Cooling analysis of self Activating Bi-Metallic Valve using Thermo –Structural Coupled FEA

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ABSTRACT: *To replace electronically actuated valves or to provide second layer of safety in case of electronic malfunction a totally mechanically actuated valve & warning system is designed. The process for which valve optimization is carried out is the process of nitrousoxide generation from ammonium nitrate. The main challenge in the process was maintaining temperatures below 200˚C as above this temp ammonium nitrate becomes explosive & safety risks are involved. The secondary objective was to maintain this temperature above 170˚C as below this temperature reaction does not proceed. All these objectives are fulfilled by employing a bimetallic valve .The primary purpose of the self actuation is achieved by selecting proper dimensions of the valve & designing warning system in which desirable deflection of the bimetallic strip is achieved. But main problem arises during cooling as there is the possibility of the bimetallic strip of may lead to high crushing stresses. The main requirement while carrying out cooling is that the bimetallic strip should again rest on the flow casing as previous i.e. it should close valve again while cooling & not crush on the flow casing or deflects beyond flow casing.*

KEYWORDS: *Thermo-Structural coupled FEA, Non linear FEA, Bi-metallic Valve, Warning system, Material Non linearity,Defining contact, Boundary Conditions, Meshing.*

I. INTRODUCTION

The primary chemical reaction for which the valve is required is the commercial production of nitrous oxide by heating of ammonium nitrate. The heating is carried out using superheated steam

NH_4NO_3 (solid) → 2 H_2O (gas) + N_2O (gas).

The chemical reaction is subjected to following thermal considerations.

a. Below 170ºC : No reaction
b. 170ºC to 200ºC : Active reaction zone
c. 200ºC to 240ºC : Warning zone
d. Above 240ºC : Possible explosion.

Based on above thermal considerations, the following design requirements are obtained for the system

1. The system should remain closed below 200ºC to maintain steam in the vessel
2. 200ºC should trigger opening of the valve (with a warning by a warning system)
3. System should close back when temperature falls to 200ºC.

When the valve opens, the super heated steam will escape, this will result in a pressure drop, which will translate into reduction of temperature of the steam.

Based on these requirements a bimetallic valve is designed in which purpose of self actuation above 200ºC is achieved.

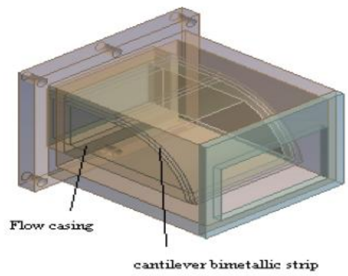


Fig 1: Thermal Bimetallic safety valve

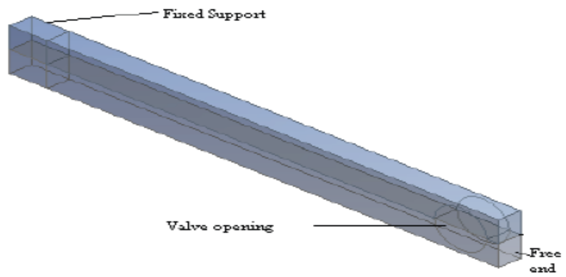


Figure2: Warning System

Figure 1& figure 2 shows thermal bimetallic control valve & warning system in which purpose of self actuation is achieved, But cooling analysis s also foremost important as when no separation contact was defined between substrate & flow casing the flow casing constrained the free expansion of the strip which may lead to high crushing stresses. Hence further cooling analysis is required to be carried out to ensure satisfactory closing of the thermal flow control valve.

II. Background Theory

A self activating bimetallic valve design is proposed on basis of thermo structural coupled analysis during opening of the valve i.e. heating analysis. At that time inside temperature of the valve is high than the outside temperature. But once the valve is opened there is sudden reduction in pressure inside the valve &now inside temperature of the valve is reduced to atmospheric temperature & as superheated stream is escaped outside temperature gets increased. at this condition it is expected that the bimetallic strip which gets open during heating should close back during cooling, but there may be the possibility of high crushing streses,which is not required at all as it may lead to war out of strip as well as flow casing. Hence we carry out thermo structural analysis again by changing temperature conditions for various descritized conditions.& comparing results we can conclude whether We can use self activating bimetallic valve or not .A finite element analysis is carried out to do the analysis.

