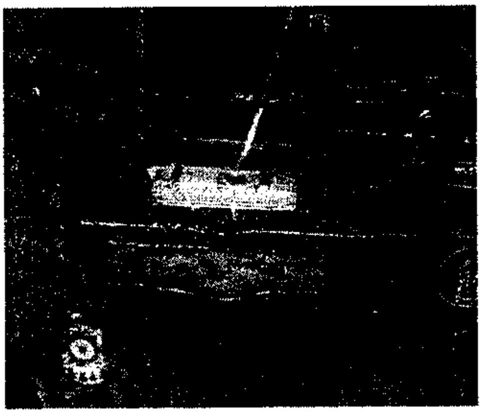


FIG 4.8 BAND SAW CUTTING OF CLADDED PLATE

FIG 4.9 SURFACE GRINDING

The clad bead profiles were traced using a reflective type optical profile projector (fig. 4.8) at a magnification of X10, in ROOTS INDUSTRIES LTD, COIMBATORE .Then the bead dimensions such as depth of penetration, height of reinforcement and clad bead width were measured. The traced bead profiles (fig. 4.9) were scanned in order to find the various clad parameters and the percentage dilution with the help of AUTOCAD software. The measured clad bead dimensions and percentage dilution are shown in Table 4.3.

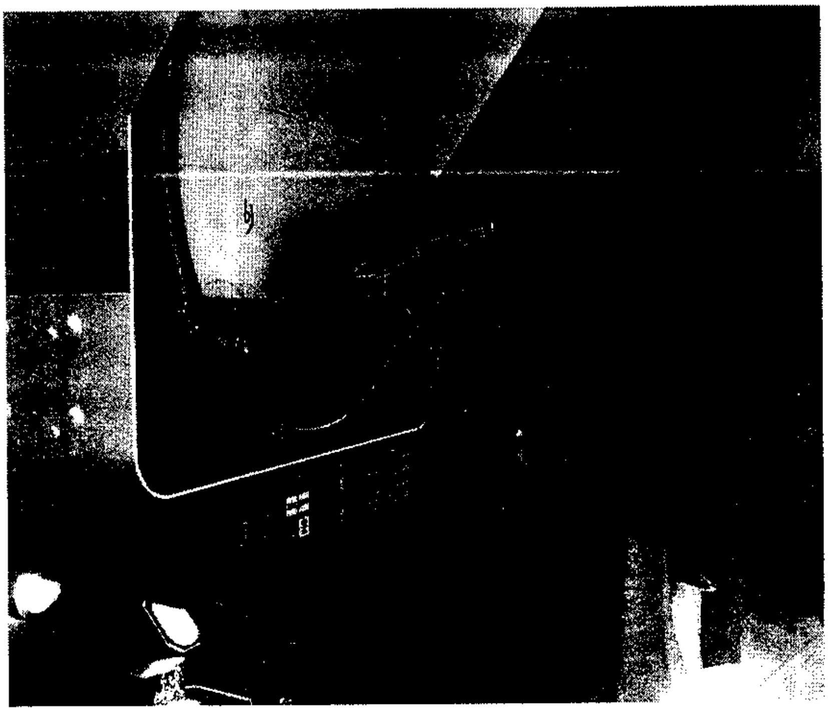


FIG 4.10 PROFILE PROJECTOR USED IN TRACING CLAD GEOMETRY

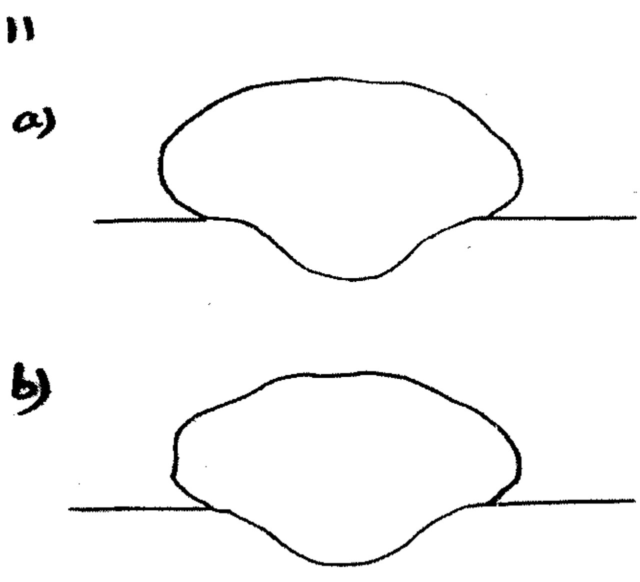


FIG 4.11 TRACED PROFILE (SPECIMEN NO. 11)

TABLE4.3 DESIGN MATRIX AND THE OBSERVED VALUES OF CLAD BEAD GEOMETRY

TRIAL NUMBER	DESIGN MATRIX					BEAD PARAMETERS			
	W	S	M	T	P	W (mm)	P (mm)	R (mm)	D (%)
1	-1	-1	-1	-1	1	8.6778	2.65135	5.5635	17.382
2	1	-1	-1	-1	-1	8.9855	2.9415	6.2854	15.6671
3	-1	1	-1	-1	-1	7.7603	2.7853	5.85495	18.1186
4	1	1	-1	-1	1	8.0891	2.6428	6.21035	13.0635
5	-1	-1	1	-1	-1	8.2821	2.44085	6.70505	12.7075
6	1	-1	1	-1	1	6.7726	2.0238	5.9401	11.1514
7	-1	1	1	-1	1	7.1973	1.98515	5.81665	11.7496
8	1	1	1	-1	-1	6.9958	2.52275	6.108	14.2798
9	-1	-1	-1	1	-1	7.2829	2.79785	5.959	16.5921
10	1	-1	-1	1	1	8.0891	2.6428	6.21035	13.0635
11	-1	1	-1	1	1	7.6847	2.531	5.58875	17.7022
12	1	1	-1	1	-1	7.9272	2.91125	6.2173	16.3146
13	-1	-1	1	1	1	8.4017	2.7507	5.7735	18.2658
14	1	-1	1	1	-1	8.1203	2.51285	6.36365	12.8279
15	-1	1	1	1	-1	7.1485	2.63895	6.17425	16.206
16	1	1	1	1	1	6.7094	2.2847	6.44065	11.9954
17	-2	0	0	0	0	7.2594	2.5745	5.8395	17.3903
18	2	0	0	0	0	7.8269	2.75545	6.58725	14.0448
19	0	-2	0	0	0	8.9086	3.08195	6.27045	15.4479
20	0	2	0	0	0	6.8884	2.90905	5.94105	17.6897
21	0	0	-2	0	0	8.4437	3.32775	5.93925	21.0202
22	0	0	2	0	0	7.0578	2.30905	6.08125	13.7311
23	0	0	0	-2	0	8.0808	2.1388	6.0257	15.124
24	0	0	0	2	0	7.3881	2.39815	6.232	14.0278
25	0	0	0	0	-2	8.2	2.24075	6.40375	16.1339
26	0	0	0	0	2	8.0284	2.46425	6.0243	16.0811
27	0	0	0	0	0	8.5204	3.0631	6.2144	18.7508
28	0	0	0	0	0	8.3657	2.6817	6.19275	18.0489
29	0	0	0	0	0	8.1532	2.7707	5.8686	17.9313
30	0	0	0	0	0	7.6813	2.6535	5.6824	16.8726
31	0	0	0	0	0	8.1802	2.79225	5.8824	16.4009
32	0	0	0	0	0	8.1802	2.79225	5.96811	16.6401

4.1.6 DEVELOPMENT OF MATHEMATICAL MODELS

Using the observed values as obtained from Table 4.3, mathematical models were developed. The response function representing any of the clad bead geometry can be expressed using the equation (4.2)

$$\mathbf{Y = f\,(A, B, C, D, E)} \qquad \text{---- (4.2)}$$

Where Y = Response variable (e.g. clad bead width)

A = Wire Feed Rate (F) in m/min.

B = Welding speed (S) in mm/min.

C = Contact tip to plate distance (N) in mm.

D = Welding gun angle (T) in degrees.

E = Pinch (P).

The second order response surface model for the four selected factors is given by the equation (5.3):

$$Y = \beta_0 + \sum_{i=1}^{4} \beta_i X_i + \sum_{i=1}^{4} \beta_{ii} X_i^2 + \sum_{\substack{i=1 \\ i<j}}^{4} \beta_{ij} X_i X_j \qquad \text{---- (4.3)}$$

The second order response surface model [equation (5.3)] could be expressed as follows:

$$Y = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 C + \beta_4 D + \beta_5 E + \beta_{11} A^2 + \beta_{22} B^2 + \beta_{33} C^2 + \beta_{44} D^2 + \beta_{55} E^2 + \beta_{12} AB + \beta_{13} AC + \beta_{014} AD + \beta_{15} AE + \beta_{23} BC + \beta_{24} BD + \beta_{25} BE + \beta_{34} CD + \beta_{35} CE + \beta_{45} DE \qquad \text{------- (5.4)}$$

where β_0 is the free term of the regression equation, the coefficients β_1, β_2, β_3, β_4 and β_5 are linear terms, the coefficients β_{11}, β_{22}, β_{33} , β_{44} and β_{55} are the quadratic terms, and the coefficients β_{12} - β_{45} are the interaction terms. The coefficients were calculated using QA six sigma software (DOE-PC IV). After determining the coefficients, the mathematical models were developed. The developed mathematical models are given as follows:

Clad bead width (W), mm =

$$8.172 - 0.381A + 0.016B - 0.318C - 0.116D - 0.051E - 0.063A^2 - 0.152B^2 - 0.100C^2 - 0.104D^2 - 0.009E^2 + 0.038AB - 0122AC + 0.016AD + 0.036AE - 0.257BC + 0.088BD - 0.241BE + 0.229CD - 0.128CE + 0.106DE \qquad \text{----} \quad (4.5)$$

Depth of Penetration (P), mm =

$$2.778 - 0.034A + 0.011B - 0.119C + 0.066D - 0.066E + 0.052A^2 - 0.030B^2 + 0.008C^2 - 0.129D^2 - 0.108E^2 + 0.059AB - 0.008AC - 0.014AD - 0.049AE - 0.053BC - 0.040BD - 0.034BE + 0.085CD - 0.006CE - 0.046DE \qquad \text{----} \quad (4.6)$$

Height of Reinforcement (R), mm =

$$6.039 - 0.044A + 0.160B - 0.072C + 0.027D - 0.120E + 0.005A^2 + 0.032B^2 - 0.019C^2 + 0.011D^2 + 0.032E^2 + 0.046AB - 0.006AC + 0.039AD + 0.095AE - 0.098BC + 0.071BD + 0.034BE + 0.008CD - 0.040CE + 0.045DE \qquad \text{----} \quad (4.7)$$

Percentage Dilution (D), % =

$$26.606 + 0.261A - 1.127B - 1.387C + 0.277D - 0.352E - 0.383A^2 - 0.596B^2 - 0.181C^2 - 0.881D^2 - 0.498E^2 + 0.257AB - 0.201AC + 0.073AD - 0.780AE + 0.188BC - 0.548BD - 0.706BE + 0.623CD + 0.164CE + 0.407DE \qquad \text{----} \quad (4.8)$$

4.1.7 CHECKING THE ADEQUACY OF THE DEVELOPED MODELS

The adequacies of the developed model were tested using the analysis of variance (ANOVA) technique. As per this technique, if the F – ratio values for the developed models do not exceed the standard tabulated values for a desired level of confidence (95%) and the calculated R – ratio values of the developed model exceed the standard tabulated values for a desired level of confidence (95%), then the models are said to be adequate within the confidence limit.. The values are shown in Table 4.4.

