FRACTURE ANALYSIS OF WELDED JOINTS TO DETERMINE THE STRESS INTENSITY FACTOR USING FEA

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Abstract — The effective uses of welding joints have its greater significance on fabrication process. The study was conducted using the Finite element method. The major study was done on welding joints with flush nugget shapes by using different materials with lap joint and butt joint. A stress intensity factor was analyzed and static structural analysis is performed for validation.

In the present analysis, ANSYS is used. In order to verify the present ABAQUS model, the stress intensity factor with their modes i.e. opening mode (K1), shearing mode (K2), tearing mode (K3) are compared with the available base paper Danijela Zivojinovicb [1] results presented in the literature. The simulations of different profile welding joints with structural steel and 2219 T-8 aluminum alloy materials with flush nugget shapes are proposed.

The results show that increasing load from 950N to 1000N and material like Structural steel with lap joint in flush shaped nugget of welding decreases the stress intensity factor with increase in load.

Keywords— *Welding, Stress intensity factor, lap joint, butt joint.*

I INTRODUCTION

Welding is a permanent joining process used to join different materials like metals, alloys or plastics, together at their contacting surfaces by application of heat and or pressure. During welding, the work-pieces to be joined are melted at the interface and after solidification a permanent joint can be finished. Sometimes a filler material is brought to shape a weld pool of molten fabric which after solidification gives a robust bond among the materials.

Different type of welding processes

Arc Welding: In arc welding process an electric power supply is used to produce an arc between electrode and the work-piece material to joint, so that work-piece metals melt at the interface and welding will be done. Power deliver for arc welding technique may be AC or DC kind. The electrode used for arc welding can be consumable or non-consumable. For non-consumable electrode an external filler material could be used.

Gas Welding: In gas welding process a focused high temperature flame produced by combustion of gas or gas mixture is used to soften the paintings pieces to be joined. An outside filler material is used for correct welding. Most commonplace kind gas welding manner is Oxyacetylene gas welding wherein acetylene and oxygen react and producing some heat.

Resistance Welding: In resistance welding heat is generated due to passing of high amount current (1000–100,000 A) through the resistance as a result of the touch between metallic surfaces. Most not unusual sorts resistance welding is Spot-welding, where a pointed electrode is used. Continuous kind spot resistance welding can be used for seam-welding in which a wheel-fashioned electrode is used.

High Energy Beam Welding: In this type of welding a Targeted power beam with high intensity together with Laser beam or electron beam is used to melt the work pieces and join them together. These sorts of welding in particular used for precision welding or welding of advanced material or sometimes welding of diverse substances, which is not possible with the aid of conventional welding process.

Solid-State Welding: Solid-state welding Processes do no longer contain melting of the paintings piece substances to be joined. Common forms of strong-nation welding are ultrasonic welding, explosion welding, electromagnetic pulse welding, friction welding, friction-stir-welding etc.

II BASIC MECHANISM OF TIG WELDING

TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is Included from surroundings through an inert defensive gas (argon or helium), and a filler metal is commonly used. The electricity is supplied from the electricity supply (rectifier), through a hand-piece or welding torch and is added to a tungsten electrode that is geared up into the hand piece. An electric powered arc is then created between the tungsten electrode and the work piece the usage of a regular-modern-day welding electricity deliver that produces power and carried out throughout the arc via a column of noticeably ionized gas and metal vapors as in paper Sanjeev Kumar et. Al.The tungsten electrode and the welding region are protected from the surrounding air via inert gasoline. The electric arc can produce temperatures of up to 20,000^{o}C and this heat can be focused to melt and join two different part of material. The weld pool can be used to join the base metal with or without filler material. Schematic diagram of TIG welding and mechanism of TIG welding.