III. FINITE ELEMENT ANALYSIS

Key characteristics of the finite element analysis (FEA) performed in ANSYS mechanical workbench are:

1. Type: Thermo – Structural coupled FEA (refer with: Fig. 5)
2. Elements: Tetra ,Quad , 2nd Order hexahedron elements (refer with: Fig. 6, Fig. 7)
3. Non linearity: Material non linearity (refer with: Fig. 8, Fig. 9),

Contact non linearity (refer with: Fig. 10, Fig. 11),

Geometric non linearity (change in response due to large deformations)

Flow chart of the thermo structural coupled analysis is as shown in the figure. Firstly we have to give various inputs to carry out thermal analysis in that it include material input i.e. material conductivity ,thermal coefficient of expansion of material etc as well as thermal boundary conditions in terms of temperature which results in temperature distribution. After temperature get distributed we have to apply thermal load which is going to act on bimetallic valve, at the same time we have to consider structural inputs like support or fixed face of valve various material in puts in case of structural analysis like Young's Modulus of elasticity etc.

After feeding all this input data meshing of the valve s carried out & by solving the analysis deformation ,von mises stresses are observed

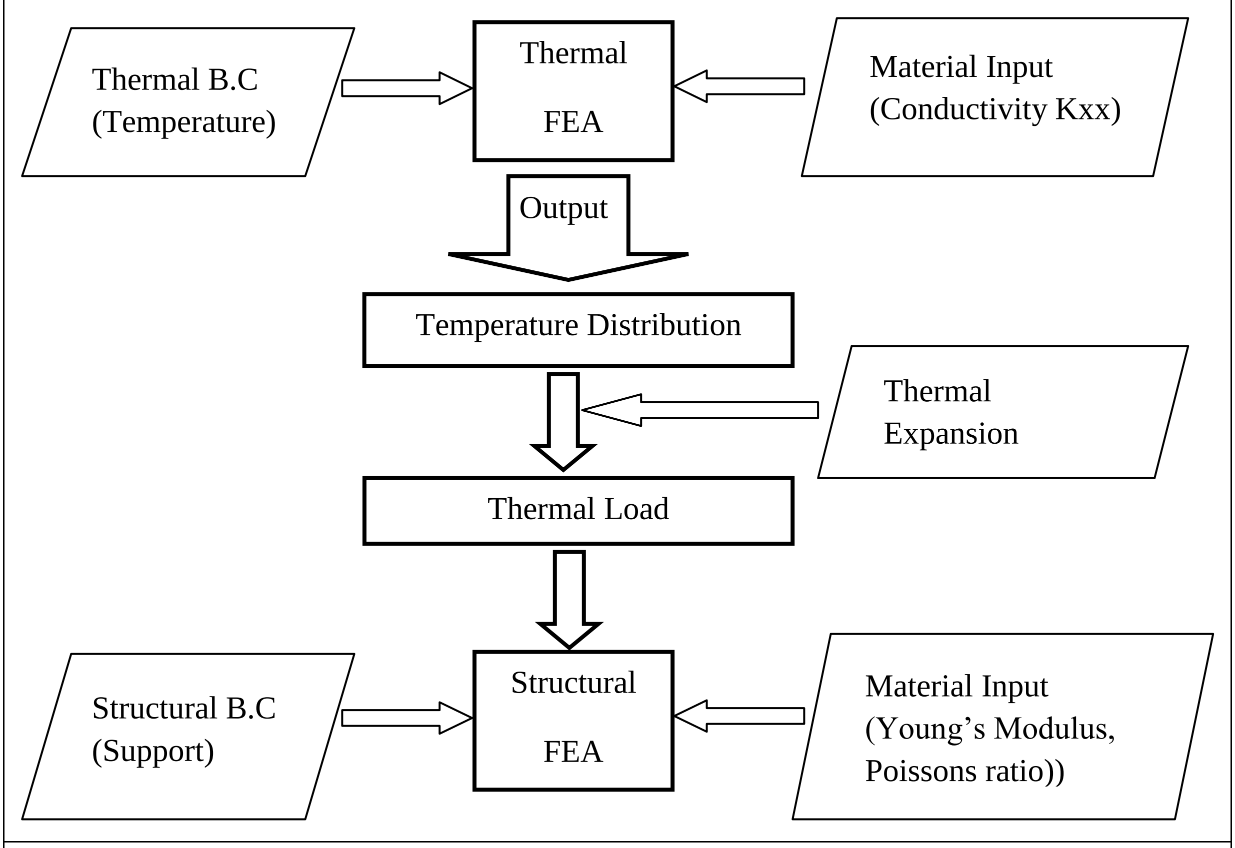


Fig 3: Flow of Thermo – Structural Coupled FEA.

3.1 Meshing : The system of interest is first descretized into elements; in this case ,the elements are tetrahedraon. The corner vertices of these tetrahedron are called nodes and are the arbitrarily point where the value of interest is solved. The system is descritized by using various elements sizes & results are analysed.

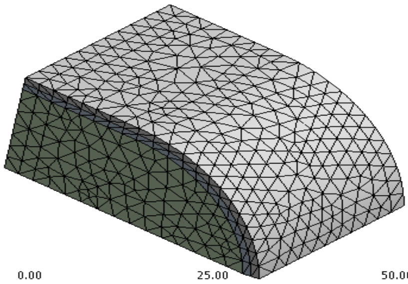


Fig 4.:Tetrahedron meshing (Default)

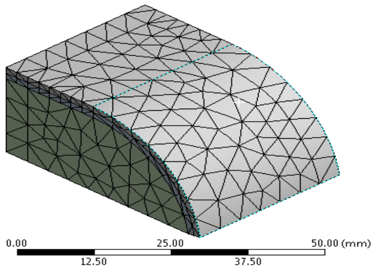


Fig 5 : Tetrahedron meshing (Ele. size-5)

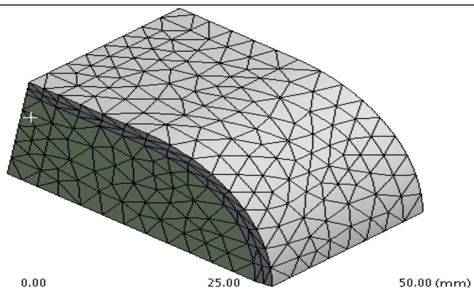


Fig6 Tetrahedraon meshing (Ele.size-4)

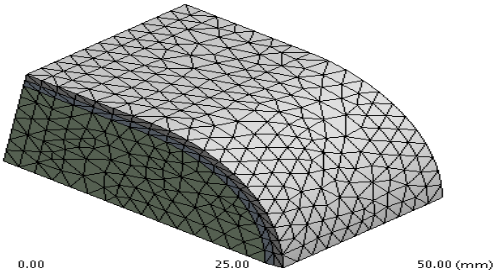


Fig.7 Tetrahedraon meshing (Ele.size-3)

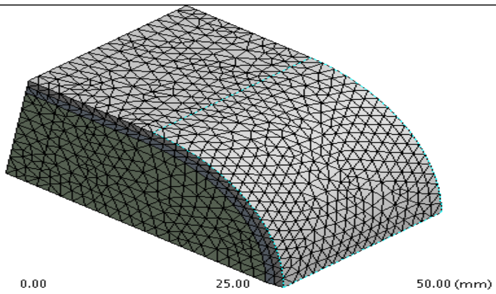


Fig.8 Tetrahedraon meshing (Ele.size-2)

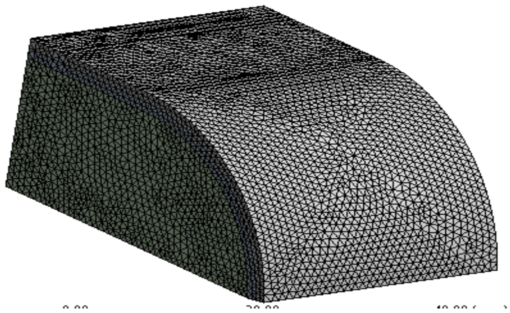


Fig.9 Tetrahedraon meshing (Ele.size-1)