TABLE 4.4 ANALYSIS OF VARIANCE FOR TESTING ADEQUACY OF THE MODELS

Parameter	1st order terms		2nd order terms		Lack of fit		Error terms		F – ratio	R – ratio	Whether model is adequate
	SS	DF	SS	DF	SS	DF	SS	DF			
W	11.143	20	0.832	11	0.432	6	0.400	5	0.901	9.968	adequate
P	2.475	20	0.341	11	0.232	6	0.109	5	1.782	5.696	adequate
R	1.916	20	0.201	11	0.090	6	0.111	5	0.672	4.304	adequate
D	154.301	20	17.358	11	12.986	6	4.372	5	2.475	8.824	adequate

F ratio (10, 6, 0.05) = 4.09
R ratio (14, 6, 0.05) = 3.96

CHAPTER 5

DEVELOPMENT OF MATHEMATICAL MODELS USING QUALITYAMERICA SOFTWARE

CHAPTER 5

DEVELOPMENT OF MATHEMATICAL MODELS USING QUALITY AMERICA SOFTWARE

5.1 SOFTWARES USED FOR THE DEVELOPMENT OF REGRESSION MODEL

Some of the softwares used in the determination of regression coefficients are as follows:

1. Quality America (DOE - PC IV)
2. Systat
3. Minitab
4. MS Excel
5. Design Expert
6. MATLAB
7. SPSS

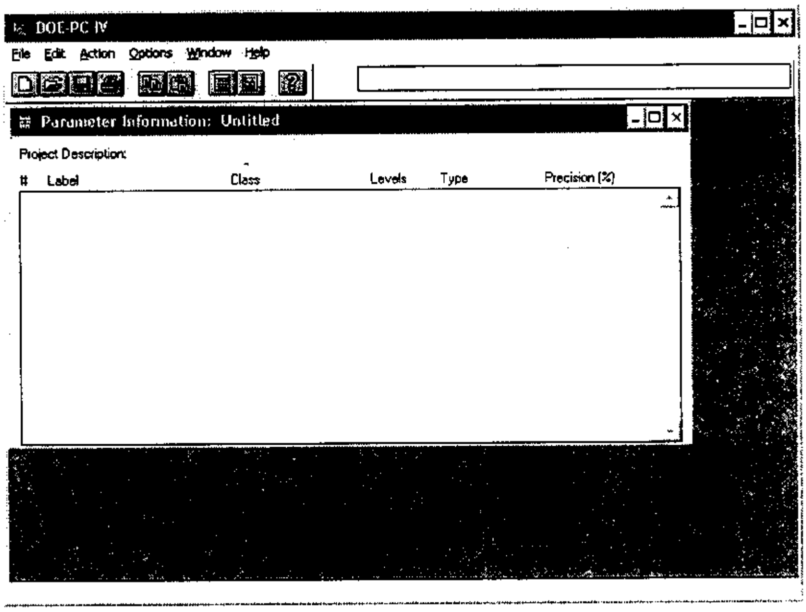
Among these softwares, using the Quality America Six Sigma Software (DOE - PC IV) has been found to be easier to calculate the regression coefficients. Hence, this software is used for the experimental study purpose.

5.2 STEPS IN FINDING REGRESSION COEFFICIENTS

The steps used in finding the regression coefficients are explained as follows:

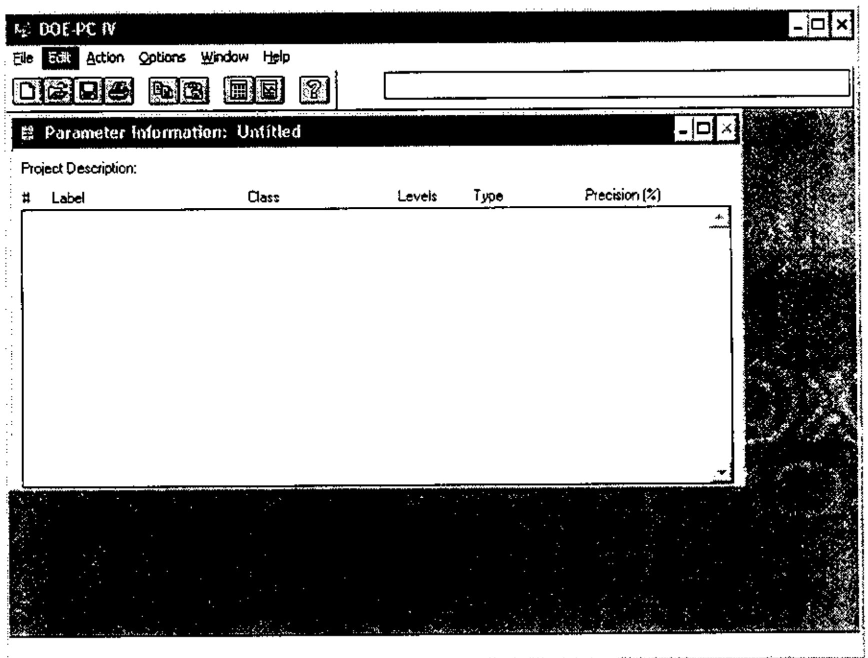
STEP 1:

A new file of DOE – PC 1V software is opened.



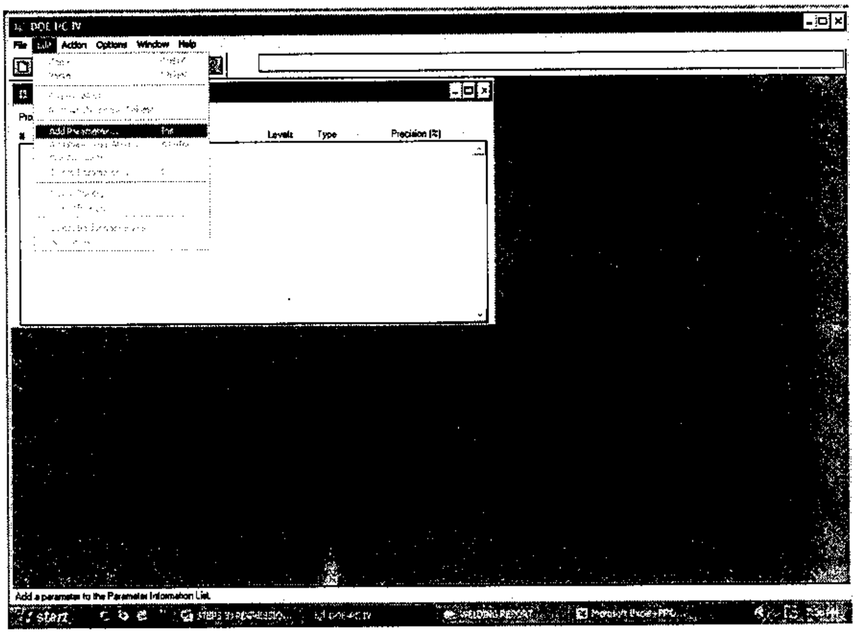
STEP 2:

'EDIT' option is chosen from the standard tool bar.



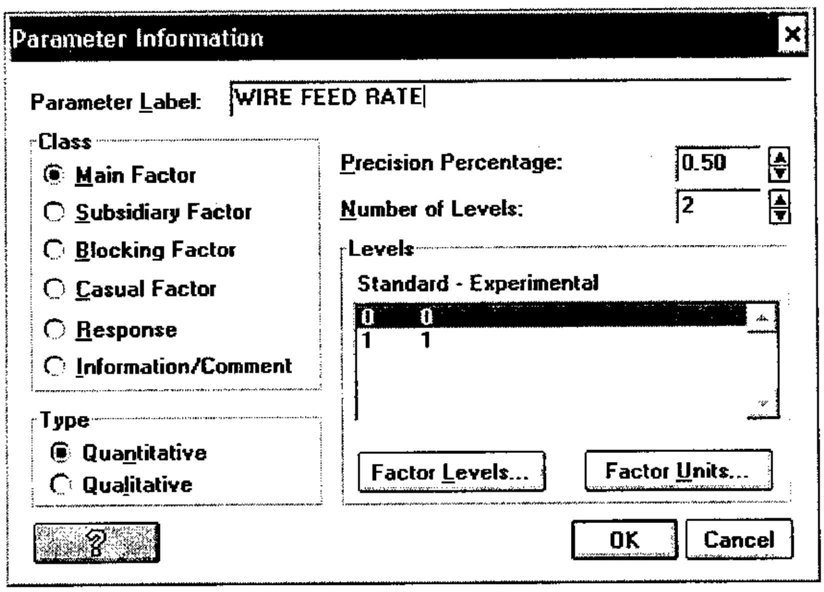
STEP 3:

Now the 'ADD PARAMETER' option is chosen from the drop down menu.



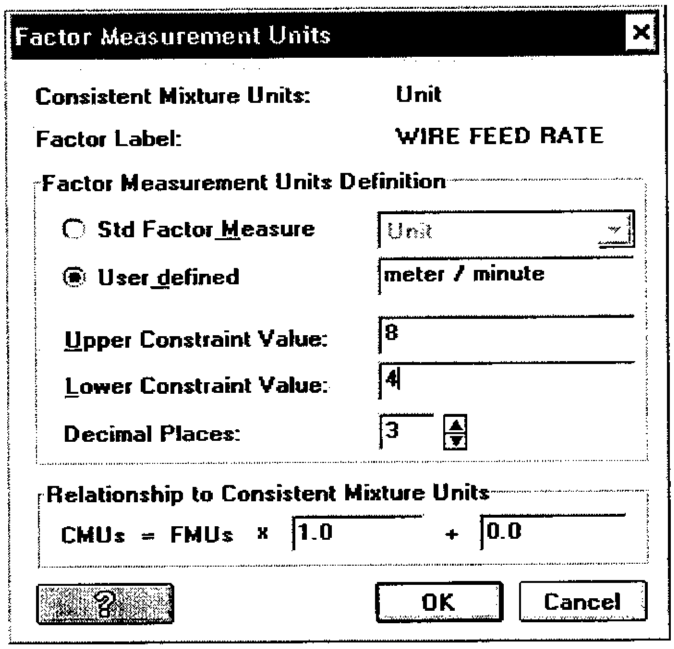
STEP 4:

Then the name of the input parameter is given in the 'PARAMETER LABEL'



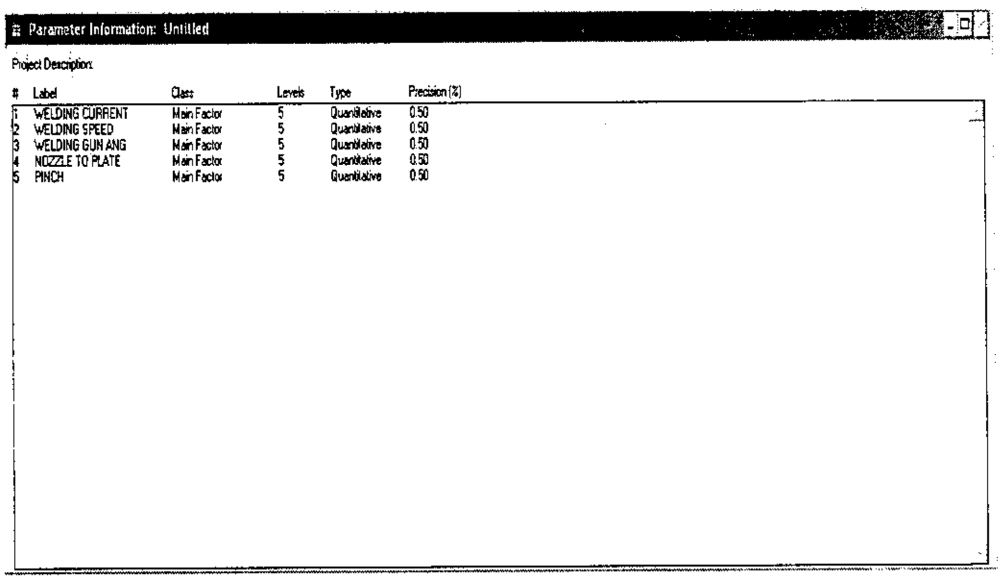
STEP 5:

Now the level of the input parameter is taken as five and the user defined unit is given. Then the upper and lower constraint values are given.



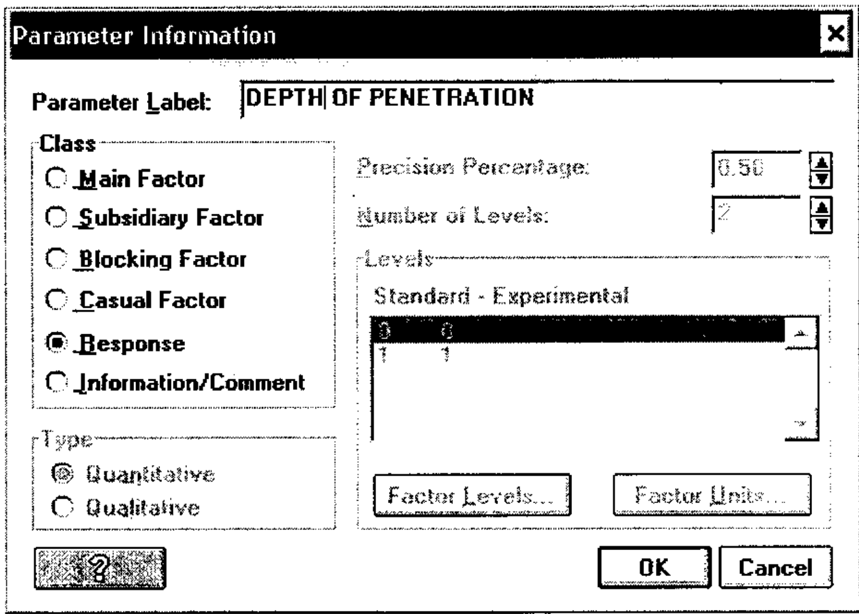
STEP 6:

Similarly, steps 3 to 5 are followed to enter all the input parameters along with their respective units and limit values.



