# ANALYSIS OF RESIDUAL STRESSES IN WELDED JOINTS PREPARED UNDER THE INFLUENCE OF MECHANICAL VIBRATION USING FEM

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***Abstract:*** *Welding is widely used for construction of many structures. Since welding is a process using locally given heat, residual stress is generated near the bead.In this paper, a new method for reduction of residual stress using harmonic vibrational load during welding is proposed.First, the welding of rolled steel for general structure for some excitation frequencies is examined. Specimens are welded along the groove on both sides.The distribution of the residual stress in the weld joint of SS400 grade high strength role steel was investigated by means of finite element method (FEM) using ANSYS software. Welding was carried out using gas shielded arc welding with a heat input of 750 J/mm. The FEM analysis on the weld joint reveals that there is a stress gradient around the fusion zone of weld joint. The stress gradient near the fusion zone is higher than any other location in the surrounding area. This is attributed as one of the significant reasons for the development of cold cracks at the fusion zone in the high strength steel. In order to avoid such welding cracks, the thermal stress in the weld joint has to be minimized by controlling the weld heat input. The finite element analysis of residual stresses in butt welding of two similar plates is performed with the ANSYS software. This analysis includes a finite element model for the thermal and mechanical welding simulation. It also includes a moving heat source, material deposit, temperature dependant material properties, metal plasticity and elasticity, transient heat transfer and mechanical analysis. The welding simulation was considered as a sequential coupled thermo-mechanical analysis and the element birth and death technique was employed for the simulation of filler metal deposition. The residual stress distribution and magnitude in the axial direction was obtained. A good agreement between the FEM and experimental results is obtained.*

## INTRODUCTION

Residual stresses are the stresses which remain within a structure when all external loads are removed. These residual stresses are generally formed near the bead during welding.Metallurgical welding joints are extensively used in the fabrication industry, including ships, offshore structures, steel bridges and pressure vessels. Among the merits of such welded structures include a high joint efficiency, water and air tightness, and low fabrication cost. However, residual stresses and distortions can occur near the weld bead due to localized heating by the welding process and subsequent rapid cooling. High residual stresses in regions near the weld may promote brittle fractures, fatigue, or stress corrosion cracking. Meanwhile, residual stresses in the base plate may reduce the buckling strength of the structure members. Therefore, welding residual stresses must be minimized to control them according to the respective requirements. Previous investigators have developed several methods, including heat treatment, hammering, preheating, vibration stress relieving, and weld sequencing to reduce the residual stresses attributed to welding. First, reduction of residual stress for some excitation frequencies is examined. Specimens are welded along the groove on both sides. Welding is completed one pass on each side. Material of specimen is rolled steel for general structure. In this case, some frequencies are selected.High strength rolled steels have a great tendency to crack during welding, the reasons being (a) the high hardenability, (b) presence of hydrogen and (c) the stresses present at the weld joint. The determination of critical residual stress that initiates crack during welding has been of interest for quite some time, followed by extensive research work.This investigation was carried out to study the residual stress in the weld joints of SS400 steel which is popularly used for high strength and wear resistance applications.

With the normally available instrumentation and measuring facilities, it is quite difficult to find out the instantaneous residual stress in the weld zone. Therefore, finite element method (using ANSYS software) was adopted in this work to find out the instantaneous distribution of residual stress.In many high temperature applications, it is necessary to join together components of same or different chemical, physical and mechanical characteristics. Undoubtedly, the joining of dissimilar metals is more challenging than that of similar metals due to differences in the properties of the base metals welded. Firstly, welded structures must meet the strength requirements and the probability of defect formation must be estimated and monitored. Moreover, residual stresses may exist in any welded structures. Welding residual stresses may be very complex and their distribution is very difficult to predict. Many techniques have been used for measuring residual stresses in metals including stress relaxation techniques, diffraction techniques, cracking techniques and techniques by use of stress sensitive properties. These techniques cannot obtain complete stress distribution and most of them ares costly and time consuming and some of them are destructive. In recent years, numerical analyses are established to solve the complex engineering problems and among them evaluation weld-induced residual stresses. The finite element method is the conventional means of calculating residual stresses. In this paper, the finite element analysis is used to perform welding simulation and to predict weld-induced residual stresses in butt welding of two similar carbon steel plates. This analysis includes moving heat source, material deposit, temperature dependant material properties, metal plasticity and elasticity, transient heat transfer and mechanical analysis.

