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Finite Element Analysis of a Weld Assembly

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Abstract*— Deformations in the object undergoing welding are one of the foremost problems encountered in the welding industry. Thus it is often required to study the factors which affect the deformations produced during welding to avoid undue errors in the geometry. Present investigation aims to study the same during hard facing of a Stainless Steel (SS304) circular ring with that of COLMONOY 52SA. Finite Element Method (FEM) has been employed to do the transient thermal and structural analysis of the assembly. The Finite Element Analysis has been done on ANSYS 12.0 Workbench. A number of factors are liable to produce unwanted effects in the job during the welding operation. Aim of this paper is to study the effects of Welding Speed. The production of Deformations, Temperature Distribution, Thermal strains is studied by varying the speed of welding of the operation.

Keywords: **ANSYS, hard facing, Colmonoy, workbench, FEM.**

I. INTRODUCTION

To develop suitable welding numerical models, we must 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. The thermal analysis is the first step and during this phase the distributions of the temperatures are calculated and saved for every load step. We assume that the thermal calculation at a given time is independent from the structural results obtained at a previous time so the thermal and the mechanical analysis can be differentiated. The trend in current design and manufacturing practice is to reduce product weight through the use of weldable high strength materials in thin sections. However, use of thin section materials increases the susceptibility of a structure to distortions during manufacturing due to the welding residual stress. Distortion can also degrade the product performance, increase manufacturing cost due to the poor fit-up and the need for straightening, reduce structural integrity and cause excessive product rejection. Distortion can be eliminated by either increasing the rigidity of the structure through improved designs or by reducing the welding residual stress through process modifications.

II. REVIEW OF LITERATURE

"Finite Element Method: An Introduction"[1] by Uday S. Dixit introduces the numerical method for solving the differential or integral equations. It explains the formulation of a Linear Differential Equation for a plane stress problem, its approximation over the boundary conditions and its solution in the domain. **"Finite Element Analysis"**[2] by David Roylance, Department of Material Science and Engineering, Massachusetts Institute Of Technology draws attention to the problems of Finite Element Method in Computer Simulations. It studies the complete Matrix Analysis of Trusses, 2D Stress problems. **"Introduction to Finite Element Method"**[3] by Georges Cailletaud & Saber El Aram, wemesurf.net presents the slides in which it discusses the discretization of geometry into elements and their interpolations in order to arrive at a consensus. "**Fatigue Analysis of a Welded Assembly Using ANSYS Workbench Environment"**[4] by Klaus-Dieter Schoenborn. **"Multipurpose ANSYS FE procedure for welding processes simulation."** [5] by Andrea Capriccioli & Paulo Frosi, discusses the ANSYS FE procedures and 3D models for both thermal and structural analysis of Welds. **"Video Lectures"**[6] by Dr. R. Krishnakumar, Department of Mechanical Engineering, IIT Madras organized by NPTEL.

III. MATERIAL PROPERTIES AND METHOD

COLMONOY No. 52SA comprises a nickel-base alloy recommended for hard facing parts to resist wear, corrosion, heat and galling. Deposits which have only moderate hardness (Rockwell C 45-50) may be machined with carbide tooling. Also, deposits have fairly good ductility and impact strength. Colmonoy No. 52SA is supplied as an atomized powder for application.

Table 1: Composition

Element	%age
Carbon	0.65
Chromium	11.50
Iron	4.25
Silicon	3.75
Boron	2.50
Nickel	Remainder

Table 2: Temp. V/s Hardness

Room and Elevated Temperature Hardness							
Test Temperature, °F	70	600	800	900	1000	1100	1200
Rockwell C Hardness	47	46	45	43	41	40	38

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Table 3: Room Temperature Mechanical Properties

Compressive Strength, psi (avg.)	275000
Tensile Strength, psi (avg.)	60000
Rockwell C Hardness	45-50
Charpy Impact, *ft-lb (avg.)	3.0

***Special specimens having ½ inch radius notch and polished ti remove all possibility f stress concentrations (Reference: Metal Progress, May 1959, "Impact testing for Calculating Tool Steels")

STAINLESS STEEL (SS 304)

Table 4: Composition range for 304 stainless steel

Grade		C	Mn	Si	P	S	Cr	Ni	N
304	Min	-	-	-	-	-	18	8	-
	Max	0.08	2	0.75	0.045	0.03	20	10.5	0.1

Hard facing is a metalworking process where harder or tougher material is applied to a base metal. It is welded to the base material, and generally takes the form of specialized electrodes for arc welding or filler rod for oxyacetylene and TIG welding. Powder metal alloys are used in (PTA) also called Powder plasma welding system and Thermal spray processes like HVOF, Plasma spray, Fuse and spray etc.

