Monte Carlo Simulation of Single Spot and Multi-Spot Welded Lap Shear Specimen by Using Finite Element Method

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ABSTRACT

This study represents simulation of single spot and multi spot welded specimen by using Monte carol method i.e. Latin hypercube sampling. A three dimensional nonlinear finite element analysis of multi-spot welded lap shear specimen is performed and uncertainty in shear strength of spot weld is analyzed. Thickness and nugget radius are randomly varied within effective range and their effect on the shear Strength of multi spot welded lap specimen is analyzed. To ensure reliability of spot welds during vehicle lifetime, probability of failure of multi spot welded lap shear specimen is determined within defined ranges of input parameters. Confirmation test is conducted to validate result

***Key words*:- Multi spot welded specimen, Monte Carlo Simulation, Shear Strength**

I. INTRODUCTION

Resistance spot welding (RSW) is a process of joining metal components through the fusion of discrete spots at the interface of the work pieces. It is one of the most useful and practical methods for the manufacture of sheet metal assemblies. This process is common for welding sheets of aluminum, stainless steel, titanium alloys etc. A typical automobile consists of more than 5000 spots [1].This study gives relationship among process parameters and strength of spot weld. Galvanized sheets are spot welded at permissible level of parameters so as to visualize interfacial mode of failure after tensile shear test [2]. Author considered processing time as parameter. It was observed that shear strength of spot weld increases with increasing processing time [3]. This study consists of application of Taguchi method to study effect of process parameters on strength of spot weld [4]. This study consists of relationship between pre-straining and shear strength of spot weld [5]. Lap shear specimen is used and its fatigue strength is obtained through experimentation .Effect of nugget diameter on fatigue strength of spot weld is studied [6]. Effect of fusion zone size on the shear strength is studied [7]. Experiments were planned on the basis of response surface methodology (RSM) [8].Strength of spot weld defines the quality of integrated structure of automobile and improves the reliability of assembled sheets[9]-[11]. Structural stability of multi spot welded structure depends upon number of spots, their locations and variable loads acting on it. So, investigation on the relations between the strength of multi spot weld and design parameters is the key to solve problem in the design of multi-spot welded structure. The diameter of the spot weld nugget, d, is chosen based on an empirical formula recommended by the American Welding Society (AWS), diameter of nugget is considered as follows.

$$d \geq 4\sqrt{t} \quad (1)$$

However, several author claim that this equation is not safe for thickness beyond 1.5 mm. Though the effect of the process parameters on the mechanical behavior of resistance spot welds on steels is well documented, study of failure modes of spot weld.

Table 1 .Chemical Composition of uncoated mild steel sheet

T.S	Y.S	Alloying elements (wt%)				
MPa						
		c	Mn	Si	S	p
350	240	0.16	0.30	0.25	0.03	0.03

II .SIMULATION

The Monte Carlo Simulation method is the most common and traditional method for a probabilistic analysis. This method lets you simulate how virtual components behave the way they are built. Lap shear specimen having single spot and three spots are modeled for simulation. There are shown in figure 1 and figure 3. FEM package ANSYS is used to perform simulation. Elements selected for meshing the geometry of the specimen are, solid 186, MPC 184, Target 170 and Contact 175.MPC184 element is used to define spot weld. Material properties of uncoated mild steels are entered. Model of same geometry is drawn in ANSYS software.

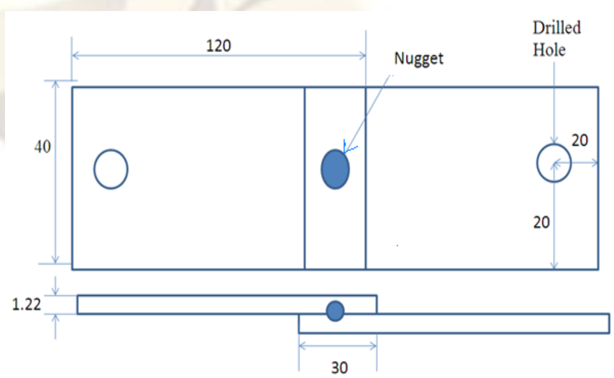

Fig.1. Dimensions of single spot lap shear tensile-shear test specimens (not to scale, dimensions in mm).