**Literature Survey:**

**Tso-Liang Teng** was tried by accurately predicting welding residual stresses and developing an available welding sequence for a weld system are pertinent tasks since welding residual stress is inevitably produced in a welded structure. This study analyzes the thermo mechanical behavior and evaluates the residual stresses with various types of welding sequence in single-pass, multi-pass butt-welded plates and circular patch welds. This is achieved by performing thermal elasto-plastic analysis is using finite element techniques. Furthermore, this investigation provides an available welding sequence to enhance the fabrication process of welded structures.

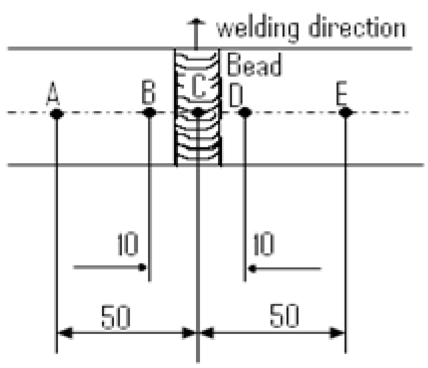
Manual Metal Arc Welding of carbon steel plates was studied by **DragiStamenkovic** and **IvanaVasov** The finite element analysis of residual stresses in butt welding of two similar plates is performed with the ANSYS software. This analysis includes a finite element model for the thermal and mechanical welding simulation. It also includes a moving heat source, material deposit, temperaturedependant material properties, metal plasticity and elasticity, transient heat transfer and mechanical analysis. The welding simulation was considered as a sequential coupled thermo-mechanical analysis and the element birth and death technique was employed for the simulation of filler metal deposition. The residual stress distribution and magnitude in the axial direction was obtained. A good agreement between the computation and experimental results is obtained.

**Shigeru Aoki** and **Tadashi Nishimura** done the investigation on Welded joints which are used for construction of many structures. Residual stress is induced near the bead caused by locally given heat. Tensile residual stress on the surface may reduce fatigue strength. In this paper, a new method for reduction of residual stress using vibration during welding is proposed. As vibrational load, random vibration, white noise and filtered white noise are used. Two thin plates are butt-welded. Residual stress is measured with a paralleled beam X-ray diffractometer with scintillation counter after removing quenched scale chemically. It is concluded that tensile residual stress near the bead is reduced by using random vibration during welding.

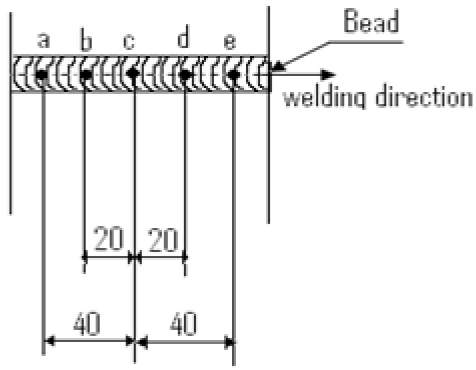
**Li Yajiang** and **Wangjuan** gives idea about the distribution of the residual stress in the weld joint of HQ130 grade high strength steel was investigated by means of finite element method (FEM) using ANSYS software. Welding was carried out using gas shielded arc welding with a heat input of 16 kJ/cm. The FEM analysis on the weld joint reveals that there is a stress gradient around the fusion zone of weld joint. The instantaneous residual stress on the weld surface goes up to 800 ~ 1000 MPa and it is 500 ~ 600 MPa, below the weld. The stress gradient near the fusion zone is higher than any other location in the surrounding area. This is attributed as one of the significant reasons for the development of cold cracks at the fusion zone in the high strength steel. In order to avoid such welding cracks, the thermal stress in the weld joint has to be minimized by controlling the weld heat input.

**Problem Definition:**

- Comparison of residual stresses of welded joints from literature with results from Finite Element method.
- When the excitation frequency is equal to the natural frequency of the specimen the residual stresses greatly reduced.
- Minimisation of residual stresses in welded joints prepared under the influence of mechanical vibration.
- Estimation of residual stresses nearer to weld bead in two directions (i.e. Longitudinal direction and on the beed.
- Estimation of residual stresses nearer to weld bead in two directions at variation of different frequencies.




