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Numerical Evaluation of Temperature Distribution and Stresses Developed in Resistance Spot Welding

M. Lakshmi Sramika, I. Shanmukha, K. Kishore Chandra Mouli, K. Harish Kumar, M. Vamsi Kiran, N. V. S. J. K. Naidu

Department of Mechanical Engineering, Avanthi Institute of Engineering and Technology, Cherukupally, Bhogapuram Mandal, Andhra Pradesh, India

ABSTRACT

Resistance spot welding is a type of electric resistance welding used to weld various sheet metal products through a process in which contacting metal surface points are joined by the heat obtained from resistance to electric current. The intense heat generated and rapid cooling of the joint produce residual stresses and distortion in the joint. The prediction of residual stresses before carrying actual welding is important for the prevention of these stresses. In this study thermo-elasto-plastic analyses are carried out to simulate resistance welding under various conditions. Mild steel sheets of equal and unequal thicknesses and aluminium sheets of equal and unequal thicknesses have been spot welded with the application of pressure which is determined by measuring force on the joint with a load cell. The size and shape of the nugget for different spot welding conditions is ascertained. The residual stresses under different spot welding conditions are compared.

KEYWORDS: *Resistance spot welding ,residual stresses , mild steel , aluminium, thermo- elasto-plastic analyses*

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INTRODUCTION

In automobile industry, spot welding is a normally used welding process to weld the automobile panels. In the welding technology, spot welding is one of the techniques, in which two overlapped metal surfaces are joined together by the heat acquired from the resistance of the joint. This operation is performed with current and pressure on the metal sheets. Spot welding is not limited to joining automobile panels and has many applications like dentistry, joining of lithium-ion batteries, nickel-cadmium battery cells. Low welding cost, ease of automation and no need of skilled labor favour the application of spot welding in sheet metal welding.

Resistance spot welding

Huge current in the order of thousands of amperes is applied for a very short period of time together with application of pressure melts the spot welded joint due to resistance heat produced in the joint and upon subsequent cooling forms a permanent spot welded joint. A typical resistance spot welding setup is shown in Fig. 1.

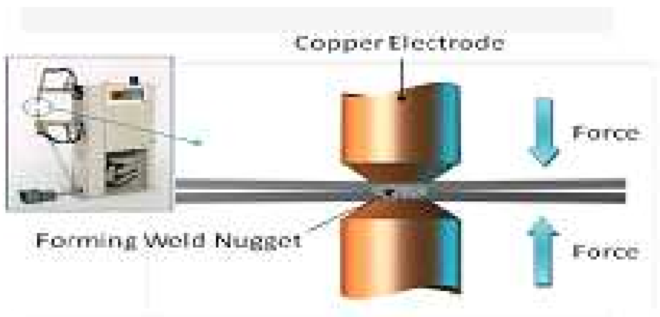

Figure 1 Resistance spot welding process

Resistance spot welding applications:

The applications of resistance spot welding are classified into two types. One is large scale businesses and the other is small scale businesses. Some of applications in this category are

Automobiles
Electronics
Battery Manufacturing
Orthodontics
Fabrication and repair shop

Automobiles: Spot welding is used universally in all the autoomobile industries to join different car parts. Spot welding plays a significant role in car manufacturing. Robots and automatic machines are preferred in assembly lines to manual welds for safety purposs.

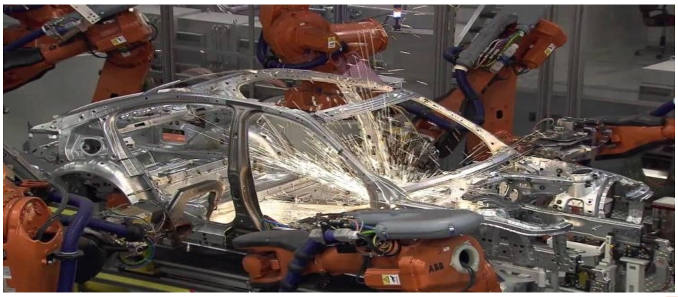

Figure 2 Spot welding process in automobiles

Electronics: From electronic components, sensors, connectors to solenoid assemblies, spot welding is used enormously in the manufacturing of electronic components. It is widely used to make printed circuit boards (PCB), gas sensors and drive assemblies. Components such as cables, PCB, switches are also spot welded. A typical spot welded PCB is shown in Fig 3.

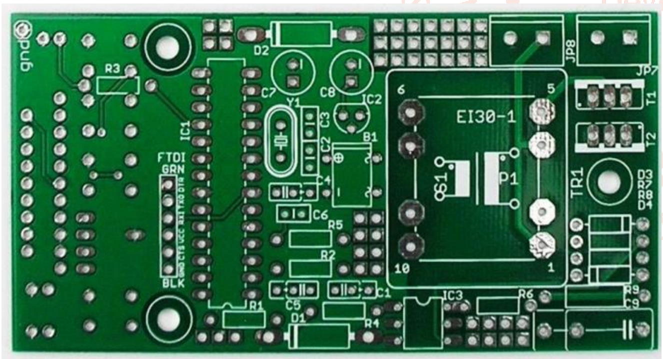

Figure 3 Spot welds in circuit boards

Spot Welding Electrodes:
The electrodes ought to be the right material and shape for spot welding. Truncated electrodes ordinarily give long electrode life. Copper/chromium/ zirconium electrodes are used for spot welding. Aluminium and copper electrodes are additionally found to give some advantage yet are significantly high cost

Residual stresses:
Residual stresses can be defined as the stresses existing within a body in the absence of external loading. These stresses are produced by localized, partial yielding during the thermal cycle of welding, and the impeded contraction of these areas during cooling. Distributed plastic strain is responsible for residual stresses. These stresses decrease fatigue life of the joint leading to premature failure. The levels of residual stresses have to be computed before actual welding of the joint for its proper design. Experimental techniques like strain gauging and X-ray diffraction can be used to measure residual stresses, but these are proved to be costly. Hence, a powerful numerical method like finite element method can be used to compute the levels of residual stresses and distortion in welded joints

METHODOLOGY
In this study, thermo- mechanical analyses have been carried out to compute temperature distribution and residual stresses in spot welded joints. Experiments are conducted on spot welding of mild steel and aluminium joints of different thicknesses separately. The recorded spot welding parameters are thicknesses of the sheets, applied voltage, welding time and applied load. Thermo-elasto-plastic analyses are carried out to find temperature distribution and residual stresses for various spot welding conditions using ANSYS APDL program. The size, shape of the nuggets and residual stresses of the spot welded joints for various welding condition are compared.

Experimental investigation on spot welded joints considered in present work is described in this chapter.

Material and equipment used:
Material: 1. Mild steel sheets (o.4 mm and o.51 mm)
Aluminium sheets (o.4 mm and o.51 mm)

Equipment used:
Resistance Spot Welding machine
Load cell
Digital multi-meter

Figure 4 Spot welding with load cell

Parameters of spot welding under different welding conditions:
The spot welding parameters, material, thickness, measured voltage and measured load of different spot welded joints are indicate the spot welded joints of

mild steel sheets and aluminium sheets with different thicknesses.