Hard facing may be applied to a new part during production to increase its wear resistance, or it may be used to restore a worn-down surface. Hard facing by arc welding is a surfacing operation to extend the service life of industrial components, pre-emptively on new components, or as part of a maintenance program. The result of significant savings in machine down time and production costs has meant that this process has been adopted across many industries such as Steel, Cement, Mining, Petro chemical, Power, Sugar cane and Food. Extensive work in research has resulted in the development of a wide range of alloys and welding procedures. The optimum alloy selection is made considering the component service conditions and feedback of the service performance.

IV. RESULTS AND DISCUSSION

Before proceeding with the simulation, let us recall the problem statement once again. The aim of this work is to study the Thermal Stresses induced in the job, temperature distribution, distortions occurred and to identify the possible causes of the failure and suggest the appropriate method to analyze this problem during the hard facing of a Stainless Steel (SS 304) component by Colmonoy (52SA).

The parameters that we will be concentrating on are:

a) Speed of Welding

b) Support of the job i.e. the Degrees of Freedom.

Calculation: Mean Radius of the base plate: 1055mm.
Circumference of the base plate: 2*π*r = 6628.76mm.
Prescribed speed or Step End Time: 74 mm/min or 5374.4 sec.

CASE I

Step End Time: 5374.4 sec.
Constraint: Base of the Job.