**(a) On the center line of the specimen**




**(b) On the bead**

**Fig 3.1 Measuring locations of residual stress (mm)**

## IDEALIZATIONS

In this work, the process of welding is simulated by the FE method. The welding process computation can be split into two solution steps: thermal and mechanical analyses. First, the temperature and phase evolution are determined as a function of time in the thermal analysis. Then, the mechanical analysis employs the previous results to get displacements at nodes and stresses at integration points. Since the thermal field has a strong influence on the stress field with little inverse influence, a sequentially coupled analysis works very well. Moreover, a 3-D FE analysis is the optimum method of ascertaining the thermal cycle of welding. Therefore, in this paper, the welding process is simulated using a sequentially coupled 3-D thermo mechanical FE formulation based on the ANSYS code. For both the thermal and mechanical analyses, temperature dependent thermo-physical and mechanical properties of the materials are incorporated. To simplify the welding simulation, it is computationally efficient to perform thermal and mechanical analyses separately. It is assumed that changes in the mechanical state do not cause a change in the thermal state. But a change in the thermal state causes a change in the mechanical state. Firstly, the computation of the temperature history during welding and subsequent cooling is completed and this temperature field is applied to the mechanical model as a body force to perform the residual stress analysis. This work includes FE models for the thermal and mechanical welding simulation. To develop suitable welding numerical models it necessary to consider the process parameter (welding speed, number and sequence of passes, filling material supplying, etc.), the geometrical constraints, the material nonlinearities and all physical phenomena involved in welding. Therefore it is a great challenge to consider all factors at the same time; so generally the models include some approximations. This work deals with the following main assumptions and features about the thermal model:

(i) the displacements of the parts, during the welding, do not affect the thermal distribution of the parts themselves;
(ii) all the material properties are described till to the liquid phase of metal;
(iii) convection and radiation effects are considered;
(iv) the element birth and death procedure is used.

The thermal analysis is the first step and during this phase the distributions of the temperatures are calculated and saved for every load step. Here it is assumed that the thermal calculation at a given time is independent from the structural results obtained at a previous time according to the point (i): so the thermal and the mechanical analysis can be uncoupled.

## Finite Element Modeling Of the Specimens:

The welding process of a butt-weld joint of two SS400 rolled steel plates with the dimensions shown in Fig.1 was simulated. Due to high temperature and stress gradients near the weld, the finite element model has a relatively fine mesh in both sides of the weld center line. The eight-node brick elements with linear shape functions are used in meshing the model. To simulate the moving heat source it is necessary to model the heat source during each time increment. In this analysis the moving heat source is simplified by assuming the welding arc stayed at an element with a constant specific volume heat generation, and then moved to the next element at the end of the load step as the welding was finished. The element type SOLID70, which has a single degree of freedom, was used for the thermal analysis. For the structural analysis the element type SOLID45, with three translational degress of freedom at each node, was used. Fig.3 shows the heat effected zone (HEZ) after attaining equilibrium conditions.