(a) (b)

Figure 5 Spot welded joints of (a) mild steel and (b) aluminium modeling of Spot Welding Using ANSYS APDL

An axi-symmetric FEM model is developed to model the resistance spot welding using ANSYS APDL software. The details are given as follows,

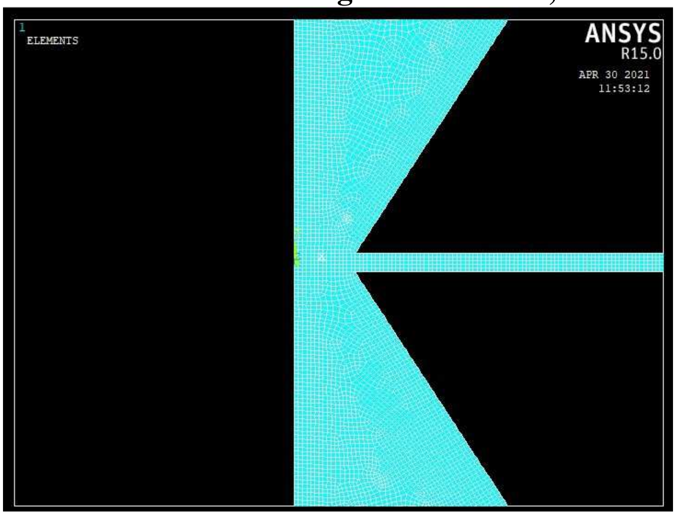

Fig.6 Mesh of mild steel joint

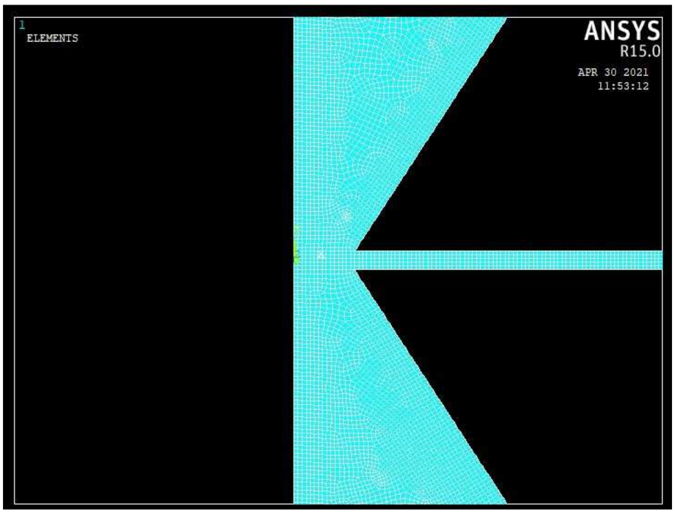

Figure 7 Mesh of aluminium joint

Table 1: Parameters of spot welding

Joint no	Materials	Gauge	Measured Voltage (V)	Corrected Voltage (V)	Measured Load (N)	Pressure (N/mm^2)	Heat Input (J)
MSS W1	Mild steel	26(0.40mm)	0.591	0.494	5.4	0.102	9630
MSS W2	Mild steel	24(0.51mm)	0.595	0.497	4.7	0.089	9760
MSS W3	Mild steel (unequal)	24 and 26	0.589	0.493	4.4	0.083	9564
ASW1	Aluminium	26(0.40mm)	0.384	0.3233	2.5	0.047	3711
ASW2	Aluminium	24(0.51mm)	0.387	0.325	2.4	0.045	3903
ASW3	Aluminium (unequal)	24 and 26	0.385	0.324	2.3	0.043	3523

RESULTS

Sequential thermo mechanical analyses have been carried out for all six spot welded joints investigated in the present study. A convergence study of thermal analyses of the joint ASW1 has been carried out with different meshes of increasing mesh density. The details of meshes have been reported in Table.5.1 In this study peak temperature occurs at the centre of the joint. The temperature corresponding to this location has been chosen to test for convergence. The temperature distribution after the end of welding time i.e.1s is shown in Figure The peak temperature is 670.627^{o}C. Temperature distribution at the end of welding (after 1 s from the start of welding) of the joint ASW1.This peak temperature value has been reported for different meshes also

Table.2. Convergence study: Details of different meshes

Mesh number	Numbers of elements	Number of nodes	Peak temperature(^oC)
M1	11047	34060	670.241
M2	15941	48924	670.442
M3	24126	73751	670.627
M4	96507	292266	670.11

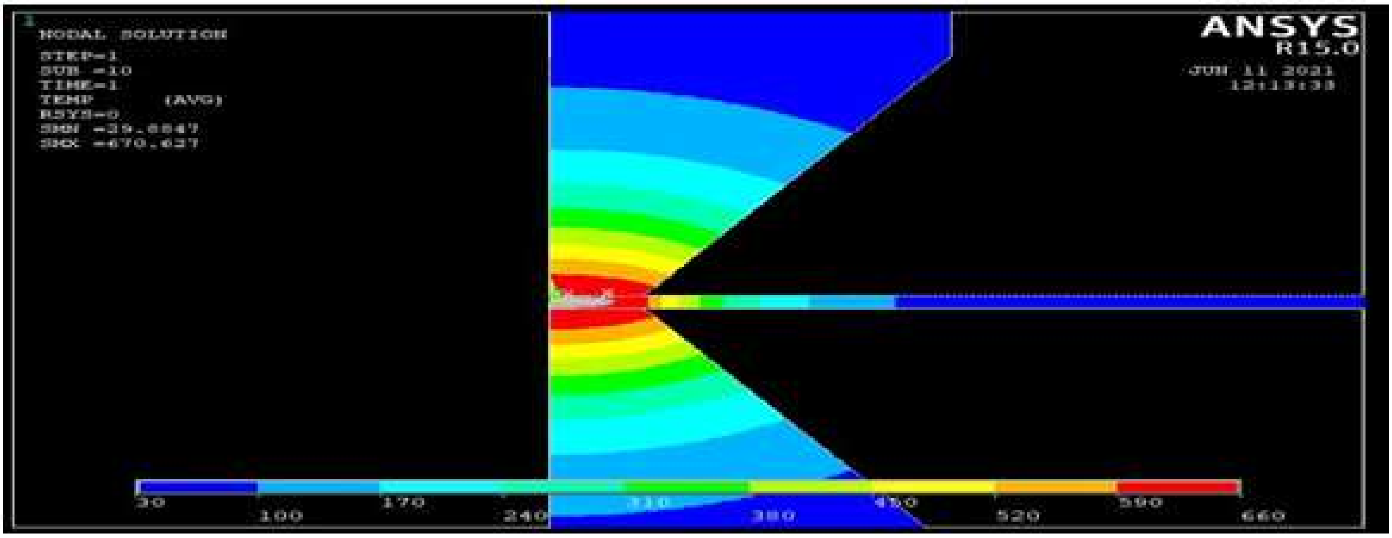

Figure 8 Temperature distribution at the end of welding (after 1 s from the start of welding) of the joint ASW1

