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Fatigue analysis of welded joints

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Abstract
Failure of welded structures/machine components lead to various direct losses such as the cost of repair work, the cost of the work to prevent future failure and accident compensation, and indirect losses such as decrease in production and a damage to company's image. Joints being the weakest elements in any structure/machine are likely to fail first. It is, therefore, imperative to understand the failure of these joints.
Understanding a failure occurrence and its propagation will lead to a better appreciation of welded joints from reliability point of view. It may be possible that a few cause events or failure causes may be crucial and could be minimized at design or fabrication stage leading to failure minimization of such joints. Arc welding, which is heat - type welding, is one of the most important manufacturing operations for the joining of structural elements for a wide range of applications, including guide way for trains, ships, bridges, building structures, automobiles, and nuclear reactors, to name a few. It requires a continuous supply of either direct or alternating electric current, which create an electric arc to generate enough heat to melt the metal and form a weld.
In this process, stress concentration at the welded joints is analyzed. The type of joints considered is Tree Joint, Butt Joint and Lap Joint. Structural and Fatigue analysis is done on the welded joints in Ansys.

Keywords: Fatigue Analysis; T-Joint; Butt Joint; Lap Joint; Welded Joints;

1. Introduction
Welding is a materials joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone, and with or without the use of filler material.
Welding is used for making permanent joints. It is used in the manufacture of automobile bodies, aircraft frames, railway wagons, machine frames, structural works, tanks, furniture, boilers, general repair work and ship building.

1.1 Tee joint
Tee joints are used when one part must be joined to the center of another part forming a "T". Like the other types of weld, there are several ways that this joint can be prepared and welded, each with their own benefits and disadvantages. Most methods of welding tee joints involve welding the two joints between the parts, with either a high or low energy density beam. Like the other weld types, there are fundamental differences in the processes used with these two types of weld.
When a tee joint is welded with either a high or low energy density system, the process usually involves first placing and clamping the parts in the necessary configuration. If necessary, the parts may be tack welded together to make welding the final joint easer. This can, however, case complications in the final weld, which will be elaborated on later. From here, the processes begin to diverge.
In the case of low energy density welding, such a GTAW and PAW, the joint is made by making a weld bead on one, or usually both, sides of the vertical plate. This is usually done with filler wire, as there is no non-critical area for the volume of the weld bead to come from, as there is in some other weld types. This method forms a very strong weld, usually with minimal distortion. However, it is not nearly as strong as the base metal. In this case, there are relatively few problems associated with spot welding before the final weld.

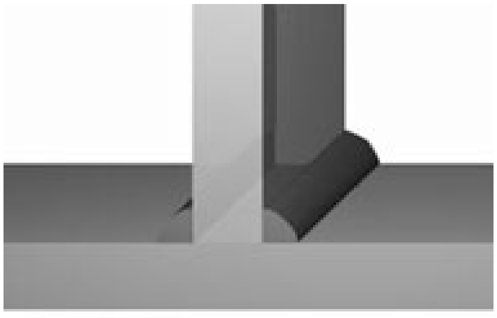

Fig 1: Low energy density welding.

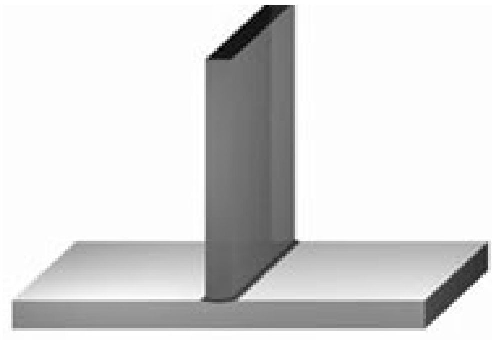

Fig 2: High energy density welding.

There are more options for welding tee joints with high energy density devices, such as the laser and electron beam. One option is to weld in a manner similar to that used in low energy density processes, along the joint. However, rather than simply welding on the surface, the beam penetrates deep into the piece, making a weld that can be comparable in strength to the base metal. Unfortunately, this method tends to case more distortion of the work piece than low energy density methods. Welding both sides of the joint can help to correct this distortion, as well as strengthen the weld.

The second option when welding tee joints with a high energy density beam is to weld through the top of the "T" and into the perpendicular. This can be faster and easier, as it does not require that the joint be followed exactly, but tends to be far weaker than a weld from the side. This method also reduces distortion and is particularly well suited for welding a relatively thick piece to a thin plate, as the beam easily melts the thin plate that it must weld through but does not heat the second plate excessively.

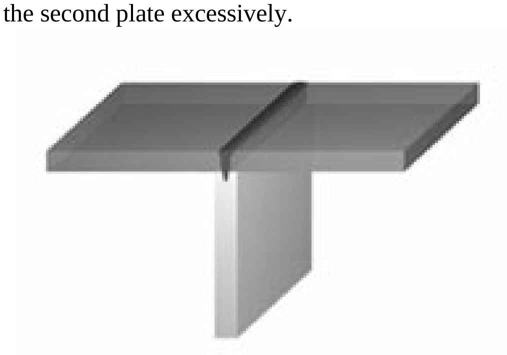

Fig 3: high energy density beam welding

As mentioned earlier, preparatory spot welding can cause severe complications in high energy density beam welding. When the spot weld is created, it usually adds material other than that of the two parts being joined. This foreign material may be included as inclusions in the weld, may evaporate under the intense heat of the beam and form porosities, or may combine metallurgical with the base metal and prevent it from crystallizing properly.