a) **Directional Deformation**

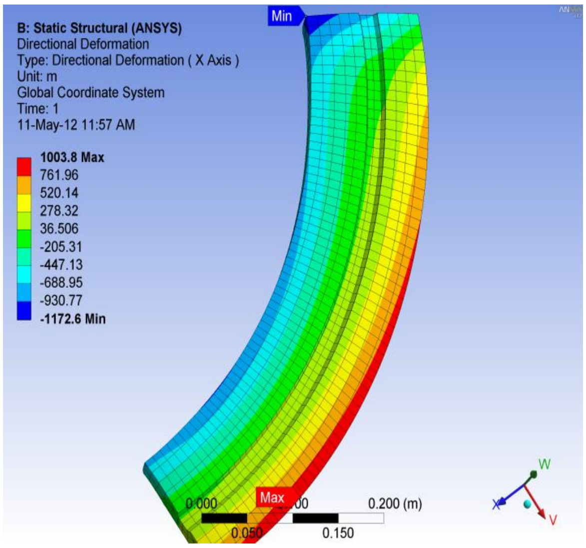

Fig: 1
Maximum deformation: 0.1003 mm
Minimum deformation: -0.1172 mm

b) **Temperature Distribution**

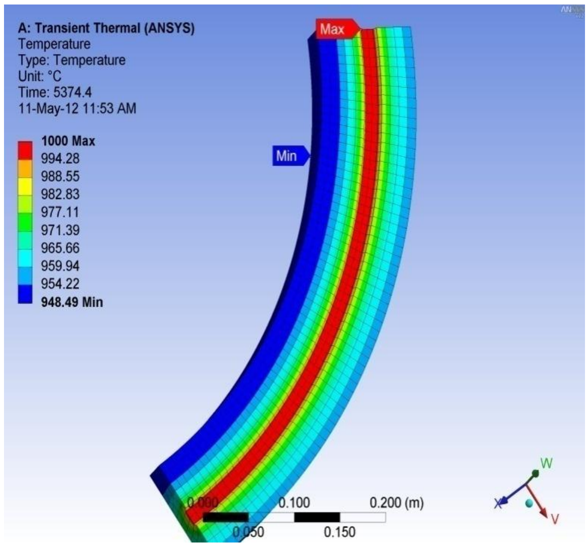

Fig:2
Maximum Temperature: 1000°C
Minimum Temperature: 948.49°C

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c) **Total Deformation**

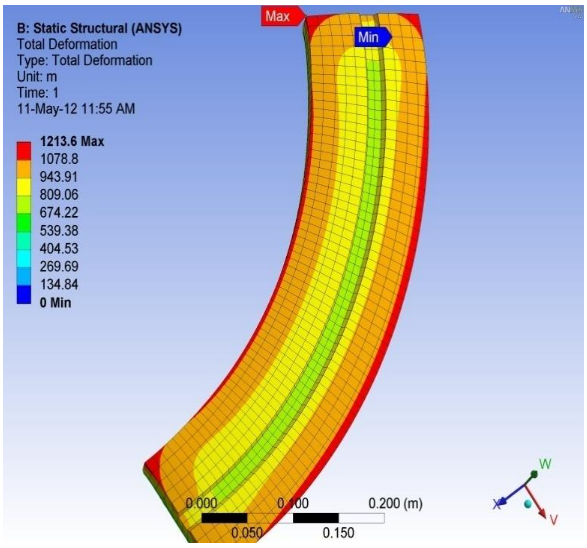

Fig: 3
Maximum Deformation: 0.1213 mm
Minimum Deformation: 0 mm

d) **Von Mises Elastic Strain**

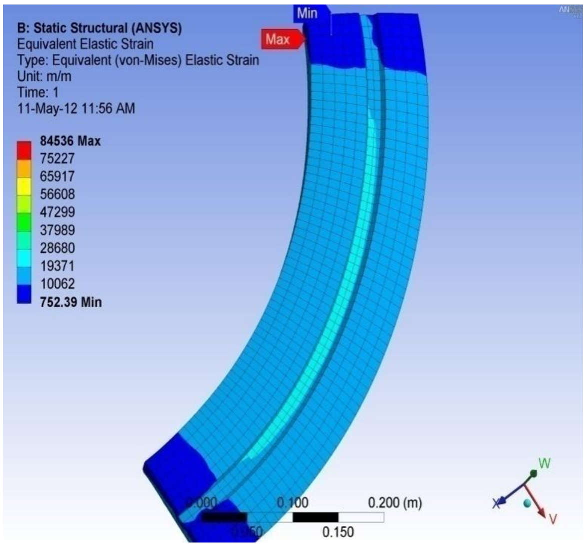

Fig:4
Maximum Strain: 0.84536
Minimum Strain: 0.07523

CASE II

The welding speed has been reduced by 25% thereby increasing the Step End Time.
Step End Time: 6717 sec.
Constraint: Base

