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Structural Analysis and Optimization of Crane Hook with Modified Cross Section for Enhanced Load-Bearing Performance

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Abstract

In this study, an innovative cross-sectional modification is explored, positioned between the T-section and trapezoidal section, with the objective of enhancing the load-bearing capacity while minimizing stress concentrations. The crane hook model incorporating this novel cross-section was designed using CATIA V5. The crane hook model with T-shape and trapezoid cross sections were designed and also as mentioned the proposed modified cross section which is intermediate between T-shape and trapezoid with different radius of curvature were designed. Total six different crane hook models were done using Catia V5. Followed by, analysis of designed crane hook models using ANSYS 15.0 was done to evaluate the stress distribution and deformation under varying load conditions. The stress distribution, and deformation development were studied in all the designed crane hook models to find the optimum crane hook cross section. A systematic parametric analysis was conducted on all considered models of crane hook and identified the optimal configuration with the highest safety factor.

Keywords: Crane Hook, Structural Analysis, Curved Beam.

1. INTRODUCTION

In order to reduce crane hook failures, the determination of stresses, their evolution and the areas of maximum values are very important. Because the geometry of the hook is complicated, the analytical calculation is complex and then the use of FEM analysis can be used in the study of the evolution of the stresses in the hook. Previous research has suggested that T-shaped and trapezoidal cross-sections provide improved performance characteristics compared to conventional designs. However, further improvements may be achieved by exploring intermediate cross-section geometries that leverage the advantages of both shapes.

2. Literature Survey

The comparative study by Mr. A Gopichand. Et al. [1] has shown that taguchi method can be used for optimization of crane hook. In his work optimization of design parameters is carried out using Taguchi method. He considered total three parameters and made mixed levels a L16 orthogonal array. The optimum combination of input parameters for minimum Von-mises stresses Are determined. From that array he found optimum combination of area radius for minimum Von-mises stress. Ram Krishna rathour. et al. [2] has worked on a general approach for the multiple responses. He started optimization with the regression models to calculate the correlation between response function and control function. An objective function is generated with the help of system for collecting various response functions together. By using artificial neural network (ANN) to find out the response function. He used multiple objective genetic algorithms (MOGA) to optimize shape function of the crane hook for same capacity by considering combination of objective function to find out the optimize shape of crane hook. The result shows that the reduction in mass as well as safety of factor is not disturbed. Nishant soni et al. [3] has worked on the optimization of low carbon steel for its self-weight. The self-weight and component load coming on the crane–hook hence he worked with objective of the optimization of the mass for cane hook-under the effect of static load comprising the peak pressure load. He used finite element analysis for the shape optimization of crane hook as well as for validation of final geometry.

Chetan N. Benkar.et al. [4] worked on crane hook for the optimization. He estimated the stress pattern of crane hook in its loaded condition by preparing a solid model with the help of ANSYS 14 workbench. He calculated stress pattern for various cross section topology such as rectangular, triangular, trapezoidal, and circular by keeping the area constant and found that rectangular cross sectional area gives minimum stress and deformation level.

Rashmi Uddanwadiker.et.al. [5] Has calculated the stress pattern produced due to the load on hook. He compared the analytical result of stress and the stress estimated from the FEM analysis and found that there was 8.26% percent error between them. Photo elasticity test is based on the property of birefringence. From the analysis he found the area at which high stress concentration occurs. For the design improvement if the inner side of hook at the portion of maximum stress is widened then the stress will get reduced. He estimated that the stress is reduced up to 17% if the thickness of the inner curvature is reduced by 3mm C. Oktay Azeloglu.et al. [6] has studied the method for the calculation of stress based on the different assumption. He adopted Timoshenko‟s curved theory and Bach approximation on the simple hooks calculation. He used finite element method to estimate the stress and compared it with different method.

M. Shaban. et al [7] prepared a solid model of crane hook to estimate the pattern of stress in the crane hook. They used ABAQUS software and obtained real time pattern of stress concentration. The value and location is very much important factor in reducing the failure. If the inner curvature of hook is widened the stress will be reduced. For complicated mechanical element it is suitable to use caustic method. In caustic method several small several holes are drilled to predict accurate stress value. Takuma Nishimura.et al. [8] studied damage factor estimation of crane hooks to recognize the tendency of the load condition. They used FEM to estimate the relation between the load condition and its deformation. First, load –deformation database that has the relation between the load condition of crane hook and its deformation using numerical calculation is constructed. After the completion of study they found that load acts in downward position and tip –end position and load direction is not downward normal in damaged hook.

Santosh Sahu.et al. [9] made a model of crane hook of trapezoidal using CATIA V5R20.Then estimated the location of stress after Appling the 2 ton load using FEM. They also analyzed the effect of variation in length of two parallel sides of trapezoidal hook on stress. Apeksha K Patel.et al. [10] has worked on reduction of weight of girder which has reduced the cost of girder and also life of girder is increased. They made a mathematical design for crane component by using ANSYS workbench V12.They also

optimized hook by using Trapezoidal cross sectional area.
Pradyumnakeshrimaharana. [11] Has estimated hook dimensions for various cross section topology by keeping the depth and cross section area. He concludes from his work that the trapezoidal section was lest stressed. Spasoje Trifkovic et al[12] worked on the stress state in the crane hook using exact and approximate methods. Stresses are calculated in various regions of the crane hook material by assuming crane hook as a straight beam and curved beam.
Torres et al [13] worked on the causes which led to failure of the crane hook in service. This study shows the simulation of the thermal history of the hook and explains the standards governing the manufacturing.

3. Modeling of Curved Beam using CATIA V5

Suitable geometry is created through modeling in CATIA V5 (computer Aided Three Dimensional Interactive Application), developed by Dassaults systems, France, is next-generation family of CAD / CAM/CAE software solution. The modeling is done in CATIAV5, using which proper geometry is produced.

3.1 Starting a New File

When Catiav5 is started a new product file with the name product 1 is visible on the screen. Close the file and select a new one in the part design work bench.
Choosing file menu starts screen of CATIAV5 is displayed. Choose part design from start > mechanical design; one can enter into the part design work bench and the new part dialogue box will be displayed. Choose ok to start a new file in a part design. The relevant dimensions were chosen. The dimension of the model is shown in fig 3. Solid modeling was performed using of the basic tools '*Sketcher*'. The procedure comprises of creating a contour cylinder, setting constraint, shafting contours, making holes, circular copy. In modeling the body, following tools are used: *Profile or Line*, *Circle*, *Constraint*, *Pad*, *Pocket.* With circle tool of Sketcher module (used in making of 2D models) the basic body model is developed. It is significant to note that sketched geometry in *Sketcher* module define using *Constraint* tool. Then, the basic form of the tube body is formed in *Part design* module using shaft tool.
The step by step procedure followed in creating the model of crane Hook with Trapezoid cross section is shown in the following figures.

