

Experimental and Numerical Investigation of Charpy Impact Test of Spin Arc Welded C1018 plates

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Abstract. AISI 1018 low carbon steels are widely used in dynamic environment where material undergo sudden loads. In this study the Finite element simulation of impact test of Spin arc welded 1018 steel plates was analysed using Abaqus Explicit 6.14. Damage evaluation of spin arc weld and base metal are proposed by Johnson-Cook failure criterion model. The geometry, material and contact properties of base and weld metal are obtained from tensile test results. The specimen and striker are controlled by linear surface to surface interface. The numerical results are compared with experimental Charpy impact test for validation.

Keywords: Spin Arc; Impact energy; Abaqus; Charpy test; Dynamic;

1. Introduction

Material selection is one of the most predominant factor while designing for industrial, transportation and structural application where it undergo sudden load. Materials experiencing dynamic loads leads to catastrophic failure which affect human life and damage to property. Energy absorption capability of material by the undetermined load are measured by conducting the impact test. Ghaith [1] studied the Charpy impact test of normalized carbon steel in LS-DYNA and compared the impact energy values from experimental approach. Tvergaard, et al. [2] investigated the impact analysis of weld joints by placing the specimen in different position with reference to the notch. Banerjee, et al. [3] formulated the Johnson-Cook failure criterion by conducting tensile tests with different strain rates on armour steel and from the obtained damage model parameters the impact simulation is performed in ABAQUS. Xuemei Wang, et al. [4] compared the experimental impact tests results with finite element model using ABAQUS under strain rate of 104 - 106 per second by foreign object damage model and JC failure data. Hisashierizawa, et al. [5] proposed the model to simulate the Charpy impact test of steel plates with sharp and round v-notch specimen with different interface function. Prawato, et al [6] compared the mechanical properties of dual phase steel (AISI 1050 and AISI 4130H) under tensile and impact test conditions with computational approach through the failure data obtained from the experimental results using Abaqus.

From the literature study it is observed that very less work has been done in the numerical modelling of spin arc welded C 1018 plates. Hence in this study numerical simulation of impact test of base and spin arc weld plates are analyzed using Abaqus 6.14. The numerical results are compared with the impact energy values obtained from experimental Charpy Impact test.



2. Numerical Analysis

The model used for impact test apparatus consists of striker and specimen (base and spin arc weld). The simulation is carried out in Abaqus 6.14. Weld and base metal are modelled as per ASTM E 23 with 45° notch angle and 2 mm depth. The specimen and hammer are defined by rigid body element with mass of the impactor as 20 Kg. Material properties of C1018 specimen and impact hammer are shown in Table 1.

Table 1. Physical Properties

S.No	Description	Density (kg/m ³)	Poisson's ratio	Young's Modulus (GPa)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)
1	Base metal	8675	0.3	205	414	414
2	Weld metal	8675	0.3	205	438	431
3	Impact Hammer	1×10 ⁶	0.28	210	-	-

FE simulation is carried out with linear elastic model for both the specimens. The boundary condition of specimen is constrained by arresting movement along x and y direction and striker to fall only in y direction by considering the simple supported beam as in real Charpy test. The impact load is assigned to the striker with the velocity of 4 m/s by striking the specimen at back of the v- notch. The kinematic contact between specimen and striker is assigned with surface to surface control interface with frictional interaction [7]. The strain energy required to determine the failure of the specimen is calculated from the tensile test result [1]. The Johnson-Cook damage model was used as the failure criterion approach to control the crack initiation and propagation through the notch [3]. The analysis is terminated when the impact energy of the specimen reaches the critical strain energy value. The impact energy values for both base and spin arc welded specimen are attained from the step time where crack is initiated.

From the numerical analysis of Charpy impact test it is observed that the specimen starts piercing at the step time of 2.05 E-3 for base metal and 2.50 E-3 for weld metal as shown in Figure 1 and 2 respectively. Based on the step time the corresponding stress and energy absorbed for weld and base specimen are observed. The deviation in impact energy of the base and weld specimen is due to variation in grain size and formation of crack in the notch which ends in cleavage fracture

