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Finite Element Analysis of Cruciform Welded joints for improved Design Characteristics and Fatigue life

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Abstract: *Welded joints invariably contain defects. These defects act as a source of stress concentration. This affects the fatigue life of the members which contains it. Most commonly found defects in welds are under cuts and slag inclusions. The depth of these defects varies from 0.15 mm to 0.4 mm. Generally the depth of toe grinding permitted is 5% of the thickness of the base plate. These welds have will also have internal stresses. To assess the stress distribution pattern in the welds and to know stress concentration cruciform welds are considered. These welds are subjected to both tensile and compressive loads. To analyse the models considered are a) fillet weld without any defect, b) fillet weld with Toe defect and c) Fillet weld with toe grinding. These models are analysed by using ANSYS package. The results show the stress are very high when ever a defect is induced. Correspondingly the life of the member is also getting reduced. But by toe grinding enough amount improvement is visualized. The same is reflected in the actual practice. As these welded joints have internal stress the welds with tensile stress have shown better results. Thus the methodology of toe grinding is partially introduced to assess the performance of the welded joints. Both the actual results and the model results showed improvement in the life of the member.*

Keywords: *FEM, Stress concentration, toe grinding, cruciform welds.*

I. Introduction

Most of the Welded structures are subjected to cyclic loads. They become unserviceable due to fatigue failure, which propagate from the toe regions of the welding. For such structures it is not possible to take advantage of improved mechanical properties of steels unless the upper limits of the cyclic loads are greater than the design stress of the carbon steels which is commonly used in structural fabrication. This is possible with low cycle fatigue conditions and with better manufacturing process.On Non-load carrying fillets grinding and peening of the welds has revealed an improvement of fatigue strength. [1] These techniques have improved the life of these joints to an extent of 100% with high quality surface finish.Further load carrying fillet weld joints with toe grinding have shown an improved fatigue life.[2].A fracture mechanics analysis has been made of the effect of semi-elliptical and continuous defects at the toes of fillet welded joints, on their fatigue strength. It is shown that, for a given joint geometry and fatigue strength, the critical defect size reduces rapidly with plate thickness or, alternatively, that with a fixed size of defect fatigue strength decreases with increasing plate thickness. It is suggested that this may in part account for the size effect often found in fatigue testing. [3]Fatigue tests have been carried out under several stress ratios, ranging from R = -4 to R = 0.67, on centre cracked sheet specimens of four structural steels. Reasonable correlation of the results could be achieved by basing the stress intensity factor range, Delta K, on the tensile part of the stress cycle although the results for R = 0 gave the minimum rate of crack propagation indicating that for R<0 the compressive part of the cycle contributes some damage and for R>0 da/dN increases with R. [4].It is also observed that the fatigue life of member improved on the tensile load on the fillet weld members [5 , 6] but on the compressive load no such improvement is seen.The effect of axial misalignment on the fatigue strength of load-carrying transverse cruciform welds has been investigated. Results from two series of fatigue tests on carbon-manganese (C-Mn) structural steel specimens are presented. Finite element (FE) analysis was used to derive stress intensity factors for toe cracks in misaligned joints. [7]In order to analyze various situations possible and worst conditions that exist, here fillet welds are analyzed using ANSYS package by applying loads on the cruciform welded joints with induced toe defects and joint configurations varying.

II. Design

In order to understand the load distribution and fatigue life of the member where fillet welds are used it is analyzed using cruciform fillet welds.The fillet weld designed are non load bearing and load bearing. These are subjected to load to know the load distribution and fatigue life. Further the cruciform weld is designed with a defect to know the level of stress it is creating.

As per the experiments and studies toe grinding improves the overall fatigue life and decreases the stress load on the member. The same is studied by creating a suitable model.