Geometry is meshed by giving element size 5mm. Mapped type of meshing is used. Meshed model of specimen is shown below in figure in 2.

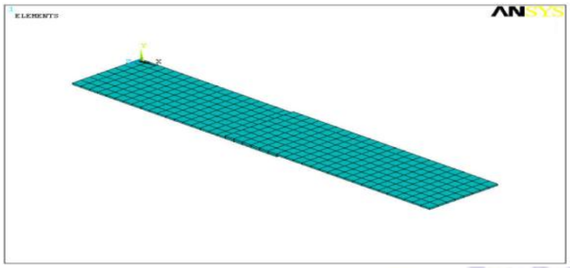

Fig 2 Meshed geometry of single spot welded specimen

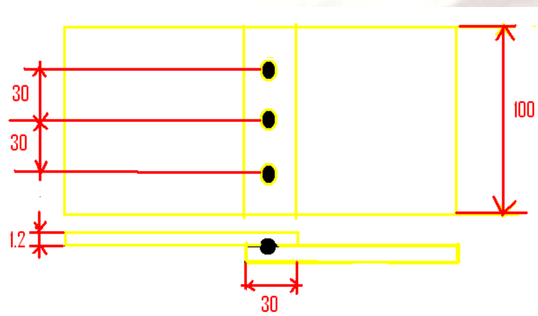

Fig.3.Dimensions of tensile-shear test specimen with three spot (not to scale, dimensions in mm).

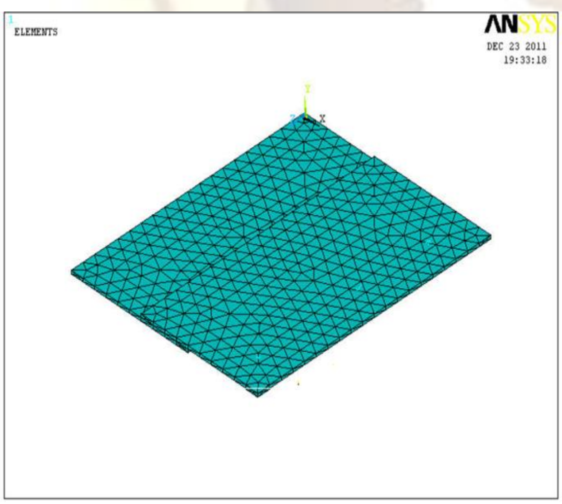

Fig.4 Meshed geometry of three spot welded specimen

Geometry is meshed by giving element size 5mm.Free type of meshing is used. Meshed model of specimen is shown in above figure 4.

Table 2. Random Input Variable Specifications for both single spot and multi spot welded specimen

No.	Name	Type	Par1	Par2
1	DISP	UNIF	0.10000	0.90000
2	R	UNIF	1.0000	5.0000
3	T	UNIF	0.71000	1.5000

DISP,R,T indicate diplacement of one end of specimen, spot weld radius and thickness respectively.Maximum shear stress at spot welding element is selected as response parameters. Non-linear properties of uncoated mild steel are entered.All degrees of freedom are made zero at one end of specimen while othe end is subjected to displacement .Range of displacement is selected in such a way that excessive distortion of the elements can be avoided.Full Transient analysis is executed in 4 steps . Each step is incremented by 1.Simulation loop is defined.It is executed170 times by varing design parameters randomly within defined range.Scatter plot of maximum shear stress is obtained at different combinations of selected parameters.

III .RESULTS AND DISCUSSION

Figure 6 shows shear stress distribution of lap shear specimen having three spots .scattered is obtained at 4th step of transient analysis .Dotted geometry indicates region around spot weld nugget. Maximum value of shear stress is 250 N/mm^2 and it is observed in region around spot weld nugget. Scatter plot for the Shear strength as a function of the most important random input variable i.e sheet thickness is shown in figure.