1.2 Butt Joint

The butt joint is a very simple joint to construct. Members are simply docked at the right angle and have a required length. One member will be shorter than the finished size by the thickness of the adjacent member. For enclosed constructions, such as four-sided frames or boxes, the thickness of the two adjacent members must be taken into consideration.

1.3 Lap Joint

Lap joints can be used in wood, plastic, or metal. A half lap joint or a halving joint is a technique of joining two pieces of material together by overlapping them. A lap may be a full lap or half lap. In a full lap, no material is removed from either of the members to be joined, resulting in a joint which is the combined thickness of the two members. In a half lap joint, material is removed from each of the members so that the resulting joint is the thickness of the thickest member. Most commonly in half lap joints, the members are of the same thickness and half the thickness of each is removed.

2. Structural Analysis

2.1 Tee Joint

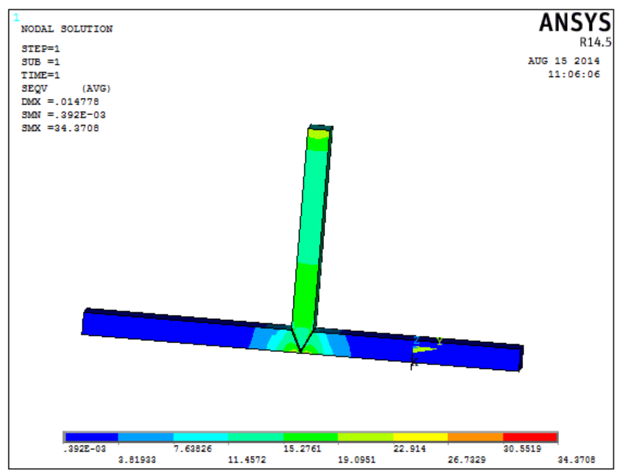

Fig 4: Stress for TEE joint

2.2 Butt Joint

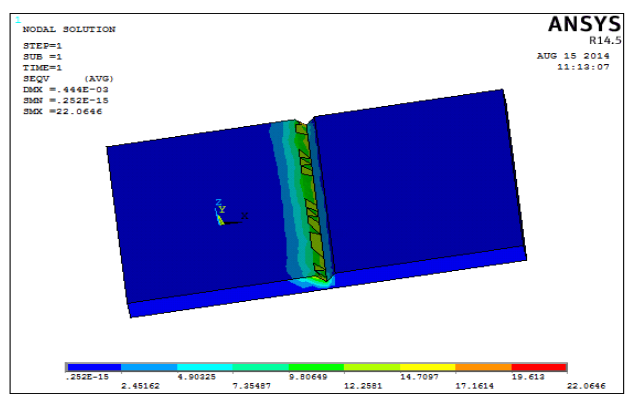

Fig 4: Stress for TEE joint

2.3 Lap Joint

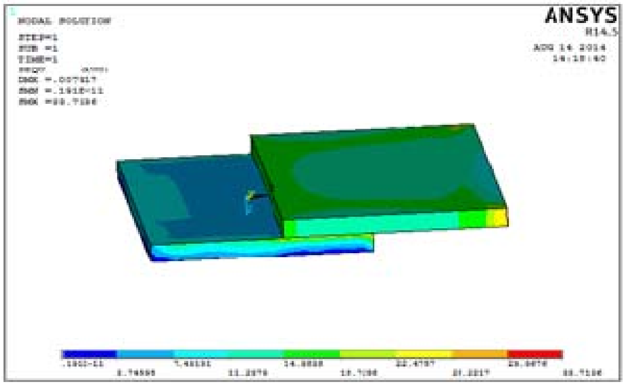

Fig 5: Stress for Lap joint

3. Results

3.1 Structural Analysis

Type of joint	Results	
Tree joint	Displacement (mm)	0.014778
	STRESS (N/mm^2)	34.3708
	Strain	0.164e-03
Butt joint	Displacement (mm)	0.444e-0.3
	STRESS (N/mm^2)	22.0646
	Strain	0.106e-03
Lap joint	Displacement (mm)	0.007917
	STRESS (N/mm^2)	33.7136
	Strain	0.163e-03

3.2 Fatigue Analysis

	Stress N/mm^2	Cumulative Fatigue Usage
Constrained area **Event 1 Load1, Event 1 500000cycles Load 2** **Event 2 Load1, Event 2 50000cycles**	$0.10000e^{-29}$	0.0001
Pressure area **Event 1 Load1, Event 1 500000Cycles Load 2** **Event 2 Load1, Event 2 50000cyclesLoad 2**	$0.10000e^{-29}$	0.5
Open area **Event 1 Load1, Event 1 500000cycles Load 2** **Event 2 Load1, Event 2 50000cyclesLoad 2**	$0.10000e^{-29}$	0.0001

4. Conclusion

The stress distribution in different welded Joints is investigated with a computer modeling technique. The finite element analysis is used for the analysis of joints in the plane – stress condition, under static load. Modeling is done in Pro/Engineer and analysis is done in Ansys.

The types of joints are T – joint, Butt Joint and Lap Joint. Structural and fatigue analysis are done in Ansys. By observing the structural analysis results, all the joints are withstanding the applied pressure as the analyzed stress values are less than the yield strength of steel. The Tree Joint has produced more stress than other joints, so if the load on the welded joint is more, the tree joint fails first than other joints. Fatigue analysis is done to analyze the fatigue usage by applying cyclic loading. By observing the analysis results, the fatigue usage is more for Butt Joint, so the life of the Butt Joint is less than other two joints.

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