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OPTIMIZATION OF WELD BEAD GEOMETRY IN MIG WELDING PROCESS USING RESPONSE SURFACE METHODOLOGY

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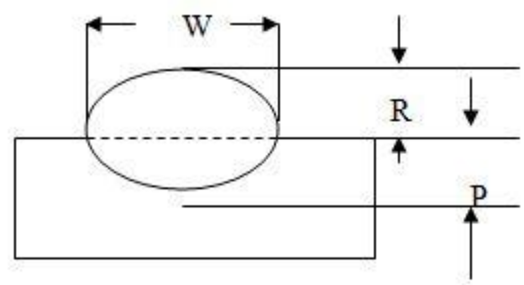
ABSTRACT

With the ever-increasing automated and robotic welding process mathematical and statistical models are gaining in importance for achieving optimum results. This topic deals the development of statistical and mathematical model response surface methodology (RSM) capable of accurate optimization of weld bead geometry, i.e., depth of penetration, weld width and height of reinforcement for input process parameters viz., arc voltage, wire feed rate, welding speed and nozzle to plate distance (Arc length) can be taken into consideration and final development models can be used to optimization bead geometry more precisely. Metallurgical study of the weld bead can be made, to improve the quality of the bead. Response surface methodology (RSM) can be used to develop statistical and mathematical models for MIG welding on mild steel the development models can be tested for their adequacy and co-efficiently for their significance to arrive at the Response surface methodology. The main interaction effects of the input parameters on bead geometry can be presented in graphical form which helps in selecting welding process parameters to achieve the optimum weld in real time welding application. The developed models can be used in automatic or robotic welding system in the form of a program for obtaining the desired high quality welds. The experiments can be conducted as per the design matrix. The data provided by these experiments can be utilized to develop mathematical models by using factorial technique to estimate the linear an interactive effects the welding variables on the bead geometry.

INTRODUCTION

The study of weld bead geometry deals with the estimation of depth of penetration (p), bead width (w), height of reinforcement (h),area of the bead (A+B),and dilution (D).These parameters are shown in the figure below



Weld bead geometry is influenced by a large number of process parameters that may affect product quality, productivity and cost effectiveness. The relationship between MIG process parameters and weld bead geometry is complex because of the number of parameters involved. Many attempts have been made by various researchers for predicting and understanding the effect of welding parameters on the weld bead geometry. These include empirical methods based on studies of actual welding situations to theoretical studies based on heat flow theory. The need of automating the welding processes was particularly felt in the hazardous and confined areas and therefore the need for developing correlations between welding parameters and weld bead geometry responses.

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OBJECTIVES:

1. Identification of important process variables.
2. Finding the upper limits of the process (control) varieties such as O.C.V., weld speed, wire feed rate, electrode to work distance.
3. Development of design matrix using the above limits.
4. Conducting experiments as per design matrix.
5. Recording of various process responses such as weld width, penetrating and reinforcement along with weld penetration shape factor and weld rein forcemeat form factor.
6. Development of mathematical models using RSM technique.
7. Calculating coefficients of the polynomial.
8. Checking adequacy of the developed models by F-test.
9. Development of final mathematical models.

IDENTIFICATION OF PROCESS VARIABLES:

The various process variables process variables such as OCV (V) weld speed (S), wire feed rate (F) and electrode to work distance (N) are identified to carry out the experiment and to develop the mathematical model.

Experiments are conduction using MIG process cored type (E70T-5) of diameter 1.2 mm and the shielding gas used was CO_2 fed at 8 liters/min. The work plate was mild steel of thickness 8mm.

FINDING OF LIMITS OF PROCESS VARIABLES:

Trial runs are conducted by changing one of the process variables and keeping ret of them at constant value. The working range is decided by inspecting the bead for smooth appearance and absence of any defect like porosity, blowholes etc. Taking the upper limit as + 1 (or) simply (+) and lower limit as – 1 (or) – a design matrix is design on the basis of fractional factorial technique. Since there are 4 variables, the total number experiments to be carried out are 2^4 = 16 experiments The upper and lower limits of the process variables in MIG Process with DCEP viz., V,F,S,N all given below:

Variables	**Upper Value** (+)	**Lower value** (-)
Voltage (V)	28V	22V
Wire feed rate (F)	4.5m/min	1.5m/min
Travel Speed (S)	0.27m/min	0.108 m/min
Electrode Stickup (N)	15mm	10mm

DEVELOPING THE DESIGN MATRIX.

