RESEARCH ARTICLE OPEN ACCESS

Parametric Data Modeling and Experimental Approach for Spot Weldment in SS202

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ABSTRACT
The interest of data modeling of process parameters in now a days based broadly upon numerical methods .variations in parametric set can be experimented for finding an optimized or desired value for a output property. This paper is to expose the experimental design approach to process parameter optimization of spot welding process for SS202.The objective of this experiment is to investigate the welding parameters performance in tensile shear failure strength and to optimize the parametric set for highest tensile strength achievable. From the experimental data achieved, the parametric relation between tensile shear stress and the parameters were found out using regression analysis .The optimum value for the parameters affecting tensile shear strength also found out by using soft computing methods like Simulated Annealing and Genetic Algorithm. There are various types of parameter that influence the mechanical properties of welding on the spot welding machine where in this experiment the parameter that will be investigate are weld cycle, squeeze time and weld current , hold time, weld force and weld current. Here also both optimized values were compared for greatest tensile shear strength value.
Keywords - Genetic Algorithm,Optimization,Regression,Scatterplot,Simulated annealing Algorithm.

I. INTRODUCTION

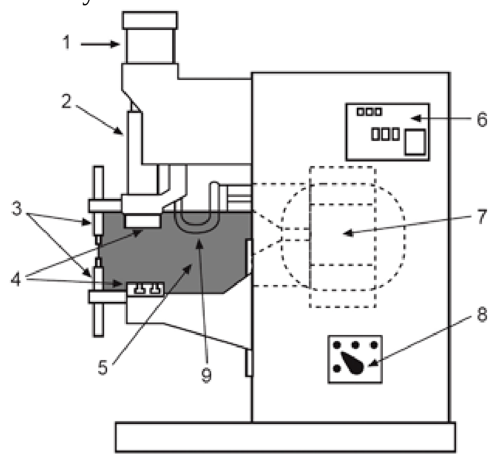
Spot welding is one of the versatile resistance welding process used widely all over the automobile industries in the world. No filler metal is needed and the heat required for the weld pool is created by means of resistance when a high welding current is directed through the welded workpieces. An electro-conductive contact surface is created between the workpieces by pressing them together. Contact is made using the shape of either the welded surfaces of the workpieces or the shape of the electrodes. Spot welding is an economical and primarily method for joining metals because its speed, precision, efficiency and resulting cost reductions afforded by automated resistance spot welding are well documented and accepted, actually in automotive industry. The method is adaptable to high speed automation and is under strict cycle times. it is the resistance of the material to be welded to current flow that causes a localized heating in the part. The pressure exerted by the tongs and electrode tips, through which the current flows, holds the parts to be welded in intimate contact before, during, and after the welding current time cycle. The required amount of time current flows in the joint is determined by material thickness and type, the amount of current flowing, and the cross-sectional area of the welding tip contact surfaces. Water-cooled electrodes made of alloyed copper are used in spot welding. Electrodes convey a pressing force to the joint and direct the welding current to the joint in the appropriate manner. After welding, the electrodes rapidly cool down the welded joint. Work stages in spot welding are very fast and precise, a narrow Heat Affected Zone (HAZ) and low destruction for base metal . The surfaces to be welded do not usually need to be cleaned before welding, in addition to which the weld does not usually require grinding or postheating. The spot welding process can be easily automated. In the spot welding it has some parameter to be considered. These parameters will affect the quality of the welds. The suitable combination of the spot welding parameter will produce strong joining and have a good quality of weld. Here in this research parameters considered were Electrodeforce (EF), Squeezetime (ST), Weldtime (WT), Holdtime (HT),Weld current(WC).

