Application of Analysis for Optimum Butt Welded Joint for Different Materials of Weldments

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ABSTRACT: *Weld failure due to vibrations can be minimized if appropriate measures are implemented to ensure forced vibration is not equal to the natural frequency of the material. This focuses on determining the optimum butt welded joint, by analyzing the various natural frequencies and mode shape responses obtained from five different types of butt joints. In this study, modal analysis was carried out using ANSYS 2019 R3 on two plates of same material in each case that are welded together. The same procedure is repeated for three different materials namely Structural steel, Copper alloy, Aluminum alloy. Five different geometries of butt joints namely: single V groove butt weld, double V groove butt weld, single U groove butt weld, double U groove butt weld and square groove butt welded joints were examined. The natural frequencies and mode shape deformations obtained were compared with the natural frequency of corresponding material of no weld plate and are found to be satisfactory.*

Keywords: *ANSYS 2019 R3, Structural steel, Copper alloy, Aluminum alloy, Natural frequency.*

I. Introduction

Welding, by contrast to the other fabrication techniques, is a metallurgical fusion process. Here, the interface of the two parts to be joined are brought to a temperature above the melting point and then allowed to solidify so that a permanent joining takes place. Because of the permanent nature of the joint and its strength being equal to or sometimes greater than that of the parent metal, welding is one of the most extensively used fabrication methods. Welding is not only used for making structures but also for repair work such as the joining of broken castings. Products obtained by the process of welding are called weldments.

1.2 DESIGN OF WELDED JOINTS

A poorly designed weld joint can lead to the failure of an engineering component in three ways namely:

- Elastic deformation (like bending or torsion of shaft and other sophisticated engineering systems like precision measuring instruments and machine tools) of weld joint beyond acceptable limits
- Plastic deformation (change in dimensions beyond acceptable limits as-decided by application) of

engineering component across the weld joint and

- Fracture of weld joint into two or more pieces under external tensile, shear, compression, impact creep and fatigue loads.

Therefore, depending upon the application, failure of weld joints may occur in different ways and hence a different approach is needed for designing the weld joints as per application and service requirements.

1.3 Loading Conditions of Welded Joints

Design of weld joints for static and dynamic loads needs different approaches because in case of static loads the direction and magnitude become either constant or changes very slowly while in case of dynamic loads such as impact and fatigue conditions, the rate of loading is usually high. In case of fatigue loading both magnitude and direction of load may fluctuate.

Under the static load condition, low rate of loading increases the time available for localized yielding to occur in area of high stress concentration which in turn causes stress relaxation by redistribution of stresses through-out the cross section while under dynamic loading conditions, due to lack of availability of time, yielding across the section of weld doesn't take place and only localized excessive deformation occurs near the site of a high concentration stress which eventually provide an easy site for nucleation and growth of cracks as in case of fatigue loading.

II. NUMERICAL ANALYSIS

Numerical analysis of the welded plates of similar metal in each case with the weld bead assumed to be mild steel material in a MIG weld. It is also assumed that their cross- section to be rectangular have been conducted by using ANSYS. Five different geometries of the butt weld are considered for the analysis. Initially geometry of these plates have been created in CATIA. Geometry was imported and meshed using ANSYS workbench. Further analysis was carried out by considering suitable boundary conditions, solver and solution constraints. Results were presented in the form of modal frequencies and respective mode shapes are also presented.

GEOMETRIC MODELLING

Geometry of each model was created in CATIA. The images of each model is shown in Fig. 3.1 No weld plates, Fig.3.2 Single-V joint, Fig. 3.3 Double-V joint, Fig. 3.4 Single-U joint, Fig. 3.5 Double-U joint, Fig. 3.6 Square joint.

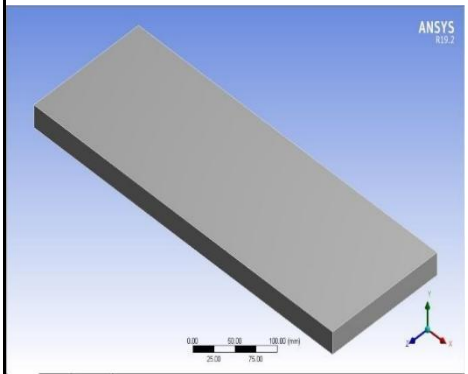	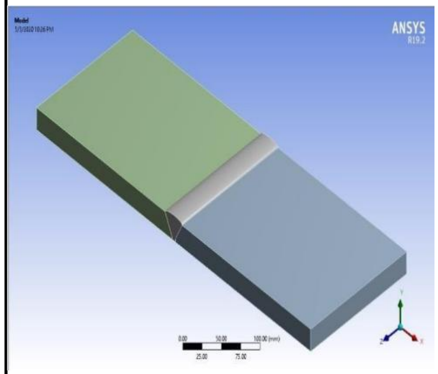
Fig. 3.1 Geometry of No weld plates	Fig. 3.2 Geometry of Single-V butt welded joint