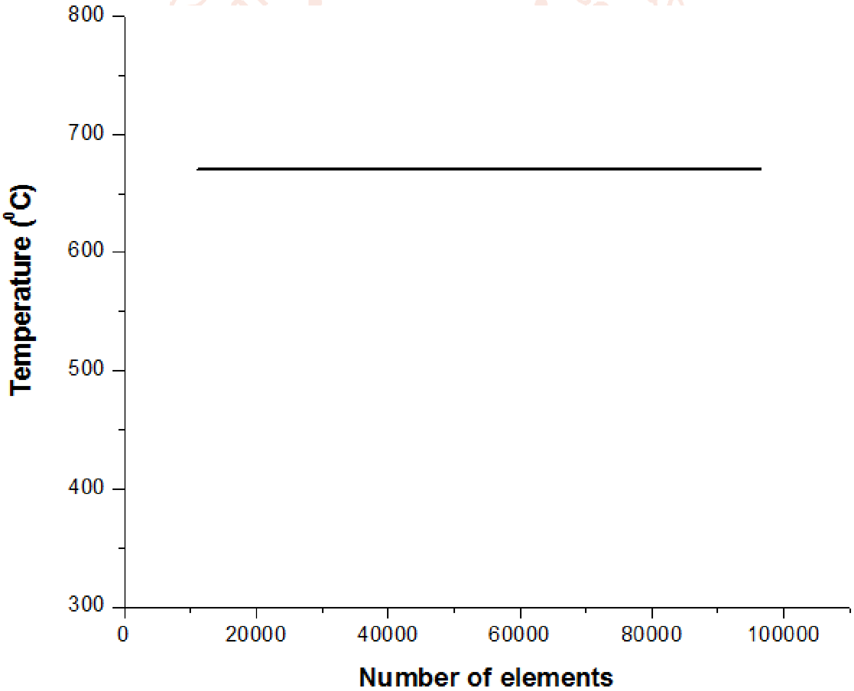

Figure 9 Convergence study

The shape of the nugget can be found from the temperature distribution of the model taking isotherm representing the melting temperature is as the lower boundary of fusion zone The shapes of the nugget for the different spot welded joint considered in the investigation are presented in Figure 5.3. The sizes of the nuggets are bigger for mild steel joint than those of aluminium joints. This is clear from the fact that heat input to the each of mild steel joint is higher than that of aluminium joint.

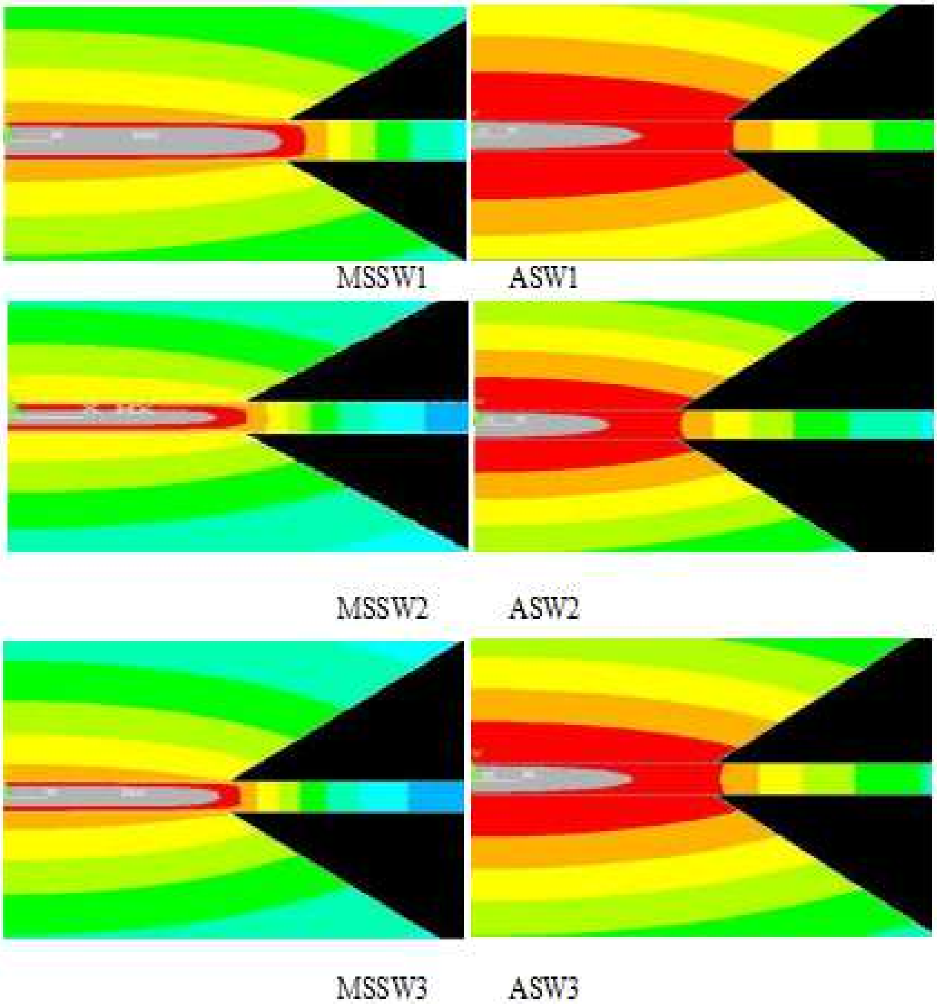

Figure 10 The shapes of nugget for different spot welded joints

The radial, axial, circumferential and von Mises residual stress distributions of the joint MSSW1 are shown

MSSW 1:

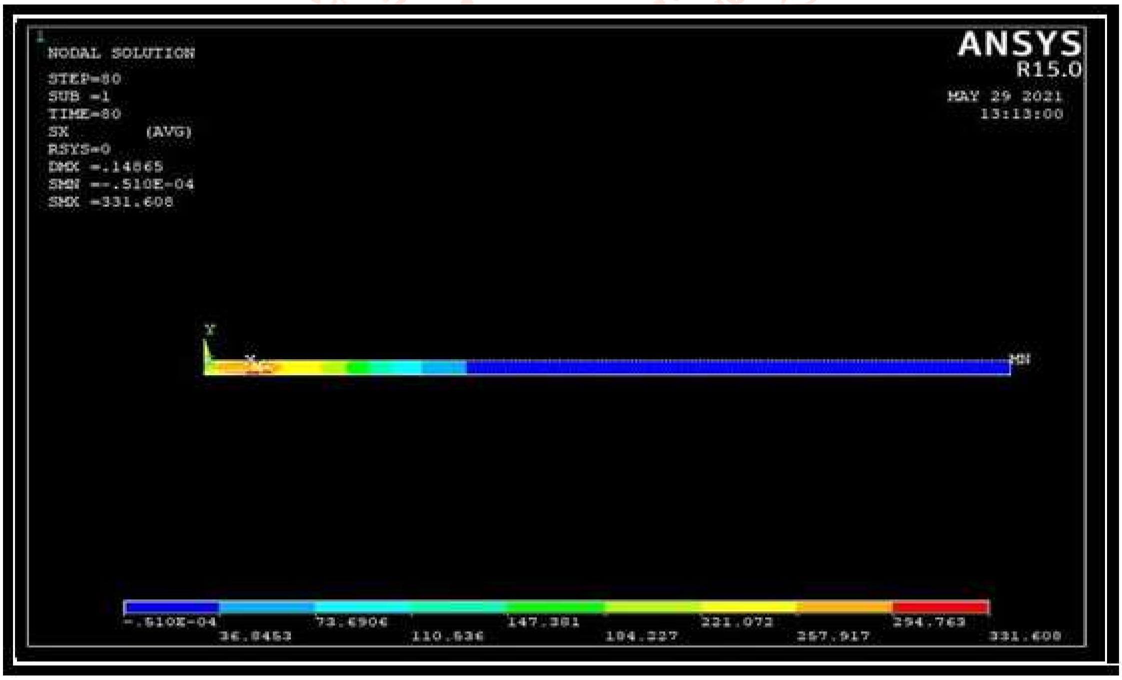

Figure 11 Radial residual stress distribution of the spot welded joint MSSW1

MSSW 1

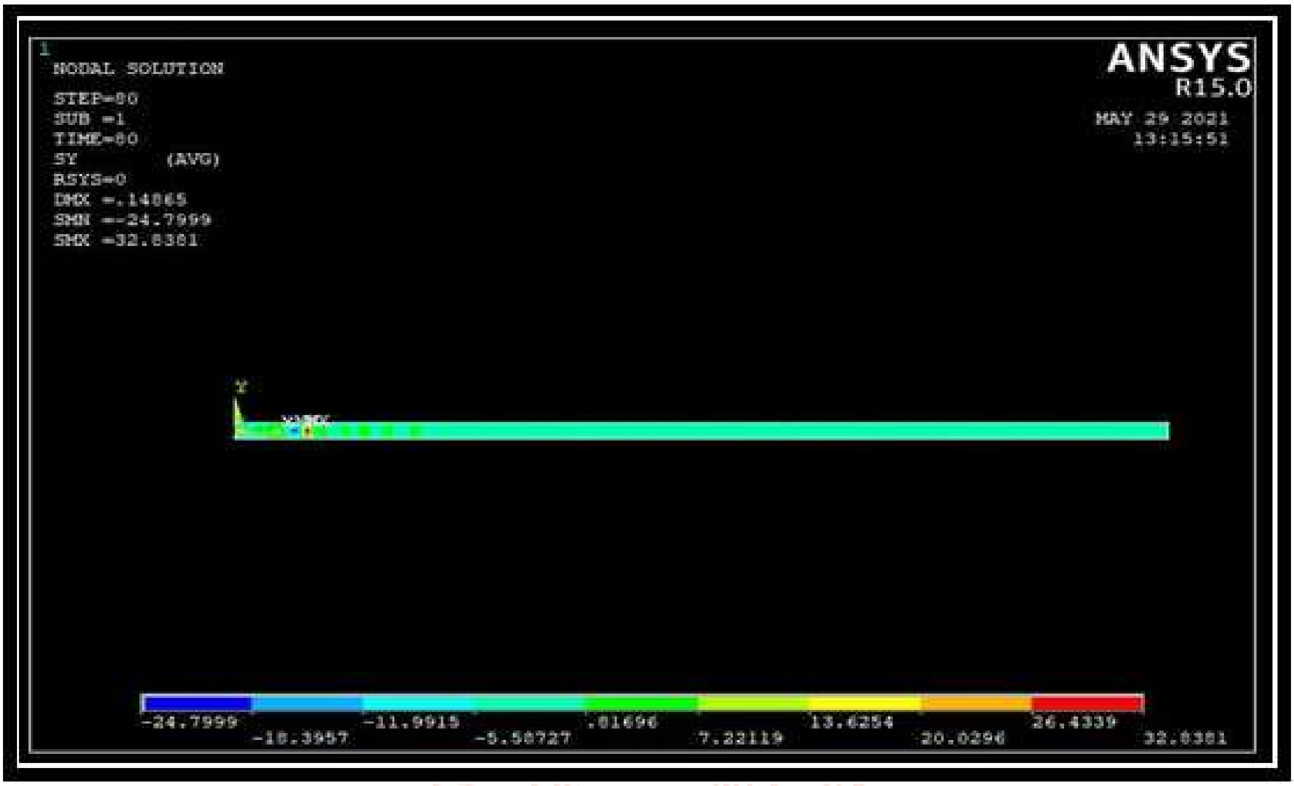

Figure 12Axial residual stress distribution of the spot welded joint MSSW1

MSSW1

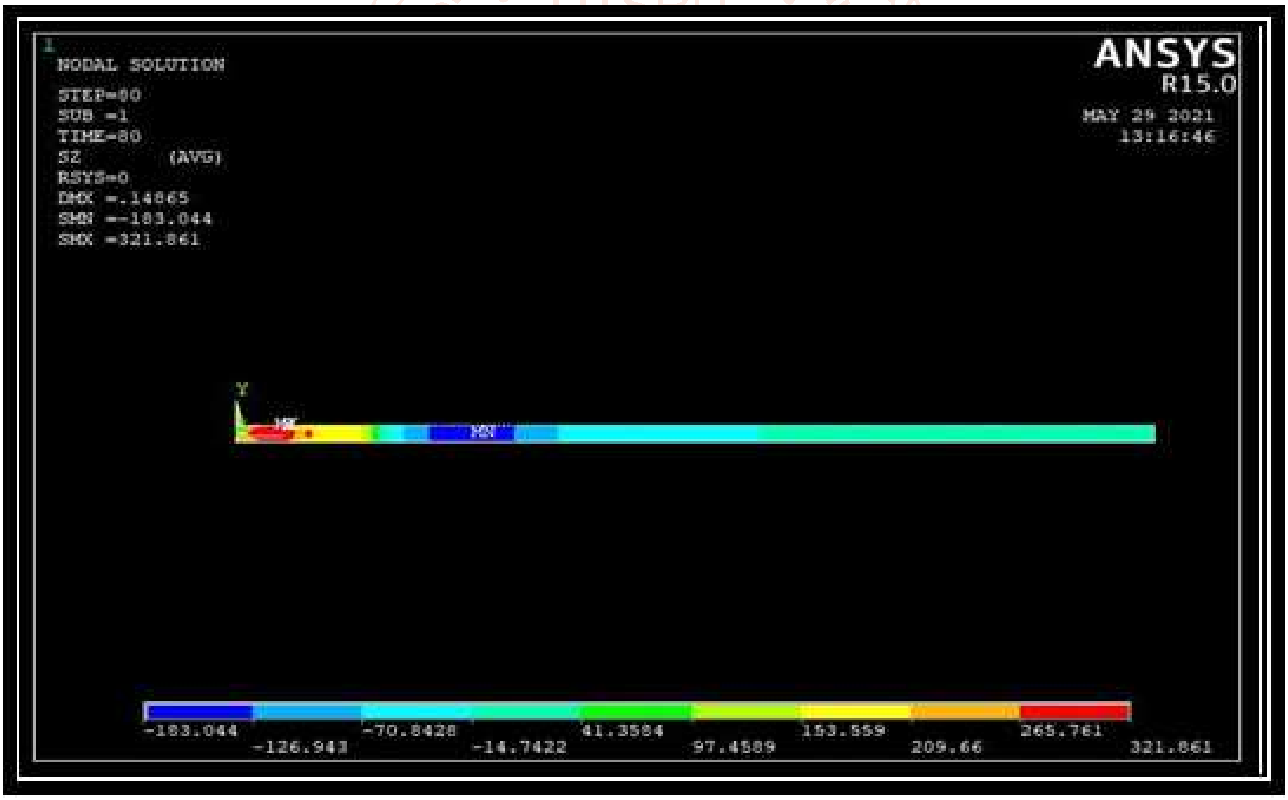

Figure 13.Circumferential residual stress distribution of welded joint MSSW1