In recent days many researchers have done works on failure mechanisms for different type of spot weldment and its modeling [1-4].chao[1] worked on failure mechanism of resistance spot welding subjected to tensile, shear or combination of tensile\shear. He found that while lap shear sample subjected to shear (normal) load at the structural level the failure mechanism at the spot weld is tensile (shear) at the structural level based on the observed failure mechanism, stress distribution is assumed and are related to the far field load from the lap shear and cross tension sample is 75% of the lap sheared sample based on classical Von Mises failure theory. The most intriguing result from his experiment is that while spot weld in a lap-shear test sample is subjected to a global shear load the failure mechanism of the weld at the microstructure level is in fact tensile. On the other hand, while the spot weld in a cross tension sample is subjected to normal load. The failure mechanism of the weld is shear. And, accordingly the failure load relations are able to explain why cross tension sample always fails at a lower load than the lap-shear sample containing similar spot weld. Ferrasse et. al.[2] work, the failure performance of spot welds have been experimentally and numerically analyzed for welds in which the base material is the TRIP (Transformation induced plasticity steel) 980 sheet. .Dancette et al[3] investigated on modelling of failure mode of laser welds in lap-shear specimen of HSLA steel sheets. He proposed results showed that the laser welds failed in a ductile necking/shear failure mode and the ductile failure was initiated at a distance away from the crack tip near the boundary of the base metal and heat affected zone. Liang et.al. [4] worked on strength prediction of sheet tube. Therefore, the reliable evaluation of their formability/failure behaviour is important to accurately predict overall crash performance of vehicles. In his work, the failure performance of spot welds has been experimentally and numerically analyzed for welds in TRIP980 sheet using inverse method based on the standard and miniature simple tension tests along with the lap-shear tests. There are also some softcomputing methods also applied[5-8] , samanta et.al.[5] worked on parametric optimization using artificial bee colony algorithm, zhiping et.al.[6] worked on Parametric Optimization Design of spot welding Aircraft Based on Hybrid Parallel Multi-objective Tabu Search Algorithm. Recently, multi-objective optimization techniques are actively imported to solve constrained problems. The main idea of this kind of methods is to treat the constraints as one or several objectives, thus the constraints and the objective function are optimized simultaneously. Surry et.al. [7], treated the constrained optimization problem as a constrained satisfaction problem when neglecting the objective function and take it as an unconstrained optimization problem by ignoring the constraints. Venter et.al. [8] treated all the constraints as one objective and solved the optimization as a bi-objective optimization problem by using a specialized bi-objective particle swarm optimization algorithm.

This paper represents the experimental and numerical study upon, Failure in spot weld joints in SS202 sheet, because of not suitable welding parameter setup and causes a low strength ,hence the best design in term of parametric orientations for maximum tensile shear strength achievable, the best fit relationship between tensile stress and parameters, so to obtain optimized design parameter matrix using regression modeling, for parametric optimization soft computing methods Simulated Annealing and Genetic Algorithm were employed.

II. EXPERIMENTAL DETAILS

The machine parts were assigned as above figure 1 .Here the overlapping work is positioned between the water-cooled electrodes, the heat for weldment is obtained by passing a large electrical current for a short period of time. There are three stages figure 2[9] in making spot weld first the electrodes are brought together against the metal and pressure applied before the current is turned on. Next the current is turned on momentarily. This is followed by the third, or hold time in which the current is turned off but the pressure continued. The hold time forges the metal while it is cooling. Hence welding done in an effective way.



1 - Pneumatic/hydraulic cylinder
2 - Push bar
3 - Electrodes and electrode holders
4 - T-plates for projection welding electrodes
5 - Throat area
6 - Control unit
7 - Transformer
8 - Transformation ratio selector
9 - Flexible conductor

Figure 1.Schematic illustration of Spot welding machine.

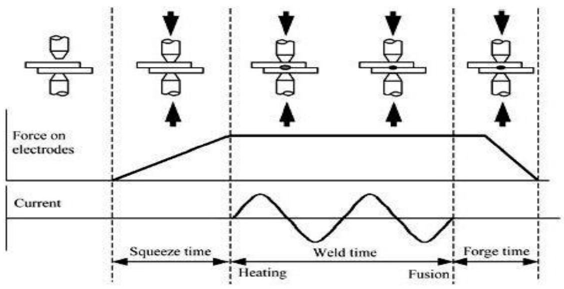


Figure 2. Basic periods of spot welding.

The amount of heat generated equation 1[1] in the weld mainly depends on welding current. A slight increase in welding current rapidly increases the diameter of the weld, root penetration and therefore also the strength of the weld. In most resistance welding machines, welding current is adjusted as a percentage of the nominal power of the machine.

$$H=I^2RT \quad (1)$$

Where:

H = Heat is generated in joules (watt- second)
I = Current (amperes)
R = Resistance (ohms)
T = Time to current flow (seconds)

A 152x62x1.25 mm stainless steel sheets were used as the base metals, in this research. The chemical composition of stainless steel (SS202) is given in tabulation 1. Spot welding was performed using a 35 kVA DC type resistance spot welding machine, controlled by a PLC. Welding was conducted after welding specimen was made as per specification described below & using a cone electrode with 6.6 mm face diameter. The welding parameter such as electrode force, squeeze time, hold time, weld time and weld current is fed to the welding machine through the electronic controller. The machine according to the programme executes the task. Strength of each weldment Fig.3 for different parametric orientation predicted by allowing it to tensile shear failure using UTM Fig.4 stated in table 2.