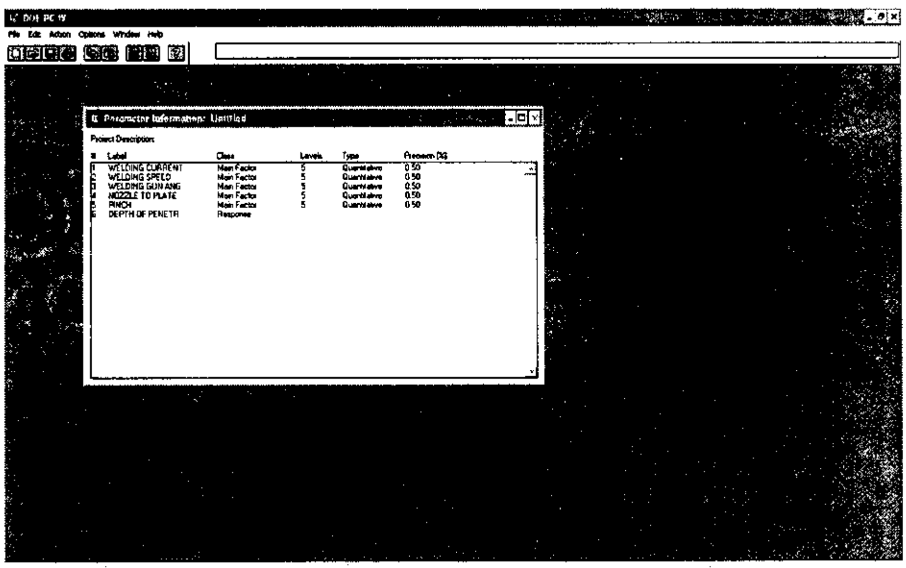
STEP 7:

After choosing the 'RESPONSE' class, the name of the output parameter is given in the 'PARAMETER LABEL'.



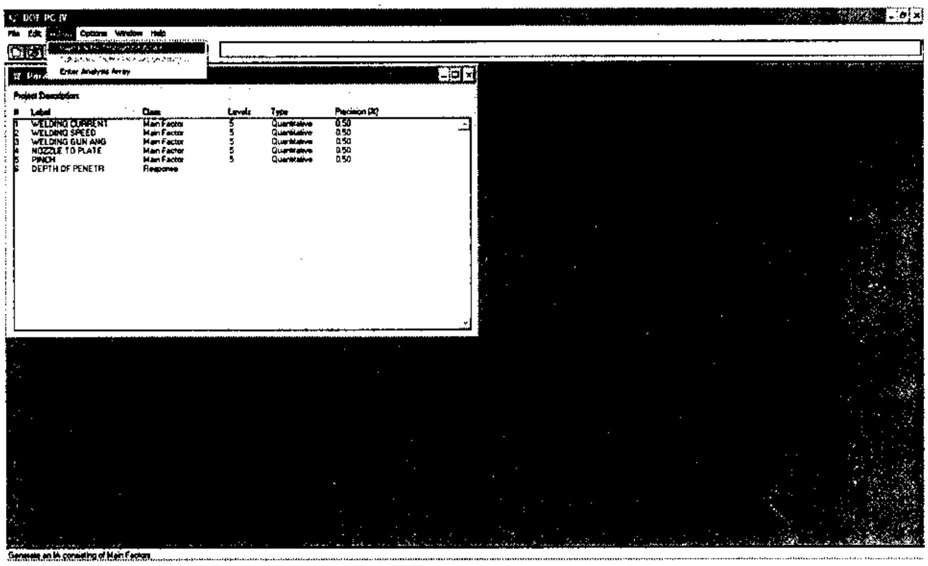
STEP 8:

Finally, a dialog box is obtained showing all the input and output parameters.



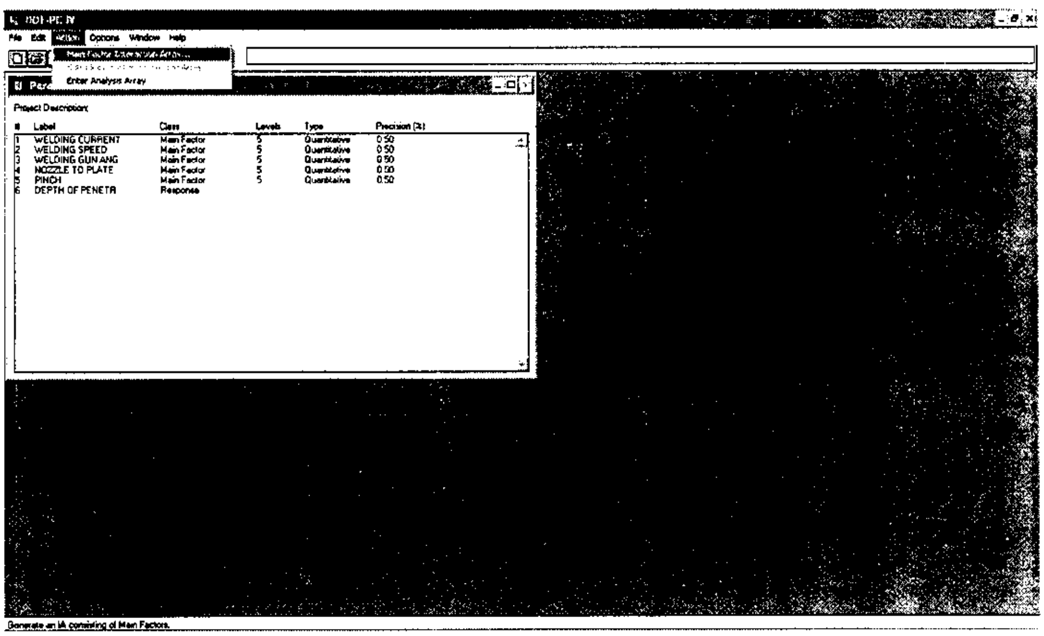
STEP 9:

'ACTION' option is chosen from the standard tool bar.



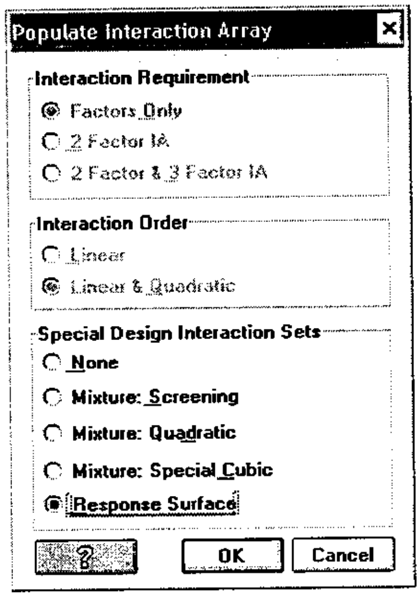
STEP 10:

Now the 'MAIN FACTOR INTERACTION ARRAY' option is chosen from the drop down menu.



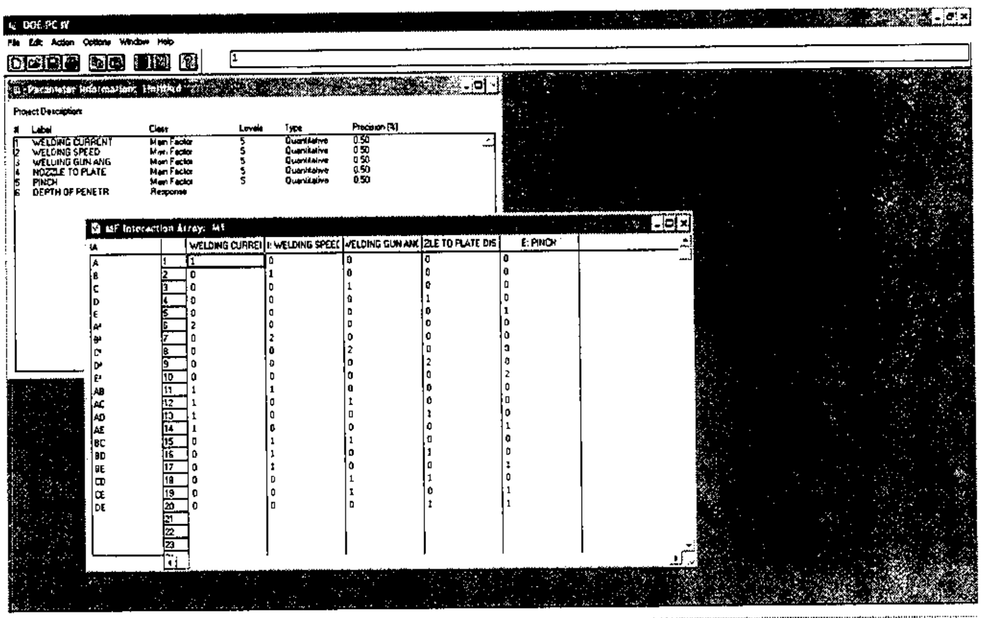
STEP 11:

Then the ‘RESPONSE SURFACE’ option is chosen from the given options.



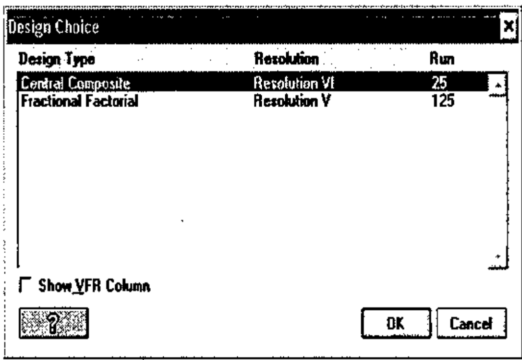
STEP 12:

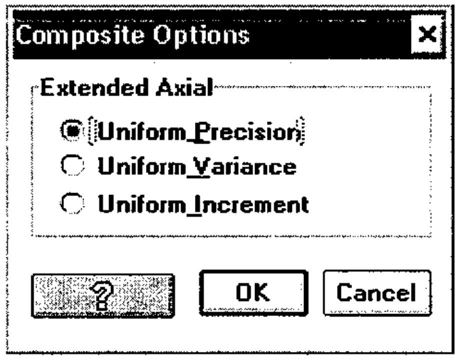
Now the ‘CHOOSE DESIGN ARRAY’ option is chosen from the drop down menu.



STEP 13:

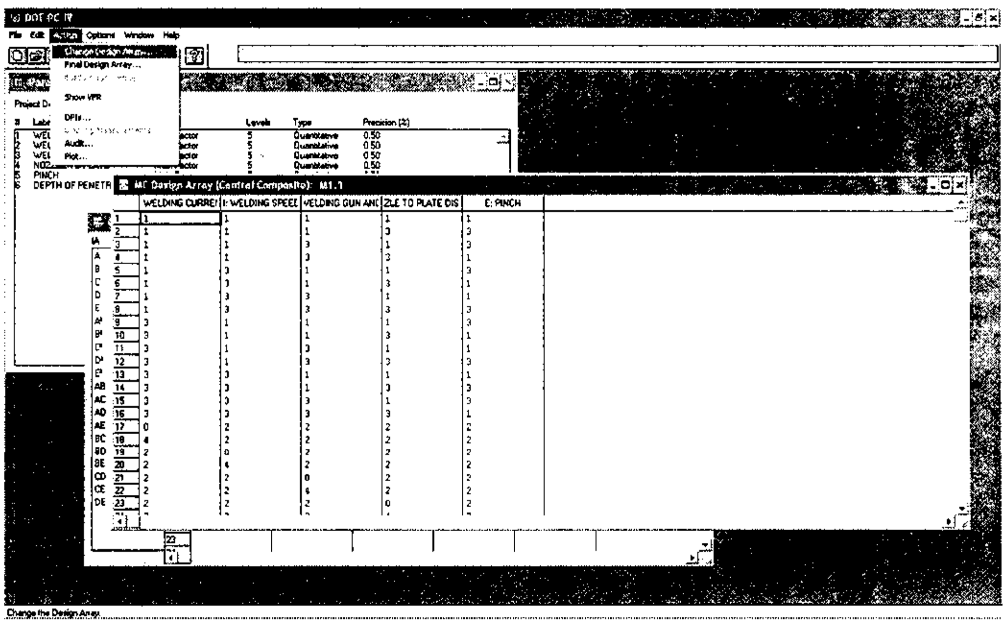
After this, the 'CENTRAL COMPOSITE' design type is chosen along with 'UNIFORM PRECISION' type.