In TIG welding process Tungsten is alloyed with thorium or zirconium for better current carrying and electron emission characteristics arc lenth is constant stable and easy to maintain in TIG welding

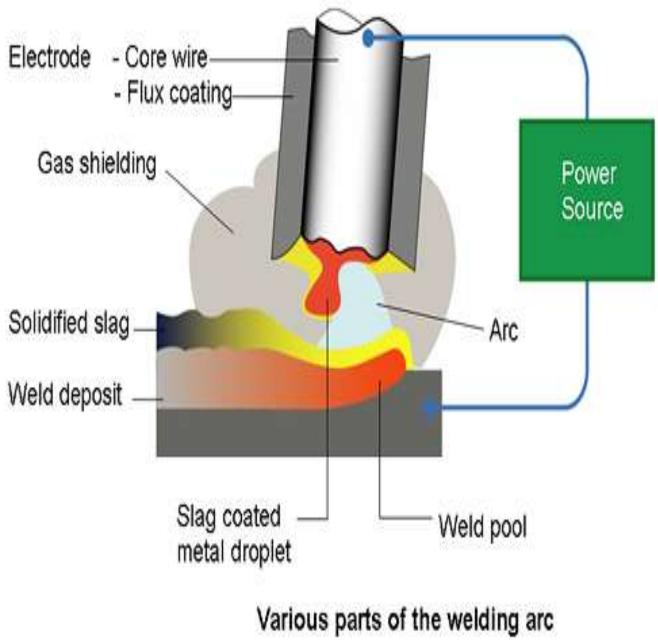

Figure 2.1 various parts of the Arc welding

III APPLICATIONS

The current industries which utilize, GMAW, and GTAW are the aerospace, railway, land transportation, shipbuilding/marine, and the construction industries. These industries have seen a push towards the usage of lightweight but strong metals which include aluminum. Many products of those industries require joining three-dimensional contours, which isn't manageable using friction stir welding heavy-responsibility machine device kind equipment with traversing systems which might be confined to best straight line or two-dimensional contours. For those packages, industrial robots could be a preferred solution for appearing friction stir welding for some of reasons, which includes: lower fees, strength efficiency, more manufacturing flexibility, and most significantly, the potential to observe three-dimensional contours.

IV ADVANTAGES OF TIG WELDING

TIG welding process has specific advantages over other arc welding process as follows -

- Narrow concentrated arc

- Able to weld ferrous and non-ferrous metals
- Does not use flux or leave any slag (shielding gas is used to protect the weld-pool and tungsten electrode)
- No spatter and fumes during TIG welding

V LITERATURE REVIEW

Danijela Zivojinovicb [1] In this paper the fatigue crack propagation in thin-walled aluminium alloy structure with two friction stir welded (FSW) joints has been numerically modelled. Crack propagation in unstiffened part of the structure between two FSW joints is analyzed. The analyzed models made from aluminium alloy 2024-T351. During its (stable) growth, the crack remains within the base material. As it gets closer to the FSW joint (HAZ), considerable crack growth leading to structure failure starts to occur, before the crack can reach the HAZ.

Andrijana Durđevic [2] In this work, fatigue crack propagation in thin-walled aluminium alloy structure with two friction stir welded T joints has been simulated numerically. Crack propagation in stiffened part of the structure between two friction stir welded T joints is analysed by using the extended Finite element method . He analyzed the stress intensity factors that obtained for each step of crack propagation along the crack. During its propagation, the crack remained within the base metal in the analyzed case, leaving more detailed analysis for future work, including crack propagation through different welded joint zones and the effect of stiffeners.

D. Fersini [3] in this paper the fatigue strength of 2024-T3 aluminum alloy friction stir welded single-lap joints is determined by the presence of two crack-like unwelded zones at the overlap ends. In this work, a finite element analysis is performed to predict the crack path and the stress intensity factor at the crack tip, then the lifetime is estimated by examining the crack propagation behavior of the base material.

S. Lomolino [4] This paper collects available fatigue data on FSW of Al alloys and statistically analyses these deriving a first set of reference fatigue curves. It is envisaged that a comparison of the reference curves obtained with the design curves given by design standards. The aim of the present work was to give, for the Al alloys, as first draft, an overview of the fatigue properties of butt joints friction stir welded, trying to use the same criteria employed in the standards for providing design data.

Wei Dong [5] In this paper the analysis of crack propagation of normal strength concrete at a crack tip the initial fracture toughness and nil-stress intensity factor (nil-SIF) are two distinguished and widely adopted types of crack propagation criteria. The beams under three-point bending with different concrete strength grades were obtained from experiment, The corresponding results obtained from numerical analysis using the nil SIF and the initial fracture toughness criteria are also presented.