Hex Dominent Meshing

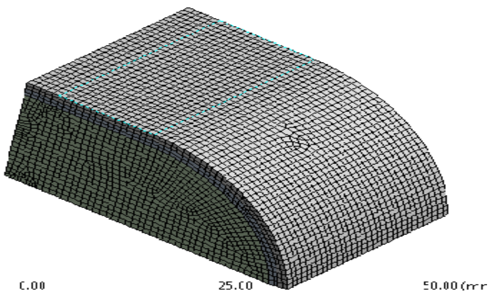


Fig 9 All Quad meshing

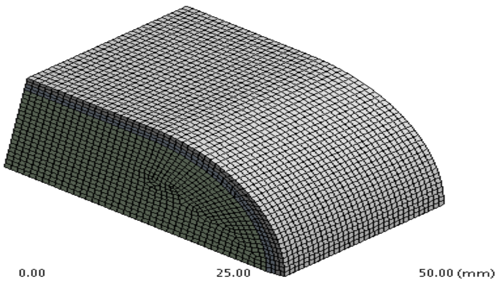


Fig10 All Quad/tri meshing(1mm)

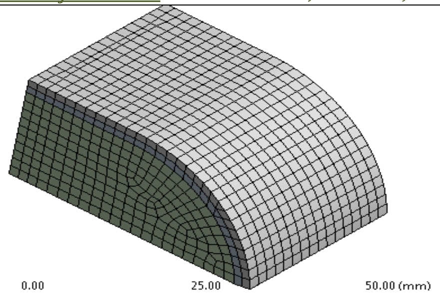


Fig 11All Quad/tri meshing(2mm)

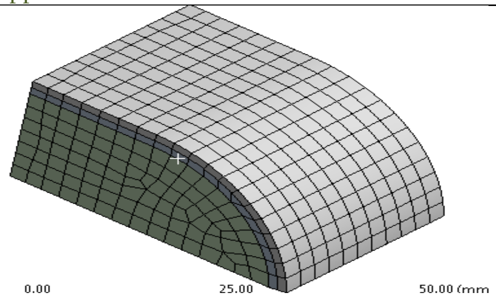


Fig12 All Quad/tri meshing(3mm)

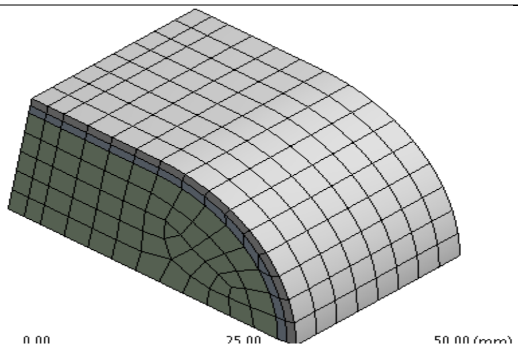


Fig13 All Quad/tri meshing(4mm)

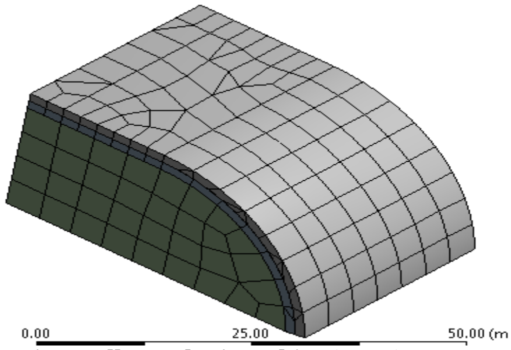


Fig14 All Quad/tri meshing(5mm)