2.1 Cruciform weld

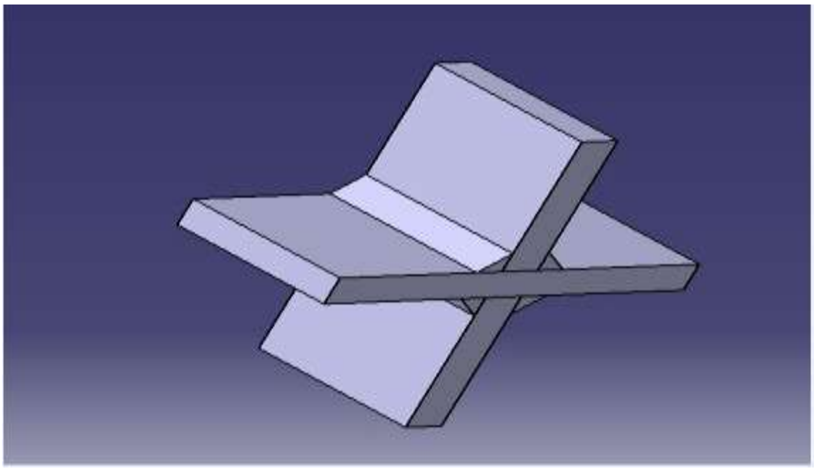

Fig.1 Cruciform welding

2.1.1 Cases under consideration **:**

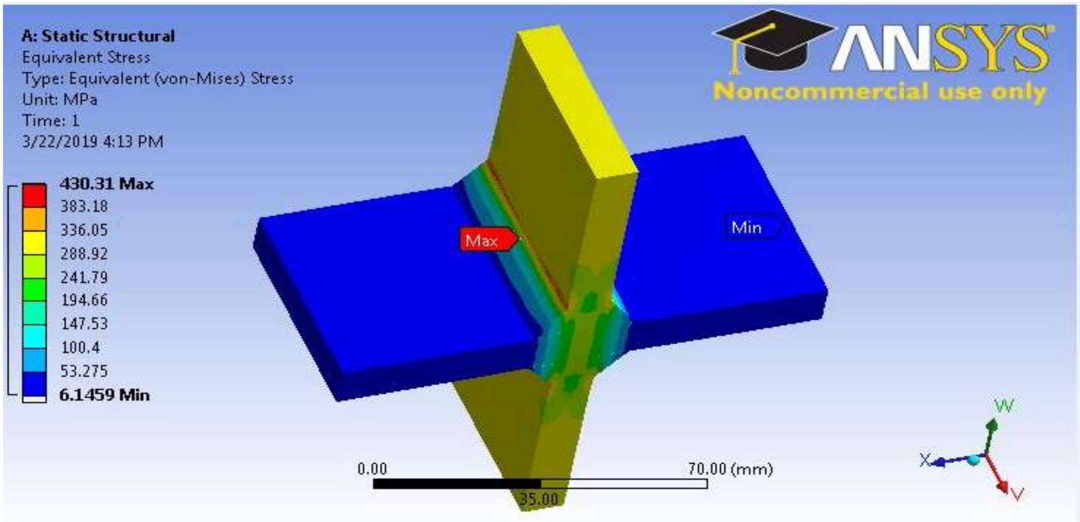

Fig-2 Tensile load with Non loaded fillet with NO load- Stress distribution.