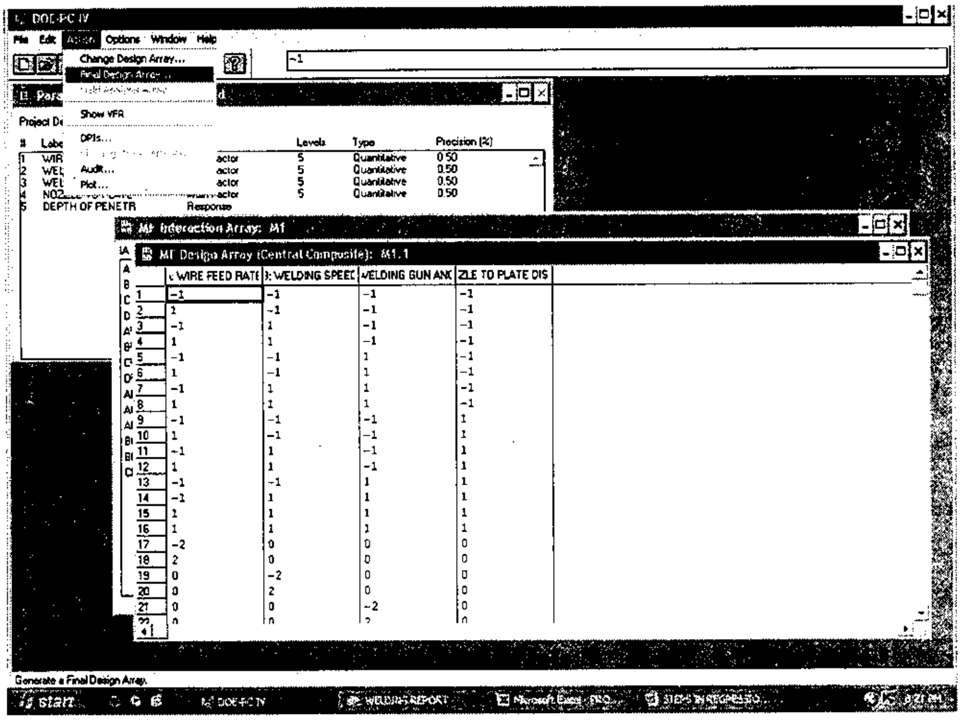
STEP 14:

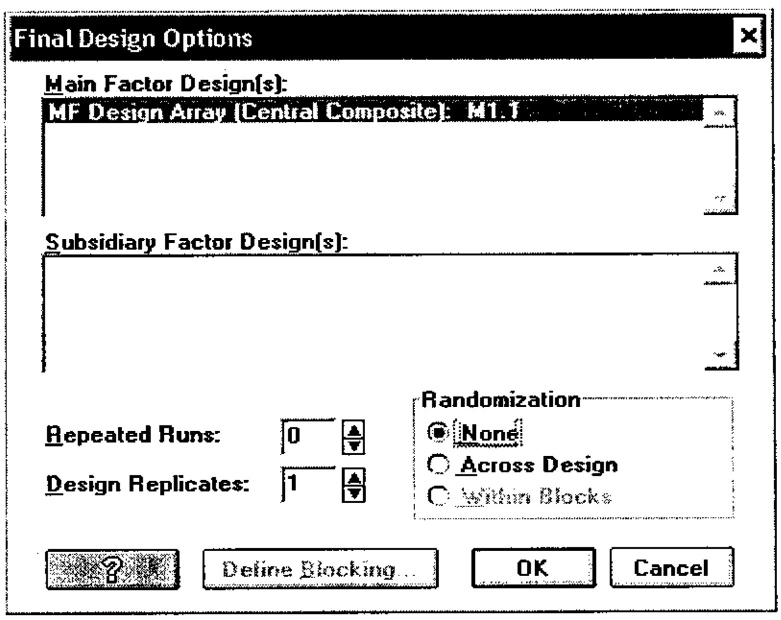
Then the 'CHANGE DESIGN ARRAY' option is chosen from the drop down menu and the design matrix from the excel sheet is copied and pasted.



STEP 15:

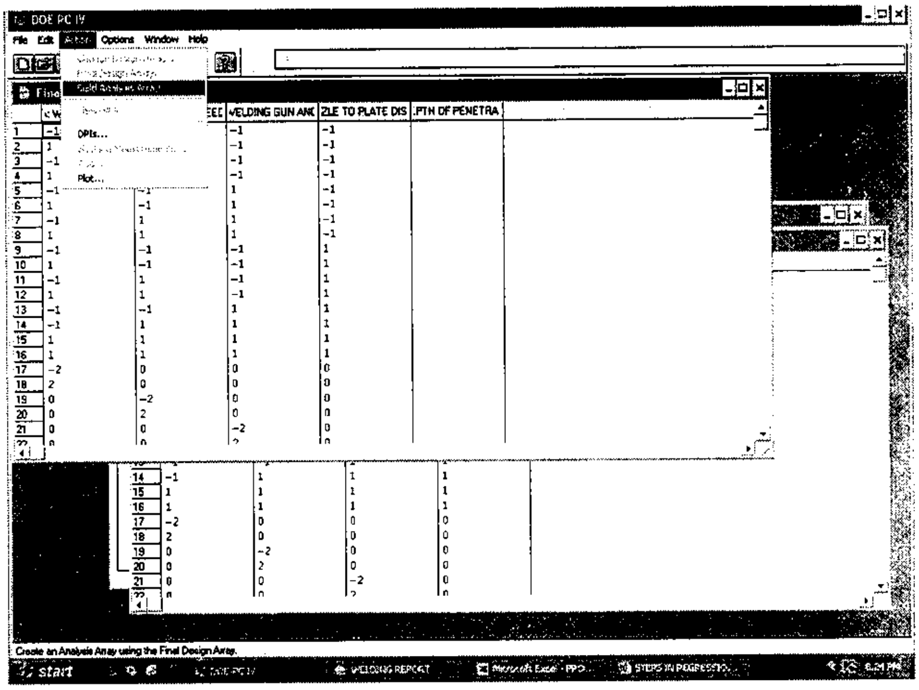
After copying the design matrix, the 'FINAL DESIGN ARRAY' option is chosen from the drop down menu after which 'NONE' randomization option is selected.





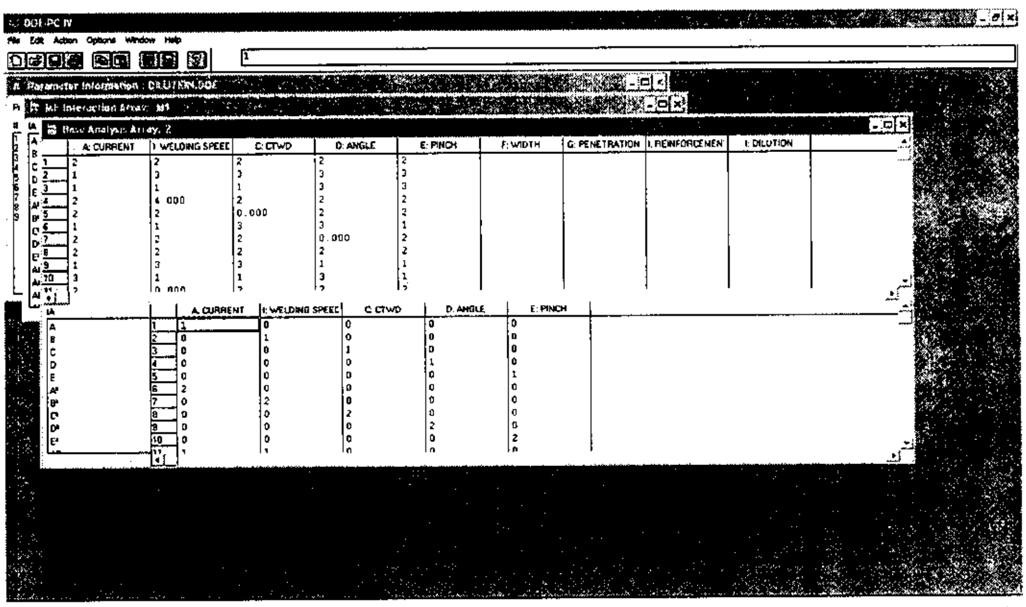
STEP 16:

Then the 'BUILD ANALYSIS ARRAY' option is chosen.



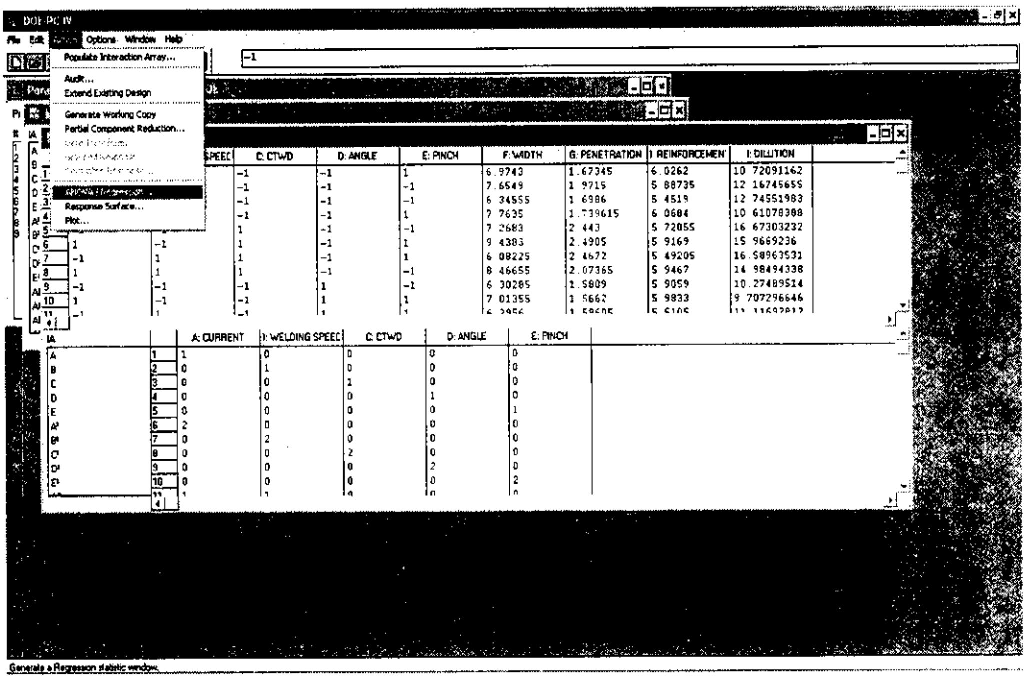
STEP 17:

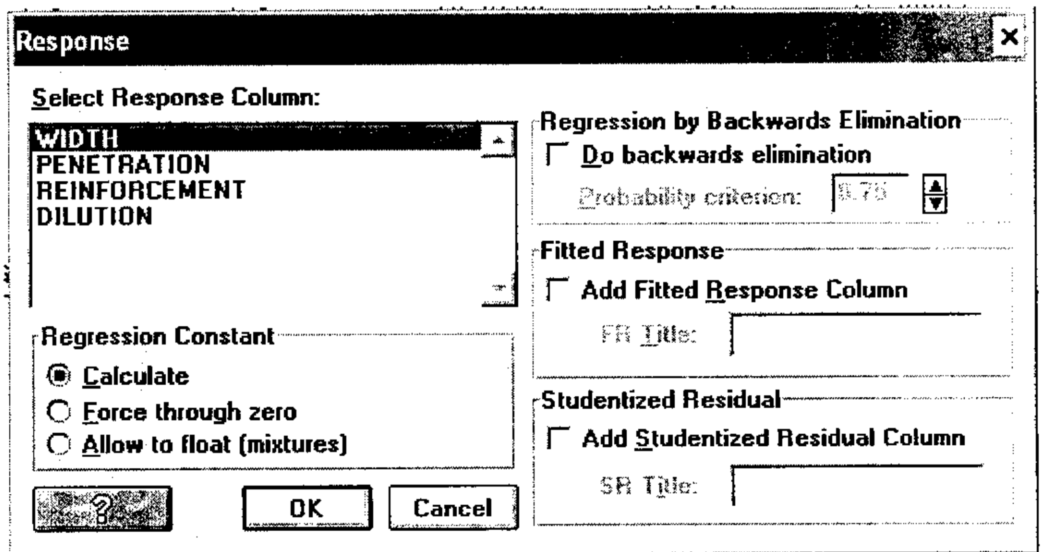
Now the observed value of the output is pasted from the excel sheet.