The two level half-factorial technique is used to construct the design matrix. The number of runs required is calculated from the relation 2n – 1 where n stands for number of control variables:

Design Matrix for four variables:

S.No.	M	A	B	C	D	INTERRACTION EFFECTS		
			Main factors			The values interaction are: A,b.c,d,ab,ac,ad,bc,db,cd,acd,bcd,		
	B_0	b_1	b_2	b_3	b_4	P	R	W
1	+	+	+	+	+	2.25	2.7	7
2	+	-	+	+	+	0.6	4.1	2.8
3	+	+	-	+	+	1.1	1.6	6.0
4	+	-	-	+	+	1.45	2.8	4.5
5	+	+	+	-	+	2.1	4.7	13.5
6	+	-	+	-	+	2.3	2.55	7.75
7	+	+	-	-	+	1.5	2.7	6.5
8	+	-	-	-	+	1.1	3.5	6.2
9	+	+	+	+	-	0.6	5.4	6.7
10	+	-	+	+	-	0.9	4.5	5.7
11	+	+	-	+	-	1.4	1.75	5.6

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12	+	-	-	+	-	1.45	2.75	3.3
13	+	+	+	-	-	2.6	4.35	12.2
14	+	-	+	-	-	0.7	5.0	4.5
15	+	+	-	-	-	1.7	3.4	7.25
16	+	-	-	-	-	0.6	3.9	4.6

CONDUCTING EXPERIMENTS:

Conducting Experiments as per design matrix neglecting interactive effects. Weld beads were laid on 0.8cm X 10 cm x 20cm mild steel plates using MIG process with MS flux cored electrode of diameter 1.2mm. The electrode was given DCEP as it was of consumable type. These beads were laid using design matrix specifications. The total numbers beads were sixteen.

RECORDING OF RESPONSE:

The weld beads were cut across at a suitable section. Polished using metallurgical methods and then etched using 2% natal solution. The bead profiles are drawn (traced) using a profile projector having a magnification of x 10. The various response parameters such as OCV (V), wire feed rate (F) weld speed (S) and electrode to work distance (N) are measured.

DEVELOPING A MATHEMATICAL MODEL:

A mathematical model is to be developed by initially assuming a polynomial, which gives the relation between bead shape (y) and responses Viz. V.F.S.N.

The polynomial is given by:

$Y= b_0 + b_1 V + b_2 F+ b_3 S + b_4 N+ b_{12} VF + b_{13} VS+ b_{14} VN+ b_{23} FS+B_{24} FN + b_{34} SN+\ldots\ldots\ldots$

The coefficients of the above polynomial are determined using regression analysis and RSM and the math mathematical models are to be constructed.

DEVELOPMENT OF FINAL MATHEMATICAL MODELS:

The significant coefficients of the above polynomial are used to determine final mathematical models, like:

Weld width $W = b_0 + b_1 V + b_2 F+\ldots..$

Penetration $P = b_0 + b_1 V + b_2 F+\ldots..$

Reinforcement $R = b_0 + b_1 V + b_2 F+\ldots..$

Results and Discussions

Bar graphs or histograms plotted for each output responds viz, P, W,R, it is evident that the values obtained by considering the polynomial to be linear and those obtained from non-linear polynomial are almost similarly or the same

Even though the values do vary very bless, they can be neglected. Since there is no effect of higher order varieties in the polynomial. We can neglect those effects and thus consider the polynomial to be linear.

By considering the polynomial to be linear, we can obtain nearly optimum output values, thus reducing much of computational effort & time. Neglecting higher order coefficients does not affect (or) alter the output response significantly.

Thus, the various graphs between control parameters V,F,S,N and output responses P.W,R are plotted by considering a linear relationship between the two.

DIRECT EFFECTS

The effect of control parameters of bead geometry parameters can be determined using graphs and observations.

Direct Effect of Welding Variables on the Weld Width (W).

1. Effect of Open Circuit Voltage (OCV)

It is evident from the fig..1 as OCV increases, W slightly increases. This is due to the fact that, are length increases due to increase in V which results in large spread of the are cone at its base and hence weld width increases.

2. Effect of wire feed rate (WFR)

It is evident from the fig. 2 as WFR

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increases, W also increases.

3. Effect of Welding speed (S)

It is evident from the fig. 3. as S increases, there is no variation in the weld width. Since atlower speed the weld bead is larger in mass, where at higher welding aped it is smaller in mass.