HE Zhen-bo [6] In order to study the welding process, microstructure and properties of Al-Mg-Mn-Sc-Zr alloy, comparative methods of friction stir welding (FSW) and tungsten inert gas (TIG) were applied to the two conditions of this alloy, namely hot rolled plate and cold rolled-annealed plate. For each condition of Al-Mg-Mn-Sc-Zr alloy, namely thick hot rolled plate and cold rolled-annealed plate, the tensile strength, elongation and welding coefficient of FSW welded joints are higher than those of TIG welded joints.

Hideo Koguchi [7] Stress singularities usually occur at vertexes in three-dimensional joints. Cracks frequently initiate at the vertex, and the joint fails under an external force or a thermal load. In the present study, the stress distribution near a small crack occurring at a vertex in a three-dimensional joint under a tensile load is examined, and the stress intensity factors at the crack tip are investigated along the crack tip front.

Hassan Mirahmadi [8] In this study, obtaining stress intensity factors (SIFs) for functionally graded cylinders with two internal radial cracks using the weight function method has been discussed. For this purpose, reference SIFs are calculated from the results of finite element analysis, using a modified domain of the J integral.

Yufeng Zhang [9] In this analysis an excellent butt joint of 5A06 and Ti6Al4V was achieved via MIG/TIG double-side arc welding-brazing process with Al-5Si wire. The conventional MIG welding-brazing process was carried out at the same welding heat input for comparison. Then formation and microstructure of joints were investigated, and the quality of joints was examined by tensile test. The results showed that weld formation, especially the formation of back weld, was improved .

Zhenhuan Zhou [10] An analytical method is presented for finding the complex stress intensity factors (SIFs) and T-stress at an edge bi-material interface crack. A Hamiltonian system is first established by introducing dual (conjugate) variables of displacements and stresses whose solutions are expanded in terms of the simplistic series.

5.1 Objective of the Work

The main objective of the current work is

- Validation of the ANSYS models by comparing the present simulated results with the simulation result of base paper Danijela Zivojinovicb [1].
- To predict stress intensity factor.
- To simulate the welded joints of the different material having different nugget shapes for variable loads.
- To define stress intensity factor (K1, K2, K3) effects for the welded joints of different nugget profile and different material at a load of 950N and 1000N.
- To determine the opening mode (K1), shearing mode (K2), tearing mode (K3) along the different welded joints.

5.2 The material properties used in present study:

Material Properties			
Physical Properties	**Structural Steel**	**2219-T8 Aluminum Alloy**	**2024-T351 Aluminum Alloy**
Youngs Modulus (GPA)	211	73.8	68
Poisson's ratio	0.3	0.33	0.33
Density (Kg/m^3)	7850	2480	2785

5.3 Problem Formulation

The study of various literatures we find the stress intensity factor is higher as compared to present study. The purpose of this study is to predict stress intensity factor effect and fatigue life with different material and comparison between different welded joints with variable nugget shapes at a load of 950N to 1000N.

VI MODELING AND ANALYSIS

Design procedure of welded joint

The procedure for solving the problem is

- Modeling butt welded joint in Unigraphics NX 10 with the dimensions of 1x20x144 mm which is to be analyzed in butt joint.
- Modeling of lap welded joint of two plates in Unigraphics NX 10 with the dimension of 1.6X20X110 for each plate.
- The crack given to the model at the center of the model in semi elliptical shape having major and minor axes are 3 mm and 2 mm respectively.
- The boundary condition given to the model is that one end is fixed and a tensile load with the magnitude of 950 N and 1000 N is acting at the another end.
- Meshing of the domain.

- Defining the input parameters.
- Simulation of domain.

Analysis Type- Structural Analysis and Modal analysis.

6.1 Preprocessing

Preprocessing include CAD model, meshing and defining boundary conditions.