MSSW1

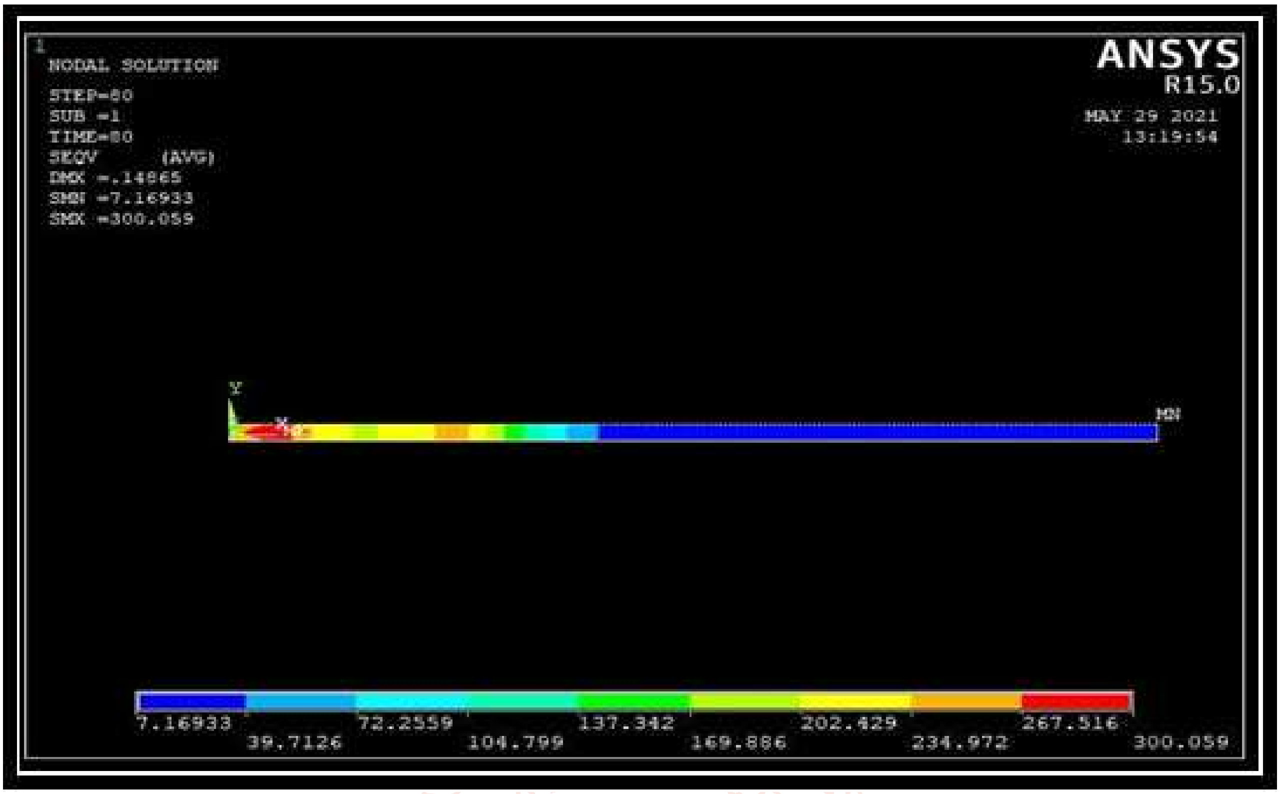

Figure 14 von Mises residual stress distribution of welded joint MSSW1

MSSW1

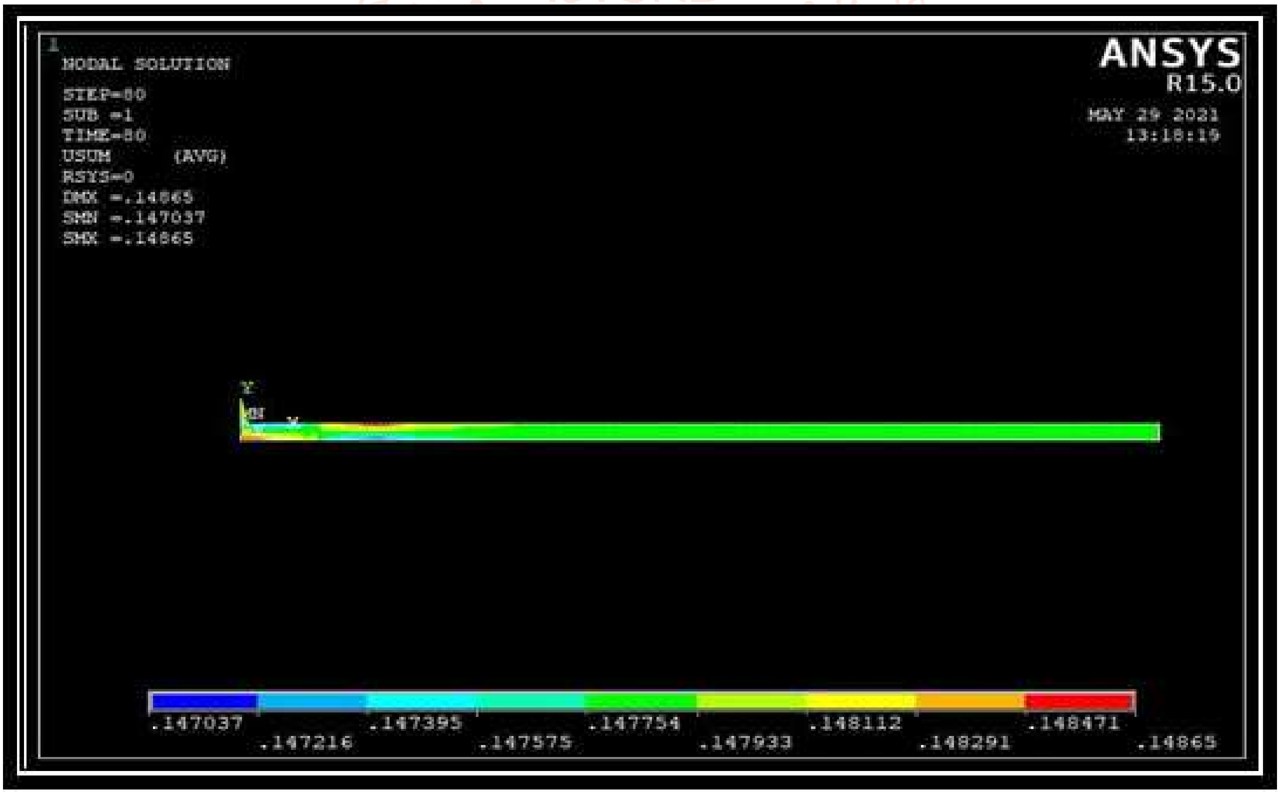

Figure 15 Vector sum displacement

The radial, axial, circumferential and von Mises residual stress distributions of the joint ASW1. are shown