STEP 18:

After this, the 'ANOVA / REGRESSION' option is chosen from the drop down menu in order to find the values of regression coefficients.





STEP 19:

Finally, the values of the regression coefficients are obtained from which the mathematical model is developed. Also, the value of F-ratio and R- ratio are obtained to check the adequacy.

DOE-PC IV - [ANOVA/Regression Results : 1:1]

File Edit Action Options Window Help

Coefficient of Determination		Subgroups	
R-squared	0.841	Number	31.000
R-squared, adjusted	0.702	Average Size	1.000
Coefficient of Variation	0.185	Minimum Size	1.000
		Maximum Size	1.000

FITTED PARAMETERS

Source / Parameter	Level of Significance	Levels	Coefficient	Standard Error	Transmitted Variance	Sum of Squares (Partial SS)	t-Ratio
Mean	0.000	0	2.496	0.000	0.000	0.000	0.000
A WIRE FEED RATE	0.272	5	0.031	0.088	0.066	0.022	0.353
B WELDING SPEED	0.195	5	-0.022	0.089	0.067	0.011	-0.252
C WELDING GUN ANGLE	1.000	5	-0.654	0.088	0.066	9.724	-7.422
D NOZZLE TO PLATE D	0.982	5	-0.231	0.088	0.066	1.216	-2.624
A^2	0.023	25	-0.002	0.079	0.059	0.000	-0.029
B^2	0.102	25	0.010	0.079	0.059	0.003	0.130
C^2	0.996	25	-0.265	0.079	0.059	1.996	-3.363
D^2	0.207	25	-0.021	0.079	0.059	0.013	-0.267
AB	0.039	25	-0.006	0.112	0.084	0.000	-0.050
AC	0.155	25	0.022	0.109	0.082	0.007	0.198
AD	0.088	25	0.012	0.109	0.082	0.002	0.113
BC	0.729	25	-0.127	0.112	0.084	0.230	-1.141
BD	0.583	25	-0.093	0.112	0.084	0.123	-0.834
CD	0.024	25	-0.003	0.109	0.082	0.000	-0.030

CORRELATION TABLE

	A	B	C	D	A^2	B^2	C^2	D^2	AB	AC	AD	BC	BD	CD
A	1.000	0.084	0.000	0.000	0.000	0.000	0.000	0.000	0.102	0.000	0.000	0.102	0.102	0.000
B		1.000	0.084	0.084	0.017	0.017	0.017	0.017	-0.007	0.102	0.102	-0.007	-0.007	0.102
C			1.000	0.000	0.000	0.000	0.000	0.000	0.102	0.000	0.000	0.102	0.102	0.000
D				1.000	0.000	0.000	0.000	0.000	0.102	0.000	0.000	0.102	0.102	0.000
A^2					1.000	-0.088	-0.088	-0.088	0.021	0.000	0.000	0.021	0.021	0.000
B^2						1.000	-0.088	-0.088	0.021	0.000	0.000	0.021	0.021	0.000
C^2							1.000	-0.088	0.021	0.000	0.000	0.021	0.021	0.000
D^2								1.000	0.021	0.000	0.000	0.021	0.021	0.000
AB									1.000	0.126	0.126	-0.008	-0.008	0.126
AC										1.000	0.000	0.126	0.126	0.000
AD											1.000	0.126	0.126	0.000
BC												1.000	-0.008	0.126
BD													1.000	0.126
CD														1.000

CHAPTER 6

PREDICTION USING ARTIFICIAL NEURAL NETWORK – AN OVERVIEW

CHAPTER 6

PREDICTION USING ARTIFICIAL NEURAL NETWORK – AN OVERVIEW

6.1 INTRODUCTION

This chapter gives the details about the approach adopted to solve the chosen problem. It gives the detailed description about the technique (Artificial Neural Network) adopted, the manner it was handled in the particular area of the problem.

6.2 ARCHITECTURE OF AN ANN

ANN is composed of simple elements operating in parallel. These elements are inspired by biological nervous system. It is a some what a replica of human brain. It imitates the human brain, in terms of learning a specific concept and functioning according to what it has learnt. It is very approximate simulated mathematical model of a biological neuron, a basic functional unit of a human brain. One such neuron is illustrated in the Fig. 6.1.

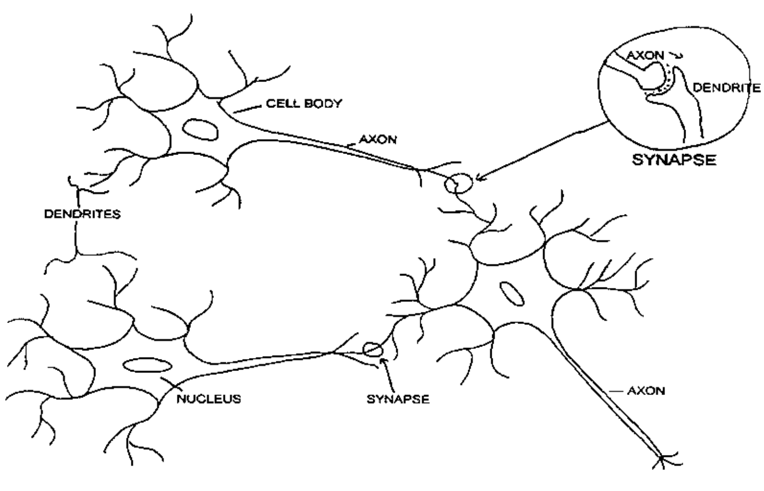


FIG. 6.1 MODEL OF A BIOLOGICAL NEURON

All the input from the different neurons is essentially summed up in the cell body. If the sum at a given time is greater than a particular threshold value then the neuron fires i.e. a signal is sends down the axon.

In a similar fashion, an artificial neuron also receives signals from other neurons through the connections between them. Each connection strength has a synaptic connection strength, which is represented by a weight of that connection strength. Thus an Artificial Neuron [AN] receives a weighted sum of outputs of all neurons to which it is connected. The weighted sum is then compared with the threshold for AN and if it exceeds this threshold, the AN fires. When an AN is fired, it goes to a higher excitation state and a signal is send down to other connected neurons. The output of a typical neuron is obtained as a result of non-linear function of a weighted sum. Fig. 6.2 shows the above processes of an AN.

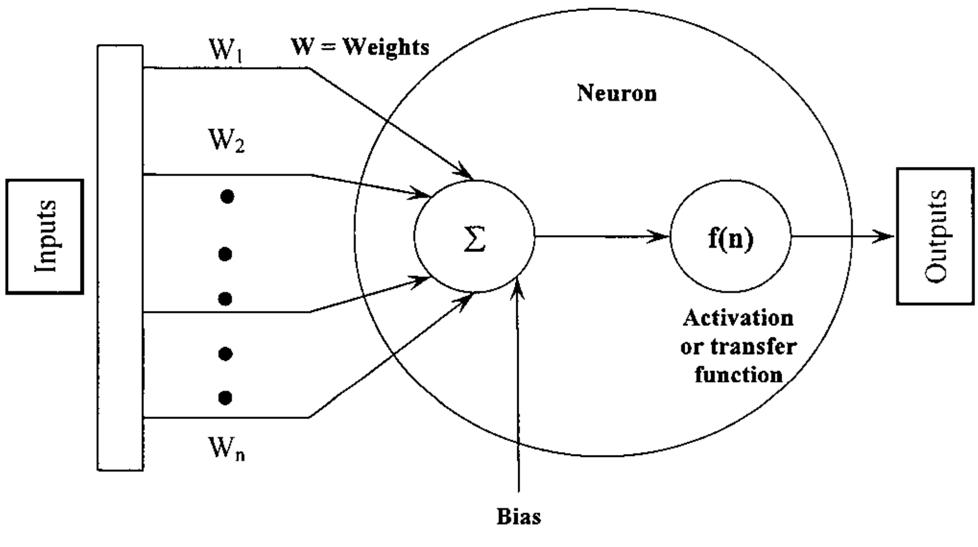


FIG. 6.2 MODEL OF ARTIFICAL NEURON

The neurons are arranged in layers. It consists of an input layer, hidden layers (may be one or more) and an output layer. An input layer has neurons representing the input fields, a hidden layer or more than one hidden layer, and an output layer with neurons representing the output field. The number of neurons constituting the hidden layers depends on the complexity of the pattern in the input data. There may be more than one hidden layers but for many problems one hidden layer is sufficient to give the model much greater representational power.

6.3 WORKING OF AN ANN

Haykin defines a neural network as "a massively parallel distributed processor that has a natural propensity for storing experiential knowledge and making it available for use". The learning or training process of an artificial neural network is established through a learning algorithm. During the learning/training process, the input and the output of the problem to be solved are provided to the neural network. Knowing the input and the output, the neural network establishes a relationship between them. This relationship is represented with synaptic weights. Then, the inputs are provided to the neural network and the network provides the answers or output using the pre-determined relationship. The neural network function is determined largely by the connection between the elements. It can be trained to perform a particular function by adjusting the values of the connections (weights) between the elements. ANN are adjusted, or trained so that particular input leads to a specific target output. Artificial neural networks are of benefit when it is difficult to determine the exact relationship between input and output variables for a system.

The neurons are connected with varying connection strengths or weights. The neural network learns by examining individual training records, generating a prediction for each data record, and adjusting the network weights whenever an incorrect prediction is made. The process is repeated many times, and the network continues to improve its predictions. Training continues until user specified stopping criteria are met. Extensive human trial and error is, however, necessary to determine the number of hidden neurons that produce a more reliable neural model. In most neural models, the system is equipped with a learning method which decides the values of connecting weights. The connection weights are the most important factors in the input and output processes of the neurons. Information generated by the neural network is determined by those weights.

6.4 FEED FORWARD BACK PROPAGATION NETWORK

Several ANN topologies have been developed for different applications, the most popular being the Feed Forward Back Propagation Network. The way that the neurons are organized forms the structure of the neural network, such as single-layer feed forward networks, multilayer-feed forward networks, etc. A feed forward back propagation network consists of an input layer (where the inputs of the problem are received), hidden layers (where the relationship between the inputs and outputs are determined and represented by synaptic weights) and an output layer (which emits the outputs of the problem). The network performs two phases of data flow. First the input pattern is propagated form the input layer to the output layer and, as a result of this forward flow of data it produces an output. Then the error signals resulting from the difference between the computed and the actual are back propagated from the output layer to the previous layers for them to update their weights. These have demonstrated their efficacy on many practical problems and have been shown to be relatively easy to use. Hence, this technique is adopted in this study. The network is shown in the Fig.6.4.

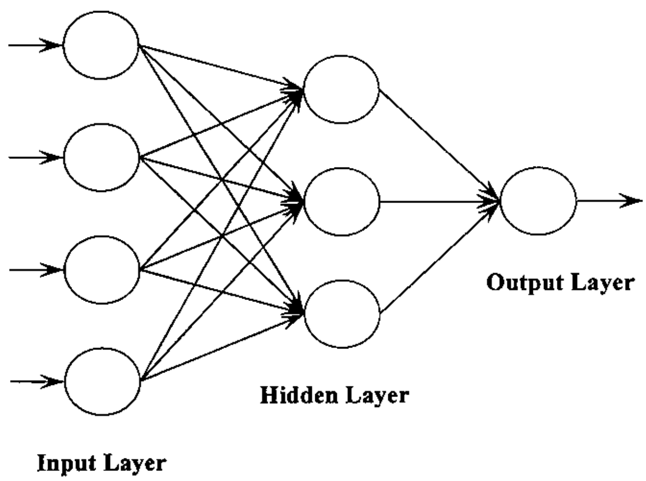


FIG 6.4. NETWORK MODEL

6.5 APPLICATIONS OF ANN

Neural networks are usually used to solve complex problems of a parallel processing nature that involve processing elements interconnected in network architecture. They can overcome complications, such as non-linear relationships, that can make it difficult to solve problems. Some of the applications of neural networks are: fault diagnosis, optimal power flow, decision making, alarm processing system, inference mechanisms, diagnostic system, machine learning, power load forecasting, facility layout design, process control, knowledge learning, gold mining process design, robotic systems, parameter setting, waste treatment, engineering ceramics, mitigation processes control, acoustic signal diagnosing, crude oil distillation, and biomedical application. Some of the applications are briefed as follows.