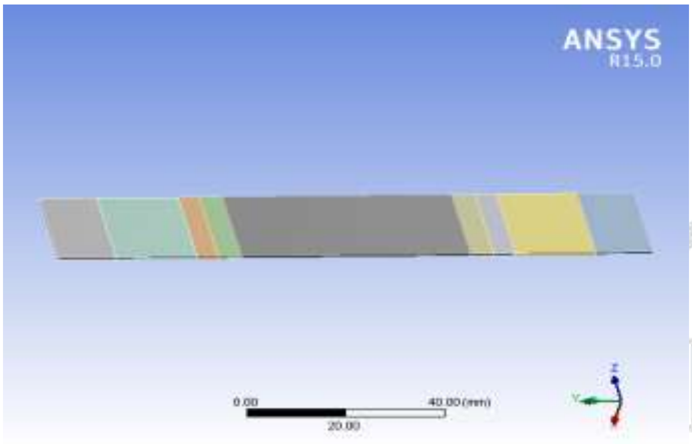

Figure No.: 6.1 CAD Model of butt joint plate

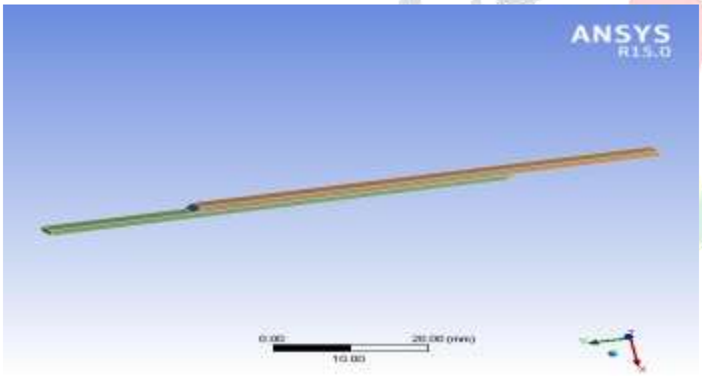

Figure No.:6.2: CAD Model of Lap joint with flush nugget shape

4.2 Meshing Domain of different welded joints:-

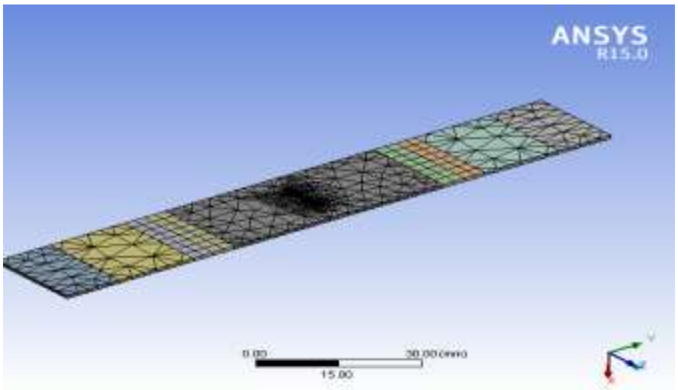

Figure No.: 6.3 meshing domain of butt joint plate with crack meshes

VII RESULT AND DISCUSSION

ANALYSIS OF LAP JOINT FLUSH SHAPED NUGGET FOR ALUMINUM ALLOY MATERIAL WITH APPLYING LOAD OF 950N

Table: 7.1 SIFS K1 of lap joint flush shaped nugget for aluminum alloy material with applying load 950N:

Steps	K1	K2	K3
1	-0.2243	0.3792	7.2596
2	-1.0372	-0.2200	5.6611
3	-1.8500	-0.8193	4.0627
4	-2.6628	-1.4186	2.4642
5	-3.4756	-2.0179	0.8657
6	-4.2883	2.6172	-0.7326
7	-5.1011	-3.2165	-2.3331
8	-5.9139	-3.8157	-3.9296
9	-6.7267	-4.4150	-5.5280
10	-7.5395	-5.0143	-7.1265