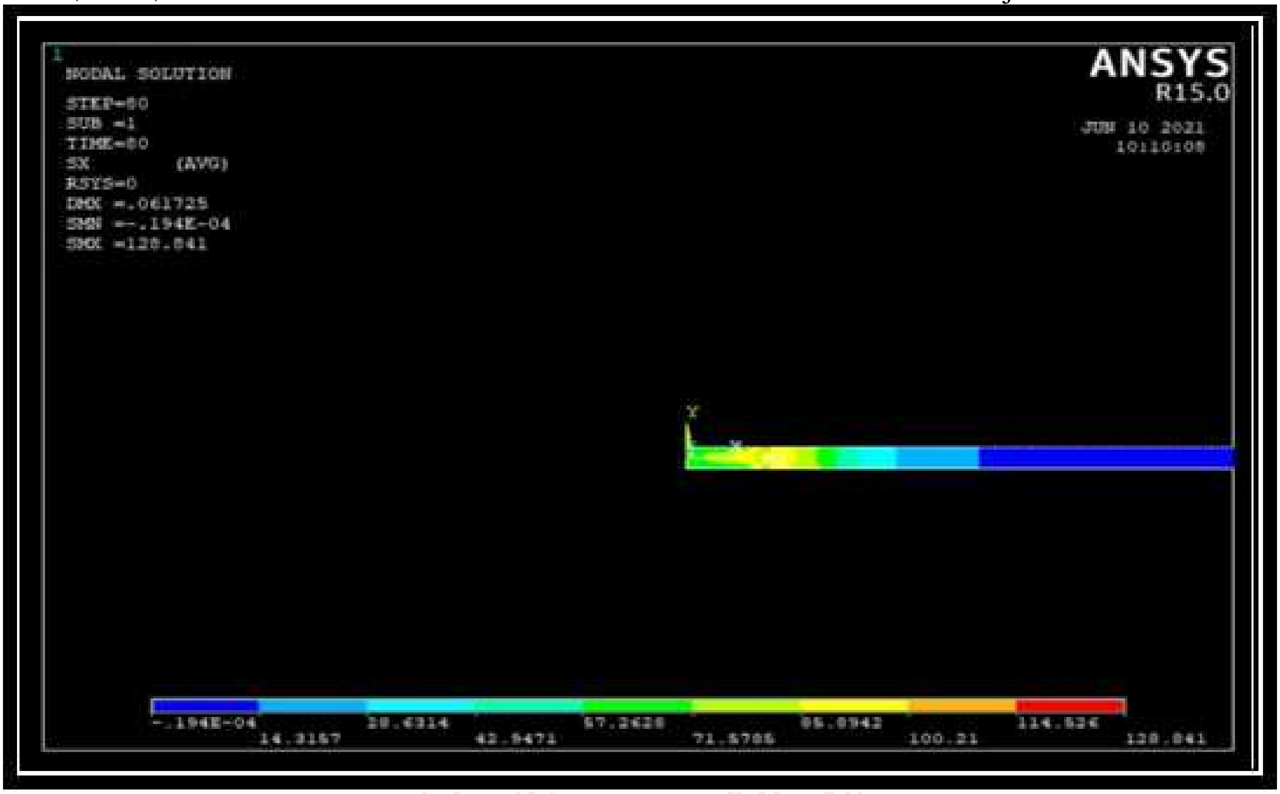

Figure 16 Radial residual stress distribution of welded joint ASW1

ASW1

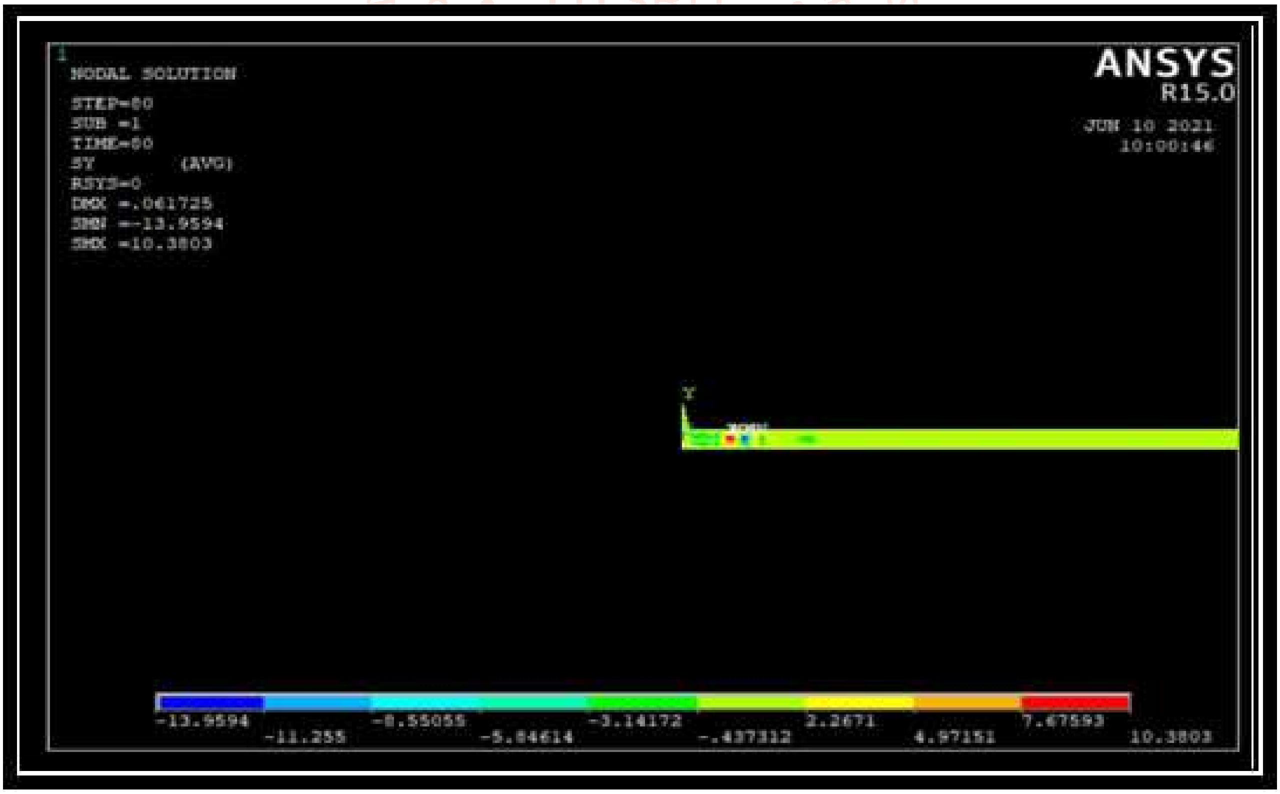

Figure 17.Axial residual stress distribution of welded joint ASW1

ASW1

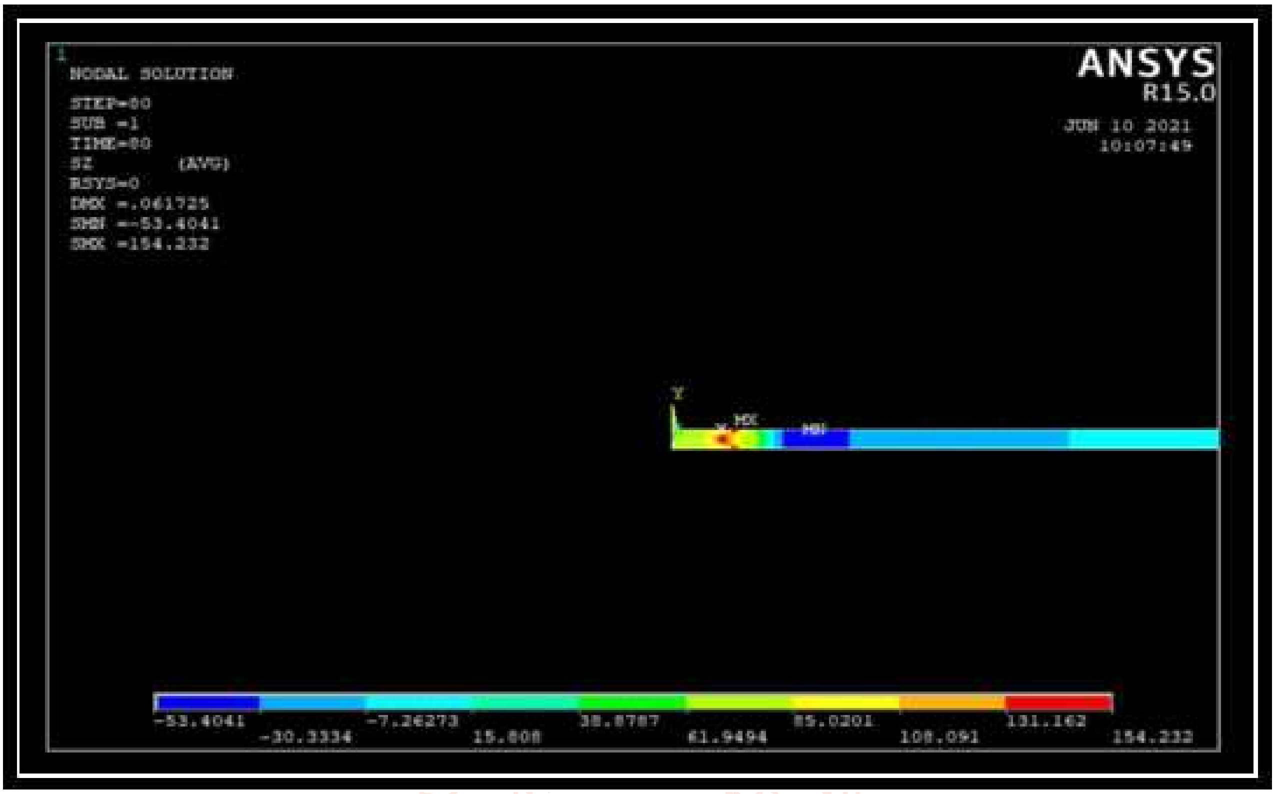

Figure 18.Circumferential residual stress distribution of welded joint ASW1

ASW1

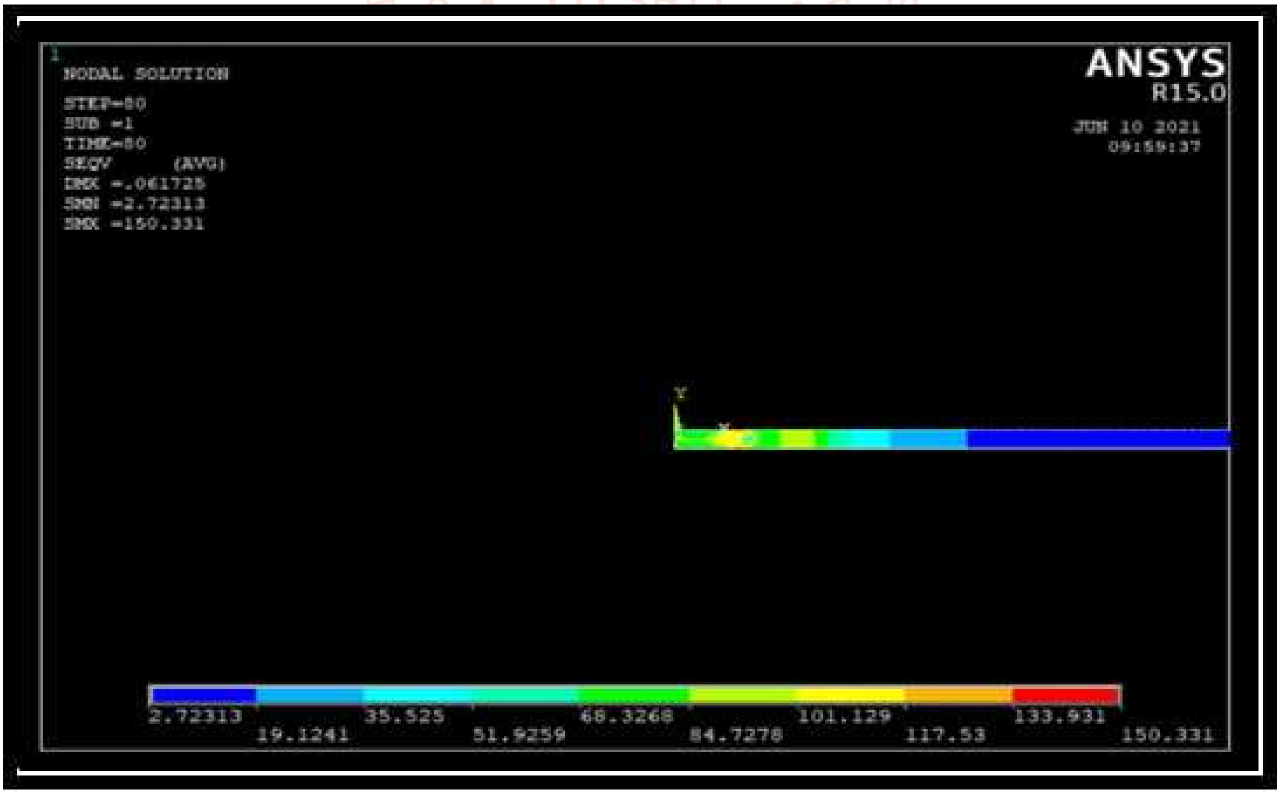

Figure 19 von Mises radial residual stress distribution of welded joint ASW

ASW1

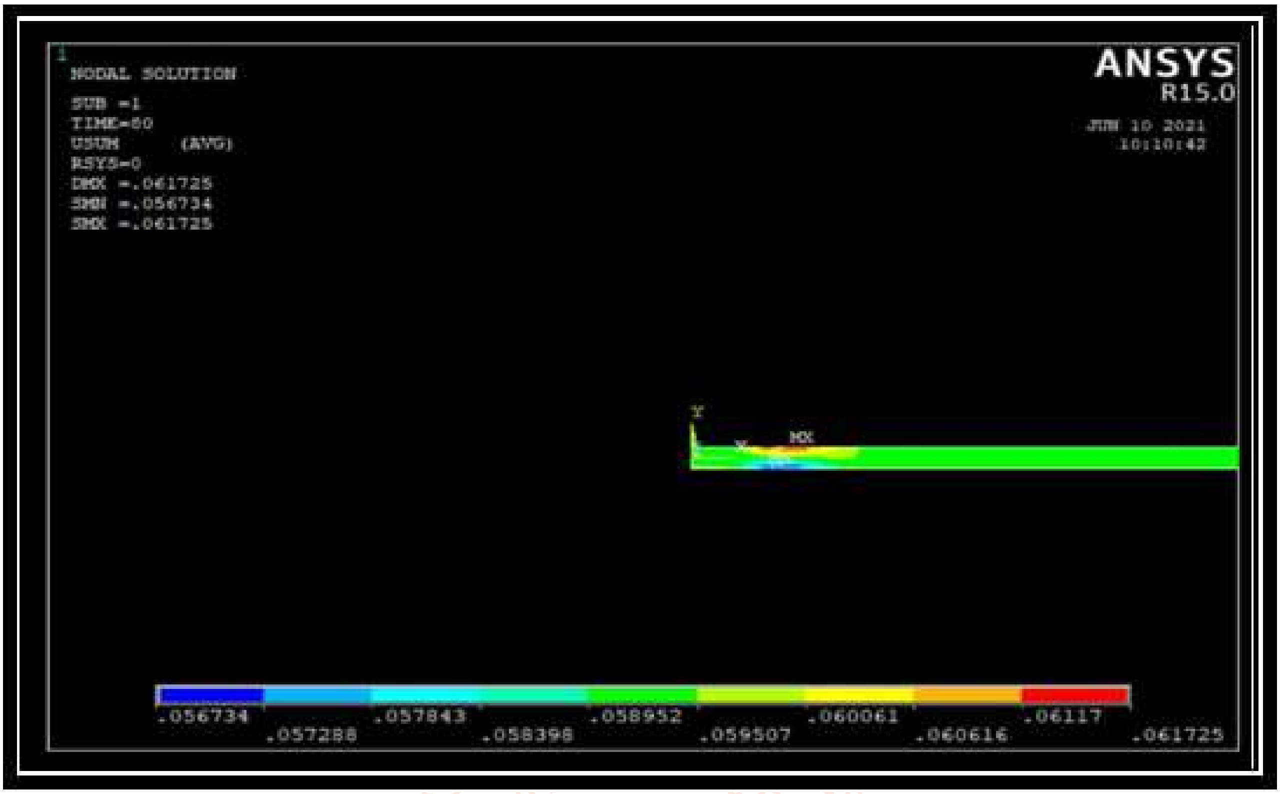

Figure 20 Vector sum displacement

Similar Way the other Analysis was done for the radial, axial, circumferential and von Mises residual stress distributions of the joints for different materials are done and tabulated

Table.3.Peak stress values of various components of the joints investigated in this study

Joint No	Materials	Value of peak stress (MPa)				
		Radial	Axial	Circumfer ential	von-Mises	Displacement (mm)
1	MSSW1	331.812	32.812	321.56	300.02	0.148
2	MSSW2	339.457	38.412	305.48	294.202	0.47
3	MSSW3	351.881	44.359	348.95	320.628	0.156
4	ASW1	128.841	10.380	154.232	150.331	0.0617
5	ASW2	130.159	9.455	155.857	152.056	0.0621
6	ASW3	132.523	9.821	155.404	151.609	0.0618

The comparisons of peak values of the component residual stresses radial, axial, circumferential and von Mises stresses for various spot welded joints are indicated in Table 3.This table also indicates the maximum values of vector displacements which are the measures of distortion of various spot welded joints also. From the table it can be inferred that radial and axial components of residual stresses are dominant. The peak value of residual stresses increases with increase in thickness. The peak values of residual stresses for mild steel joints are more than those of aluminium joints. This is due to the fact that heat inputs to the respective mild steel joints is more than those of aluminium joints. The vector sum of displacement for respective mild steel joints are more than those of aluminium joints. This is also due to the greater heat inputs received by respective mild steel joints than those of aluminium joints.