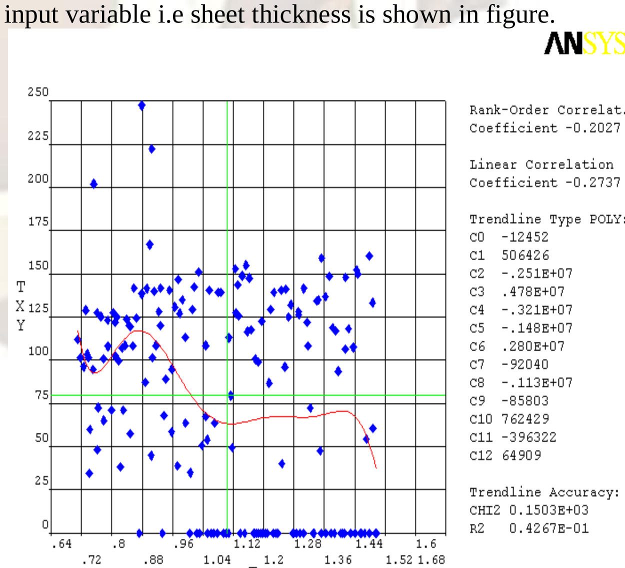

Fig.6 scattered plot of shear stress Vs thickness distribution of spot welded specimen.

Figure 7 shown shear stress distribution of lap shear specimen having three spots .Scattered plot is obtained at 4^{th} step of transient analysis. Maximum value of shear force is 6559N and it is observed in region around spot weld nugget. It is observed that multi spot welded specimen is about to fail and it has reached breaking limit.

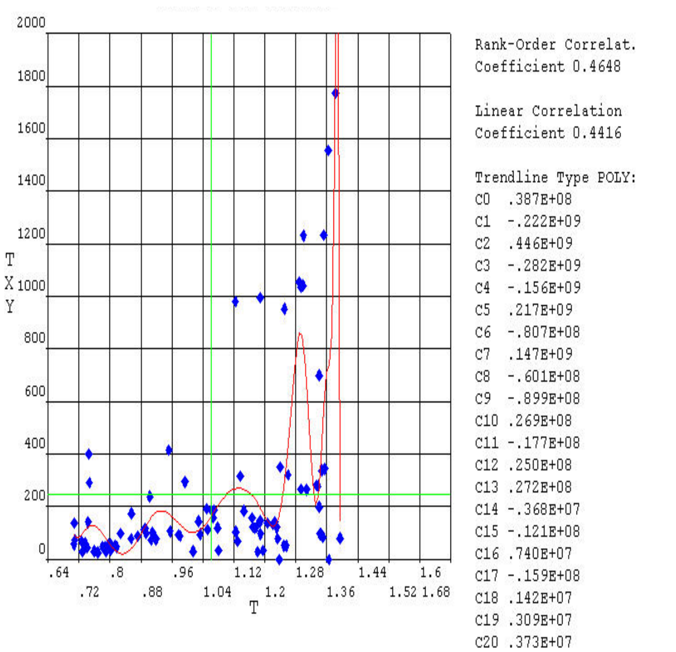

Fig.7 scattered plot of shear stress Vs thickness distribution of three spot welded specimen.

It is obtained after 170 samples (tests). Output parameter with combination of input parameters is plotted. Higher order Polynomial of 20 degree is used to plot scattering. It is observed that there is more scatter of shear strength from polynomial line within the thickness range 1.12 -1.22mm. TXY= 2.5594002e+001 which has rank 3 out of 170 samples. The confidence bounds are evaluated with a confidence level of 95.000%.Figure 7 shows Shear strength N/mm2Vs Thickness in mm. C0 to C20 indicates degree of polynomial. Linear correlation coefficient between shear strength and thickness is 0.4416.value of shear stress is obtained at different values of thickness. Value of shear stress at 1.22mm thickness is around 800N/mm2. Particularly, above relationship between thickness and tensile shear strength is obtained for lap shear specimen having three spots. There is considerable bending when specimen having more than three spots. As analysis is done in four steps with increment of one step, load is applied gradually .It can be said that obtained strength is static shear strength. At the same time, tensile shear strength is obtained at different combinations of specimen thickness and nugget radius. .At the thickness value 1.36mm, tensile shear strength is 1678.98N/mm2. .