4. Effect of NPD

It is evident from the fig. 4 as NPD increases there is no variation in the weld width.

Direct Effect of Welding Variables on Height of Reinforcement R

1. Effect of Open Circuit Voltage (OCV)

It is evident from the fig. 1 as OCV increases there no change in R.

2. Effect of Welding speed (S)

It is evident from the fig. 3 as S increases, R decreases sharply because of decreased amount of metal deposited per unit length of bead.

3. Effect of wire feed rate.

It is evident form fig. 2 as the W FR increases, there is no change in R.

4. Effect of NPD

It is evident from fig. 4 as the NPD increases, R decreases slightly

Effect of welding variables on depth of penetration P

1. Effect of Open Circuit Voltage (OCV)

It is evident from the fig.1 that P increases with increase in voltage this may be attributed to the welding of the are cone with increases in are voltage initially further increase in the are voltage increases the heat input resulting increase of P

2. Effect of wire feed rate (WFR)

From the fig. 2 it is evident that P increases with increase in WFR keeping V,S & NPD constant. This was obviously due to the fact that welding current increases with increase in wire feed rate. The increase in current causes the temperature of droplet increase and hence the heat content of the droplet increases, Which results in, more heat of the droplet transferred to the base plate. Hence deeper penetration occurs. Increase in current also increases the moment of the droplets, which on sticking the weld pool causes a deeper penetration.

3. Effect of welding speed (S)

It is apparent from the fig. 3 that as S increases, there is no change in penetration.

4. Effect of NPD

It is apparent from the fig. 4 that as NPD increases, there is no change in penetration.

<u>CONCLUSIONS.</u>

Response surface methodology is a fast, easy and accurate method for developing mathematical models for optimizing weld bead geometry and shape relationship within the working region of the process variables viz. open circuit voltage (V) welding speed (S), wire feed rate (WFR), Nozzle plate distance (NPD). The developed models can be used in automated or robotic welding systems in the form of a programme for obtaining the desired quality welds. This topic may be extend to some more parameters like inclination of nozzle to the plate, wire diameters, polarity etc. and final models developed can be used to optimize bead geometry more precisely.