Show the stress intensity factor K1,K2, K3

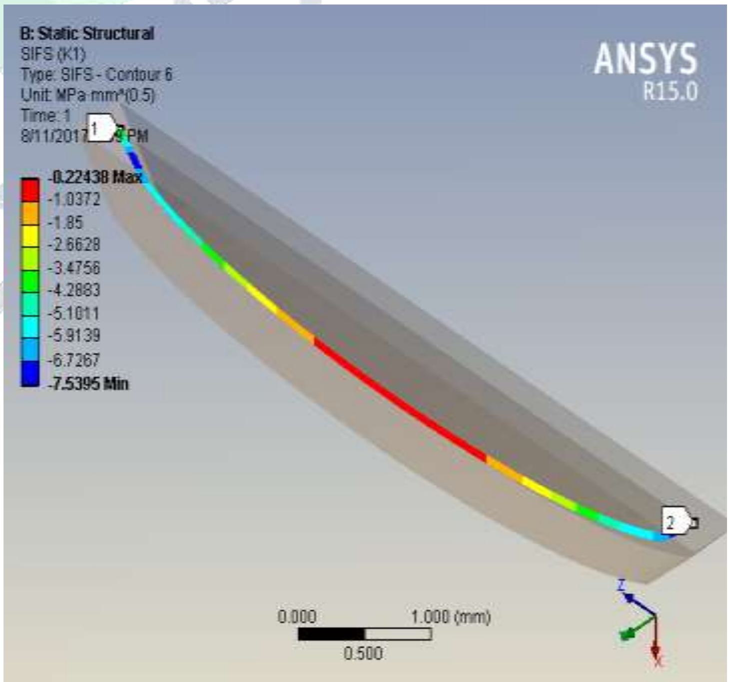

Figure 7.1. Show the stress intensity factor K1

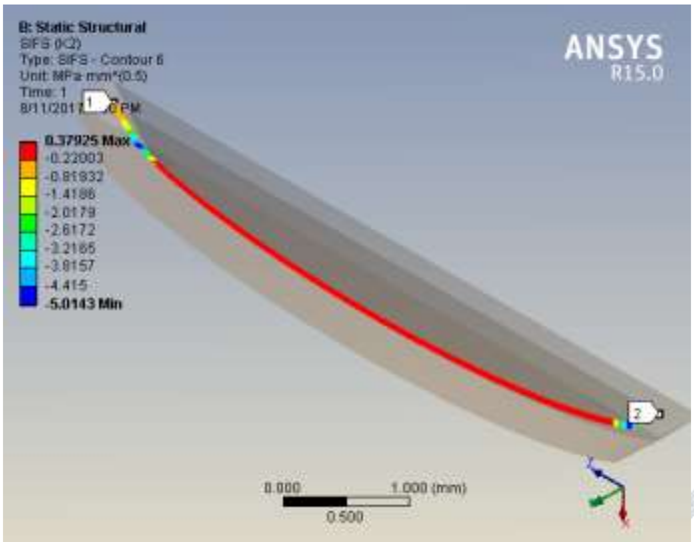

Figure 7.2. Show the stress intensity factor K2

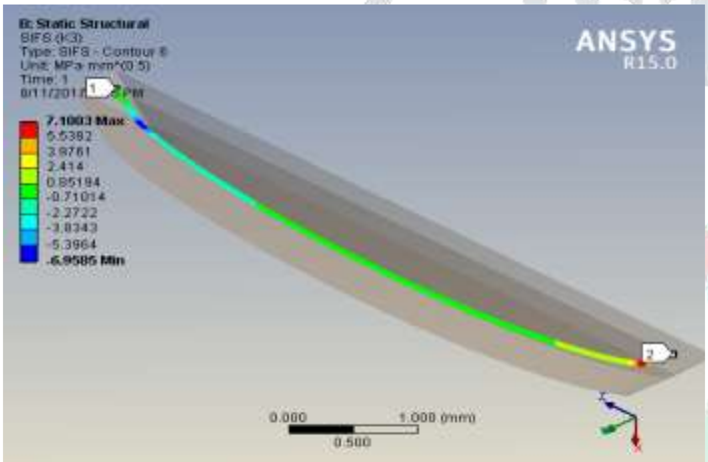

Figure 7.3 Show the stress intensity factor K3

Comparison for SIFS K1, K2 AND K3 of aluminum alloy material.