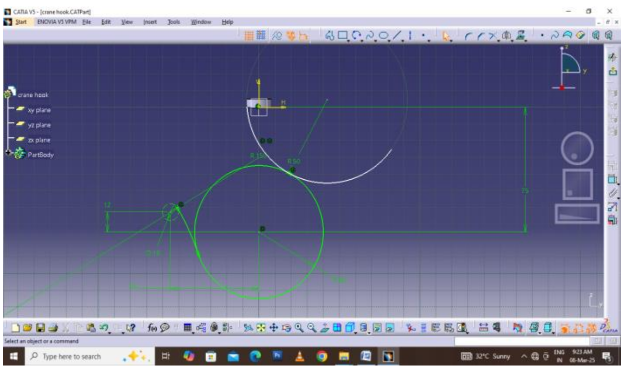

Fig 3.1 Basic sketch of the profile of crane Hook in Catia V5

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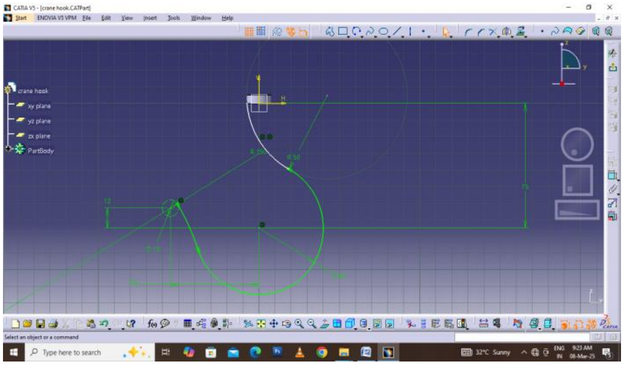

Fig 3.2 The complete profile of considered crane hook in Catia V5

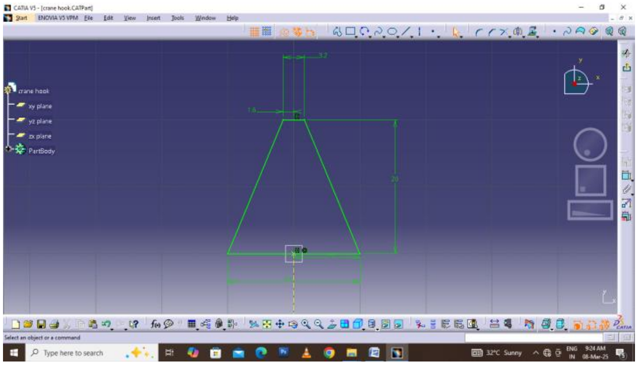

Fig 3.3 The sketch of cross section of the crane hook in Catia V5

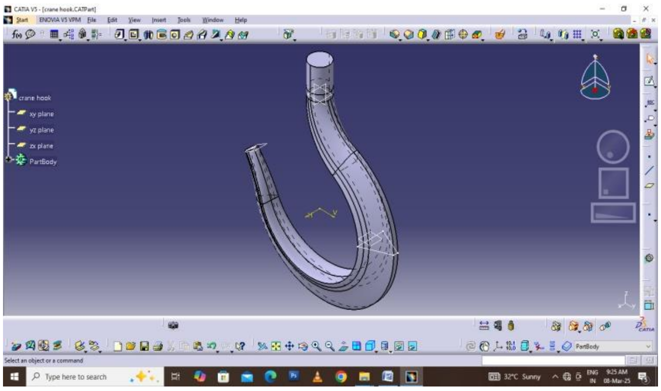

Fig 3.4 The created model of Crane hook model with trapezoid cross section in Catia V5

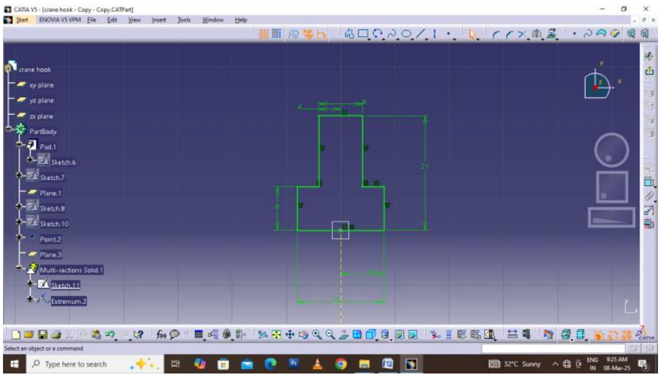

Fig 3.5 Basic sketch of T shape cross section of crane Hook in Catia V5

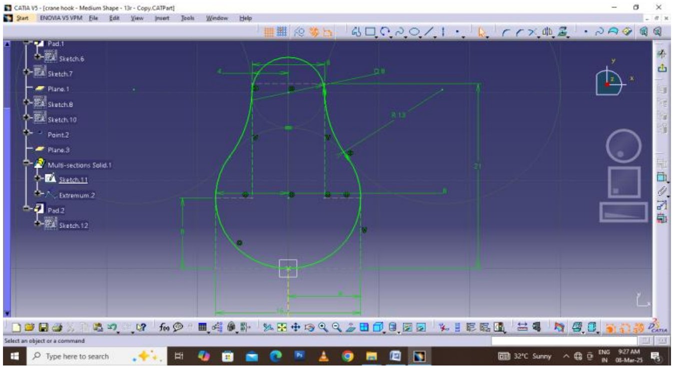

Fig 3.6 Basic sketch of intermediate shape of crane hook

Similar procedure is followed to create all the models as follows.
Model 1: Crane Hook with Trapezoid cross section
Model 2: Crane Hook with T-Shape cross section
Model 3: Crane Hook with intermediate shape cross section of 18mm radius of curvature
Model 4: Crane Hook with intermediate shape cross section of 15mm radius of curvature
Model 5: Crane Hook with intermediate shape cross section of 13mm radius of curvature
Model 6: Crane Hook with intermediate shape cross section of 10mm radius of curvature

4. Analysis of the Crane Hook

4.1: Step by Step Analysis Procedure

Step 1: At first the ansys structural analysis is to be loaded. Then the material required is selected as shown in fig 4.1.
Step 2: The Catia model is to be imported in igs format as shown in fig 4.2
Step 3: The model is need to be edited in geometry module of Ansys 15.0 for making provision of load application only at the middle of the model as shown in fig 4.3
Step 4: The model is divided in finite parts and meshed model is as shown in fig 4.4
Step 5: The fixed constraints are applied as shown in fig 4.5.
Step 6: The load (1000N) is applied to the model as shown in fig 4.6
Step 7: Then to solve the problem using solver option as shown in fig 4.7.