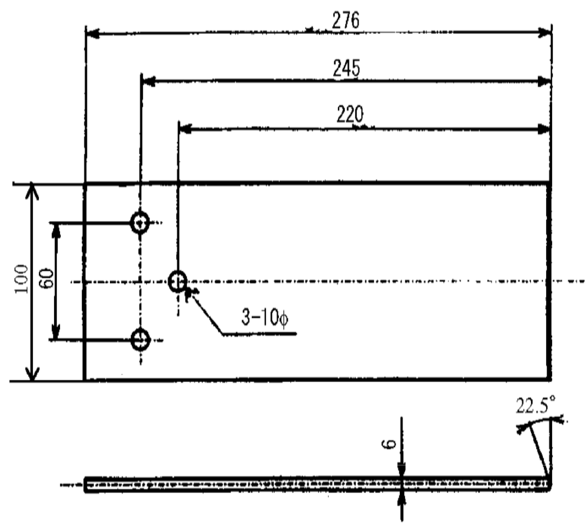



**Fig.1Geometry of the model used in the Analysis**

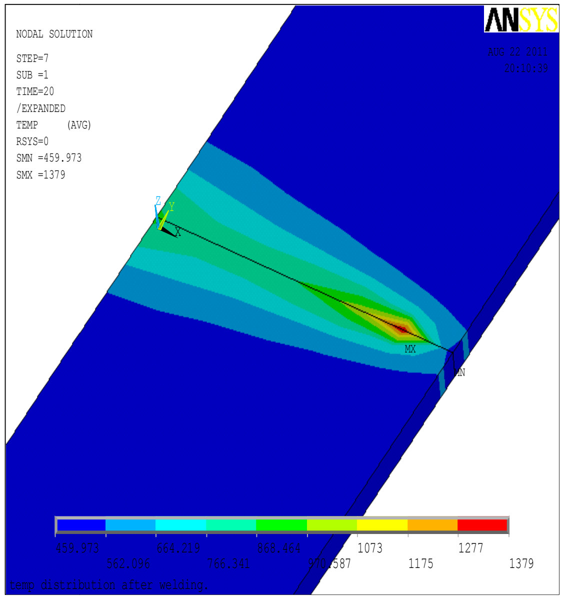



**Fig.2 TEMPERATURE DISTRIBUTION AFTER WELDING**

## RESULTS AND ANALYSIS

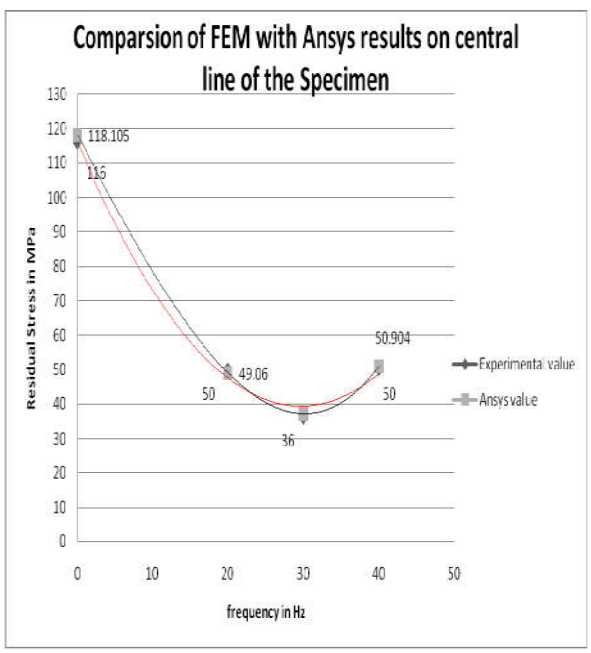



**Fig 5.33 Comparison of FEM with Ansys results on central line of the Specimen**

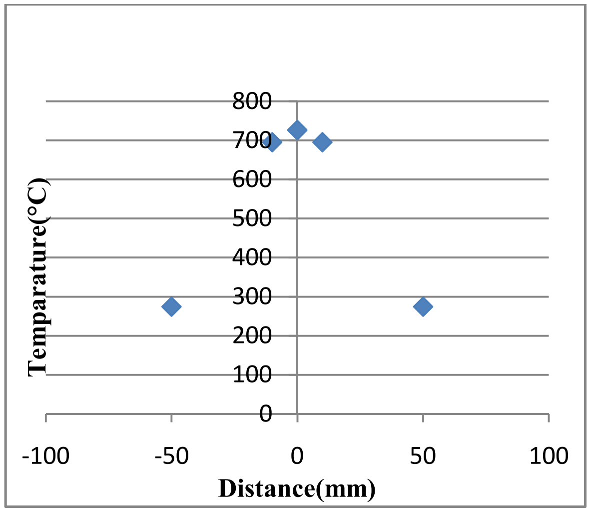



**Fig 5.34 Temperature acting on the centre line of the specimen**

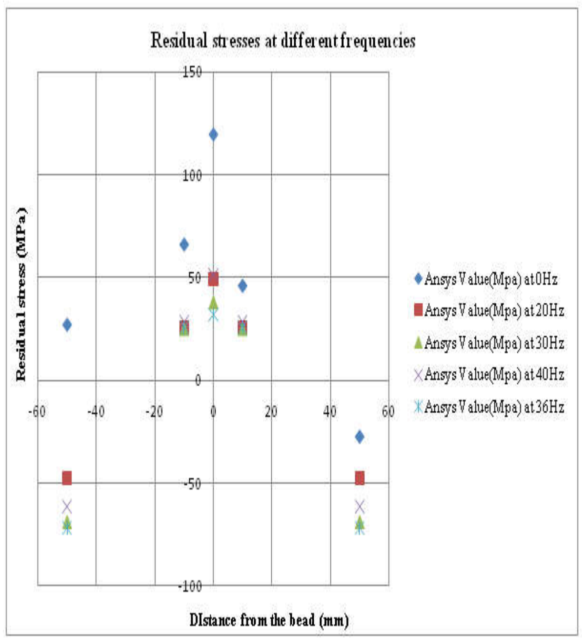
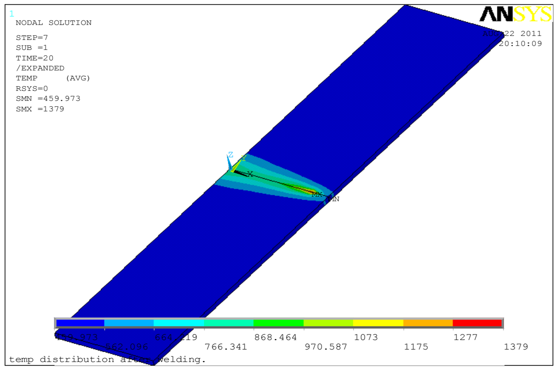



**Fig 5.36 Residual stresses at different frequencies**

From the graph 1 it is observed that the residual stresses are greatly reduced when the excitation frequency is equal to the natural frequency of the specimen.

It is also observed that from the graph 2 the temperature acting on the central line of the specimen is very high and is low at the end of the specimen.

Graph 3 shows the comparison of residual stresses at different frequencies i.e., 10Hz, 20Hz, 30Hz, 40Hz and 36Hz respectively.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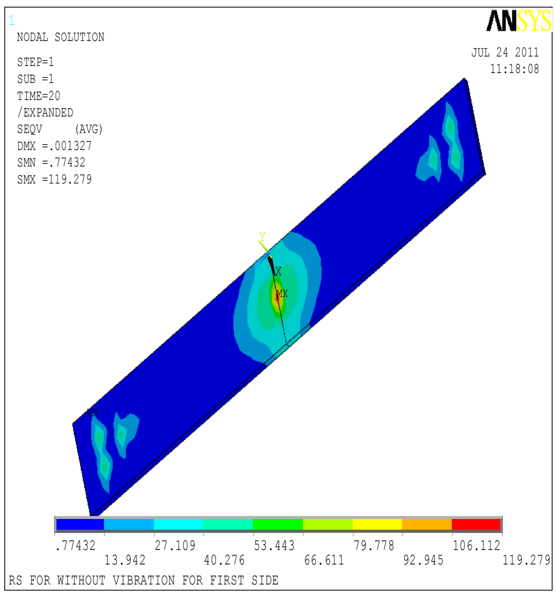