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FIGURE-1

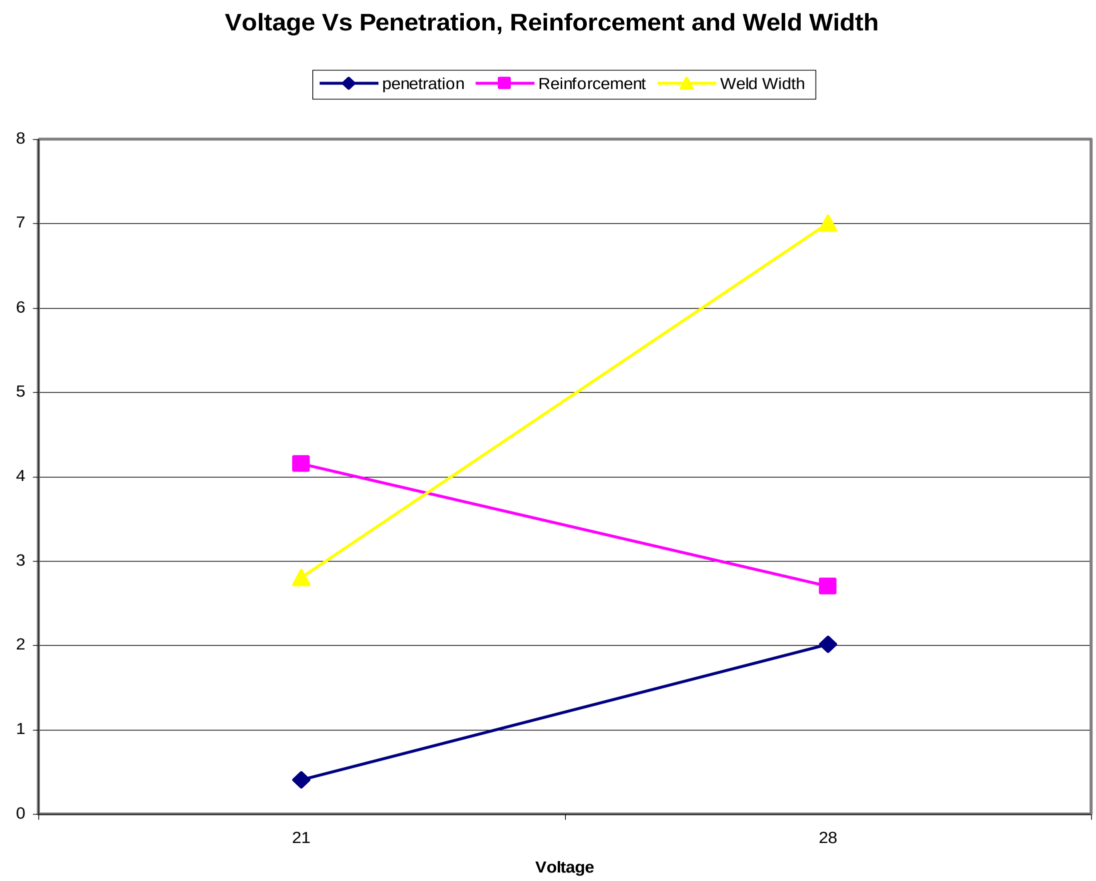

FIGURE-2

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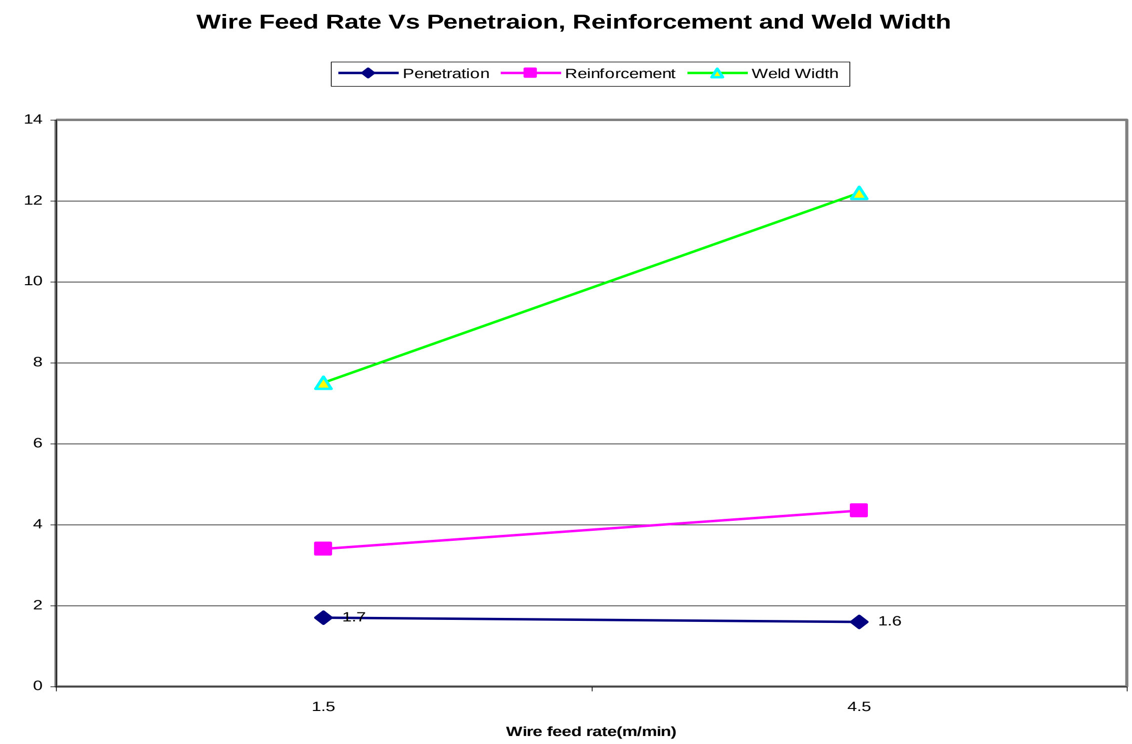

