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Comparative Study of Responses of Resistance Spot Welding Obtained From Genetic Algorithm, Response Surface and D-Optimal Method

A.S.Panchakshari[1] , Dr .M.S.Kadam[2] .
[1] ME (Mechanical) student of Jawaharlal Nehru Engineering College, Aurangabad.
[2] H.O.D, Mechanical Engineering Department, Jawaharlal Engineering College, Aurangabad.

Abstract- Main purpose of research work is to find out comparative study of responses of resistance spot welding process obtained from three methodologies of Genetic algorithm, Design of Experiments and Response surface method. Low carbon steel is material selected as specimen of research work. Mathematical model developed by using regression analysis and ANOVA. Trails are done on NASH ROBOTIC Resistance spot welding machine. The specification of the process parameters and responses specified from Indian Standard-513.

***Keywords*- ANOVA, Resistance spot welding, regression analysis.**

I. INTRODUCTION

Now a day's resistance spot welding has been the dominant process in sheet metal joining specially for automobile industry. Low carbon steel is compiler material for spot welding and most consumed by industries. But actual in practice "20 to 30 "percent of these spot welds contains uncertainty in quality of spot welds, hence external pushup required to optimize these welding process. Spot burn and deep indentation are two basic defects which occurs more probably during welding run. Cycle time (Weld, Hold, and Squeeze) and welding current are selected as the input variable parameters and Nugget diameter, Weld strength are the responses. Non linear technique like Genetic algorithm is selected for research work .Base for research work depends on design of experiments. Results obtained are cross validating by using D-Optimal method.

II. LITERATURE REVIEW

Kadam and Basu [1],focused on to determine the generalized relationship of cutting speed and surface roughness depending upon variable input process parameter using adequate mathematical models of regression and ANOVA in electrical discharge cutting process. Bhosle and Kadam optimized [2] the grinding process with variable process parameters like feed depth of cut against surface roughness and material removal rate. To Optimize the Resistance Spot and Seam welding process for specimen made from two dissimilar non-ferrous materials is the main aim of Mr. Elangovan and Venkateshwaran [3]. Kadlag and Kawade [4], determined generalized relationship of cutting speed and surface roughness dependent on variable machining parameters of wire cut electrical discharge machining. Bhatti and Quisse [5] ,optimized the resistance spot welding process to design the spot in structure. Reddy and Suresh Kumar predicted the surface roughness model of P20 graded steel by using genetic algorithm [6].

III. EXPERIMENT

Foot pressed resistance spot welding machine made from **Nash Robotics &Automation**. Table-I & Table-II shows specification of welding machine and range of process parameters. The Responses are Nugget Diameter "Y1" in the range of "5 to 6 mm& Weld strength "Y2"within "270 to 350" N/mm^2. These ranges were selected from Indian Standard of low carbon steel for resistance welding **IS-513**.The Mathematical relations between these selected input parameters and responses developed by regression analysis.

Where-

$$Y1 = -3.89 - 0.146X1 + 0.00415X2 - 0.0042X3 + 0.984X4 \quad \text{---------- (1)}$$

$$Y2 = 804 + 12.6X1 - 0.168X2 + 0.489X3 - 60.4X4 \quad \text{---------- (2)}$$

Response surface methodology is used for design of experiments .The experiment arranged in centre composite design method. Four input variables with their five levels each and then 2x4x4x4x4=512 run were required.

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Using Taguchi's orthogonal array, the number of experiments reduced to 25 experiments called as L_{25} design of experiment. Above two plotted equations were generated on the base significant factors of process variables. Following table -III shows the arrangements of variable parameters.

Table-I: Specification of welding machine

Make of RSW machine	Nash Robotics &Automation Put Ltd, Nasik.
Electrode	Dome shaped cap electrode with diameter 11.5 mm
Supply	415Volt
Frequency	50 Hz
Cooling water flow	12-15 Lits/min
Maximum electrode force	400 Kgf

Table-II: Range of process parameters

Factor	Notation		-2 Lowest	-1 Low	0 Mid	1 High	2 Highest
Weld Time	Cycle	X1	10	11	12	13	14
Hold Time	Cycle	X2	10	15	20	25	30
Squeeze time	Cycle	X3	15	20	25	30	35
Current	Ampere	X4	11	11.1	11.2	11.3	11.5

Genetic algorithm is Non-linear methodology which developed from Darwin's theory of evolutionary concept "Fit to Survive". The designs with higher fitness values have greater chance of being selected for mating and further genetic action. Mutation and cross over are further operations. All of these possible by using software of Genetic Algorithm optimization for Microsoft excerl-7.0. Table- IV shows selected parameters for method. Three levels of generation that were 500,750&1000 considered for further analysis. A roulette wheel technique is used to select the value of parameters. These three levels are iterated up to twenty numbers and observed the each iteration of three generation level. Within limit values are selected from these iterations .Table-V shows values of input parameters and responses at three levels of generation.