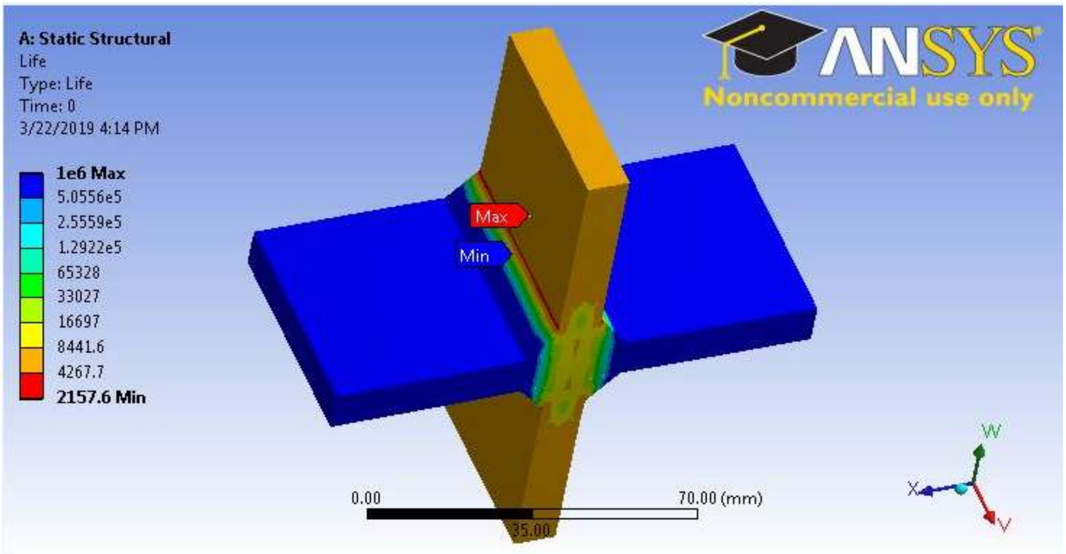

Fig-3 Tensile load with Non-loaded fillet with NO load for- Fatigue life

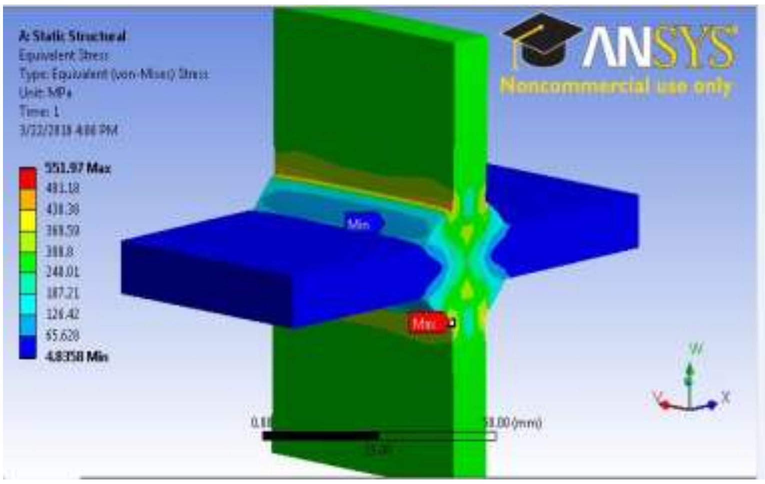

Fig-4 Tensile load with Non- loaded fillet with compressive load

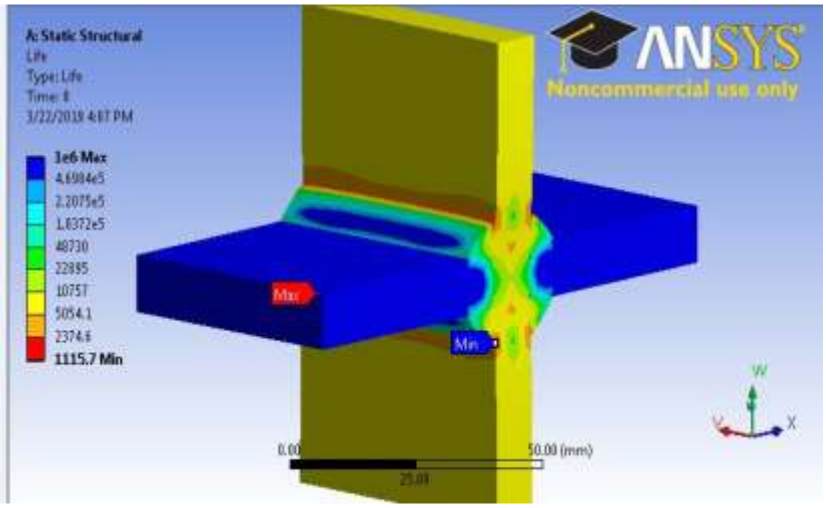

Fig-5 Tensile load with Non- loaded fillet with compressive load for Fatigue life.