CONCLUSION

Thermo-elasto-plastic analyses of resistance spot welding of mild steel and aluminium joints of different welding conditions have been carried out using nonlinear axi-symmetric finite element analyses to compute residual stresses and distortion. The following results show the voltage and pressure which are obtained from the experimental results and the corresponding component residual stresses values which are obtained from the numerical analyses. The voltage applied for MSSW1 is 0.497V and the pressure applied is 0.089 N\mm^2.

The peak values of radial, axial, circumferential and Von-Mises residual stresses are 331.6 MPa, 32.812 MPa, 321.56 MPa and 300.02 MPa respectively.The voltage applied for MSSW2 is 0.495V and the pressure applied is 0.106 N\mm^2. The peak values of radial, axial, circumferential and Von-Mises residual stresses are 339.4 MPa, 38.4 MPa, 3o5.48 MPa and 294.2o MPa respectively.

The voltage applied for MSSW3 is o.493V and the pressure applied is o.o83 N\mm^2. The peak values of radial, axial, circumferential and Von-Mises residual stresses are 351.8 MPa, 44.359 MPa, 348.95 MPa and 32o.628 MPa respectively. The voltage applied for ASW1 is o.3233V and the pressure applied is o.o476 N\mm^2. The peak values of radial, axial, circumferential and Von-Mises residual stresses are 128.841 MPa, 1o.38o MPa, 154.232 MPa and 15o.331 MPa respectively.

The voltage applied for ASW2 is o.325V and the pressure applied is o.o458 N\mm^2. The peak values of radial,axial, circumferential and Von-Mises residual stresses are 13o.159 MPa, 9.455 MPa, 155.857 MPa and 152.o56 MPa respectively. The voltage applied for ASW3 is o.324V and the pressure applied is o.o438 N\mm^2. The peak values of radial, axial, circumferential and Von-Mises