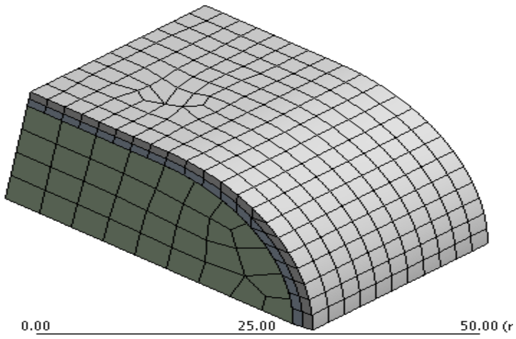
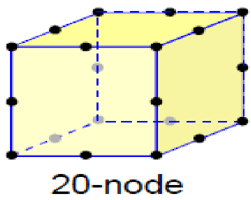


Fig15 All Quad/tri meshing(Default)



By meshing with various elements & element size & verifying results we come to conclusion that 2nd order hexahedron meshing give us accurate results. Hence we choose 2nd order hexahedron meshing.

3.2 Material Non linearity: - Non linear material properties such as conductivity K,Young's modulus of elasticity E of the film meal (CZ-1400-E) and the substrate metal (IN-4082-SP)as shown in graphs are used in analysis.

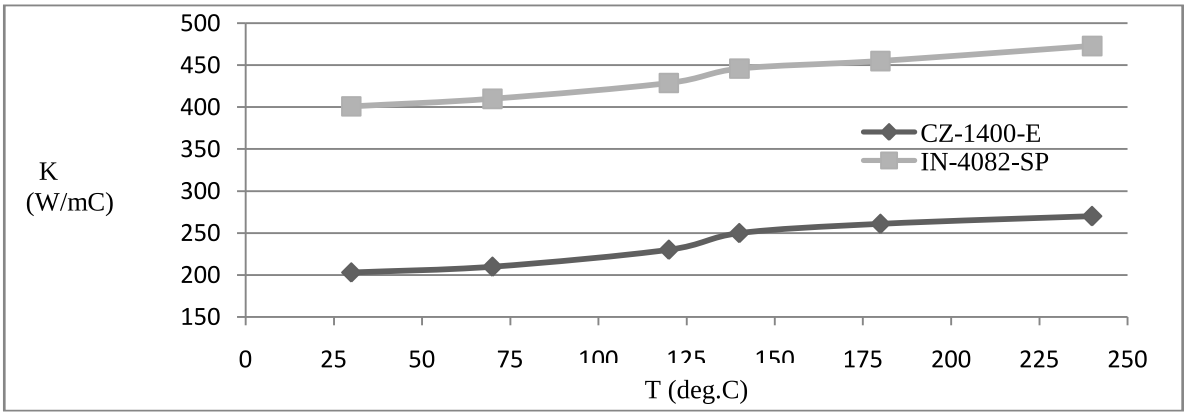


Fig 16 Conductivity as function of temperature T

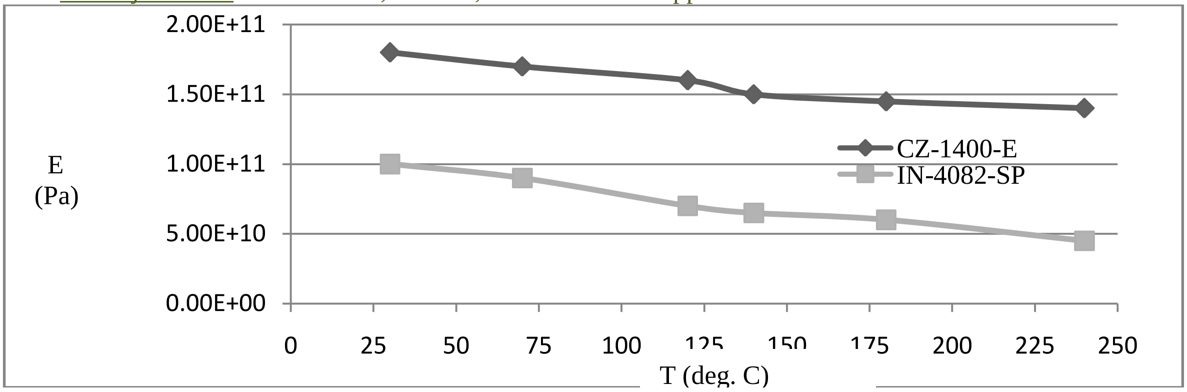


Fig 17 Modulus of Elasticity as function of T

Similarly poisons ratio and non linear thermal coefficient of expansion α of the film metal (CZ-1400-E) & the substrate metal (IN-4082-SP) as a function of temperature are used.