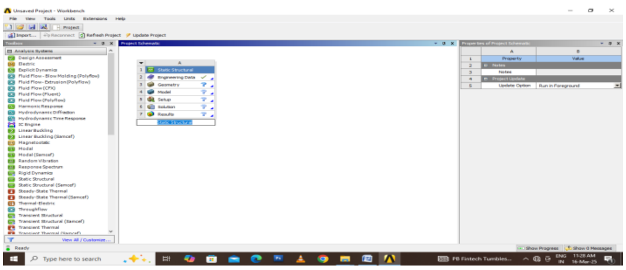

Fig 4.1 Structural analysis & selection of material in Ansys 15.0

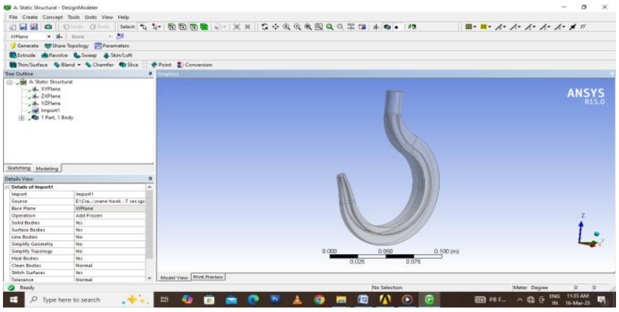

Fig 4.2 The catia model of crane hook is imported to Ansys 15.0

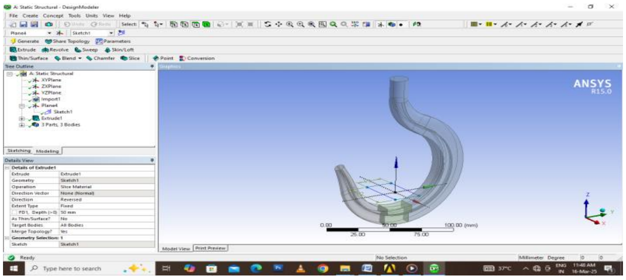

Fig 4.3 Dividing the model in to required parts for load application provision

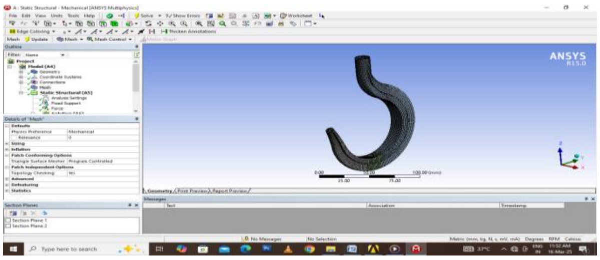

Fig 4.4 Meshed model of Crane Hook in Ansys 15.0

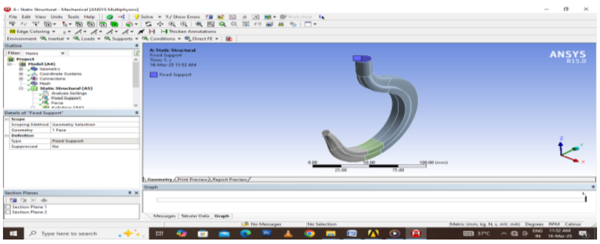

Fig 4.5 Applying fixed constraints in Ansys 15.0

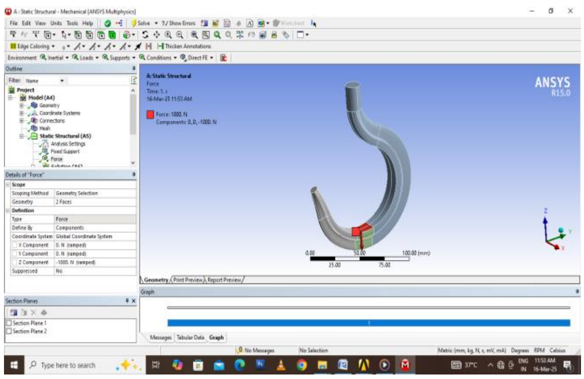

Fig 4.6 Applying load to the model.

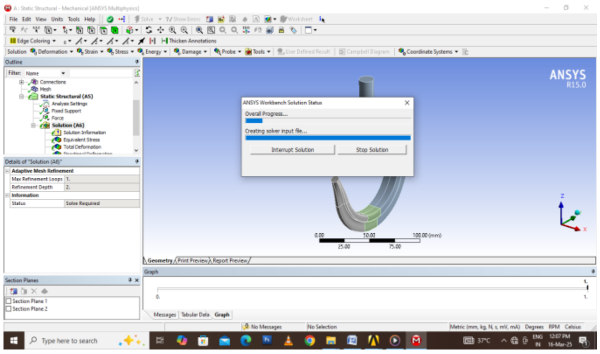

Fig 4.7 Solving problem in solver of Ansys 15.0

Similar procedure is applied to all the models and results are discussed in the next section

5. Results and Discussions

5.1 Details of Model used in Ansys

Material	*Structural Steel*
Object Name	*Mesh*
Element Size	1.50 mm
Minimum Edge Length	0.342920 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Statistics	
Nodes	64104
Elements	12898

5.2 Ansys Results of Crane Hook with Trapezoid Cross section: Model-1

The fig 5.1 shows the equivalent von-mises stress distribution at different views of the crane hook model with trapezoid cross section: Model-1. The resulting color image shows that the stress has been developed between the section of load application and the fixed section of the crane hook. The other part; loaded section to free end of crane hook is represented with blue color, indicates that the respective portion is under neglegible stress intensity. Also the color representation indicates that, the maximum stressed cross section is the section between loaded section and fixed cross section. The highly stressed cross section is under different stress intensity which is represented different colors, indicates that the stress varies from fibre to fibre along the depth of the trapezoid cross section. The red color is the indication of maximum von-mises stress development, which can be observed at the both the extreme fibres at the highly stressed cross section. But the nature of stress is different, which can be confirmed by blue color at the middle of the section with higher stress intensities on aither sides. Thus it indicates the neutral axi sof the crane hook. The maximum stress developed in this model-1 is found to be 76.04MPa. Also from the fig 5.1b, it is observed that the red color towards inner fibre is stread to lesser amount than that of at the outer fibre. This can be understood that the inner fibre is under tensile nature and the outer fibre is under compressive stress.

The fig 5.2 shows the directional deformation developed in crane hook model-1. The resulting color image shows that the deformation is not in same direction throughout the crane hook. The deformation in the crane hook other than red color represents the negative deformation, which shows that only the red color zone is the portion which mainly takes the load applied. But still may have a doubt regarding the opposite nature of the stress at the extreme fibers, but to get clear understanding directional deformation along y-axis is also need to study. The maximum directional deformation developed along z-axis is 0.048mm in the positive direction and 0.389mm along negative direction.