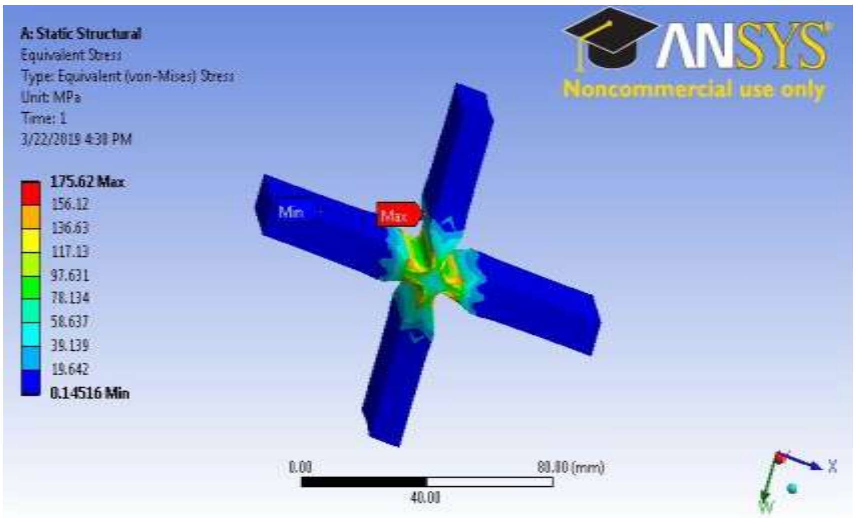

Fig-6 Tensile load with loaded fillet with compressive load for Stress distribution.

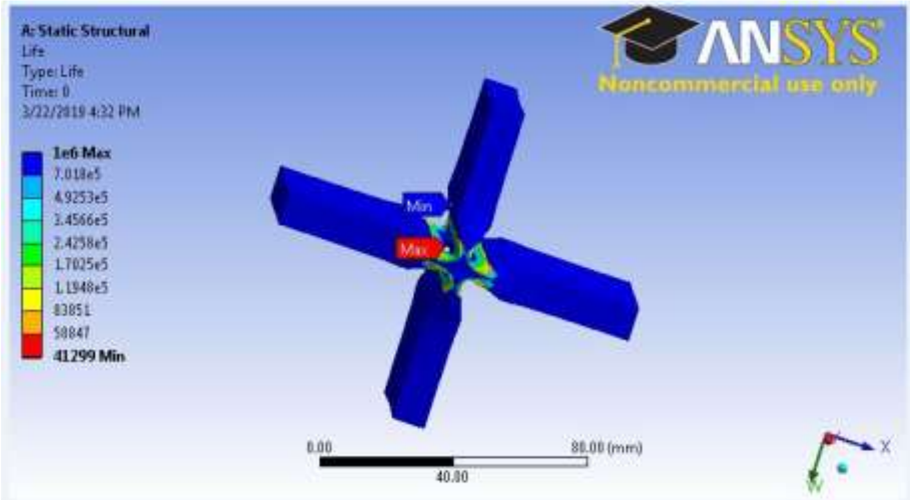

Fig-7 Tensile load with loaded fillet with compressive load for fatigue life.