3.3 Defining contacts : Contact between film & substrate metal is defined as bonded contact. Accuracy achieved using multiple sub steps.

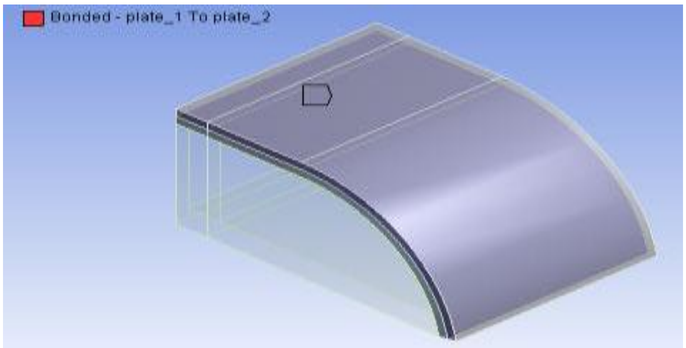


Fig 18 Bonded contact

While carrying out opening of the valve one of the contact region is no separation contact, which is required to be suppressed while carrying out cooling analysis.

3.4 Boundary Conditions: Thermal boundary condition for the analysis of the thermal safety valve and the warning system are applied as shown

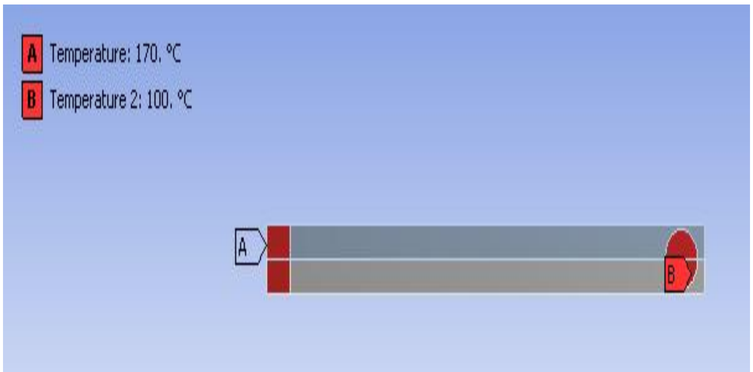


Fig 19 Boundary conditions of the warning system

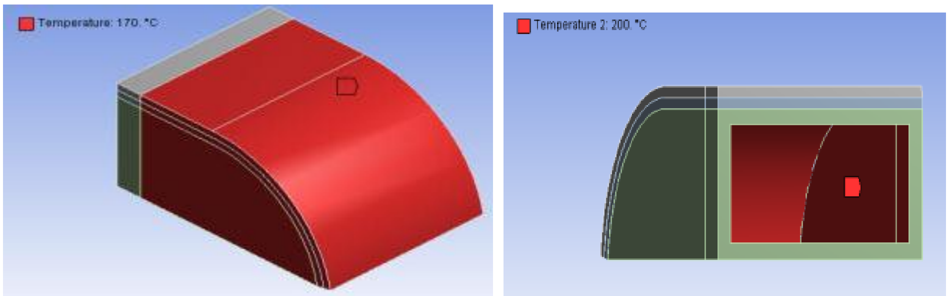


Fig 20 Boundary conditions for thermal safety valve

IV. RESULTS

Deformation and Von-Mises stresses were observed after performing the simulations. The main focus of analysis is on closing position of the bi-metallic valve with respect to change in temperature of superheated steam inside the process vessel.

