# Stress Distribution along Outer Most Fiber in Semi Circular Curved Beam Subjected To Out-Of-Plane Load for Different Cross Sections

**Rakshith N[1], Karthik Kumar M[2], Rohith S[3], Ramanuja C M[4]**

[1,2,3,4] *Assistant Professor, Department of Mechanical Engg, ATME College of engineering, MYSURU, Karnataka, India*

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**Abstract** - *Curved beams are used as machine or structural members in many applications. Based on application of load they can be classified into two categories. Curved beams subjected to In-Plane loads are more familiar and are used for crane hooks, Clamp's etc. The other categories of curved beams are the ones that are subjected to out-of-plane loads. They find applications in automobile universal joints, raider arms and many civil structures etc. The results of this research on semicircular curved beam subjected to out-of-plane loads have revealed some interesting results. For semicircular curved beams subjected to out-of-plane loads, it is shown that every section is subjected to a combination of transverse shear force, bending moment and twisting moment. By using ANSYS tool it is shown that Maximum principal stress occurs at section other than at fixed end. Moreover it is observed that fixed end of this curved beam is subjected to a state of pure shear. Since crack initiates from surface, in order to study and suggest best cross section semicircular curved beam for out of plane load condition stress distribution over outer surface Square, circular and elliptical cross sections are studied.*

**Key Words:** Out of Plane Load, Semi-circular, Torsion, Curve Beam.

## 1. INTRODUCTION

Curved beams are the parts of machine members found in C clamps, crane hooks, frames of presses, punching machines, planers automobile components etc. In straight beams the neutral axis of the section coincides with its centroidal axis and the stress distribution in the beam is linear. But in the case of curved beams the neutral axis of is shifted towards the centre of curvature of the beam causing a non-linear distribution of stress. Rakshith et al.[1]derived an expression for semi-circular curved beam subjected to out of plane load. . Rakshith et al.[2] validated the expression for semi-circular curved beam subjected to out of plane load. Rakshith et al.[3] validated the expression for semi-circular curved beam subjected to out of plane load by experimental Method. Fonseca et al. [4] studied curved pipes subjected to in-plane loads, Stefano Lenci et al.[5] a 3-d mechanical model of curved beam is analysed by them, Saffari et al.[6] sudies by using circular arc element based on trignometric functions foe in-plane loads, Clive et al.7] investigated end loaded shallow curved beams of in-plane load type, Öz et al.[8] analysed in plane vibrations of curved beam having open crack, Aimin Yu et al.[9] made a work on naturally twisted curved beams of thin walled sections that of inplane loads.

Stress analysis of curved beams subjected to out-of-plane loads also is important as such beams are used in many machine and structural applications. This paper attempts to analyse the stresses induced in such a curved beam by using analysis tool Ansys.

Some of the assumptions made to derive expression of principle stress for curved beam subjected to Out-Of-Plane load case are as follows,

- The radius of curvature is assumed much larger than the section radius.
- The material is assumed to be linearly elastic.
- The beam is assumed to be geometrically planar, i.e., the un-deformed axis of the beam is assumed to be a circle lying in the plane of the beam.
- The cross section is assumed to be constant and with the same orientation with respect to the plane of the beam, so that there is no initial torsion.

## 2. EXPRESSION FOR OUT-OF-PLANE LOAD CONDITION

A semi-circular curved beam of circular cross section lying in the plane of paper as shown in figure 1(a). The beam is fixed at one end 'A' and an out-of-plane load 'F' is applied at the other end 'B'[1].

F = Applied load in N

$R_o$ = Outer radius of beam in mm.

$R_m$ = Mean radius of beam in mm.

$R_i$ =Inner radius of beam in mm.

α = angle made by the section X-X w.r.t loading line.

d = diameter at any section X-X .