Table 1. composition of SS202

Element	C	Mn	Cr	Si	Ni	P	S	N
Weight%	0.15	7.5-1	17.0	1.0	4.0-6.0	0.06	0.03	0.025

Figure 3.stainless steel SS202 weldment.

Figure 4. Tensile strength testing.

III. EXPERIMENTAL DATA ANALYSIS

We have used multiple linear regression(2) modeling for finding out correlation between welding parameters and tensile strength value and for finding out best fit correlation between parameters and tensile value were used in scatterplots ,as the best fit relation was accepted .

General formula: $y = b_0 + b_1x_1 + b_2x_2 + \dots b_px_p$ +error
or $y = b_0 + \Sigma_i b_ix_i$ +error $i=1,2,\dots p$ 2

as y is dependent variable , x_i is independent variable ,b_i is constant.

Optimization is a process that finds best or optimal solution of a problem. An optimization problem can be defined as finding best values for variables for the objective function while satisfying the constraints. The optimization problems are centered on three factors, objective function which is to be minimized or maximized, set of decision variables that affect the objective function, A set of constraints that allow taking certain values to decision variables but exclude others. Here optimization of parameter done by using simulated annealing algorithm and genetic algorithm under boundary value of welding current and weld pressure.

3.1 simulated annealing and genetic algorithm used for experiment

Simulated annealing is a popular local search meta-heuristic used to address discrete and, to a lesser extent, continuous optimization problems. The key feature of simulated annealing is that it provides a means to escape local optima by allowing hill-climbing moves (i.e., moves which worsen the objective function value) in hopes of finding a global optimum.

Simulated annealing (SA) is a random-search technique which exploits an analogy between the way in which a metal cools and freezes into a minimum energy crystalline structure (the annealing process) and the search for a minimum in a more general system; it forms the basis of an optimization technique for combinatorial and other problems. SA approaches the global maximization problem similarly to using a bouncing ball that can bounce over mountains from valley to valley. It begins at a high "temperature" which enables the ball to make very high bounces, which enables it to bounce over any mountain to access any valley, given enough bounces. As the temperature declines the ball cannot bounce so high, and it can also settle to become trapped in relatively small ranges of valleys. A generating distribution generates possible valleys or states to be explored. An acceptance distribution is also defined, which depends on the difference between the function value of the present generated valley to be explored and the last saved lowest valley. Structure of SA represented as in Fig. 5.

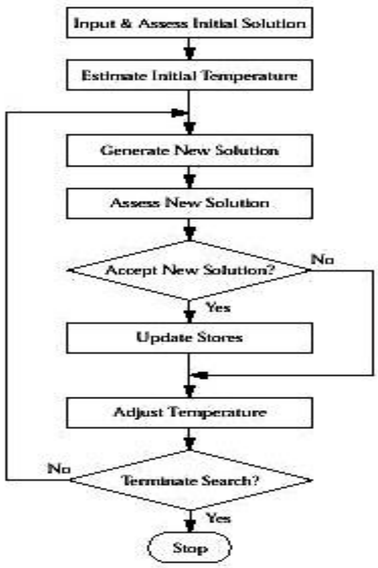


Figure 5. Structure of simulated annealing algorithm

A genetic algorithm is one of a class of algorithms that searches a solution space for the optimal solution to a problem. This search is done in a fashion that mimics the operation of evolution – a "population" of possible solutions is formed, and new solutions are formed by "breeding" the best solutions from the population's members to form a new generation. The population evolves for many generations; when the algorithm finishes the best solution is returned. Genetic algorithms are particularly useful for problems where it is extremely difficult or impossible to get an exact solution or for difficult problems where an exact solution may not be required.

Genetic algorithms evaluate the target function to be optimized at some randomly selected points of the definition domain. Taking this information into account, a new set of points (a new population) is generated. Gradually the points in the population approach local maxima and minima of the function .Genetic algorithms can be used when no information is available about the gradient of the function at the evaluated points. The function itself does not need to be continuous or differentiable. Genetic algorithms can still achieve good results even in cases in which the function has several local minima or maxima. These properties of genetic algorithms have their price: unlike traditional random search, the function is not examined at a single place, constructing a possible path to the local maximum or minimum, but many different places are considered simultaneously. The function must be calculated for all elements of the population. The creation of new populations also requires additional calculations. In this way the optimum of the function is sought in several directions simultaneously and many paths to the optimum are processed in parallel. The calculations required for this feat are obviously much more extensive than for a simple random search. Structure of GA as stated below Fig.6.