The fig 5.3 shows the safety factor attained in the crane hook model-1. The resulting image shows that the portion between fixed section and loaded section is under lower safety, compared to the remaining portion. This can be understood by observing green and dark yellow region in the picture. Also the statement mentioned above, regarding the higher stress intensity on either sides of the neutral axis is also confirmed with this diagram, showing lower safety factors on either sides of fibers from middle of the cross section. The critical safety factor is found to be 3.2875 in this model-1.

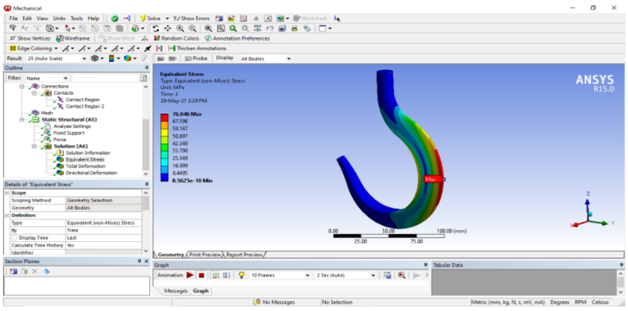

Fig 5.1(a) Equivalent Von-mises Stress distribution in Crane Hook with Trapezoid cross section: Model-1

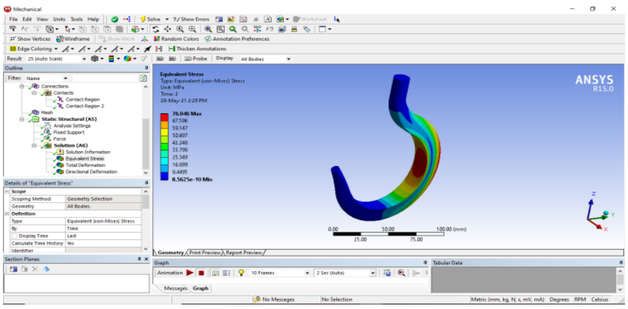

Fig 5.1(b) Equivalent Von-mises Stress distribution in Crane Hook with Trapezoid cross section: Model-1(other view)

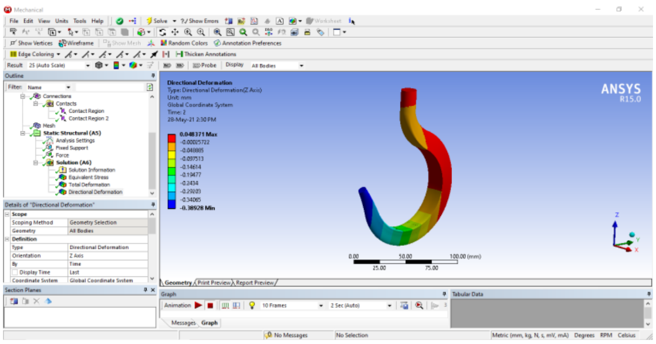

Fig 5.2 Total deformation development in Crane Hook with Trapezoid cross section: Model-1

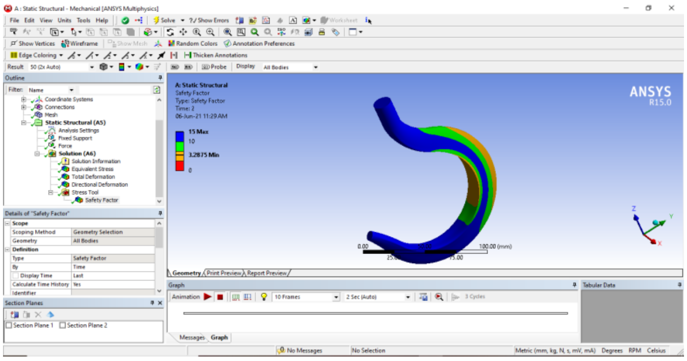

Fig 5.3 Safety Factor attained in Crane Hook with Trapezoid cross section: Model-1

5.3 Ansys Results of Crane Hook with T- Cross section: Model-2

The fig 5.4 (a) to 5.4(b) shows the von-mises stress deformation in the crane hook model-2 with T-Shape cross section. The resulting color image shows that the pattern of variation of stress in this model-2 is similar to the model-1, but the intensity of the stress is reduced. It can be observed that the inner fibers in this model-2 are under higher stress than the outer fibers. The maximum stress developed in this model-2 is found to be 66.49MPa, which is 12.5% lower than that of model-1. In the previoud model-1 (with trapezoid cross section), the depth of fibersfrom outer fiber, under the action of higher stress intensity is more than that of the depth of higher stress intensity in model-2. Also it can be observed that the blue color representation extends through out the active length of the crane hook (load bearing portion), which is higher than the pattern in model-1 (in which it vanishes at little distance beyond the maximum stressed section).

The fig 5.5 shows the directional deformation along z-axis developed in the crane hook model-2. The resulting color image reveals that the pattern of development of deformation in this model-2 follows the same trend of model-1. But clear observation reveals that positive directional deformation in the previous model-1 was represented with red color, where as in this model, it extends from red to even dark yellow color. This shows that the positive deformation takes place right from the cross section just little bit next to the loaded region and continues up to fixed section. Thus the load bearing active portion of the crane hook increases in this model-2, compared to previous model-1. The maximum deformation developed in this model is found to be 0.04002mm in positive direction and is 0.317mm in negative direction, which are 17.2% and 18.5% lower than that of model-1.

The fig 5.6 shows the safety factor attained in the crane hook model-2. The resulting color image shows that the pattern is similar to the previous model, the depth of critical safety in this model-2 at the outer edge side is not extended to much depth of the cross section, compared to the previous model. The critical safety factor attained in this model is found to be 3.76, which is 14.4% higher than the model-1.