Table 7.2 SIFS K1, K2 and K3of modeling plate with applying load 1000N

Steps	K1	K2	K3
1	-0.2361	0.3992	7.6417
2	-1.0918	-0.2316	5.9591
3	-1.9473	-0.86244	4.2765
4	-2.8029	-1.4933	2.5939
5	-3.6585	-2.1241	0.9113
6	-4.5140	-2.7549	-0.7712
7	-5.3696	-3.3857	-2.5438
8	-6.2252	-4.0166	-4.1364
9	-7.0808	-4.6474	-5.8190
10	-7.9363	-5.2782	-7.5015

Comparison for SIFS K1, K2 and K3 of Structural Steel material:

Table 7.3 SIFS K1, K2 AND K3of Structural Steel lap joint flush shaped welding plate with applying load 950N:

Steps	K1	K2	K3
1	-0.0225	0.3833	7.1003
2	-0.8495	-0.2083	5.5382
3	-1.6766	-0.7995	3.9761
4	-2.5036	-1.3916	2.4140
5	-3.3306	-1.9832	0.8519
6	-4.1577	-2.5748	-0.7101
7	-4.9847	-3.1665	-2.2722
8	-5.8117	-3.7581	-3.8343
9	-6.6387	-4.3498	-5.3964
10	-7.4657	-4.9414	-6.9585

Above shown table represents the comparison between all three modes of stress intensity factor i.e. opening mode, shearing mode and tearing mode of structural steel material with an applied load of 950N.

Comparison for SIFS K1, K2 and K3 of Structural steel material:

Table 7.4 SIFS K1, K2 AND K3 of Structural Steel lap joint flush shaped welding plate with applying load 1000N:

Steps	K1	K2	K3
1	-0.0237	0.4035	7.4740
2	0.8943	-0.2192	5.8427
3	-1.7649	-0.8420	4.1854
4	-2.6354	-0.1.46	2.5411
5	-3.5059	-2.0800	0.8967
6	-4.3765	-2.7104	-0.7475
7	-5.2470	-3.3331	-2.3918
8	-6.1176	-3.3331	-0.4038
9	-6.9881	-4.5787	-5.6804
10	-7.8587	-5.2015	-7.3247

Above shown table represents the comparison between all three modes of stress intensity factor i.e. opening mode, shearing mode and tearing mode of structural steel material with an applied load of 1000 N, thus all three modes shows average deviation with each other.

RESULT AND DISCUSSION:

It is evident that there is an increase in the stress intensity factor along the crack tip on 2219 T-8 Aluminium alloy welded plate than structural steel. The following graph shows the comparison of 2219 T-8 aluminim alloy with structural steel at 950 N of K1 ,K2 K3 modes:

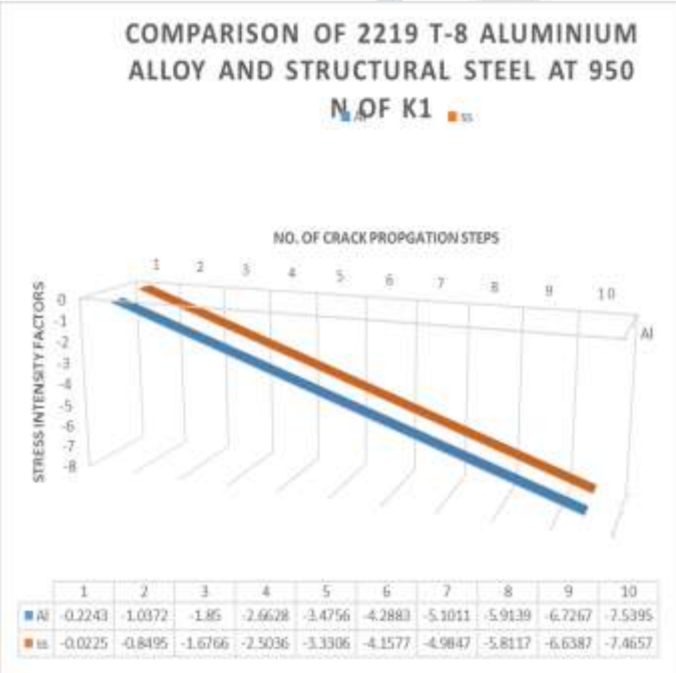

Fig no 7.4 comparison of 2219 T-8 Aluminium alloy and structural steel at 950 N of K1