FIGURE-3

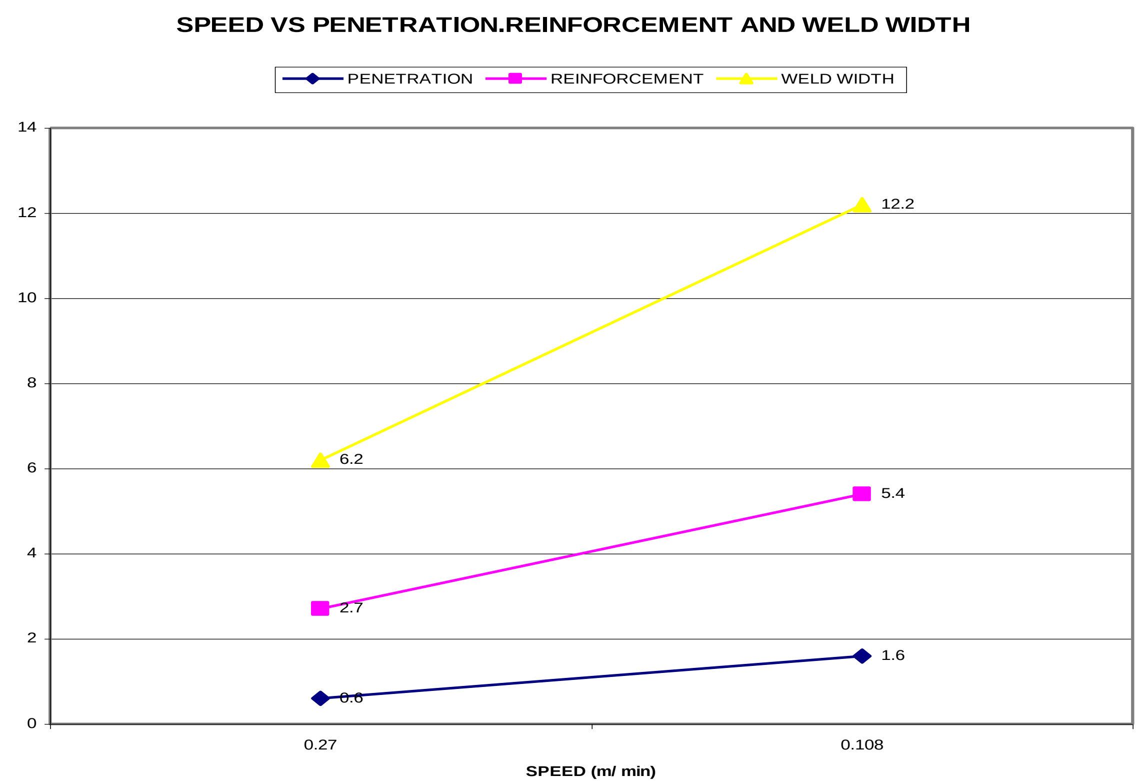

FIGURE-4

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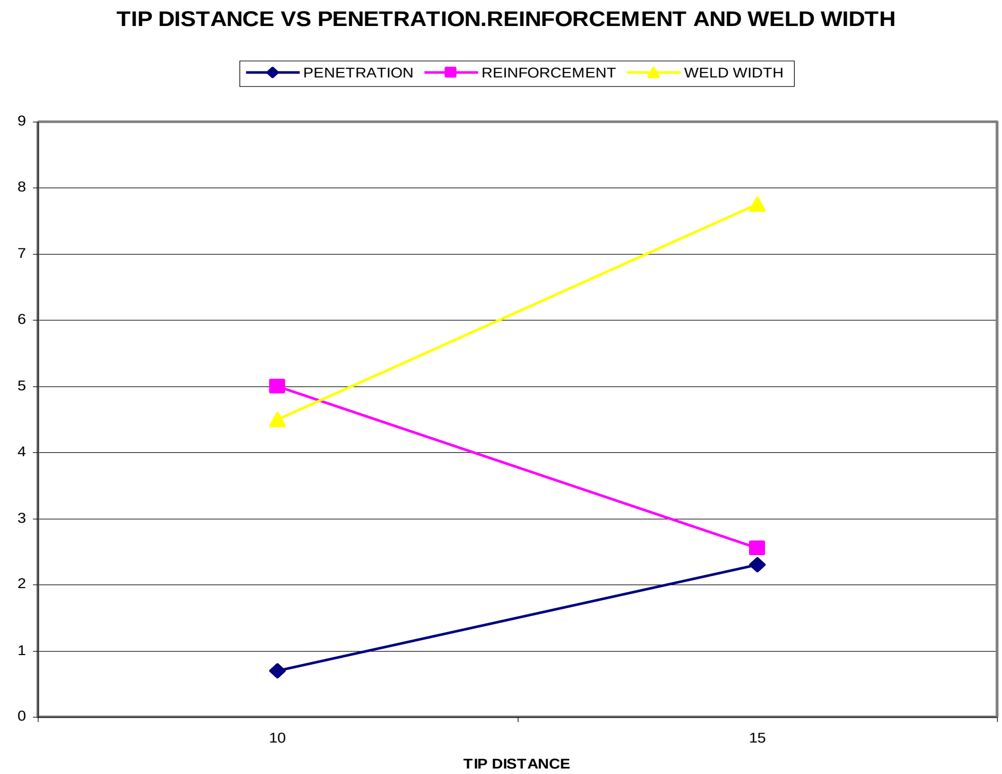