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Sr No	Weld Cycle X1	Hold Cycle X2	Squeeze Cycle X3	Current X4	Nugget Dia in mm Y1	Breaking Load in N	Tensile Strength N/mm2
1	11	15	20	11.1	5.5	9516	275.5
2	13	15	20	11.1	5.1	9887	312.4
3	11	25	20	11.1	5.4	9693	276.3
4	13	25	20	11.1	5.2	9957.15	304.9
5	11	15	30	11.1	5.5	9614	278.3
6	13	15	30	11.1	5.1	10006.2	318.5
7	11	25	30	11.1	5.4	9731	281
8	13	25	30	11.1	5.2	10006.2	306.3
9	11	15	20	11.3	5.6	9609	273.35
10	13	15	20	11.3	5.4	9825.1	289.9
11	11	25	20	11.3	5.7	9712	271.28
12	13	25	20	11.3	5.3	9957	299.2
13	11	15	30	11.3	5.5	9516	275.5
14	13	15	30	11.3	5.2	9810	300.4
15	11	25	30	11.3	5.7	9712	271.3
16	13	25	30	11.2	5.2	9957	304.8
17	10	20	25	11.2	5.6	9597.5	273.3
18	14	20	25	11.2	5.1	9947	310.5
19	12	10	25	11.2	5.2	9723	301.9
20	12	30	25	11.2	5.3	9957	299.2
21	12	20	15	11.2	5.4	9764	282
22	12	20	35	11.2	5.3	9908	297.7
23	12	20	25	11	5.1	9880	314
24	12	20	25	11.5	5.7	9761	272.65
25	12	20	25	11.2	5.2	9859	301.9

Table-III: Design of Experiment

Sr No	Parameters	Range of Parameter	Selected Parameter
1)	No of Chromosome	2N-4N,even	16N
2)	Cross over probability	0.6 to0.8	0.7
3)	Cross over type	One /second/Random	One point
4)	Mutation probability	0.01-0.02	0.01
5)	No of Generation	0-1000	500,750 and1000

Table-IV: Selected Parameter range for GA method

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Table-V: Result obtained from Genetic Algorithm

Generation	X1(W.C)	X2(H.C)	X3(S.C)	X4(CUR)	Y1(ND)	Y2(BL)	Y3(TS)
500	11.58	18.77	21.28	11.19	5.41	9709.58	285.9
750	11.30	16.24	33.0	11.24	5.44	9681.57	285.67
1000	11.80	17.27	28.86	11.17	5.37	9751.10	293.6

IV. RESULT

The result obtained from genetic algorithm cross verified by D-optimization of Response surface methodology. Composite desirability of result is 1.0 and equal weight age given to both response parameters. It is seen that as the generation level increases, gives more &more specific results. For our research 1000 level of generation is sufficient to obtain optimal result .It is observed that few readings from design of experiments are approximately matched with result obtained from genetic algorithm and response surface method. All of these were included in Table –VI with their percentage deviation.

Parameters	Result Obtained By Genetic Algorithm Method			By DOE Table			By RSM method
	At 500	At 750	At 1000	22th Reading	8th Reading	25th Reading	
Weld Cycle (X1)	11.58	11.30	11.80	12	11	12	12
Hold Cycle (X2)	18.77	16.24	17.26	20	25	20	20
Squeeze Cycle (X3)	21.28	33.0	28.86	35	30	25	29
Current(X4)	11.19	11.2	11.17	11.2	11.1	11.2	11.2
Nugget Diameter (Y1)	5.40	5.44	5.36	5.3	5.4	5.2	5.4
Strength of Weld (Y2)	285.9	285.67	293..63	298	281	302	290
Deviation of responses in Percentage	Comparison Between Results obtained by GA and RSM			Comparison Between Result obtained by DOE and RSM			
Nugget Diameter	0.18	0.7	0.5	1.8	0	3.7	
Strength of Weld	1.4	1.5	1.24	2.7	3.10	3.9	

Table-VI : Comparison of result

By comparing above data feasible values are feeded in machine for trial and observed the result.

Weld Cycle- X1	Hold Cycle-X2	Squeeze Cycle-X3	Current-X4	Nugget Diameter-Y1	Weld Strength Y2
12	20	30	11.2	5.38	291
Percentage Difference with GA, For Y1=0.18&Y2=1.01					

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Percentage Difference with RSM, For Y1=0.37&Y2=0.34

Table-VII: Result of last Trial.

During comparison of results from all these three results that 1000 generation level of algorithm is approximately close towards reading obtained from surface response methodology. It is seen that result obtained by feasible reading shows very little deviation up to 1.5% with other two methods. This indicates that value obtained is eligible for further production run.