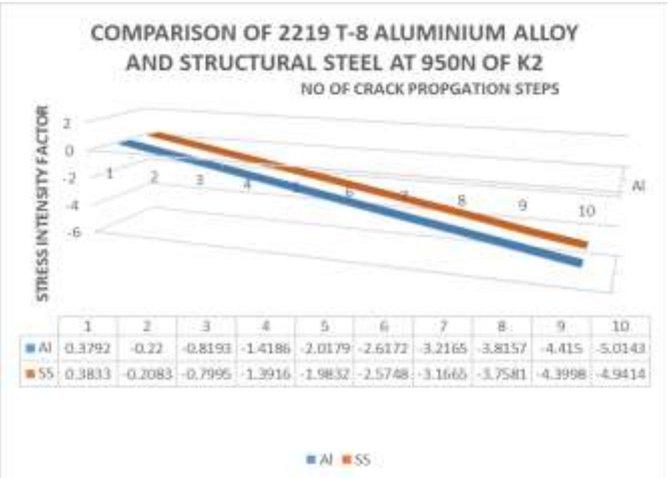

Fig no 7.5 comparison of 2219 T-8 Aluminium alloy and structural steel at 950 N of K2

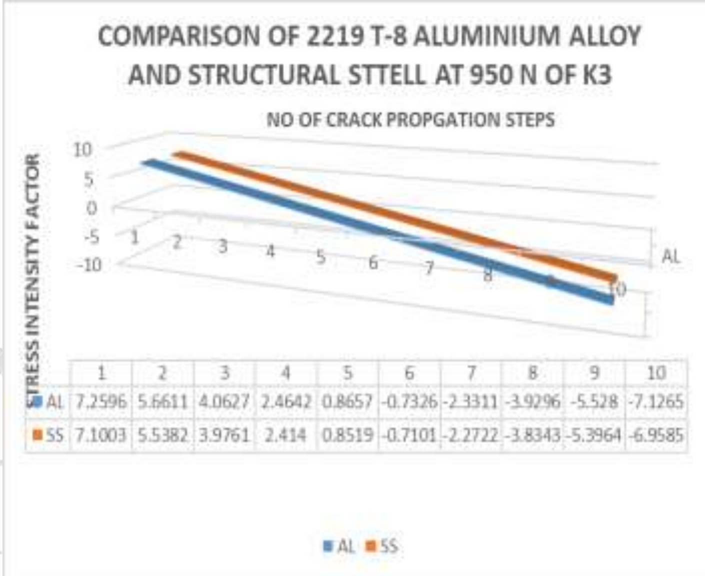

Fig no 7.6 comparison of 2219 T-8 Aluminium alloy and structural steel at 950 N of K3

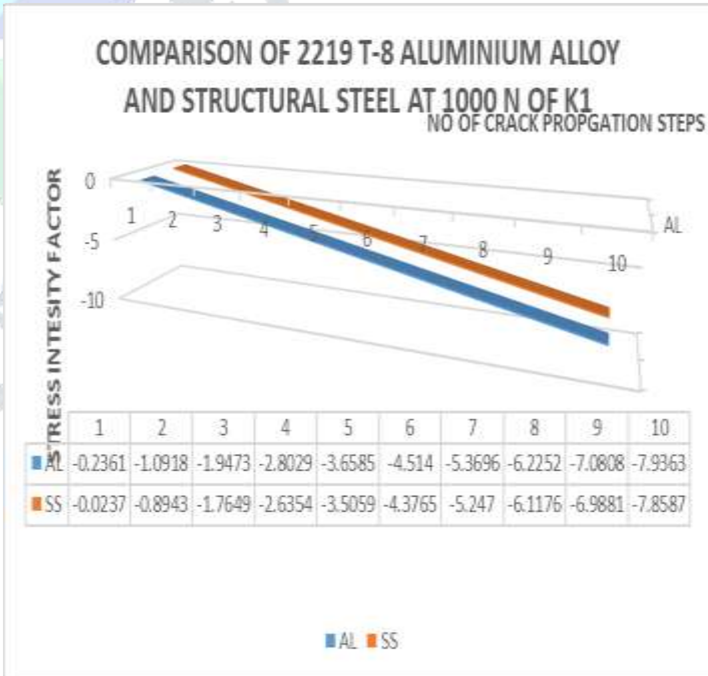

Fig no 7.7 comparison of 2219 T-8 Aluminium alloy and structural steel at 1000 N of K1