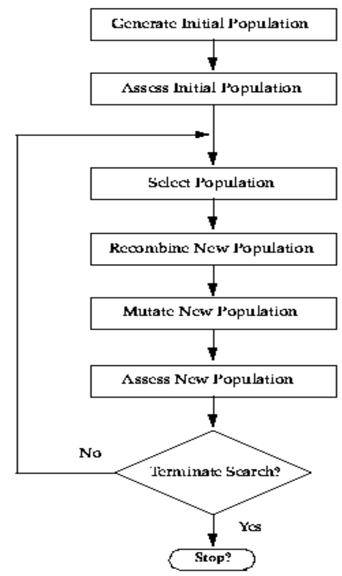


Figure 6. Structure of genetic algorithm.

IV. RESULTS

Experiments with different parametric setup done and respective data investigated were found out as in Table 2.As per regression the parametric relation between tensile strength and different parameters found to be in (3). Different scatter plots as regression between tensile strength and parameters as stated below as in figures

Tensile Strength(TS) = 91.9 - 9.44*Weld Pressure(WP) + 7.60*Weld Current(I)+ 0.36*Weld Cycle(WC) - 0.36*Hold Time(HT)+ 1.23*Squeeze Time(ST) 3

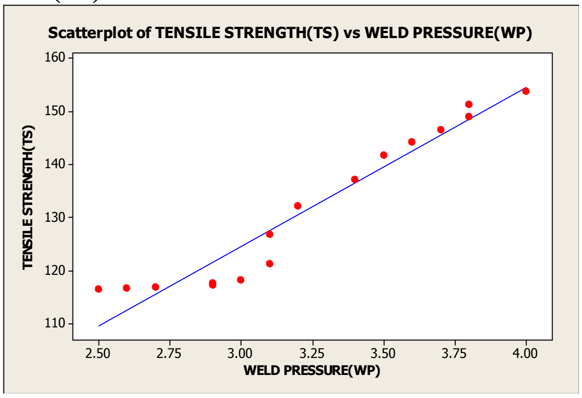


Figure 7. Scatter Plot Of Tensile Strength Vs. Weld Pressure.

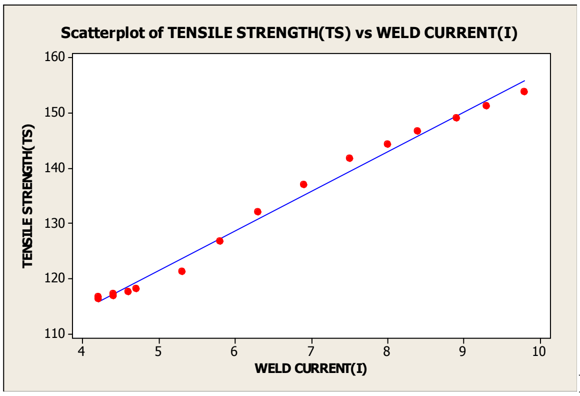


Figure 8. Scatter Plot Of Tensile Strength Vs. Weld Current.