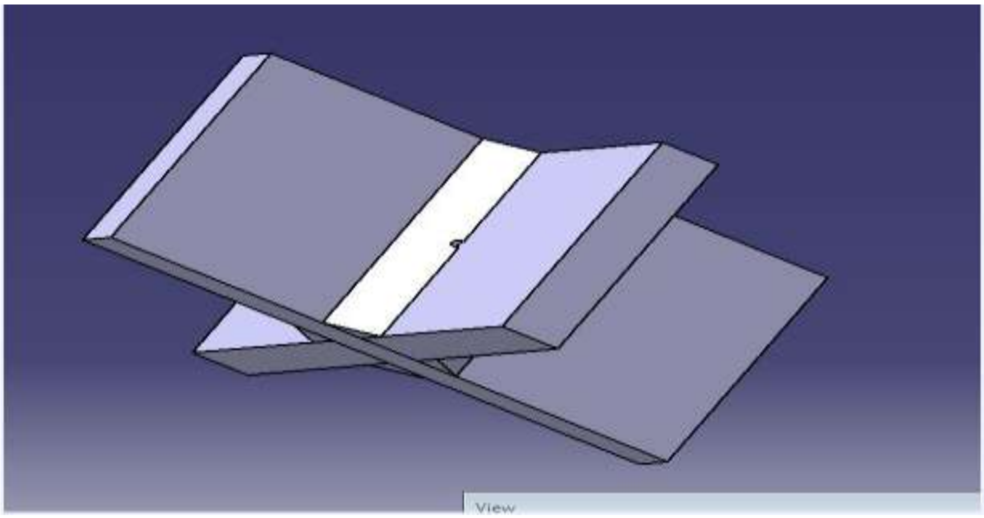

Fig-8 Model considered for Toe Defect

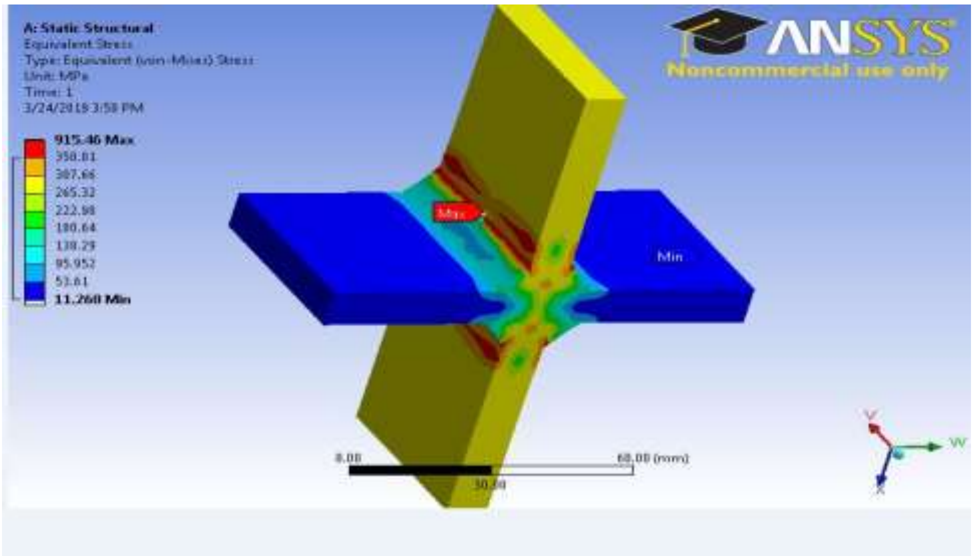

Fig-9 Tensile load fillet with toe defect for stress distribution

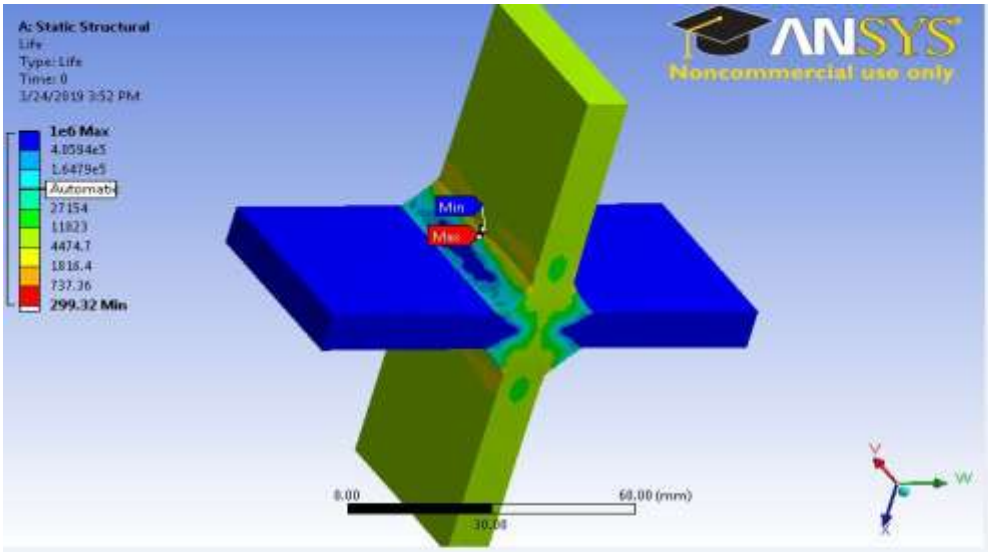

Fig-10 Tensile load fillet with toe defect for Fatigue life.