a) Directional Deformation

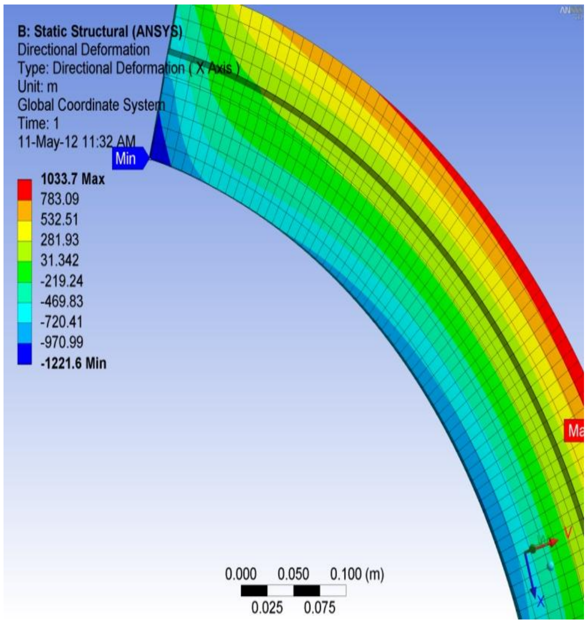

Fig:5
Maximum Deformation: 0.1033 mm
Minimum Deformation: -0.1221 mm

b) Temperature Distribution

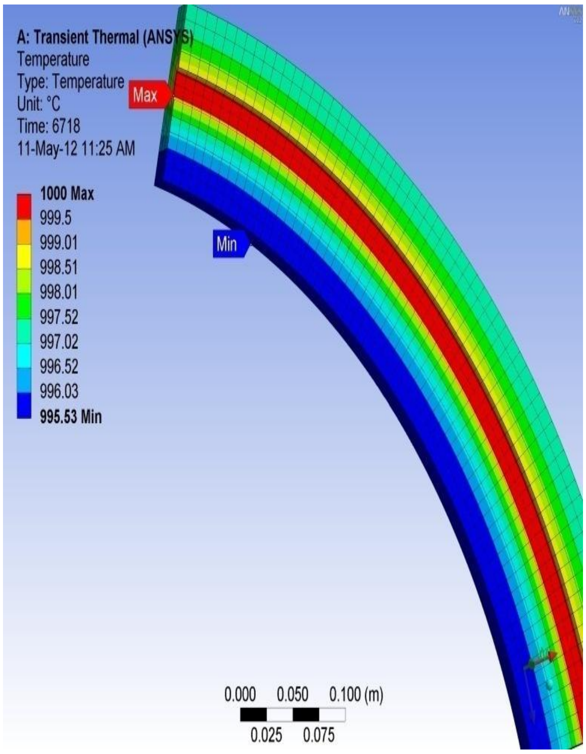

Fig: 6
Maximum Temperature: 1000°C
Minimum Temperature: 995.42°C

c) Total deformation

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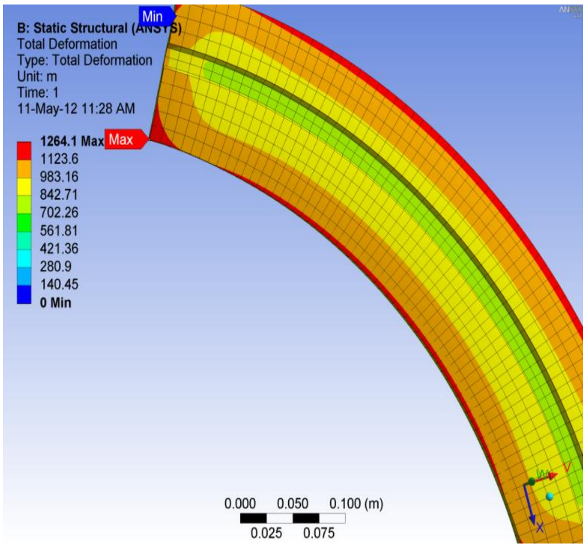

Fig: 7
Maximum Deformation: 0.1264 mm
Minimum Deformation: 0 mm

d) Von Mises Elastic Strain

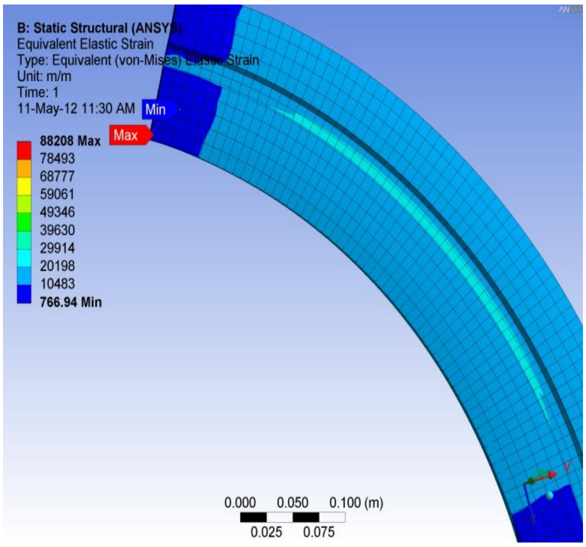

Fig:8
Maximum Strain: 0.88208
Minimum Strain: 0.07669

CASE III

Welding speed has been increased by 25% of the prescribed speed thereby decreasing the Step End Time.