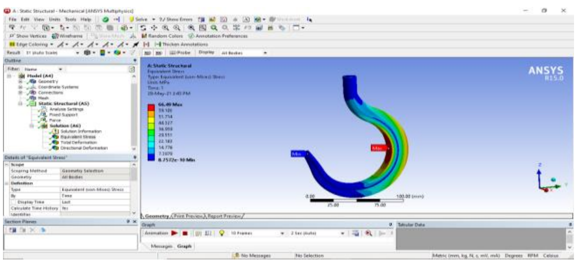

Fig 5.4(a) Equivalent Von-mises Stress distribution in Crane Hook with "T" cross section: Model-2

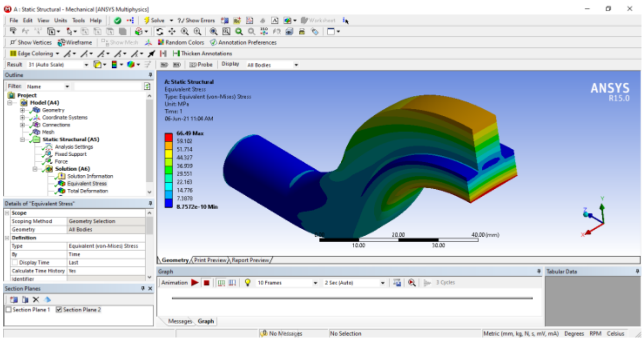

Fig 5.4(b) Equivalent Von-mises Stress distribution in Crane Hook Model-2 (Cross section view at highly stressed section)

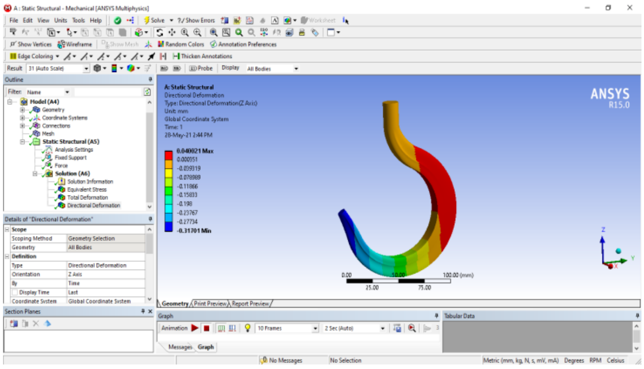

Fig 5.5 Total deformation development in Crane Hook with T- cross section: Model-2

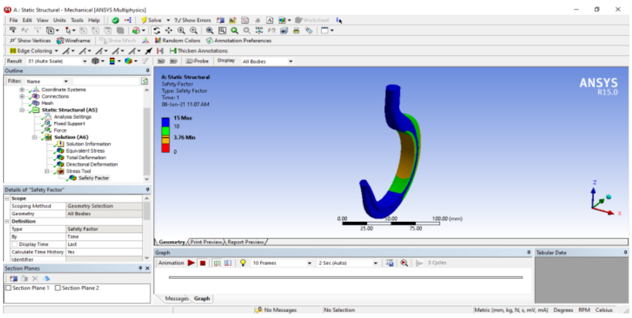

Fig 5.6 Safety Factor attained in Crane Hook with T-cross section: Model-2

5.4 Ansys Results of Crane Hook with intermediate section: Model-3

The fig 5.7 shows the equivalent von-mises stress development in the crane hook with intermediate cross section, model-3. Though the pattern of variation of stress in this model-3 is similar to the previous models, the intensity of stress is reduced to a higher level. Especially looking at the color representation in the active portion of the hook, it can be observed that the dark blue color is clearly developed throughout the active length of the hook, representing the neutral axis fibers (with negligible stress). This represents that the load is almost uniformly distributed throughout the active portion of crane. Also looking at the color representation along the depth of the cross section of the crane hook, it can be observed that red color at the inner edge got vanished within very thin depth, followed by lower stress intensity up to the center of cross section. And again increases beyond that, but ended up with lower stress intensity at the outer edge represented with green and yellow colors. This might be due to smooth

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transition curved surface between inner and outer edges of the cross section. Also it can be seen that outer edge fibers are with low intensity stress values, which is far better than that of in previous models. This is very good indication, for the improvement of load bearing capacity. The maximum stress developed in this model-3 is found to be 58.77MPa, which is 22.7% lower than the trapezoid cross section model and 11.6% lower than the “T” section model.

The fig 5.8 shows the directional deformation along z axis, developed in the crane hook model-3. The resulting color image shows that the pattern of developemnt of deformation is similar to the previous models. The maximum deformation developed in this model is 0.03599mm along positive side and 0.2076mm along negative direction. The positive side deformation is 25.6% lower than the model-1 and 10.08% lower than the model-2, whereas the negative side deformation is 46.6% lower than the model-1 and 34.5% lower than the model-2. Especially looking at the negative side deformation, which represents the deformation beyond the active loaded portion of the crane hook, which is represented by colors other than yellow and red, gives a clarity regarding the effect of load on the crane hook. Because there is significant improvement in the deformation, compared to previous standard shapes like trapezoid and T shape cross sections. Higher deformation at the free end, leads to weakening of the hook with time. Thus this proposed cross sectional shape of smooth transition between T shape trapezoid shape cross section, gives efficient results as predicted. But it is furtehr need to study for possible levels of smooth transition to find the optimum shape of cross section.

The fig 5.9 shows the safety factor attained in the crane hook model-3. The resulting color image represents that the critical safety is restricted to only inner edges of the highly stresses cross section of the crane hook, i.e; the dark yellow color indication is only limited to inner edge fibers. Even at the inner side of the cross section, the critical safety zone is limited to small portion (area under dark yellow color), which indicates that the safety factor of this model is improved in quantity point of view. The critical safety value attained in this model-3 is found to be 4.2538, which is 29.3% higher than the model-1 and 13.2% higher than the model-2.

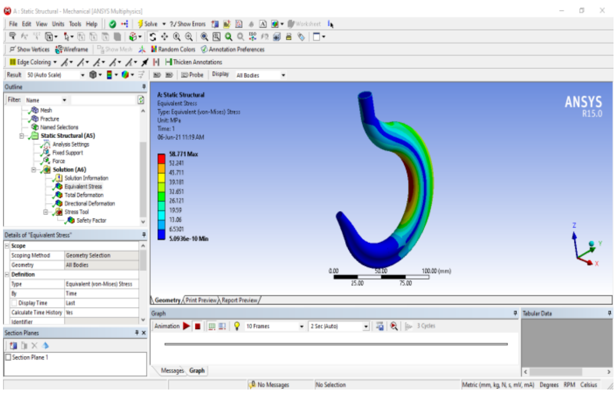

Fig 5.7(a) Equivalent Von-mises Stress distribution in Crane Hook Model-3 (Intermediate Cross section)

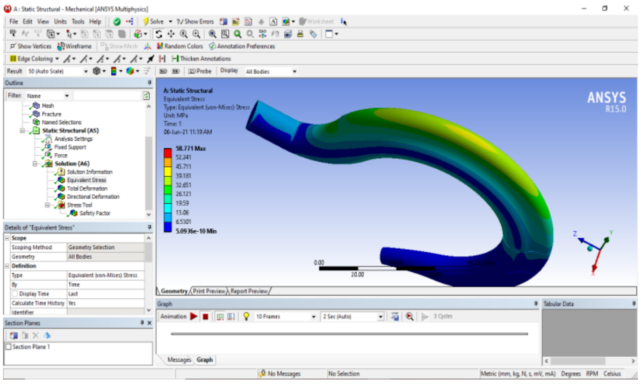

Fig 5.7(b) Equivalent von-mises Stress distribution in Crane Hook Model-3 (other view)