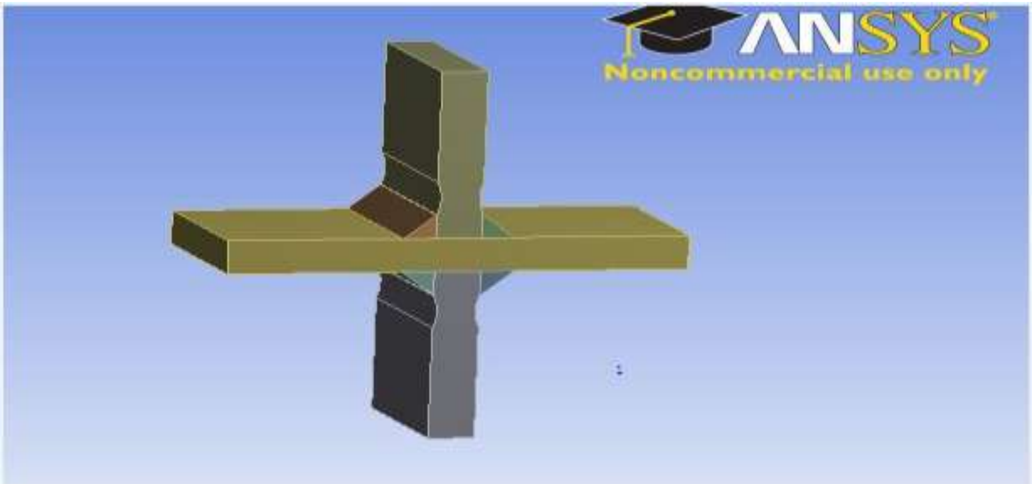

Fig-11 Model considered for Toe grinding

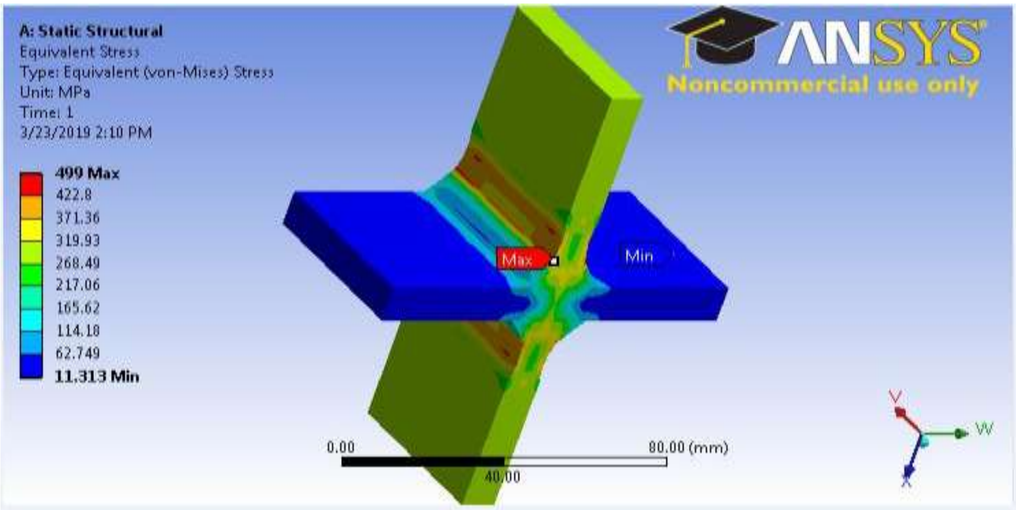

Fig 12 Tensile load fillet with toe grinding for- Stress distribution.