REFERENCES

[1] BW. Cha and S-J. Na, "A study on the relationship between welding conditions and residual stress of resistance spot welded 3o4-Type Stainless Steels", Journal of Manufacturing System (2o13) 181-189.

[2] Ranjbar nodeh, S. Serajzade and A. H. Kokabi, "Simulation of welding residual stresses in resistance spot welding, FE modeling and X-ray verification", Journal of Materials Processing Technology (2oo8)2o5 6o-69.

[3] Soran Hassanifard and Mohsen Feyzi, "Analytical solution of temperature distribution in resistance spot welding", Journal of Mechanical Science and Technology 29 (2) (2o15) 777-784.

[4] Ugur Ozsarac, "Investigation of Mechanical Properties of Galvanized Automotive Sheets Joined by Resistance Spot Welding" ASME International. Journal of Materials Engineering and Performance, Volume 21(5) (2o12) 74-755.

[5] Yang, J. Huang, D. Fan, Z. Ye, S. Chen, and X. Zhao, "Temperature and Stress Simulation of the Hard facing for Cr5Mo1VRE Alloy", Welding Research Supplement (2o16) 3o9s-323s.

[6] Rasoul Moharrami, Behzad Hemmati, "Numerical stress analysis in resistance spot-welded nugget due to post-weld shear loading", Journal of Manufacturing Processes 27 (2o17) 284–29o.

[7] S. Aslanlar, A. Ogur, U. Ozsarac and E. Ilhan, "Welding time effect on mechanical properties of automotive sheets in electrical resistance spot welding", Journal of Materials and Design (2oo8) 1427-1431.

[8] Han, J. Orozco, J. E. Indacochea and C. H. Chen, "Resistance spot welding: A heat transfer study, Real and simulated welds were used to develop a model for predicting temperature distribution", Welding Research Supplement (1989) 343- 371.

[9] Majid Pouranvari, Pirooz Marashi, "Resistance Spot Welding of Unequal Thickness Low Carbon Steel Sheets", Advanced Materials Research (2o1o) 2o5- 1211.

[10] Xin Long, Sanjeev K. Khanna, "Numerical Simulation of Residual Stresses in a Spot Welded Joint", ASME International, 222 Vol. 125(2oo3)222-226