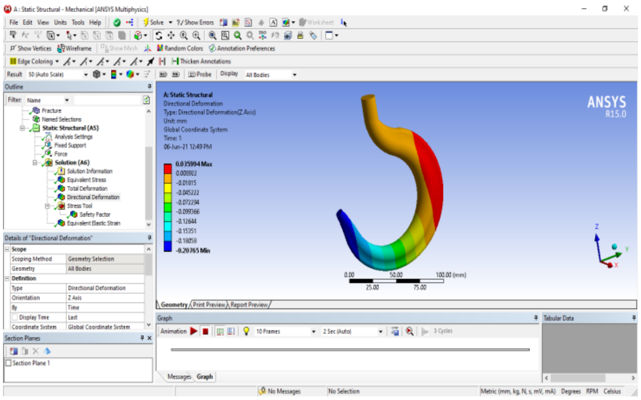

Fig 5.8 Total deformation development in Crane Hook Model-3

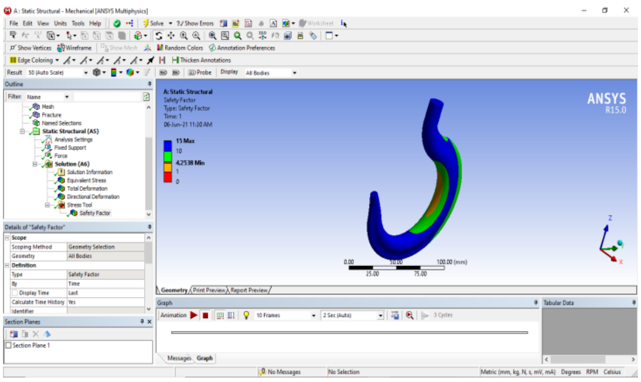

Fig 5.9 Safety Factor attained in Crane Hook Model-3

5.5 Ansys Results of Crane Hook with intermediate section: Model-4

The fig 5.10 shows the von-mises stress distribution in the crane hook model-4, which is with lower radius of curvature for transition from trapezoid to T section, compared tp model-3. The resulting color image gives the paatern of development of stresses in this model similar to the model-3. The maximum stress developed in this model-4 is found to be 41.97MPa, which is 28.5% lower than the model-3. This results are tremendous with very low stress intensities. It can be observed from the cross sectional view, that the stress towards the outer edge are with lower stress intensity, and inner edges are with higher intensities, which is similar to the previous model-3, but still better than that. The maximum stress vaues with red color at the inner edge side and yellow color at the outer edge side are restricted to just to the external surface of the cross section, and this data gives very useful information for further improvement of the model through some modification sin the manufacturing process by providing any lining material at the inner fiber to improve the strength of the hook further.

The fig 5.11 shows the directional deformation along the direction of the load application developed in the crane hook model-4. The resulting color image shows that the pattern of deformation development is similar to the previous model, but with still lowers magnitudes of deformation. The maximum deformation developed in this model-4 is 0.02571mm in the positive direction and 0.1483mm in the negative direction, which are 28.5% lower than that of in model-3.

The fig 5.12 shows the safety factor attained in the model-4. The resulting color image shows the similar pattern of previous model-3. The critical safety factor attained in this model-4 is 5.955, is 39.9% higher than that of model-3.

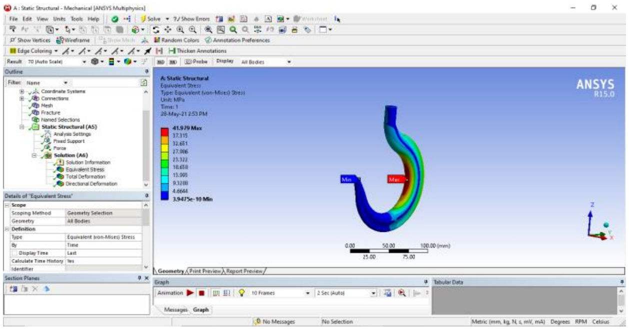

Fig 5.10(a) Equivalent von-mises Stress distribution in Crane Hook Model-4 (Intermediate Cross section)

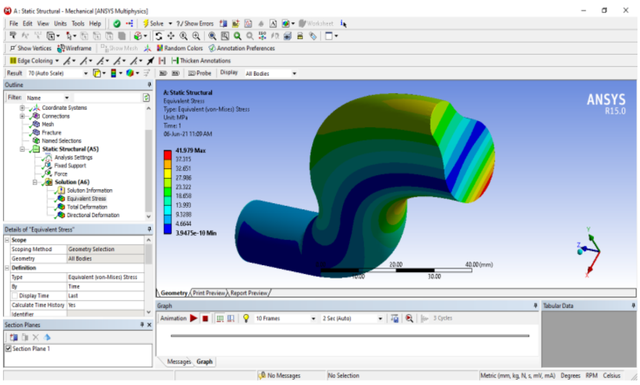

Fig 5.10(b) Equivalent von-mises Stress distribution in Crane Hook Model-4 (Cross sectional view at highly stressed section)

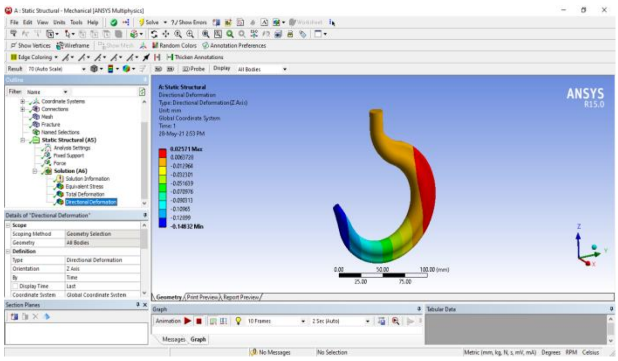

Fig 5.11 Total deformation development in Crane Hook Model-4

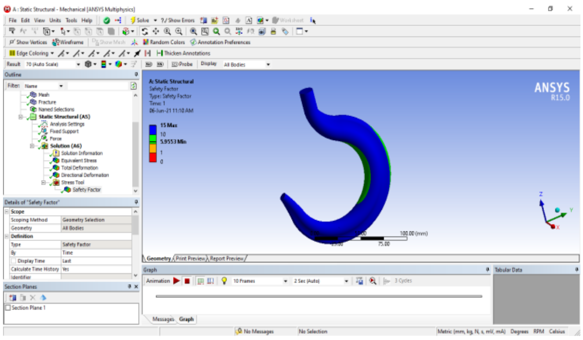

Fig 5.12 Safety Factor attained in Crane Hook Model-4

5.6 Ansys Results of Crane Hook with intermediate section : Model-5

The fig 5.13 shows the von-mises stress distribution in the crane hook model-5, which is with still lower radius of curvature for transition from trapezoid to T section, compared tp model-4. The resulting color image gives the paatern of development of stresses in this model similar to the model-4. The maximum stress developed in this model-5 is found to be 54.573MPa, which is 30% higher than the model-4. Thus it is clear that further increase of radius of curvature, in this model compared to previous model-4, once again leads to increase of stress intenmsity. This might be due to over curvature that does not permits the stress lines to take a smooth diversion during the change in cross section from inner edge to outer edge. This need to be confirmed by taking one more model with still higher radius of curvature.