temp distribution after welding.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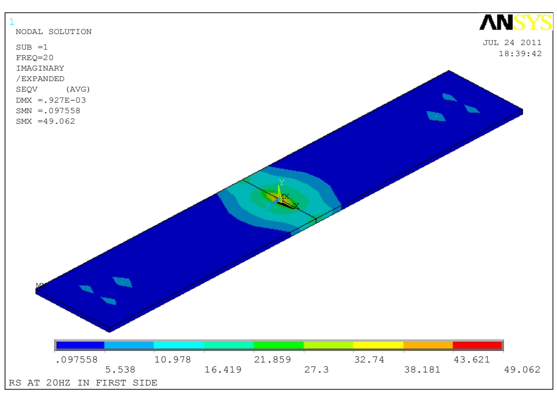
RS FOR WITHOUT VIBRATION FOR FIRST SIDE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## CONCLUSIONS

- In this work welding of FEM was performed for rolled steel SS400 by using thermal and structural analysis to find out the residual stresses.
- The residual stresses was found by using Finite Element software for rolled steel (SS400) is 119MPA.
- Natural frequency was found out by using model analysis at 20HZ,30HZ,36HZ and 40HZ.For these frequencies coupled-thermo mechanical analysis was performed and it is found residual stress greatly reduced at natural frequency of 36HZ.
- Second-side welding process was performed for which the residual stress slightly increased from 119MPa to 123MPa.
- The residual stress for different time periods after welding upto half an hour was calculated and found to greatly reduced to normal value i.e., 29.23 MPa.
- Hence residual stress can be greatly reduced by maintaining frequency of forced vibration nearer to the natural frequency of the specimen and increasing the welding speed.

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