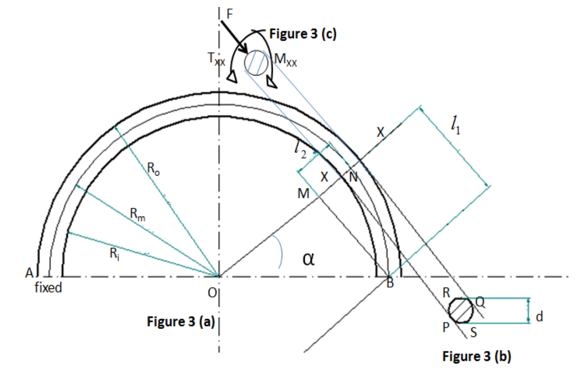


**Figure 1(a):** Detailed view of semi circular beam.

**Figure 1(b):** Cross section of beam at X-X with Extreme points indicated.

**Figure 1(c):** Loads and moments acting on cross section X-X

Let X-X is a plane passing through the centre of curvature and perpendicular to cross section of the beam. Let the angle made by this plane X-X with respect to the free end be α as shown in fig 1(b). The effect of Out-Of-Plane load F at the section is to cause i). Transverse shear due to direct force F. ii) A bending moment $M_{XX}$ and iii) A twisting moment $T_{XX}$ as shown in fig 1(c). The magnitudes of the stresses due to these loads can be given by,

$$\sigma_{1,2} = K\left[\sin\alpha \pm 2\sin\frac{\alpha}{2}\right]$$

Where, $K = \left[\frac{16FR_m}{\pi d^3}\right]$

## 3. STRESS DISTRIBUTION IN DIFFERENT CROSS-SECTIONS

### 3.1 Square Cross Section

A square cross section curved beam of cross sectional area equal to circular section is analyzed with same boundary conditions and magnitude of load as in earlier chapters. The principal stress get here is much larger than the circular one in both the semi and quarter circular curved beams. Here we can clearly observe that the stress concentration near the edges will more. This is shown in figure 2 and 3. Same is plotted in figure 4.

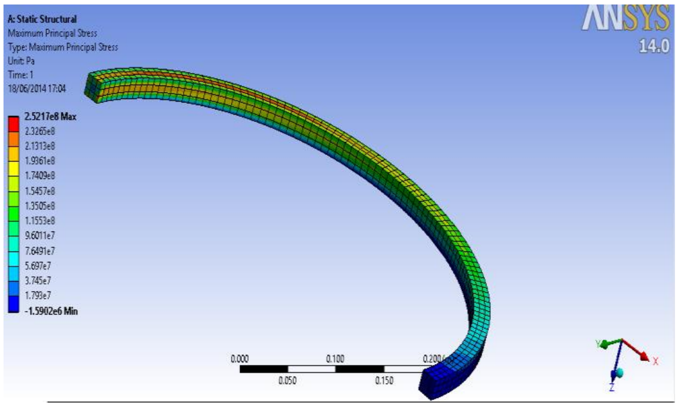


**Figure 2:** Variation of principal stress over square c/s curved beam for Out-Of-Plane load .

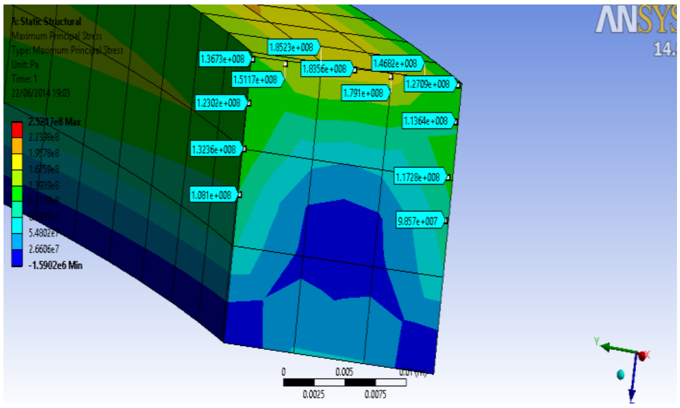

**Figure 3**: Variation of principal stress over square c/s of curved beam for Out-Of-Plane load

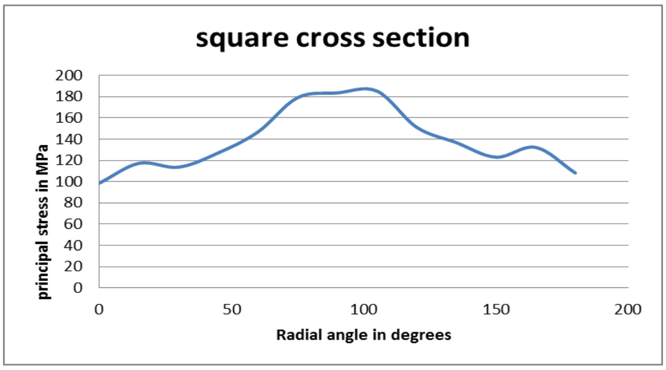


**Figure 4 :** Graph shows Variation of principal stress over rectangle c/s of curved beam for Out-Of-Plane load

### 3.2 Rectangular Cross Section

Figure 5 and 6 shows the variation of principal stress across the rectangle cross section where height of rectangle is equal to twice the width. The stress is less at the edges as compared at the middle region of outer surfaces. So it is not suitable for torsional load, but it can be used for bending loads.