The fig 5.14 shows the directional deformation along the direction of the load application developed in the crane hook model-5. The resulting color image shows that the pattern of deformation development is similar to the previous model, but with higher magnitudes of deformation. The maximum deformation developed in this model-5 is 0.03342mm in the positive direction and 0.19282mm in the negative direction, which are around 30% higher than that of in model-4.

The fig 5.15 shows the safety factor attained in the model-5. The resulting color image shows the similar pattern of previous model-4. The critical safety factor attained in this model-5 is 4.581, is 23% lower than that of model-4.

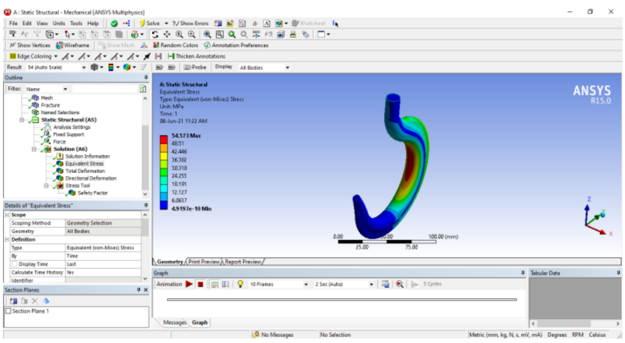

Fig 5.13(a) Equivalent von-mises Stress distribution in Crane Hook Model-5 (Intermediate Cross section)

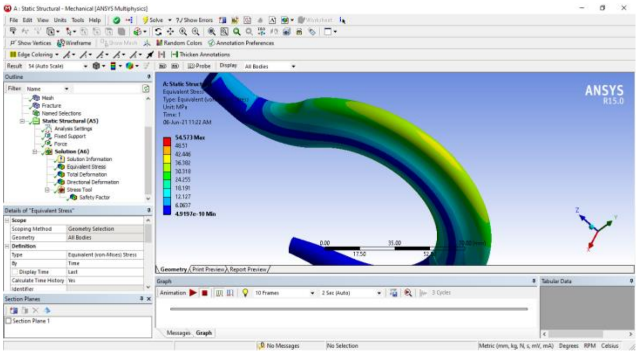

Fig 5.13(b) Equivalent von-mises Stress distribution in Crane Hook Model-5 (other view)

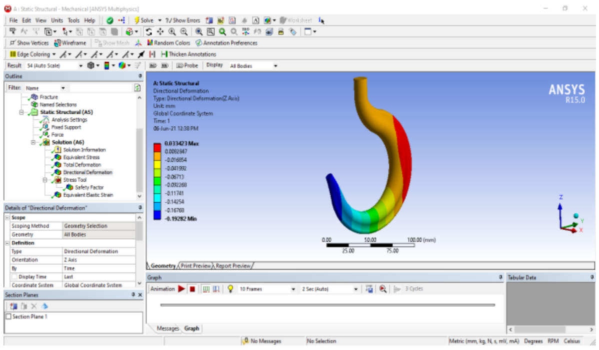

Fig 5.14 Total deformation development in Crane Hook Model-5

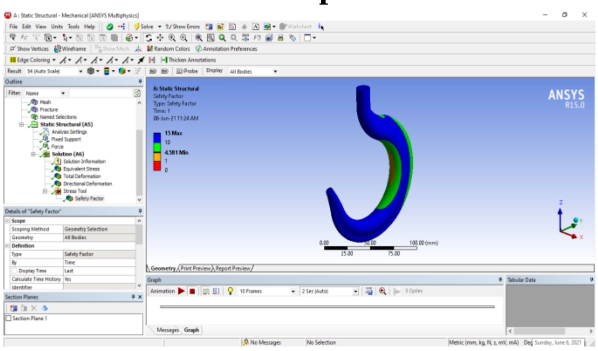

Fig 5.15 Safety Factor attained in Crane Hook Model-5

5.7 Ansys Results of Crane Hook with intermediate section: Model-6

The fig 5.16 shows the von-mises stress distribution in the crane hook model-6, which is with still lower radius of curvature for transition from trapezoid to T section, compared to model-5. The resulting color image gives the paatern of development of stresses in this model similar to the model-5. The maximum stress developed in this model-6 is found to be 60.87MPa, which is 11.5% higher than the model-5. Thus it is clear that further increase of radius of curvature, in this model compared to previous model-5, leads to further increase of stress intenmsity. This might be due to the same reason mention in the previous section.

The fig 5.17 shows the directional deformation along the direction of the load application developed in the crane hook model-6. The resulting color image shows that the pattern of deformation development is similar to the previous model, but with higher magnitudes of deformation. The maximum deformation developed in this model-6 is 0.0372mm in the positive direction and 0.215mm in the negative direction, which are around 11.5% higher than that of in model-5.

The fig 5.18 shows the safety factor attained in the model-6. The resulting color image shows the similar pattern of previous models. The critical safety factor attained in this model-6 is 4.107, is 10.3% lower than that of model-5.

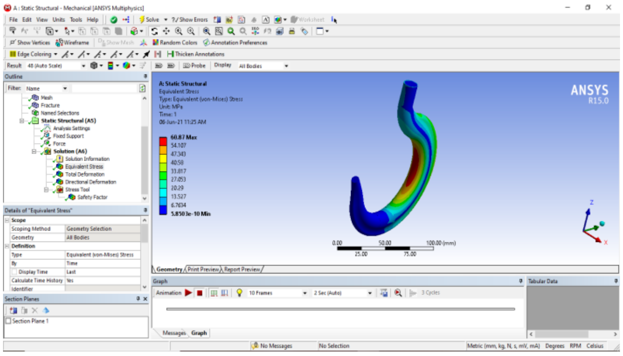

Fig 5.16(a) Equivalent von-mises Stress distribution in Crane Hook Model-6 (Intermediate Cross section)