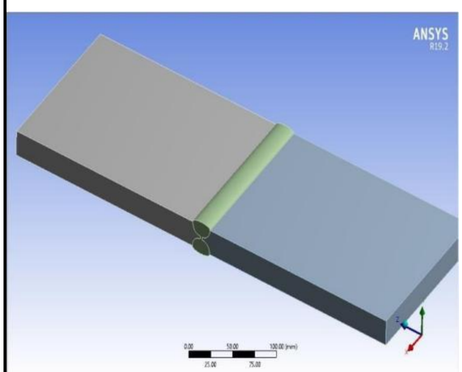	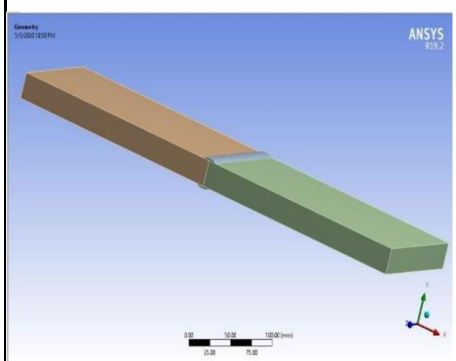
Fig. 3.5 Geometry of Double-U butt welded joint	Fig. 3.6 Geometry of Square butt welded joint

BOUNDARY CONDITIONS

The analysis on the respective geometries was performed in order to obtain the natural frequencies. The sides of the plate are constrained to all DOF making it a case of fixed fixed beam. The materials that have been selected are structural steel, copper alloy, aluminum alloy and the plate dimensions are taken as 500mm x 175mm x 25mm

GRID INDEPENDENCE TEST

Numerical simulations were carried out for different mesh sizes and optimum mesh size was found by comparing the natural frequencies given in the Table 3.1.

TABLE 3.1

COMPARING FREQUENCIES IN GRID INDEPENDENCE TEST TO OBTAIN THE OPTIMUM GRID SIZE

S No.	Mesh Size (mm)	Number of Mesh Elements	Natural Frequencies
1	10	3798	523.95
2	5	21560	523.6
3	3	99651	523.46
4	2	312136	523.41

Hence the optimum mesh size as observed from table 3.1 is 2mm.

RESULTS & DISCUSSIONS

Numerical simulations carried out on five different types of butt welded joints adapting procedure given in chapter 3. The first five mode shapes of different geometries for structural steel have been presented. Each mode represents the transverse vibrational component of the welded plate.

TABLE- 4.2

COMPARISON OF NATURAL FREQUENCIES OF STRUCTURAL STEEL

Mode shapes	No weld	Single-V	Double-V	Single-U	Double-U	Square
1	529.31	525.21	523.04	525.51	523.9	524.17
2	1430.5	1413.8	1413.1	1415.7	1414.3	1415.7
3	2740.1	2732.9	2713.5	2723.9	2725.1	2719.5
4	4403.9	4328.6	4326.1	4336.3	4333.7	4335.6
5	6370.8	6293.2	6274.7	6297.4	6310.3	6290.5

TABLE-4.3

COMPARISON OF NATURAL FREQUENCIES OF COPPER ALLOY

Mode shapes	No weld	Single-V	Double-V	Single-U	Double-U	Square
1	380.2	380.66	379.33	380.36	379.63	380.1
2	1024.4	1024.4	1024.3	1024.3	1024.3	1024.4
3	1956.4	1970.7	1963.4	1967	1969.6	1962.7
4	3134	3132.6	3131.7	3132.6	3131.3	3133.1
5	4517.4	4546.9	4532	4539.2	4545.9	4530.2

TABLE-4.4

COMPARISON OF NATURAL FREQUENCIES OF ALUMINUM ALLOY

Mode shapes	No weld	Single-V	Double-V	Single-U	Double-U	Square
1	527.75	528.37	526.52	527.96	526.94	527.6
2	1422.3	1422.2	1422.1	1422.2	1422.1	1422.2
3	2716.6	2736.6	2726.3	2731.3	2735	2725.3
4	4352.5	4350.3	4349.1	4350.3	4348.5	4351.1
5	6274.8	6316	6295.1	6305.2	6314.5	6292.6