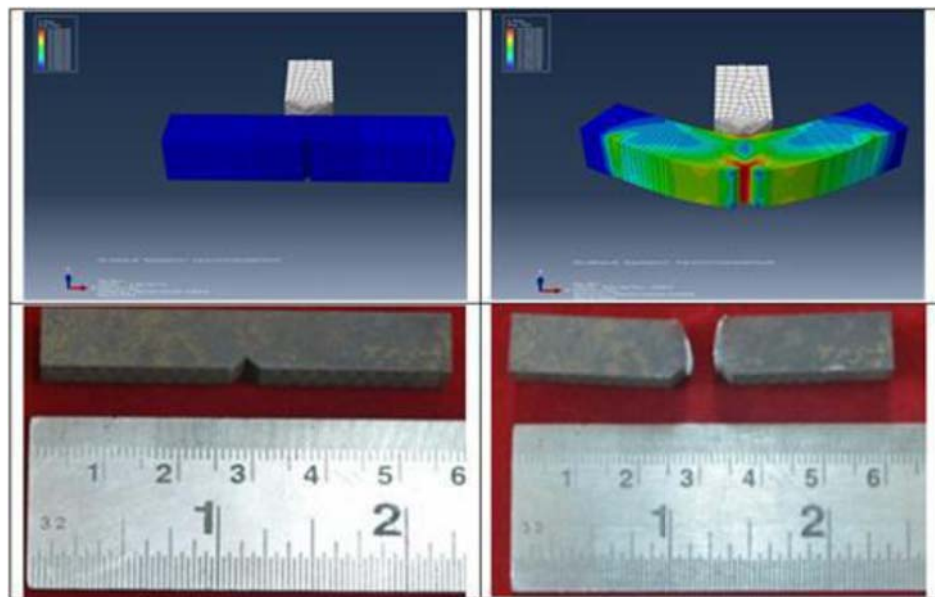


Figure 1. Numerical and Experimental Charpy Impact Test of C 1018 Specimen

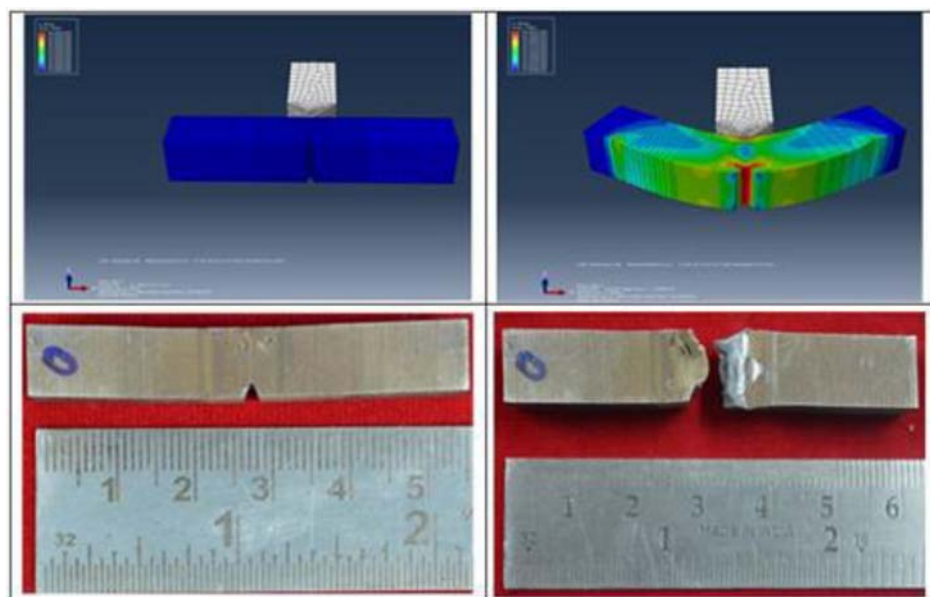


Figure 2. Numerical and Experimental Charpy Impact Test of C 1018 Spin Arc Weld Specimen

Table 2. Numerical and Experimental Impact Test result

S.No	Description	Impact Toughness from FE Simulation(J)	Impact Toughness from experiment (J)	Max. Von Mises Stress (Mpa)
1	Base metal	95.33	91.1	401.4
2	Weld metal	106.85	106	405.4