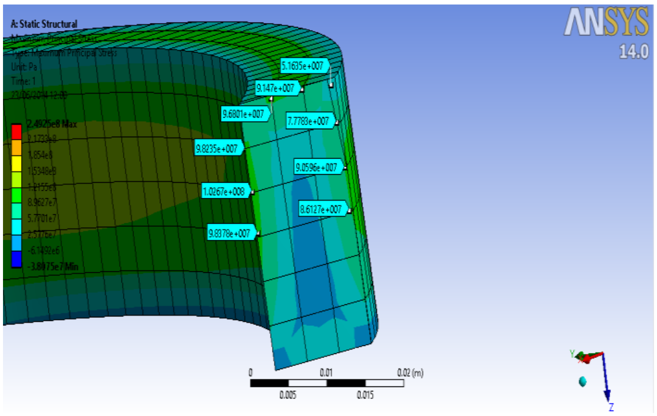


**Figure 5:** Variation of principal stress over rectangle c/s of curved beam for Out-Of-Plane load

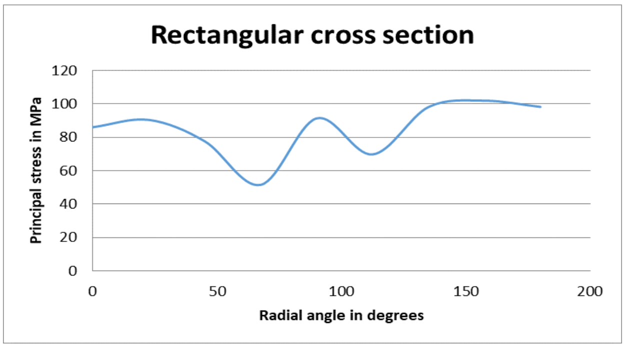


**Figure 6** : Graph shows Variation of principal stress over rectangle c/s of curved beam for Out-Of-Plane load

### 3.3 Circular Cross Section

Figure 7 and 8 shows the variation of principal stress across the circular cross section. Stresses are varying slightly along the circumference of cross section as shown. It suits for torsional load and bending load as compared to square and rectangular cross section.

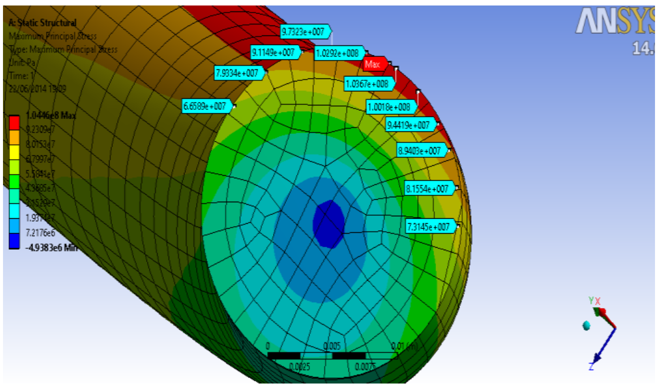


**Figure 7** : Variation of principal stress over circular c/s of curved beam for Out-Of-Plane load

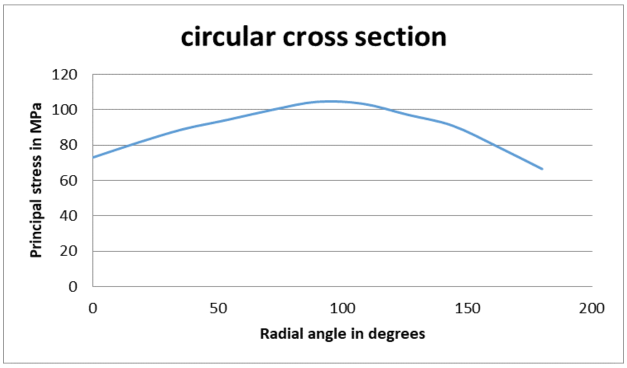


**Figure 8** : Graph shows Variation of principal stress over circular c/s of curved beam for Out-Of-Plane load

### 3.3 Elliptical Cross Section

Figure 9 and 10 shows the variation of principal stress across the elliptical cross section. Stresses are varying along the circumference of cross section as shown. It suits more for torsional load and bending load as compared to square, rectangular and circular cross section. It is the best one for combined loading.