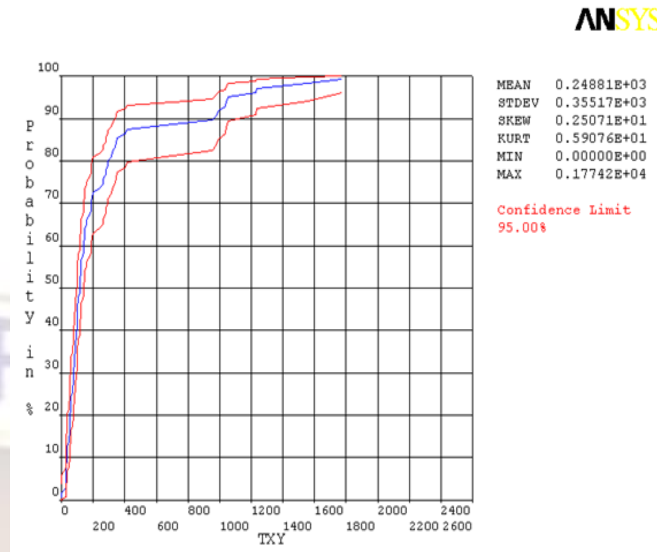

Fig.8 Shear strength Vs Probability

The curve shows that there is a about a 93% probability that the shear stress remains below 2000N/mm^2. It indicates that multi spot welded specimen will not fail within the selected ranges of input parameters. The graph indicates that only the random input variables thickness is important for the random output parameter shear stress.

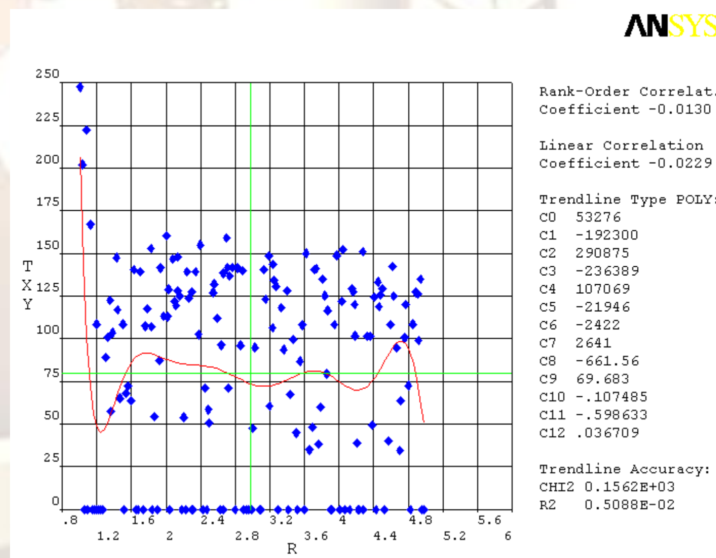

Fig.9 scattered plot of shear stress Vs radius for single spot welded specimen

It is observed that there is more scatter of shear strength from polynomial line within the radius range 2.8- 4.8 mm. TXY= 1.6794002e+001 which has rank 3 out of 170 samples. The confidence bounds are evaluated with a confidence level of 95.000%.Figure 9 shows Shear strength N/mm^2Vs radius in mm. value of shear stress is obtained at different values of thickness. Value of shear stress at 4.8 mm spot weld radius is around 150N/mm^2.

Table 3 Confirmation Test

Sr. No	Nodal shear force by FEM (N)	Experimental (N)
1	4801.1	4806.77
2	3330.1	3319.13
3	4567.890	4499.947
5	6789.67	6702.35
6	3427.45	3439.97
7	2561.34	2563.56

IV CONCLUSION

The influence of the design parameters on the tensile-shear strength of spot welds on a uncoated mild steel is studied.The conclusions obtained are summarised as follows.

-It is found that there is significant increase in shear strength of spot weld when thickness and spot weld radius increase.

-Probability of failure of three spot welded sheet decreases when number of spot increases. At the same time, there is more scatter of tensile shear strength.

-The probability that the maximum Shear stress remains below a specified value is determined and the correlation coefficients between shear strength and input variables are determined. Confirmation test is conducted to validate the results.

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