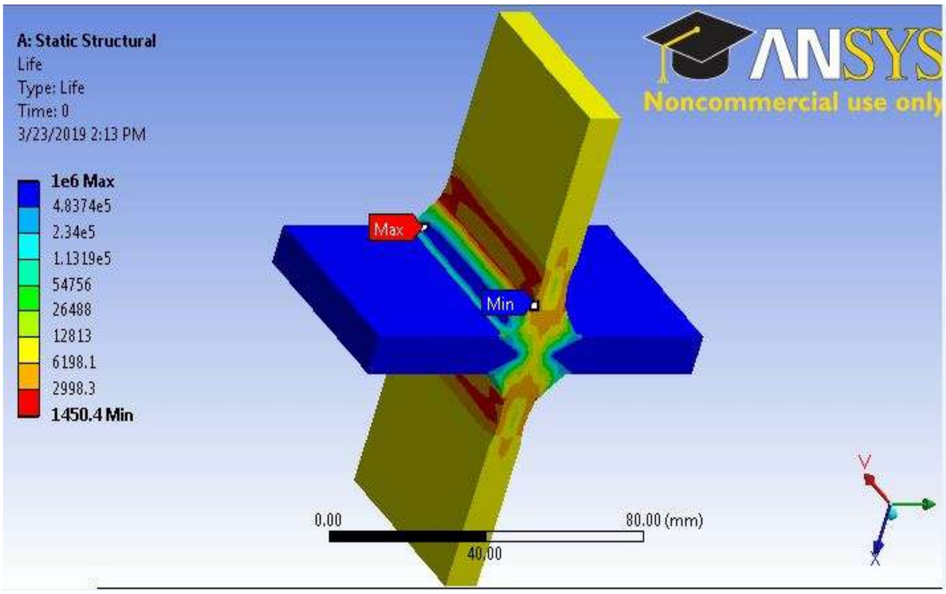

Fig-13 Tensile load fillet with toe grinding for fatigue life.

III. Analysis

It is seen from the welded joints when the welds of fillet are under direct load without any defect the load taking capacity is high. The expected life is also very high as per the ANSYS data presented above.To understand the effect of a toe defect a model similar to the above fillet joint is made. Both loaded fillets and not loaded fillets are subjected to tensile load with compressive load are evaluated. The fillet welds which are loaded with tensile load have shown huge increase in the local stress. When subjected for fatigue life the members have shown significantly reduced values.In order to improve the life and design toe grinding is performed but here model is made in line with toe grinding model as shown in Fig-11. When subjected for tensile stress a significant amount of improvement is observed. As shown in fig -12, 13. Both on load front which half of that of toe defect (fig-9 and 10) for stress values and 4 time on fatigue life.The obtained results from the ANSYS are as tabulated in table-1. This shows the significant improvement.

Table-1 Comparison of parameters between Toe defect weld and toe grinded weld

S.N	configuration	Max Stress (kg/cm2)	Min fatigue life (Min)
1	Tensile load fillet with toe defect for stress distribution	915	293
2	Tensile load fillet with toe grinding for-Stress distribution	499	1450
3	Ratio of improvement	1.8	5

IV. Conclusions

4.1 Stress Intensity: Toe end of the cruciform welded joints show stress intensity due to change of cross sections. But when observed in ANSYS the toe ends where defects are observed there is huge stress concentration. This situation exists invariably in most of the welds. So all the joints with fillets have to be designed by considering higher factor of safety.
4.2 Toe Grinding: AWS standards – Structural welding code steel D1.1 permits grinding depth up to 5% of the thickness. If there is higher depth it will increase stress concentration. In order to improve situation a smooth curve with lower depth and higher radius is considered which is showing lot of improvement. As shown in fig 12,13.
4.2 Internal stresses: it is seen that the welds having internal when grinded get there stress relieve. So when toe grinding is performed the life of the member increases.

V. Further Scope

Lot number of process can be developed to improve the situation like melting the weld toe's by using argon arc. This locally fills the defect.

Conflict of interest The authors declare that there is no conflict of interests regarding the publication of this paper.

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