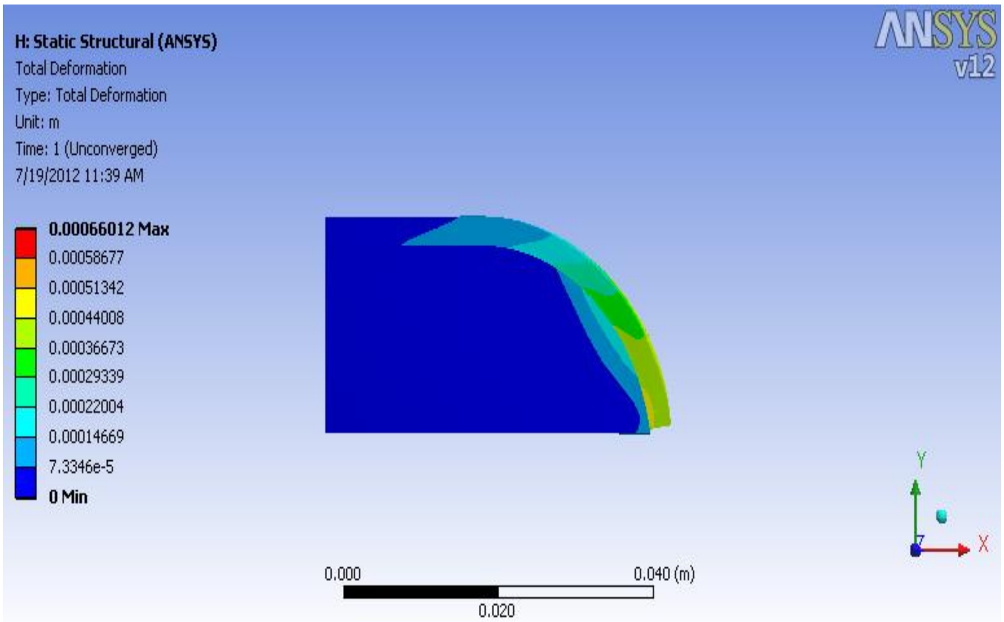


Figure 20.1: Deflection of Curved Bimetallic Strip in No Reaction Zone (No Separation).

Above results are of cooling analysis when no separation contact was defined between substrate and flow casing. The flow casing constrained the free expansion of the strip which will leads to high crushing stresses as shown in below figure

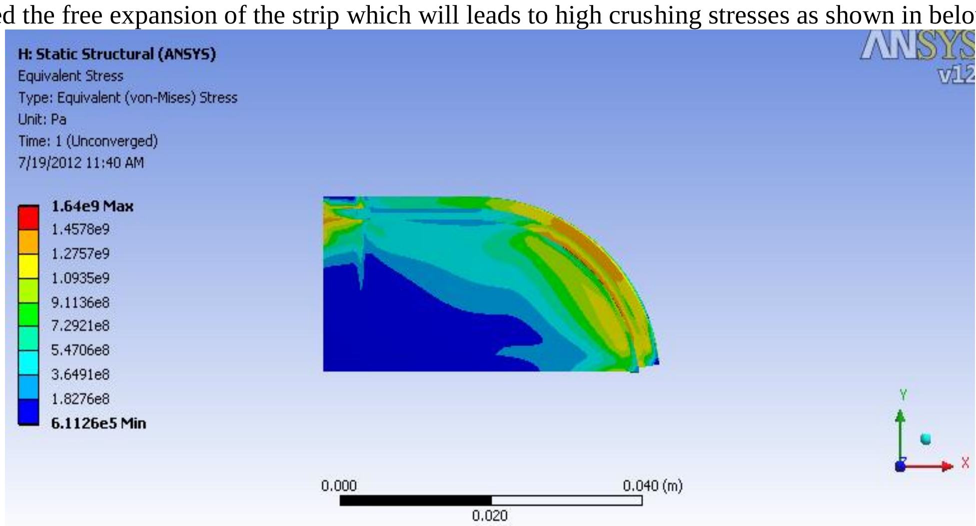


Figure 20.2 : Von Mises Stresses in Curved Bimetallic Strip in No Reaction Zone (No Separation).

The crushing stresses are coming high up to 1.49e9 Pa while doing cooling analysis The flow casing constrained the free expansion of the strip & closes the valve,which is our desired condition

V. CONCLUSION

Usage of non linear FEA alters the results significantly, hence for realistic determination of performance non linear FEA is recommended.Using a cantilever arrangement for a warning system, under which both the materials are exposed to the heat, is more effective in giving a range bound mechanism.

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