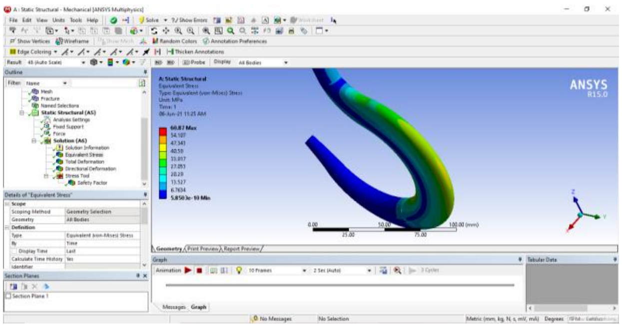

Fig 5.16(b) Equivalentvon-mises Stress distribution in Crane Hook Model-6 (other view)

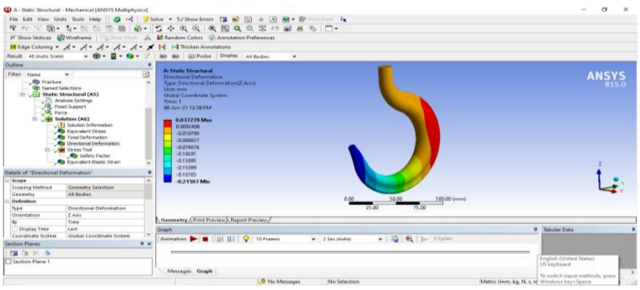

Fig 5.17 Total deformation development in Crane Hook Model-6

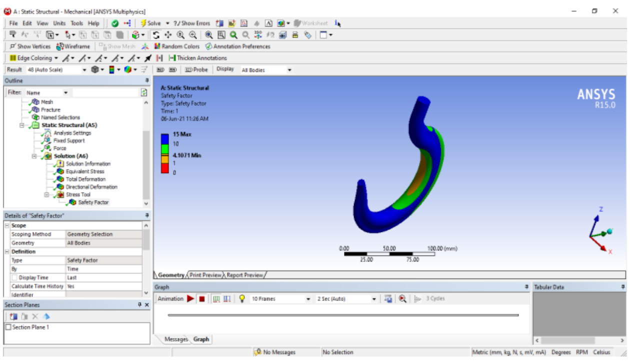

Fig 5.18 Safety Factor attained in Crane Hook Model-6

Thus by observing all the above results it is clear that intermediate cross section crane hook models are efficient than that of either trapezoid and T shape cross section crane hook. Thus it is to find the superior among the intermediate shape crane hook models.

5.8 Effect of the radius of curvature in the transition of cross section of crane hook from Trapezoid to T shape.

The fig 5.19 and 5.20 shows that the stress and deformation decreases with increase of radius of curvature from 18mm to 15mm and increases thereafter. Thus it can be identified that the crane hooks model-4 with 15mm radius of curvature results in lower stress and deformation, compared to all the models. From the fig 5.21 it can be observed that the crane hook model is the optimum with higher critical safety factor of 5.95.

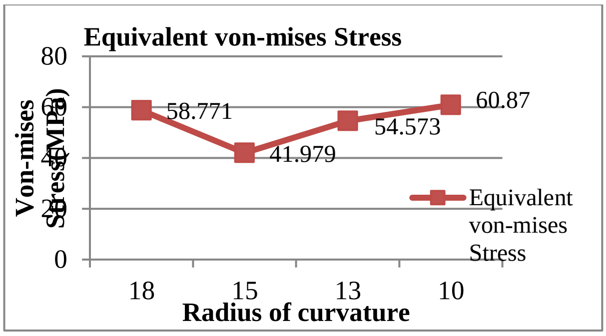

Fig 5.19 Effect of radius of curvature on the von-mises stress development

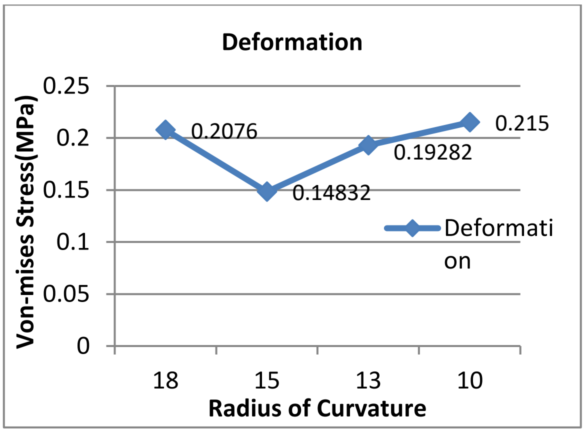

Fig 5.20 Effect of radius of curvature on the deformation development

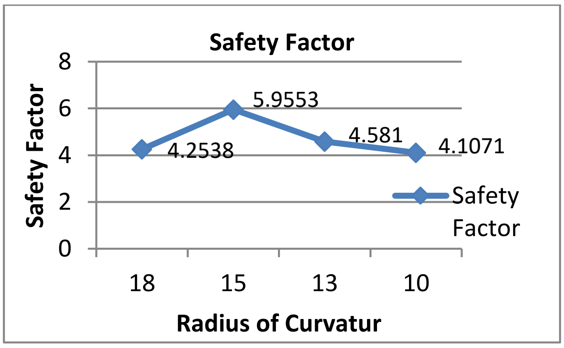

Fig 5.21 Effect of radius of curvature on the critical safety factor

6. Conclusions

The following conclusions were drawn from the series of analysis tests carried on crane hook with different cross sections, i.e; Trapezoid, T-Shape, series of Intermediate shapes between above trapezoid and T shape.

- The maximum von-mises stress in the crane hook model-2 with T-shape cross section is 12.5% lower than that of stress in crane hook model-1 with trapezoid cross section.
- The maximum directional deformation (along the direction of load application) developed in the crane hook model-2 with T-shape cross section is 18.5% lower than that of deformation in crane hook model-1 with trapezoid cross section.
- The critical safety factor attained in the crane hook model-2 with T-shape cross section is 14.3% higher than the crane hook model-1 with trapezoid cross section.
- The von-mises stress and deformation in intermediate cross section shape crane hook model, decreases with radius of curvature of transition from 18mm to 15mm and again increases with further decrease of radius. Hence the crane hook model-4 with 15mm radius is optimum among all intermediate shaped crane hook models
- The maximum von-mises stress in the crane hook model-4 with intermediate cross section of 15mm radius of curvature, is 36.8% lower than that of stress in crane hook model- 1 (Trapezoid) and 44.8% lower than that of model-2 (T-Shape).
- The maximum directional deformation(load direction) in the crane hook model-4 with intermediate cross section of 15mm radius of curvature, is 61.8% lower than that of deformation in crane hook model- 1 (Trapezoid) and 53.2% lower than that of model-2 (T-Shape).
- The critical safety factor in the crane hook model-4 with intermediate cross section of 15mm radius of curvature, is 81.1% higher than the crane hook model- 1 (Trapezoid) and 58.3% higher than that of model-2 (T-Shape).

  Thus concluding with intermediate shaped cross sectional crane hook model with 15mm radius of curvature is optimum among all the analyzed models.

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