Fig –I, Experimental and Counter plots for Nugget Diameter

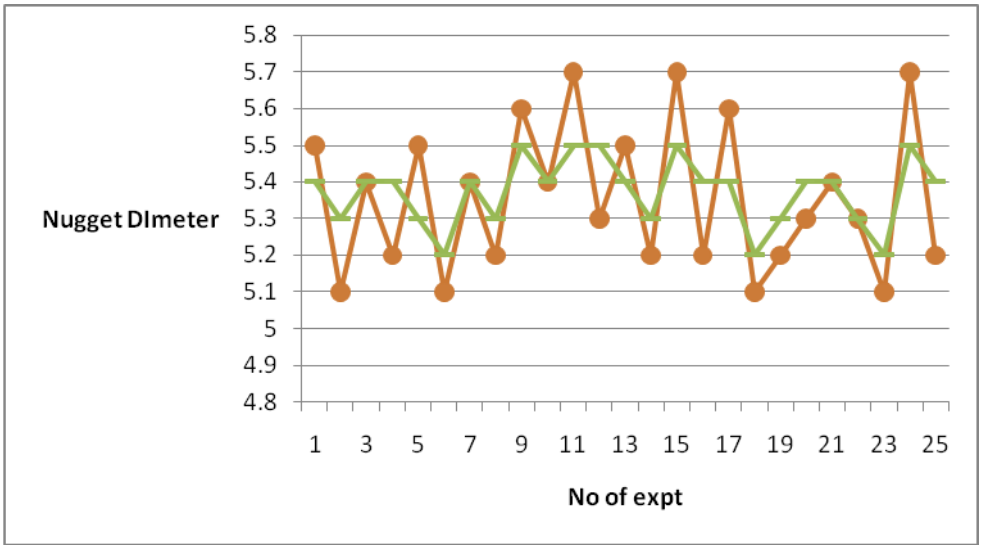
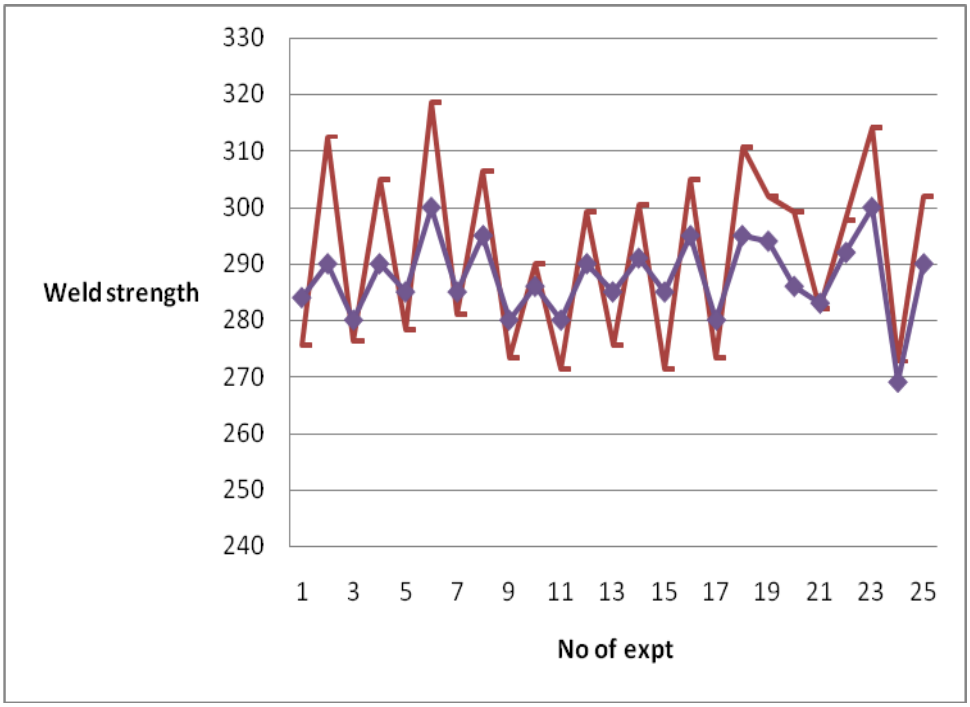


Fig-II: Experimental and counter plots for weld strength



In between the production run survey of weld quality done , where found as process qualification level increased from 93 to 96 percent and defect percent reduced from 7 to 4 This result is beneficiary for horizontal deployment of other spot welding machine of assembly stage.

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V. CONCLUSION

On the basis of experimental results, the analysis of variance (ANOVA), the developed mathematical models and confirmation test results, the following conclusions are drawn for effective resistance spot welding foe welding of low carbon steel in automobile industries.

- To obtain high qualitative result, nugget diameter and strength of weld just equal to 5.4 mm and 290 N/mm^2 respectively.
- Weld cycle and welding current are most significant factors for welding to obtain above mentioned values of nugget diameter and strength of weld, both these variables should be at middle values of their range @ 12 cycles and 11.2 KA respectively.
- Hold cycle time is less significant, to obtain optimal result it should always at it mid value of range that is 20 cycle.
- Squeeze cycle take part in formation of nugget diameter and to maintain strength of weld it should be at its high value of range equal to 30 cycles.

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