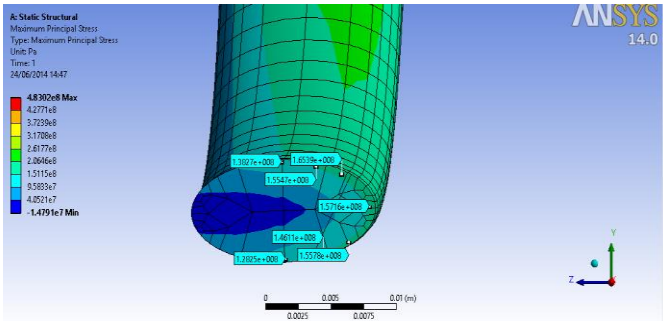


**Figure 9 :** Variation of principal stress over elliptical c/s of curved beam for Out-Of-Plane load

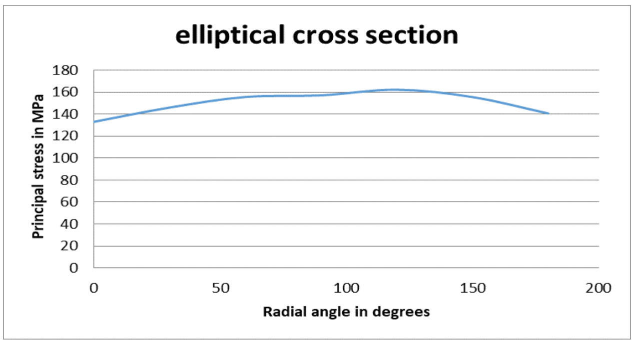


**Figure 10 :** Graph shows Variation of principal stress over elliptical c/s of curved beam for Out-Of-Plane load

## 4. CONCLUSIONS

It is observed that for semicircular curved beams subjected to Out-Of-Plane loads the variation of principal stress is ascending first up to an extent then it follows descending values. But in case of quarter circular curved beams it will goes on increasing towards fixed end. Since there is combined effect of bending and torsion is present in Out-Of-Plane loading case in curved beam, it is suggested that circular cross sections are better to use for such environments. And compared to circular cross section elliptical cross sections are the best choices of selection for such type of environments.

## REFERENCES

[1] Theoretical Analysis Of Semi Circular Curved Beam Subjected To Out-Of-Plane Load- D S Ramakrishna & Rakshith N, International Journal of Mechanical Engineering (IJME), IASET, ISSN(P): 2319-2240; ISSN(E): 2319-2259 Vol. 3, Issue 6, Nov 2014, 37-44.

[2] FE-Investigation of Semi Circular Curved Beam Subjected to Out-Of-Plane Load" in International Journal of Research in Engineering and Technology (IJRET), p-ISSN; 2321-7308, eISSN: 2319-1163, Vol 4, Issue 8, August 2015.

[3] Experimental Approach to Determine the Stress at a Section of Semi Circular Curved Beam Subjected to Out-Of-Plane Load Using Strain Rosette, International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 03 | Mar-2016.

[4] Numerical solution of curved pipes submitted to in-plane loading conditions. - E.M.M. Fonseca, F.J.M.Q. de Melo ELSEVIER-2009

[5] Simple Mechanical Model of Curved Beams by a 3D Approach.-Stefano Lenci and Francesco Clementi-ACSE july 2009

[6] A Curved Beam Element and Its Application to Traffic Poles.-Thesis by-Cheng Zhang -Department of Mechanical and Industrial Engineering University of Manitoba Winnipeg, Manitoba-1998

[7] A Finite Circular Arch Element Based on Trigonometric Shape Functions.-H. Saffari and R. Tabatabaei-2007

[8] End-loaded shallow curved beams.-Clive L. Dym, F.-ACSE2011

[9] In-Plane Vibrations of Circular Curved Beams With A Transverse Open Crack-H. R. Öz and M. T. Das-Mathematical and Computational Applications, Vol. 11, No. 1, Pp. 1-10, 2006

[10] Theory And Application of Naturally Curved And Twisted Beams With Closed Thin-Walled Cross SectionsAimin Yu - Rongqiang Yang - Ying Hao-Journal Of Mechanical Engineering 55(2009)12, 733-741.