FIGURE-5
SERIES 1: LINEAR
SERIES 2: NON LINEAR
SERIES 3: REAL

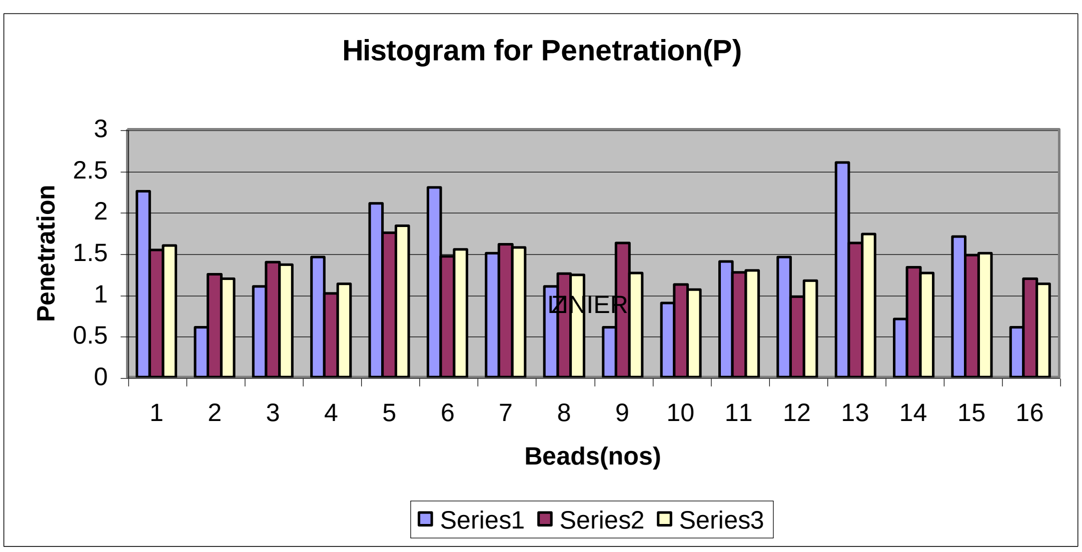

FIGURE-6

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SERIES 1: LINEAR
SERIES 2: NON LINEAR
SERIES 3: REAL

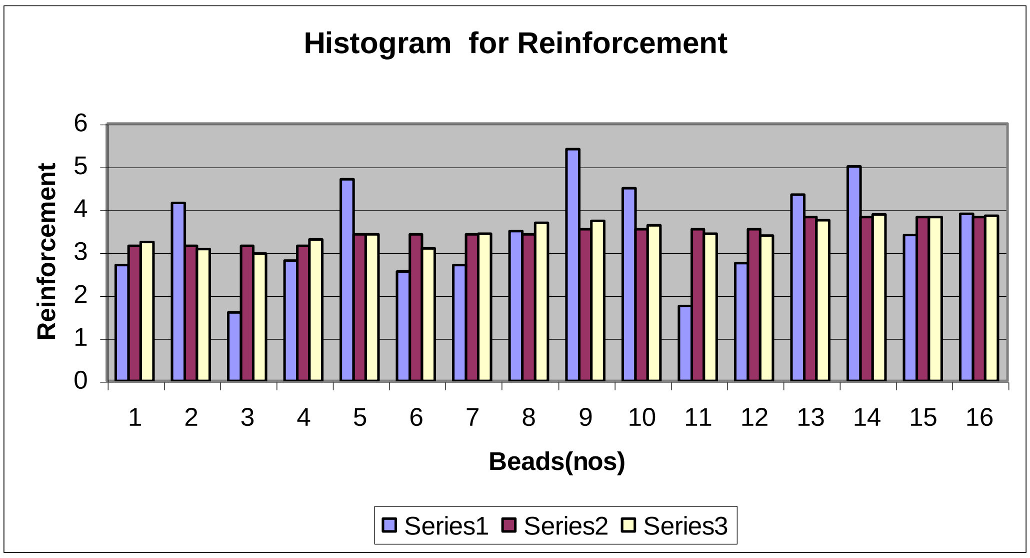

FIGURE-7
SERIES 1: LINEAR
SERIES 2: NON LINEAR
SERIES 3: REAL