6.6 NORMALIZATION

Once the most appropriate raw input data has been selected, it must be pre-processed (i.e. is to be normalized) otherwise, the neural network will not produce accurate forecasts. The decisions made in this phase of development are critical to the performance of a network.

Normalization is a transformation performed on a single data input to distribute the data evenly and scale it into an acceptable range for the network. Knowledge of the domain is important in choosing pre-processing methods to highlight underlying features in the data, which can increase the network's ability to learn the association between inputs and outputs.

In normalizing data, the goal is to ensure that the statistical distribution of values for each net input and output is roughly uniform. In addition, the values should be scaled to match the range of the input neurons. This means that along with any other transformations performed on network inputs, each input should be normalized as well.

Data must be scaled into the range used by the input neurons in the neural network. This is typically the range of -1 to 1 or zero to 1. In practice it has been found better to use values of -0.9 to 0.9 and 0.1 to 0.9, respectively. This function can be performed in a spreadsheet or custom-written program.

In this project work, the datasets are normalized using the following formulae and it was performed using MS EXCEL software.

$$X_{norm} = 0.1 + 0.8\left(\frac{X - X_{min}}{X_{max} - X_{min}}\right) \quad \text{----------------------} (2)$$

Where X_{norm} - Normalized value (range between 0 to 1)

X - Value to be normalized

X_{min} - Minimum value in the particular dataset range

X_{max} - Maximum value in the particular dataset range

In this study, a 5-11-4 neuron configuration (5neurons in input layer, 11 neurons in hidden layer and 4 neurons in output layer) with a feed-forward backpropagation algorithm has been employed to train the neural network. This section describes the detailed process adopted in the selection of optimum set of network for the accuracy of the predictions.

The transfer function used in this work was ‘tansig’ and ‘logsig’ in the hidden layer and output layer respectively.

The processing of the data for all the samples at a time is called a “cycle” or “epochs”. The feedback from that processing is called the “average error” or “performance”. Once the average error is below the required goal, the neural network stops training and is, therefore, ready to be verified. During the training process, it was found that an increase of the number of neurons in the hidden layer is not directly related to the decrease of the MSE. No further reduction of the MSE is achieved even if the number of iteration was increased. So the network is selected by trial and error method.

From the results obtained, it was observed that the MSE from the different network configurations is able to converge to the final error goal value. The lowest MSE obtained was 0.06 with 12 neurons in the hidden layer.

The accuracy of prediction may be decreased with the increase of the number of neurons in the hidden layer in other words the increase of the number of neurons would not directly improve the capability of the function approximation of the network.

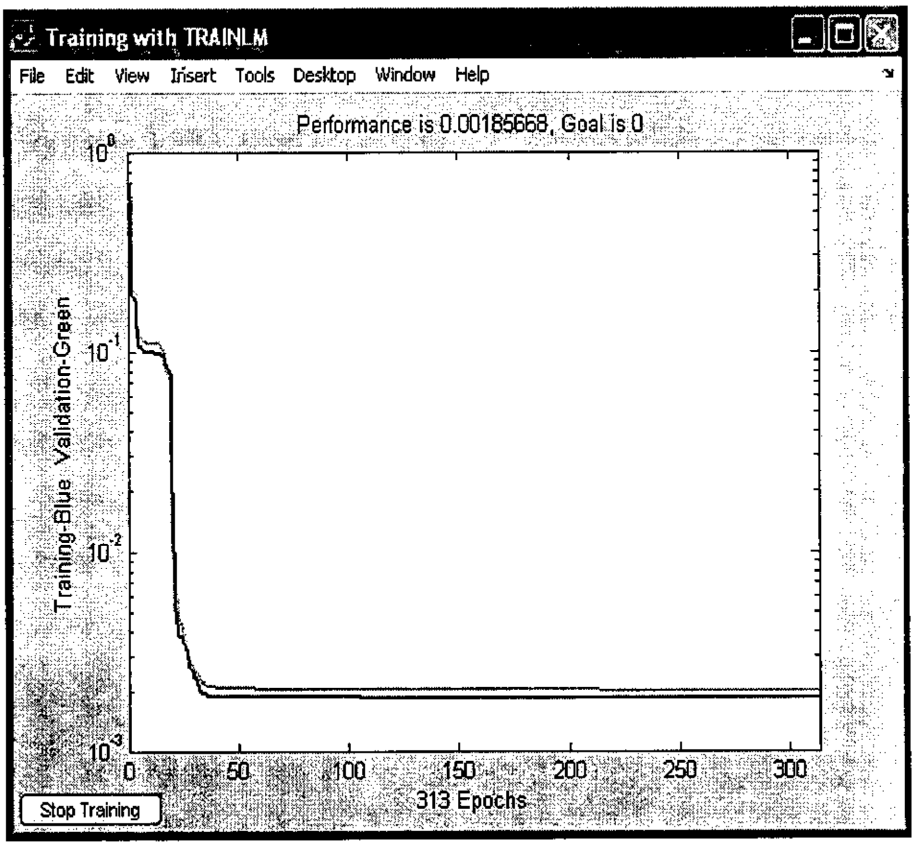


FIG 6.4 NETWORK MODEL GRAPH

$$\% \text{ Error} = \frac{(\text{Actual value} - \text{Predicted Value})}{\text{Actual Value}} * 100$$

TABLE 6.1 COMPARISION BETWEEN ACTUAL VALUE AND PREDICTED VALUE

ACTUAL VALUE OF BEAD PARAMETERS	0.629361	0.641586	0.514811	0.524348	0.763309	0.442931	0.819573
	0.476776	0.544254	0.18616	0.489572	0.351169	0.315514	0.7125
	0.444249	0.477167	0.397168	0.728015	0.028934	0.334588	0.363326
	0.56479	0.541043	0.370719	0.409745	0.615747	0.300021	0.9
PREDICTED VALUES OF BEAD PARAMETERS	0.6059	0.6661	0.5115	0.5129	0.7508	0.4553	0.8438
	0.4673	0.5635	0.1919	0.472	0.3602	0.2995	0.7526
	0.471	0.4577	0.3829	0.7006	0.0296	0.3309	0.3683
	0.5956	0.5122	0.3508	0.4171	0.6423	0.3107	0.9212
PERCENTAGE ERROR	3.727679	-3.82084	0.643229	2.183348	1.63877	-2.79257	-2.95603
	1.987599	-3.53613	-3.08354	3.58935	-2.57159	5.075506	-5.62807
	-6.02172	4.079706	3.592513	3.765659	-2.30104	1.102139	-1.36897
	-5.45521	5.330943	5.373179	-1.79504	-4.31238	-3.55954	-2.35556

CHAPTER 7

OPTIMIZATION OF GAS METAL ARC WELD CLADDING USING GENETIC ALGORITHM TECHNIQUE

CHAPTER 7
OPTIMIZATION OF GAS METAL ARC WELD CLADDING USING GENETIC ALGORITHM TECHNIQUE

7.1 INTRODUCTION

Compiler writers constantly invent new optimization algorithms to improve the state of the art. They frequently arrive at significantly different algorithms for a particular compiler optimization. Often, however, there is no clear winner among the different algorithms. Each algorithm has situations in which it is preferable to the other algorithms. For example, many different register allocation algorithms have been invented that achieve either a good running time performance, possibly at the expense of increased allocation time, or a reduction in allocation time at the expense of performance. Two register allocation algorithms that differ in these seemingly mutually exclusive goals are graph coloring and linear scan.

Graph coloring is an aggressive technique for allocating registers, but is computationally expensive due to its use of the interference graph, which can have a worst-case size that is quadratic in the number of live ranges. Linear scan (LS), on the other hand, does not build an interference graph, but instead allocates registers to variables in a greedy fashion by scanning all the live ranges in a single pass. It is simple, efficient, and produces a relative good packing of all the variables of a method into the available physical registers. Graph coloring can sometimes lead to more effective packing of the registers, but it can be much more expensive than linear scan.

7.2 CLASSIFICATION OF OPTIMIZATION ALGORITHM

Generally, optimization algorithms can be divided in two basic classes: deterministic and probabilistic algorithms. Deterministic algorithms are most often used if a clear relation between the characteristics of the possible solutions and their utility for a given problem exists. Then, the search space can efficiently be explored using for example a divide and conquer scheme. If the relation between a solution candidate and its "fitness" are not so obvious or too complicated, or the dimensionality of the search space is very high, it becomes harder to solve a problem deterministically.

7.3 ADVANTAGES OF NON-TRADITIONAL OPTIMIZATION TECHNIQUES

The advantages of non-traditional optimization techniques are as follows:

1. A population of points is used for starting the procedure instead of a single design point.
2. GA uses only the values of the objective function. The derivatives are not used in the search procedure.
3. Search method is naturally applicable for solving discrete and integer programming problems. For continuous design variables, the string length can be varied to achieve any desired resolution.
4. The objective function value corresponding to a design vector plays the role of fitness in natural genetics.
5. In every new generation, a new set of strings is produced by using randomized parents selection and crossover from the old generation.

7.4 OBJECTIVES OF OPTIMIZATION

Following are the objectives of optimization

1. To reduce wastage of material, money and processing time.
2. To decrease the fatigue of the worker who is on the shop floor.
3. To increase productivity of the organization gradually.
4. Procurement of material will be very less because of the higher productivity.

7.5 GENETIC ALGORITHM

7.5.1 INTRODUCTION

Definition: A Genetic Algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. Genetic algorithms are a particular class of evolutionary algorithms (also known as evolutionary computation) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination).

The idea of applying the biological principles of natural evolution to artificial systems, introduced more than three decades ago, has seen impressive growth in the past few years. The basic concept of Genetic Algorithm is to encode a potential solution to a problem as a series of parameters. A single set of parameters value is treated as the genome of an individual solution. An initial population of individuals is generated at random or statistically.

Every evolutionary step, known as a generation, the individuals in the current population are decoded (evaluated) according to some predefined quality criterion, referred to as fitness function. The chromosomes with the highest population fitness function. The chromosomes with the highest population fitness score are selected for mating. The genes of the two parents are allowed to exchange to produce offsprings. These children then replace their parents in the next generation. Thus, the old population is discarded and the new population becomes the current population. The current population is checked for acceptability of solution. The iteration is stopped after the completion of maximal number of generations or on the attainment of the best result.

7.5.2 OUTLINE OF BASIC GENETIC ALGORITHM CYCLE

The genetic algorithm cycle used in this study is illustrated in Figure X.1. The various steps involved are briefly described as given below.

Start

Random populations of 'n' chromosomes (suitable solutions for the problem) are generated.

Fitness

The fitness function of each chromosome in the population is evaluated.

New Population

A new population is created by repeating following steps.

Selection

Two parent chromosomes are selected from the population according to their fitness, better the fitness, bigger the chance to be selected.

Cross-over

The parents are crossed over to form a new offspring with a cross-over probability.

Childless

If no cross-over is performed, offspring is an exact copy of parents.

Mutation

New offsprings are mutated with a mutation probability.

Accepting

New offsprings are placed in a new population.

Replace

Newly generated population is used for a further run of algorithm, that is, individuals from old population are killed and replaced by the new ones.

Test

The generation is stopped, if the condition is satisfied and returns the best solution in current population.

Loop

If the termination criteria are not met, the loop is repeated from the fitness step again as reported above.

7.6 SIMULATION PROCEDURE

The aim of this study is to find the optimum adjusts for the Wire Feed rate (F), welding speed (S), welding gun angle (T), nozzle-to-plate distance (N) and pinch (Ac) in a GMAW Cladding process. The optimum parameters are those who deliver responses the closest possible of the cited values and is shown in the Table 7.1.

Table 7.1 GA SEARCH RANGE

PARAMETERS	RANGE
Wire Feed rate (W)	275-355 In/min
Welding speed (S)	150-182 mm/min
Welding gun angle (T)	70-110°
Nozzle-to-plate distance (M)	10-26 mm
Pinch (P)	(-10) – (10)

When the MATLAB command window is opened, M-file has been created and saved as the file name dot m. Then, the GA program is written and saved as a M-file in MATlab. To executive the program, first the input range is coded form should be stored in a variable. Then the GA parameters have to be specified while calling the GA function. The GA parameters are given in Table 7.1

To open GA tool, type gatool and press enter. When GA toolbox is opened, enter the fitness function as @file name (same file name where the M-file has been saved), number of variables that is used for the fitness function and select the plots required. Following Table 7.2 show the options used for the study.