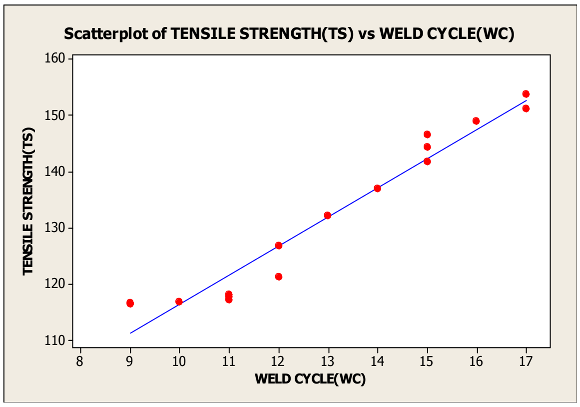


Figure 9. Scatter Plot Of Tensile Strength Vs Weldcycle

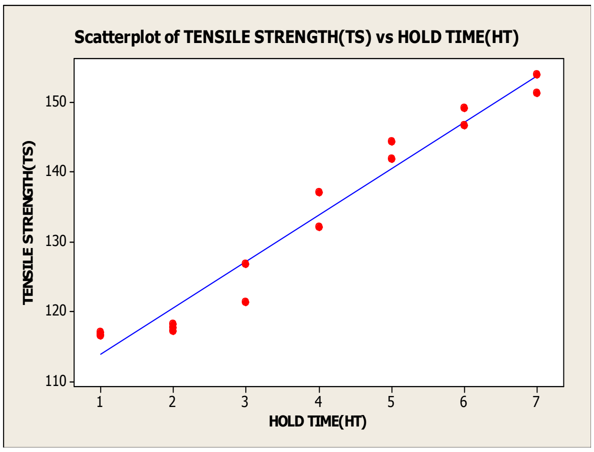


Figure 10. Scatter Plot Of Tensile Strength Vs. Hold Time

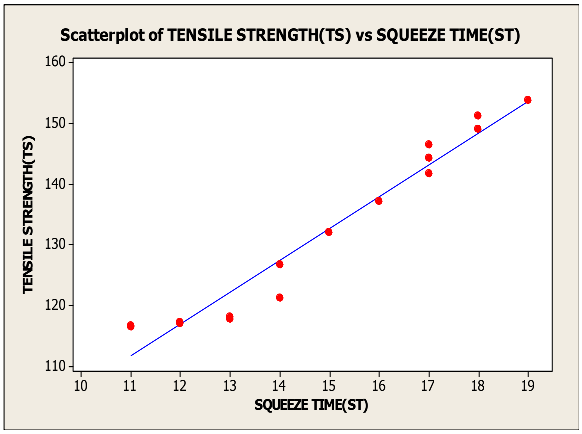


Figure 11. Scatter Plot Of Tensile Strength Vs. Squeeze Time

As per the goodness of fit we have considered variables that affect the objective functions were weld pressure and weld current ,the regression is as equation 4,and the surface plot investigated as Fig. 12.

Tensile Strength (TS) = 92.1 - 3.60*Weld Pressure(WP) + 7.98*Weld Current(I) 4

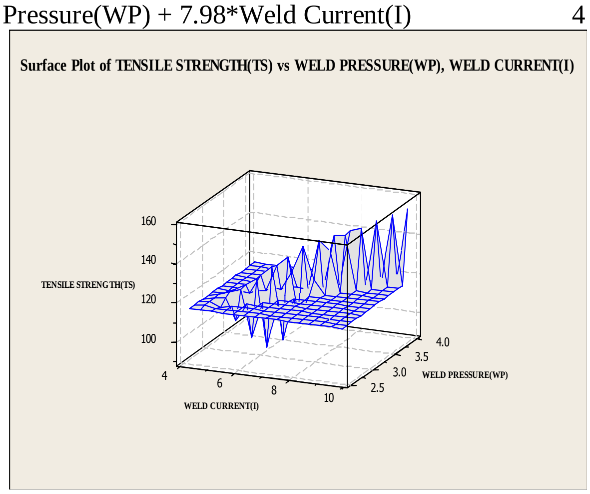


Figure 12. Surface Plot Of Tensile Strength Vs. Weld Current, Weld Pressure

So taking the variable as WP and I the maximized tensile strength value found for respective optimum values under boundary values of WP between 2.5-4 Bar and I between 4-10 KA as in Table 3.hence the plots were as follows.