Step End Time: 4030.8 sec.
Constraint: Base

a) Directional Deformation

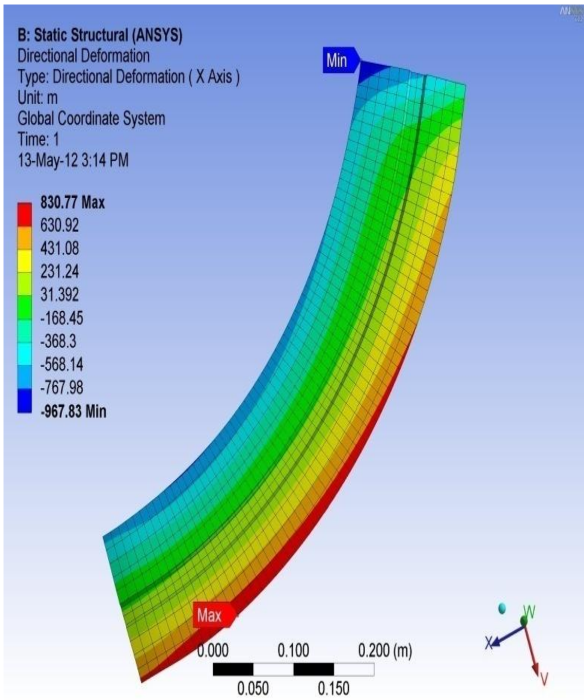

Fig:9
Maximum Deformation: +0.0830 mm
Minimum Deformation: -0.0967 mm

b) Temperature Distribution

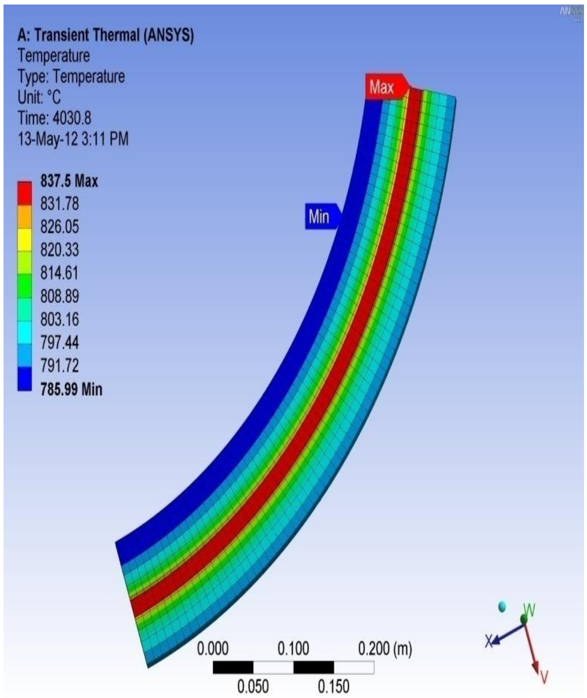

Fig:10
Maximum Temperature: 837.5°C
Minimum Temperature: 785.99°C

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c) Total Deformation

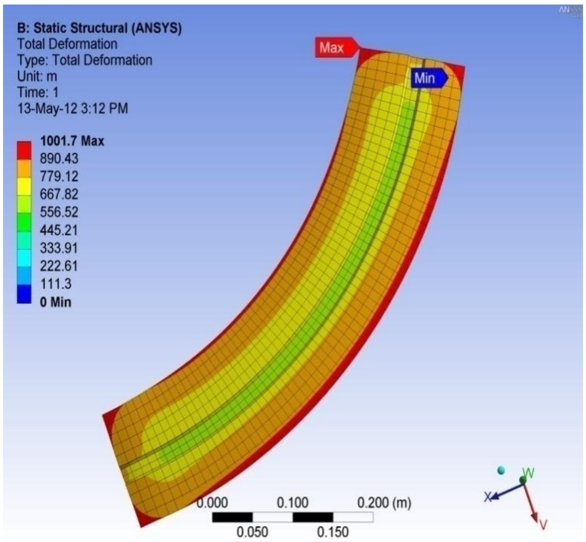

Fig:11

Maximum Deformation: 0.1001 mm
Minimum deformation: 0 m

d) Von Mises Elastic Strain

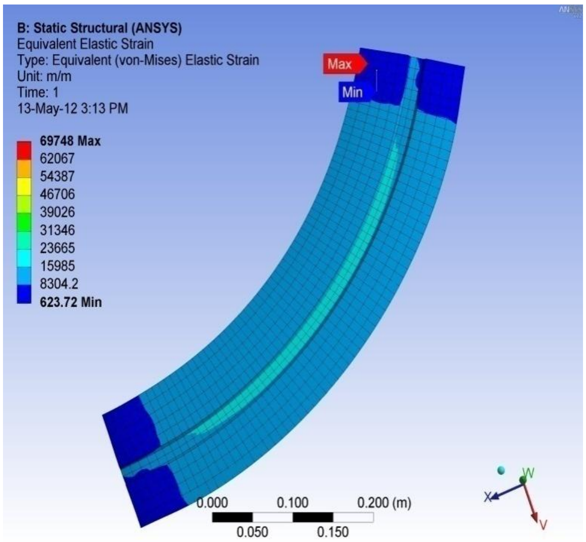

Fig: 12

Maximum Strain: 0.6978
Minimum Strain: 0.0623

<u>CASE IV</u>

Prescribed Welding speed has been kept, constraints has been changed.