Table 7.2 OPTIONS OF GA COMPUTATION

Population type	Double Vector
Population size	32
Fitness scaling function	Rank
Selection function	Roulette
Reproduction elite	2
Crossover rate	100%
Crossover function	Intermediate
Mutation function	Uniform
Mutation rate	1%
Number generations	52
Migration	Forward

In the GA, the population size, crossover rate and mutation rate are important factors in the performance of the algorithms. A large population size or a higher crossover rate allows exploration of the solution space and reduces the chances of settling for poor solution. However, if they are too large or high, it results in wasted computation time exploring unpromising regions of the solution space.

About mutation rate, if it is too high, there will be much random perturbation, and the offspring will loose the good information of the parents. The 1% value is within the typical range for the mutation rate. The crossover rate is 100% i.e., 100% of the pairs as crossed, whereas the remaining 10% are added to the next generation without crossover. The chosen type of the crossover was Intermediate. Accuracy is the bit quantity for each variable.

7.7 SELECTION OF OBJECTIVE FUNCTIONS AND CONSTRAINTS

The objective function selected for optimization was percentage dilution (D). The response variables bead width (W), penetration (P) and reinforcement (R) were given as constraints in their equation form. In optimization, generally the constraints with their upper bounds should be given in such a way that their value will be less than or equal to zero. Also, the objective function will usually be minimized. To obtain good quality of claddings in any application, it is always desirable to have maximum weld bead width and reinforcement with minimum penetration. The process parameters and their notations used in writing the M-file using MATLAB 7.0 software are given below.

X (1) = Wire Feedrate (W)

X (2) = Welding speed (S)

X (3) = Welding gun angle (T)

X (4) = Nozzle-to-plate distance (M)

X (5) = Pinch (P)

7.8 OPTIMIZATION OF THE FUNCTION

The main purpose of this paper using other important clad quality parameters with their limits as constraints. The model is a nonlinear equation with constraints. The constrained minimum of a scalar function of several functions of several variables at an initial estimate, which is referred as "constrained nonlinear optimization" is mathematically stated as follows

Minimize f(x)

$$\text{Subject to } g(x1, x2, x3 \ldots xn) < 0$$

The limits of the constraints bead width; penetration and reinforcement were established by data obtained from past experience with a view that they should provide a sound and defect-free clad quality along with a feasible solution to the objective function.

Several numerical methods are available for optimization of non linear equation with constraints. A Genetic Algorithm method is efficient and quickest one, and this method was used to determine the optimum percentage dilution. The step by step procedure of minimization of percentage dilution using the GA optimization tool box available in MATLAB 7 software is given below.

Step 1: Writing M-file function [F, G] =F(X)

F(1)=26.606 + 0.261*X(1) - 1.127*X(2) - 1.387*X(3) + 0.277*X(4) - 0.352*X(5) - 0.383*X(1)^2 - 0.596*X(2)^2 - 0.181*X(3)^2 - 0.881*X(4)^2 - 0.498*X(5)^2 + 0.257*X(1)*X(2) - 0.201*X(1)*X(3)+ 0.073*X(1)*X(4) - 0.780*X(1)*X(5) + 0.188*X(2)*X(3) - 0.548*X(2)*X(4) - 0.706*X(2)*X(5)+ 0.623*X(3)*X(4) + 0.164*X(3)*X(5)+ 0.407*X(4)*X(5); Percentage dilution.

G(1)=8.172 - 0.381*X(1) + 0.016*X(2) - 0.318*X(3) - 0.116*X(4) - 0.051*X(5) - 0.063*X(1)^2 - 0.152*X(2)^2 - 0.100*X(3)^2 - 0.104*X(4)^2 -0.009*X(5)^2 + 0.038*X(1)*X(2) - 0122*X(1)*X(3) + 0.016*X(1)*X(4) + 0.036*X(1)*X(5) - 0.257*X(2)*X(3) + 0.088*X(2)*X(4) - 0.241*X(2)*X(5) + 0.229*X(3)*X(4) - 0.128*X(3)*X(5) + 0.106*X(4)*X(5) - 8.9855; Bead Width and its upper limit.

G(2)=6.70935 - 8.172 - 0.381*X(1) + 0.016*X(2) - 0.318*X(3) - 0.116*X(4) - 0.051*X(5) - 0.063*X(1)^2 - 0.152*X(2)^2 - 0.100*X(3)^2 - 0.104*X(4)^2 -0.009*X(5)^2 + 0.038*X(1)*X(2) - 0122*X(1)*X(3) + 0.016*X(1)*X(4) + 0.036*X(1)*X(5) - 0.257*X(2)*X(3) + 0.088*X(2)*X(4) - 0.241*X(2)*X(5) + 0.229*X(3)*X(4) - 0.128*X(3)*X(5) + 0.106*X(4)*X(5); Bead Width and lower limit.

G(3)=2.778 - 0.034*X(1) + 0.011*X(2) - 0.119*X(3) + 0.066*X(4) - 0.066*X(5) + 0.052*X(1)^2 - 0.030*X(2)^2 + 0.008*X(3)^2 - 0.129*X(4)^2 - 0.108*X(5)^2 + 0.059*X(1)*X(2) - 0.008*X(1)*X(3) - 0.014*X(1)*X(4) - 0.049*X(1)*X(5) - 0.053*X(2)*X(3) - 0.040*X(2)*X(4) - 0.034*X(2)*X(5) + 0.085*X(3)*X(4) - 0.006*X(3)*X(5) - 0.046*X(4)*X(5)- 3.32775; Penetration and its upper limit.

G(4)=1.98515 - 2.778 - 0.034*X(1) + 0.011*X(2) - 0.119*X(3) + 0.066*X(4) - 0.066*X(5) + 0.052*X(1)^2 - 0.030*X(2)^2 + 0.008*X(3)^2 - 0.129*X(4)^2 - 0.108*X(5)^2 + 0.059*X(1)*X(2) - 0.008*X(1)*X(3) - 0.014*X(1)*X(4) - 0.049*X(1)*X(5) - 0.053*X(2)*X(3) - 0.040*X(2)*X(4) - 0.034*X(2)*X(5) + 0.085*X(3)*X(4) - 0.006*X(3)*X(5) - 0.046*X(4)*X(5); Penetration and its lower limit.

G(5)=6.039 - 0.044*X(1) + 0.160*X(2) - 0.072*X(3) + 0.027*X(4) - 0.120*X(5) + 0.005*X(1)^2 + 0.032*X(2)^2 - 0.019*X(3)^2 + 0.011*X(4)^2 + 0.032*X(5)^2 + 0.046*X(1)*X(2) - 0.006*X(1)*X(3) + 0.039*X(1)*X(4) + 0.095*X(1)*X(5) - 0.098*X(2)*X(3) + 0.071*X(2)*X(4) + 0.034*X(2)*X(5) + 0.008*X(3)*X(4) - 0.040*X(3)*X(5) + 0.045*X(4)*X(5)- 6.70505; Reinforcement and its upper limit.

G(6)=5.5635 - 6.039 - 0.044*X(1) + 0.160*X(2) - 0.072*X(3) + 0.027*X(4) - 0.120*X(5) + 0.005*X(1)^2 + 0.032*X(2)^2 - 0.019*X(3)^2 + 0.011*X(4)^2 + 0.032*X(5)^2 + 0.046*X(1)*X(2) - 0.006*X(1)*X(3) + 0.039*X(1)*X(4) + 0.095*X(1)*X(5) - 0.098*X(2)*X(3) + 0.071*X(2)*X(4) + 0.034*X(2)*X(5) + 0.008*X(3)*X(4) - 0.040*X(3)*X(5) + 0.045*X(4)*X(5); Reinforcement and its lower limit.

G(7) =F(1) - 0.210202; upper limit of percentage dilution.

G(8)=0.111514- F(1); lower limit of percentage dilution.

Step 2: Invoke GA function

Select and type the corresponding boxes as per the requirement as shown in the Table 5.1.

Step 3: Running the M-file.

After evaluating using GA, the following optimum values of process parameters in coded form was obtained

X (1) = Wire Feed rate (F) = 0.78243

X (2) = Welding speed (S) = 1.57304

X (3) = Welding torch angle (T) = 1.46649

X (4) = Nozzle-to-plate distance (N) = -1.88949

X (5) = Pinch (Ac) = 1.49681

CHAPTER 8

RESULTS AND DISCUSSION

CHAPTER 8
RESULTS AND DISCUSION

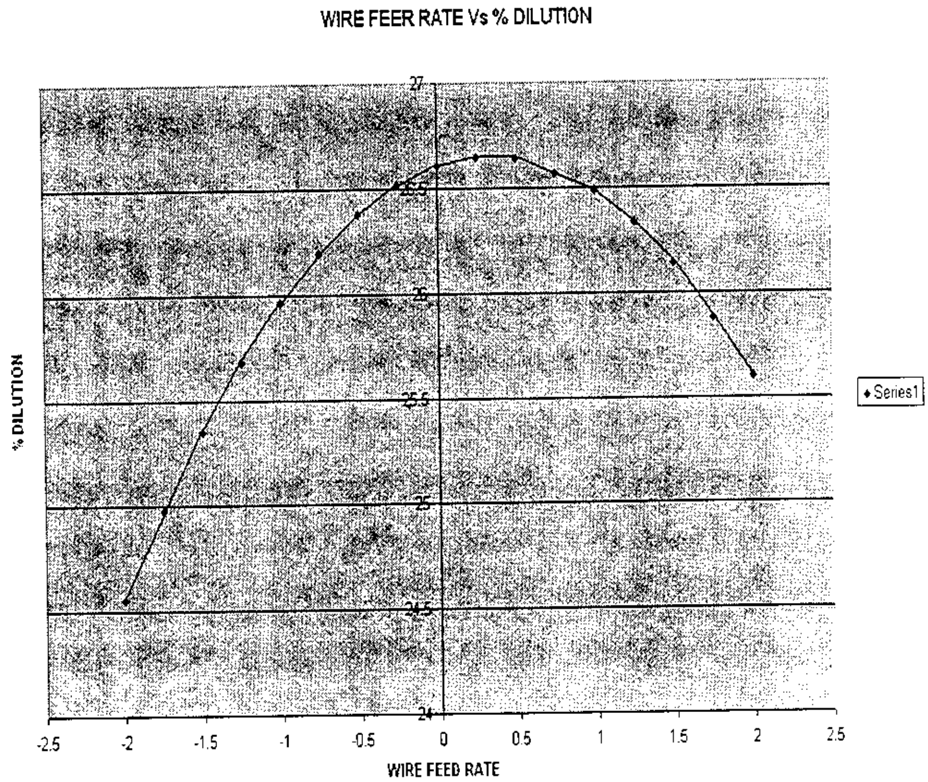


FIG 8.1 WIRE FEED RATE Vs PERCENTAGE DILUTION

The above graph is drawn between wire feed rate and percentage dilution. From the graph, when the wire feed rate increases the percentage dilution is increased because of more amount of metal melts so the dilution is increased, but after a certain value the percentage dilution is decreased because, when more wire comes at a faster rate the melting of wire is reduced so the dilution is decreased.

WELDING SPEED Vs %DILUTION

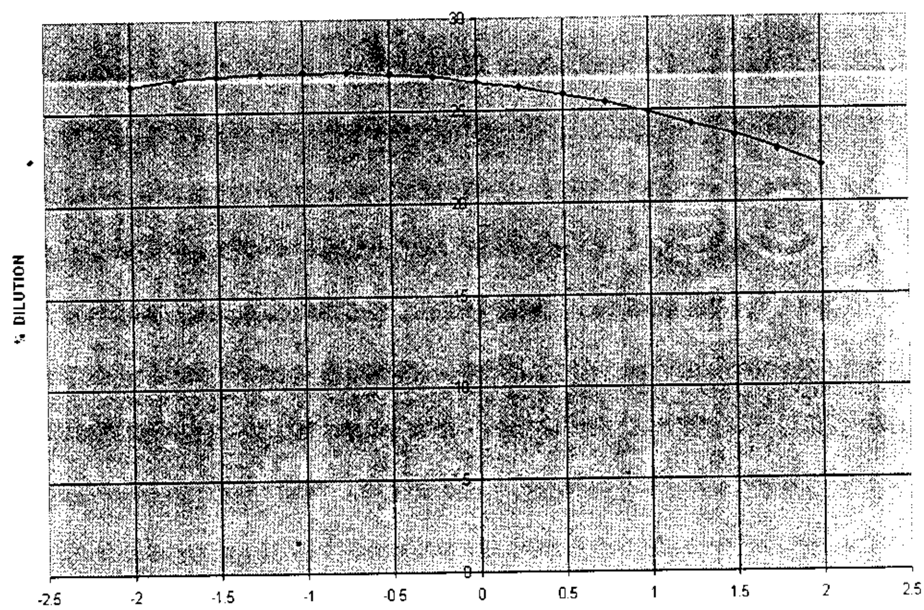


FIG 8.2 WELDING SPEED Vs PERCENTAGE DILUTION

The above graph is drawn between welding speed and percentage dilution. From the graph, when the welding speed is increased the percentage dilution varies very slightly i.e. the dilution level is almost constant. But after some point it starts decreasing because when the speed increases the rate of cooling is increased and so the percentage dilution is decreased.