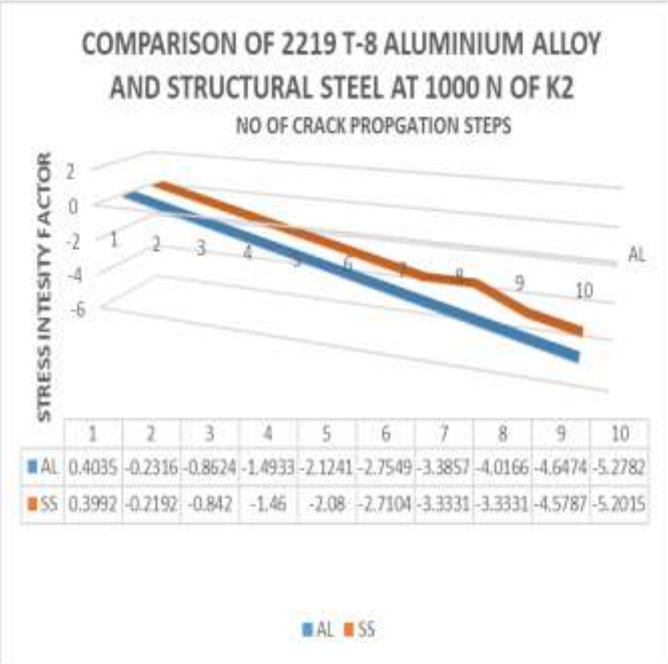

Fig no 7.8 comparison of 2219 T-8 Aluminium alloy and structural steel at 1000 N of K2

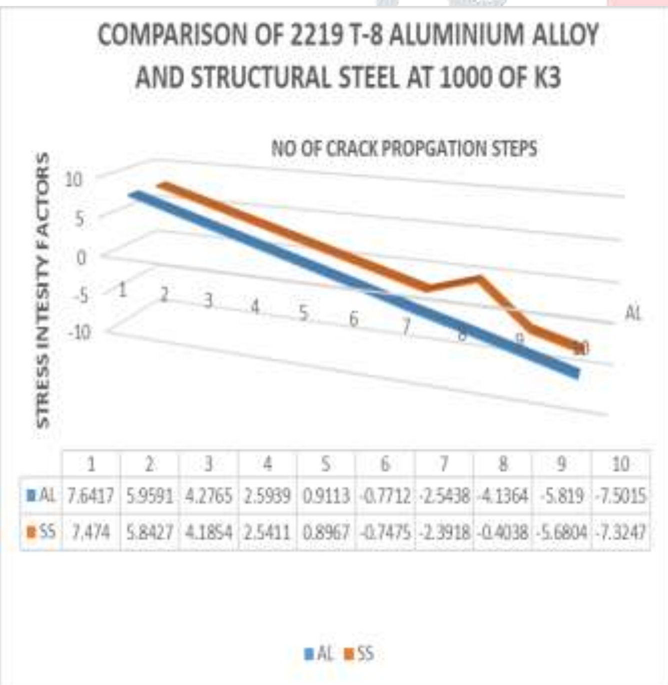

Fig no 7.9 comparison of 2219 T-8 Aluminium alloy and structural steel at 1000 N of K3

VIII CONCLUSION

The current analysis has presented a study of stress intensity factor, characteristics of a welded joint with Flush shaped nugget of different joints. Static structural analysis was carried out on Aluminum alloy, Structural Steel and 2219 T-8 Aluminium alloy. The effect of crack with different welded joints of the lap joint plates with variable loading conditions were analyzed on different profile and materials of plate and distribution along the plate was studied. From the analysis of the results, following conclusions can be drawn.

Influence of different welded joint profiles

- The stress intensity factor of the plate with lap profile is found to be minimum of the Structural Steel material profile with Flush shaped welded nugget. The load bearing ability is found maximum for Structural Steel of a plate with flush shaped nugget.
- The nature of the opening mode, shearing mode and tearing mode (K1, K2, and K3) is minimum lap joint and nugget of flush shaped.
- In a comparison with the Structural Steel of all three modes i.e. opening mode, shearing mode and tearing mode the stress intensity factor for 2219 T-8 Aluminium alloy is found more than structural steel .
- It is found that the flush shaped nugget in lap joint has maximum life in the case of different loading condition and less stress intensity factor and minimum for Structural Steel profile. Thus more strength was determined in flush shape nugget of structural steel lap joint.

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