Step End Time: 5374.4 sec.
Constraint: Base and Side Walls

a) <u>Directional Deformation</u>

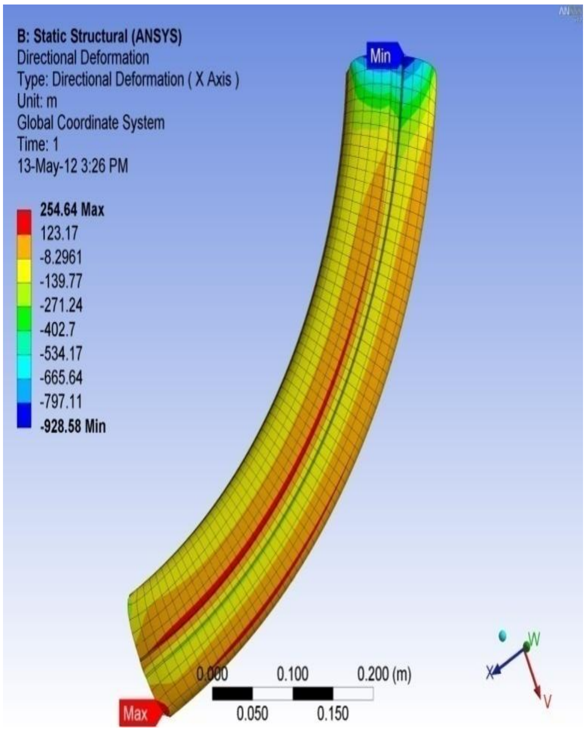

Fig:13

Maximum Deformation: +0.0254 mm
Minimum Deformation: -0.0928 mm

b) Temperature Distribution

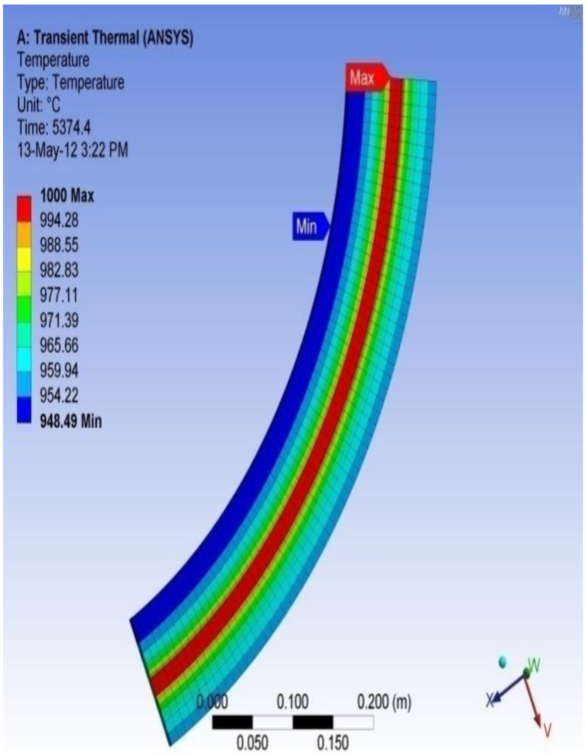

Fig:14

Maximum Temperature: 1000°C
Minimum Temperature: 948.49°C

c) **Total Deformation**

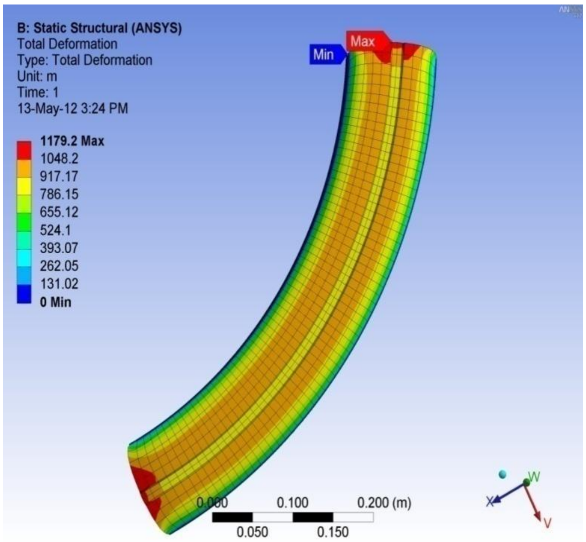

Fig: 15

Maximum Deformation: 0.1179 mm

Minimum Deformation: 0 mm

d) **Von Mises Strain**

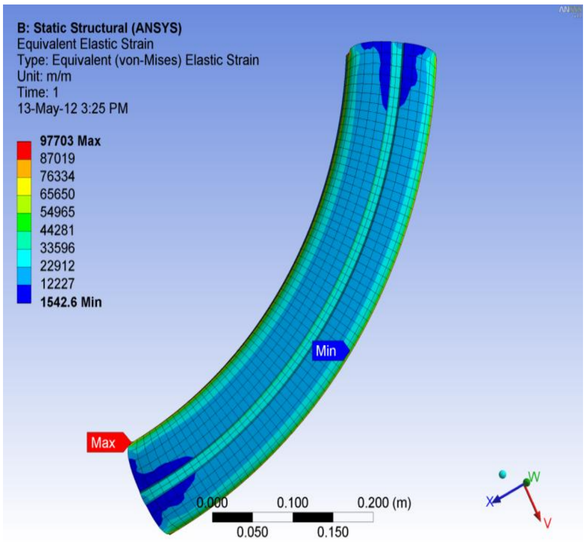

Fig: 16

Maximum Strain: 0.9770

Minimum Strain: 0.0154

V. SUMMARY

Table 5: Summary

	Step End Time (sec.)	Directional Deformation (max.), mm	Temperature Distribution (max.), °C	Total Deformation (max.), mm	Von Mises Strain (max.) mm/mm
CASE I	5374.4	0.1003	1000	0.1213	0.8453
CASE II	6717	0.1033	1000	0.1264	0.8820
CASE III	4030.8	0.0830	837.5	0.1001	0.6974
CASE IV	5374.4	0.0254	1000	0.1179	0.9770

VI. CONCLUSION

Deformation of the job during welding, pose a serious problem in the industry and there can be a number of factors which affect it. As studied here, welding speed plays an important role in deciding the amount of deformation in the job. It has been found that on decreasing the welding speed the deformations increase while increase in the speed, decrease the deformations. Although the deformations reduce on increasing the speed of welding but the quality of weld cannot be commented upon as there are a number of factors which are to be considered for producing a perfect weld.

VII. FUTURE SCOPE

In order to study the deformations, stress and temperature distributions during welding, a number of other factors can also be studied upon. The number of cases can be increased so that much clearer deformation v/s speed variation can be studied. Depending upon the geometry of the job various arrangements of applying constraints can be studied.

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[4] "Fatigue Analysis of a Welded Assembly Using ANSYS Workbench Environment" by Klaus-Dieter Schoenborn.

[5] "Multipurpose ANSYS FE procedure for welding processes simulation." by Andrea Capriccioli & Paulo Frosi.

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