The graph shown in Fig 8.3 is drawn between contact tip to welding distance and percentage dilution. From the graph, when the contact tip to welding distance increases the percentage dilution is decreased because when the gap between the torch and the plate increases the total heat transferred to the plate is reduced gradually ,so the percentage dilution is reduced.

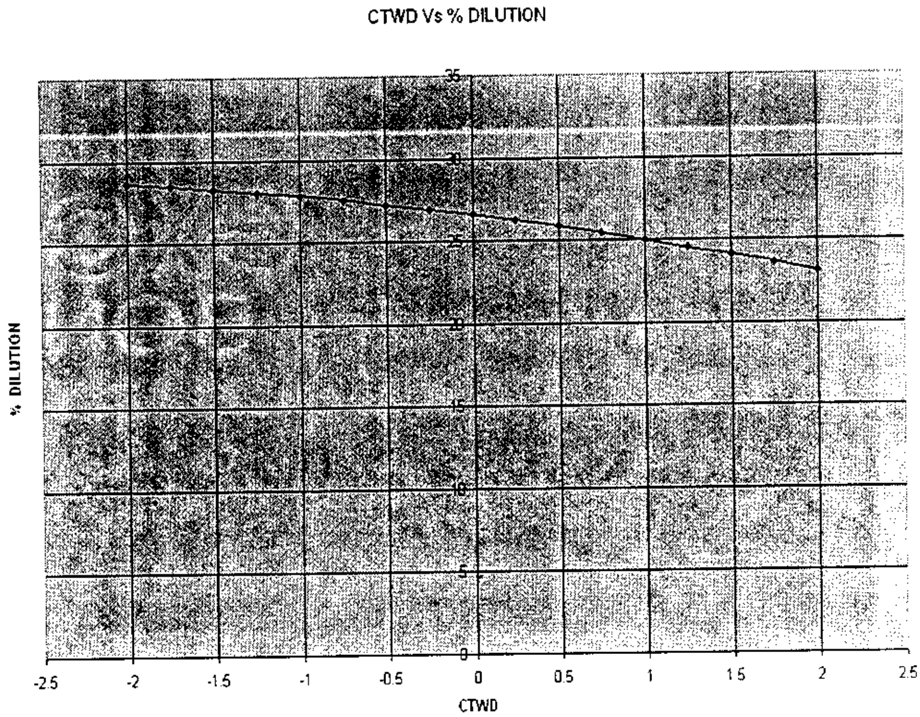


FIG 8.3 CTWD Vs PERCENTAGE DILUTION

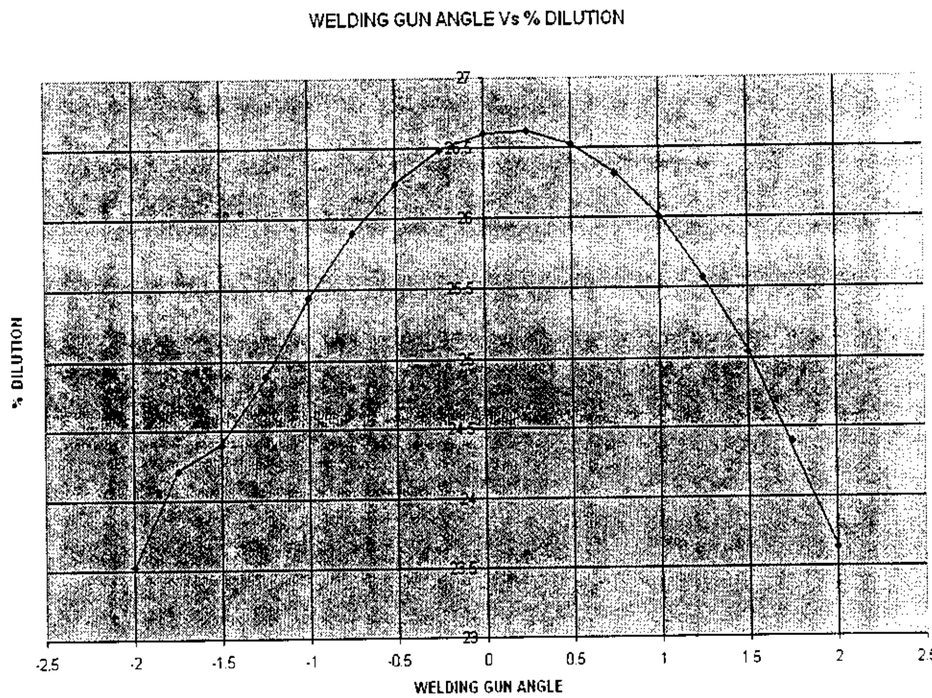


FIG 8.4 WELDING GUN ANGLE Vs PERCENTAGE DILUTION

The graph shown in Fig 8.4 is drawn between welding gun angle and percentage dilution. From the graph, when the welding gun angle is increased the percentage dilution is decreased and the maximum dilution is obtained at 90 degree position, because at 90 degree the torch is focused to a single point so the dilution is maximum, but in other position the torch focuses some particular area so the dilution is decreased.

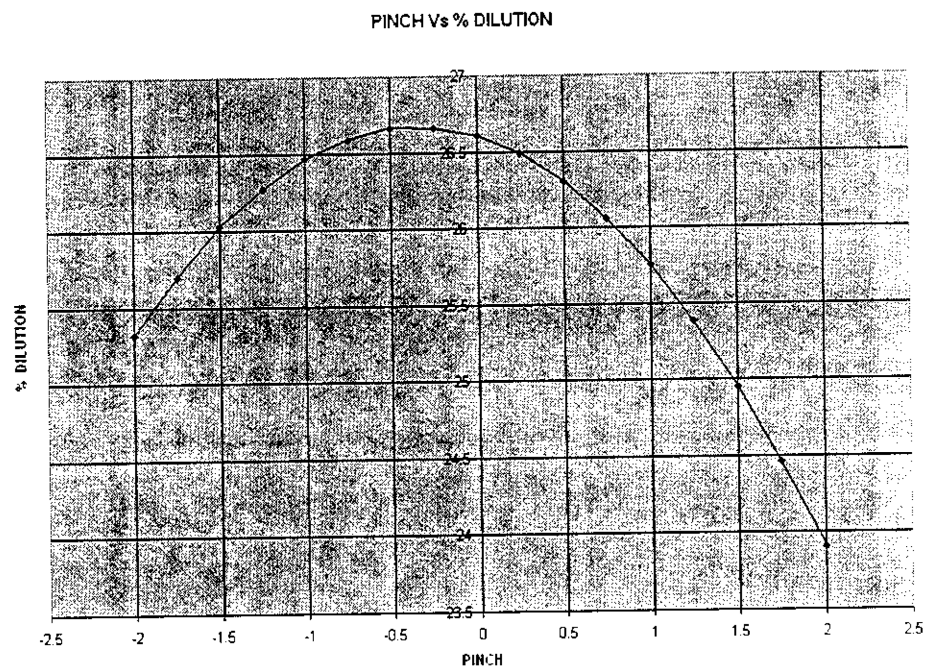


FIG 8.5 PINCH Vs PERCENTAGE DILUTION

The graph shown in Fig 8.5 is drawn between pinch and percentage dilution. From the graph, when the pinch is increased the percentage dilution also increases and after some point it starts decreasing because as arc control is focused to a point when its value is negative and becomes widened when it has a positive value.

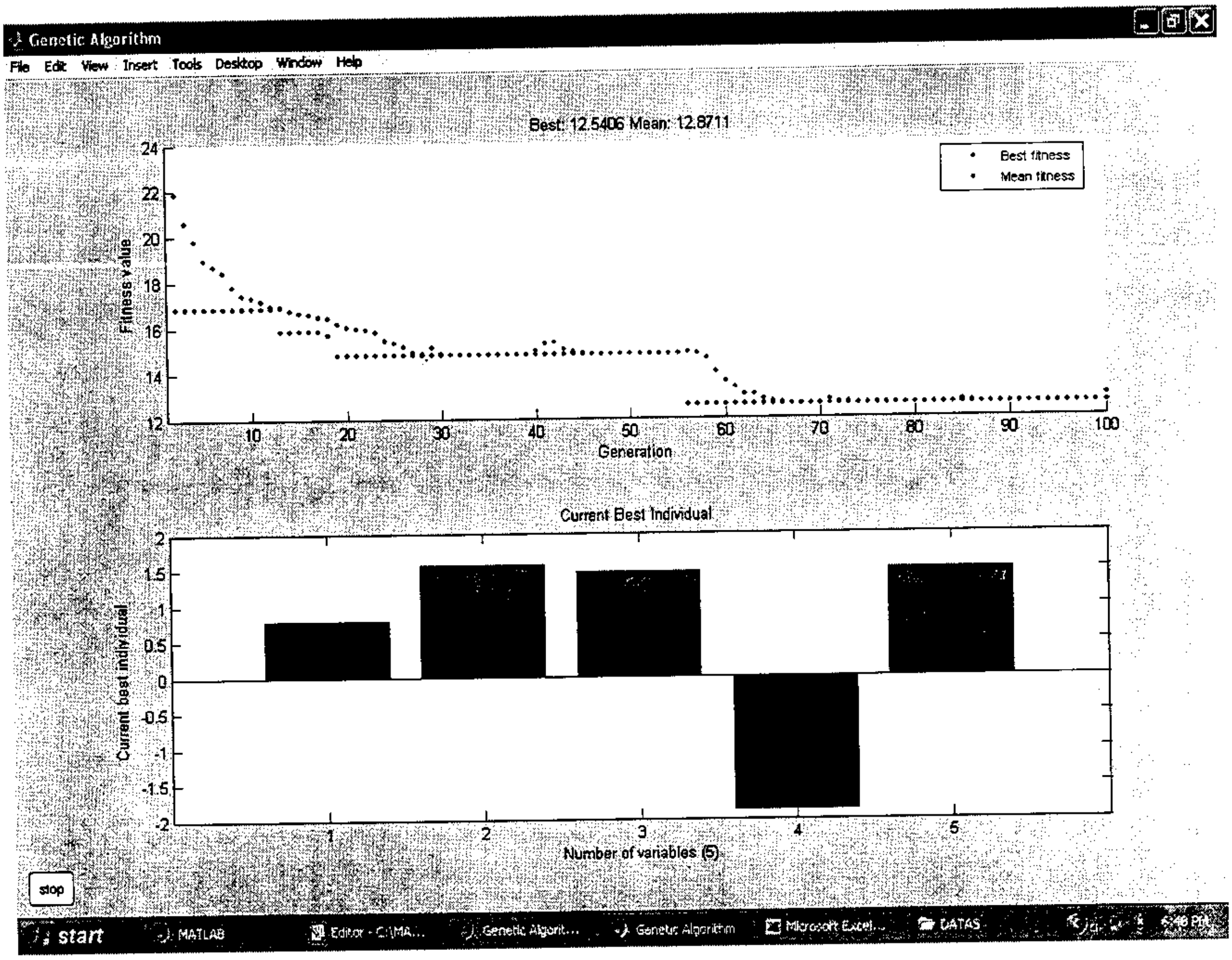


FIG 8.6 GA FITNESS AND BEST INDIVIDUAL GRAPH

CHAPTER 9

CONCLUSION

CHAPTER 9

CONCLUSIONS

The working ranges of welding speed, wire feed rate, nozzle to plate distance, welding gun angle, and Pinch for ER308 Stainless steel claddings using GMAW have been established based on bead appearance, lack of defects, etc.

A five factor, five level full factorial design matrix based on the central composite rotatable technique was used for the development of mathematical model to predict the clad bead parameters for stainless steel cladding using GMAW.

The developed mathematical model is very useful for the purpose of robotic welding, wherein the machine can be programmed based on the obtained mathematical model. This improves the quality of the claddings.

The predicted value in neural network is very useful for the comparison with actual value and the percentage error is calculated which comes within the acceptable range and the optimization is done based on the developed mathematical models. The optimization is by using the genetic algorithm technique which gives the optimum values for the selected parameters of weld cladding in GMAW.