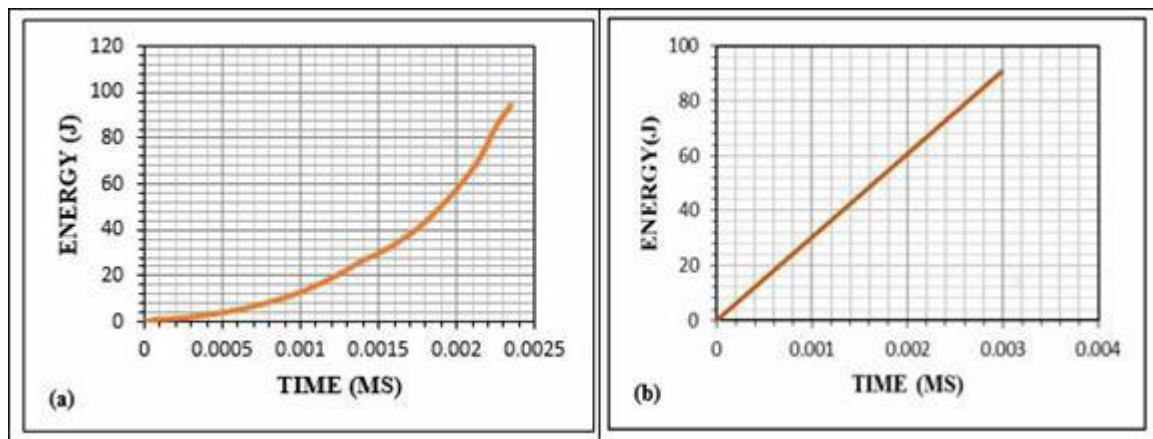


Figure 3. Impact Energy plot for C1018 Specimen (a) Numerical, (b) Experimental

The impact energy values obtained from the numerical analysis of the C1018 specimen is 95.33 J at the step time of 2.05×10^{-3} second and 91.1 J at step time 3×10^{-3} second for experimental impact test (Figure 3).

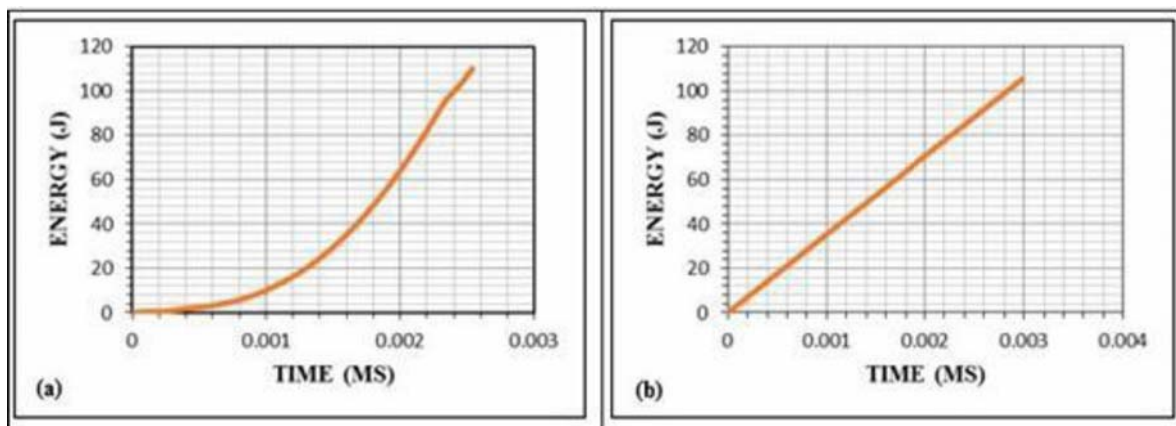


Figure 4. Impact Energy plot for C1018 Spin Arc Weld Specimen (a) Numerical, (b) Experimental

The impact energy of weld specimen is more than the base metal because the weld region undergoes grain refinement which increases the toughness. Figure 4 shows the impact energy of C1018 spin arc welded specimen in numerical simulation is 106.85 J at the step time of 2.50×10^{-3} second and 106 J for experimental analysis at the step time of 3×10^{-3} second. The numerical and experimental results of Charpy impact model are detailed in Table 2. From the result it is evident that the impact energy values obtained from the numerical and experimental results for base metal and spin arc weld C 1018 low carbon steel are well correlated. The maximum stress values obtained from the numerical solution is 401.4 Mpa for base metal and 405.4 Mpa for the weld metal.

3. Conclusion

The impact energy values of spin arc welded 1018 low carbon steel specimen and base specimen are obtained by conducting Charpy impact test in Abaqus 6.14. From the numerical analysis the impact energy for the base specimen is 95.33 J and maximum Von Mises Stress is 401.4 Mpa and for weld specimen the impact and stress values are 106.85 J and 405.4 Mpa respectively. The impact energy values obtained from experimental impact test are 91.1 J and 106J for base and weld specimen respectively. From the study it is observed that experimental results are very well agreed with numerical results with minimum deviation.

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