COMPARISION OF NATURAL FREQUENCIES

- **VARIATIONS IN STRUCTURAL STEEL COMPONENTS**

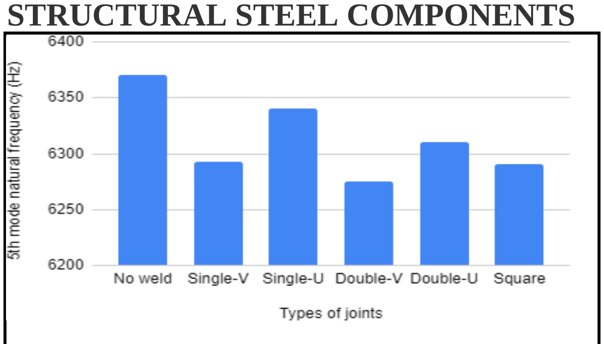

Fig. 4.35 Variation of 5th mode natural frequency

VARIATIONS IN COPPER ALLOY MATERIAL VARIATION IN ALUMINUM ALLOY MATERIAL

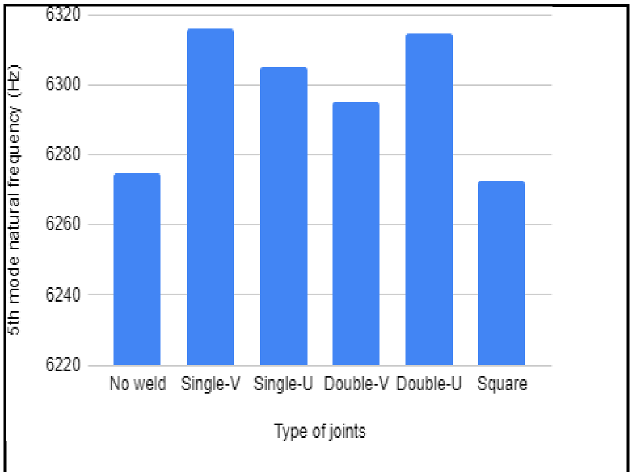

Fig. 4.45 Variation of 5th mode natural frequency

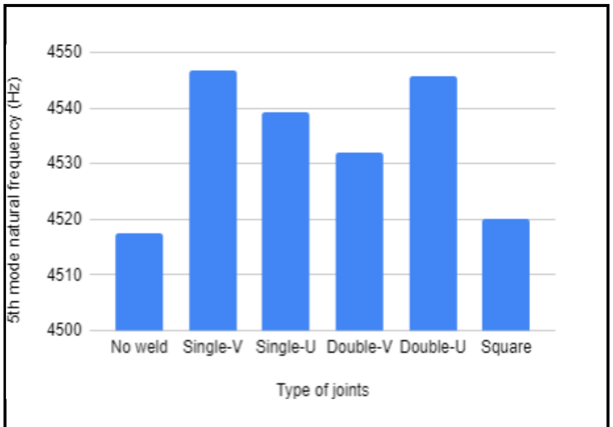

Fig. 4.40 Variation of 5th mode natural frequency

CONCLUSION & SCOPE

CONCLUSION

From the above graphs it is evident that the natural frequencies of the no weld plate is approximately equal to a specific butt welded joint in each case i.e

- Single-U groove is the optimum joint when we use a structural steel component.
- Square Butt joint is the optimum joint in case of Copper alloy material.
- Square Butt joint is the optimum joint when we use an Aluminum alloy material.

Therefore, these combinations could provide better weld quality in case of welds of heavy structural elements in various Construction works or in different support elements.

Also it has been found that the weld bead material has negligible effect on the natural frequencies that have been deduced through analytical method via ANSYS.

SCOPE OF FURTHER WORK

➢ The scope of this analysis was restricted to only three most commonly used materials in structural support elements i.e structural steel, copper alloy, aluminum alloy. However, the Analysis can be further extended to various other materials like brass alloy, mild steel, low carbon steel, medium carbon steel, high carbon steel etc.

➢ Also further thermal analysis is not considered here and analysis has been carried in ideal conditions which doesn't happen in real time. Hence, thermal analysis at the welded joints would be more feasible to identify how the weldment behaves in the HAZ.

➢ The Weld bead could be further replaced by other materials apart from mild steel like aluminum alloy 4043, Brass etc.

➢ The Analysis could be further extended to other joints like T- joint, Corner joint, Lap joints etc.

➢ The same analysis could be further extended to the weld of dissimilar metals and also they could be checked for dynamic loading situations.

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