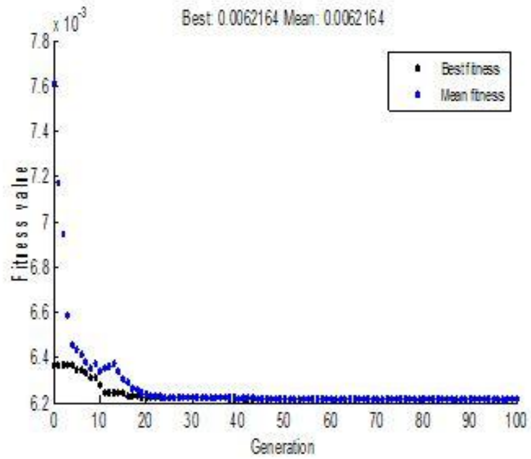


Figure 13. Plots In GA For Optimum Response

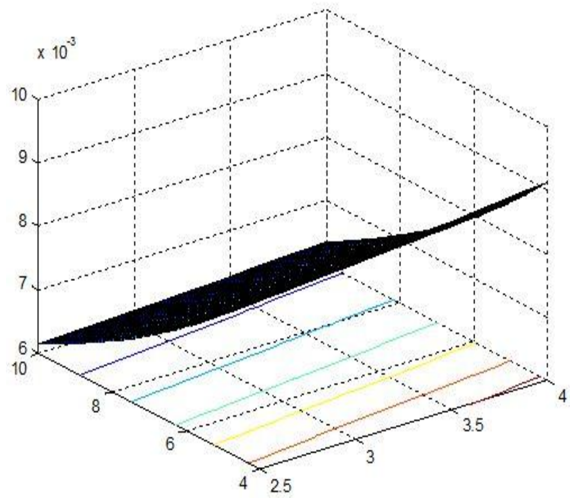


Figure 14. Surface Response In SA Algorithm For Optimum Values.

Table 2.Tensile strengths for diff. parameter setup

Serial No.	Weld Pressure(WP) in BAR	Weld Current(I) in KA	Weld Cycle(WC)	Hold Time(HT)	Squeeze Time(ST)	Tensile Strength(TS) in N/mm²
1	2.5	4.2	9	1	11	116.423
2	2.6	4.2	9	1	11	116.61
3	2.7	4.4	10	1	12	116.925
4	2.9	4.4	11	2	12	117.216
5	2.9	4.6	11	2	13	117.694
6	3	4.7	11	2	13	118.11
7	3.1	5.3	12	3	14	121.206
8	3.1	5.8	12	3	14	126.783
9	3.2	6.3	13	4	15	132.112
10	3.4	6.9	14	4	16	137.096
11	3.5	7.5	15	5	17	141.808
12	3.6	8	15	5	17	144.308
13	3.7	8.4	15	6	17	146.625
14	3.8	8.9	16	6	18	149.083
15	3.8	9.3	17	7	18	151.236
16	4	9.8	17	7	19	153.823

Table 3.Comparative result for optimal values

Algorithm	Weld Current(KA)	Weld Pressure(Bar)	Tensile Strength(N/mm^2)	Nos. Of runs
Genetic algorithm	2.5876 ≈2.6	9.6587≈9.7	160.8658	100 Generations
Simulated annealing	2.6753≈2.7	9.4976≈9.5	158.2604	6000 Iterations

V. CONCLUSION

The soft computing methods like SA and GA can be applied effectively with broad constraint conditions to optimization problem of spot welding process. Both the kind of technique used in this research for optimization of parameter for maximization of tensile strength. when comparative study done as in result it was clear that under mild condition there exist greater probability of success rate of genetic algorithm as compared to later. Over variety of genetic algorithm will be used for better optimized value ,which has implications for the performance of other types of optimization problems.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge to Dr.P.R.Dash and Mr.S.Jena for kind support and encouragement.

REFERENCES

[1] Yuh J.Chao,Ultimate Strength and Failure Mechanism of Resistance Spot Weld Subjected to Tensile, Shear,or Combined Tensile/Shear Loads, *Journal of Engineering Materials and Technology April 2003, Vol. 125,125-132.*

[2] S.Ferrasse, P.Verrier ,F.Meesemaecker, Resistance spot weldability of high strength steels for use in car industry,*welding in the world,41(3)1998,177-195.*

[3] S.Dancette,D.Fabregue,V.Massardier, Investigation of the Tensile Shear fracture of Advanced High Strength Steel spot welds, *Engineering Failure Analysis 25 (2012),112–122.*

[4] C.Liang,X.Liu ,Strength prediction of sheet to tube single sided resistance spot welding, *Materials and Design 30(2009),4328-4334.*

[5] Suman Samanta, Shankar Chakraborty, Parametric optimization of some non-traditional machining processes using artificial bee colony algorithm, *Engineering Applications of Artificial Intelligence 24 (2011),946–957.*

[6] Q.Zhiping,Z.Yuxing,Parametric optimization Design of Aircraft Based on Hybrid Parallel Multi-objective Tabu Search Algorithm, *Chinese Journal of Aeronautics 23(2010) ,430-437.*

[7] P.D.Surry, N.J.Radcliffe, The COMOGA method: constrained optimization by multi-objective genetic algorithms, *Control and Cybernetics, 26(3), 1997.*

[8] G.Venter,R.Haftka,Constrained particle swarm optimization using a biobjective formulation. *Struct Multidisc Optim 40(2010),65-76.*