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COBEM-2017-2228 NUMERICAL ANALYSIS OF THE STRESS FIELD AND STRAIN FIELD OF THE CRACK PRESENT IN A DISSIMILAR WELDED JOINT

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Abstract. *The search for structural efficiency in mechanical systems has been strongly used with the objective of economic optimization and structural safety. Studies carried out in recent years have sought to understand the response of materials to the presence of cracks in dissimilar welded joints, but are not yet sufficient to fully discover fracture resistance responses due to the heterogeneity present in these joints. This work analyzes the behavior of the crack tip zone, from the perspective of fracture mechanics, located in a dissimilar welded joint used in the union of pipes present in the offshore oil production lines investigated by Almeida (2014). It was possible observing critical stress area due to numerical tool of the finite element method. A preferential plastic flow was also observed in samples of dissimilar welded joints, which the literature claims to be a precursor of the crack growth path. The numerical analysis showed a convergent behavior in relation to the plastic flow and developed during the tests performed. The results obtained are in agreement with the literature and the experimental study of Almeida (2014).*

Keywords: *crack, stress field, strain field, numerical analysis*

1. INTRODUCTION

With the advent of Fracture Mechanics many researches have been carried out in order to achieve greater clarity on this subject. Due to the wide application as well as the complexity involved in the process, there are concentrated efforts in the investigation of cracks present in dissimilar welded joints, however because it is difficult to access or confection of evidence body not trivial, numerical methods especially finite element method (FEM) have been a very significant analysis tool (LIU; ZHANG, ZHENG, 2012; PAREDES; RUGGIERI, 2012; ROTH; MOHR, 2016), besides an economic and timely character, to understand this phenomenon in dissimilar welded joints.

Bowen, Druce and Knott (1987) described a thermal dependence of fracture toughness K_{IC}, and fracture stress by cleavage of the material, after analyzing a wide range of microstructural conditions in pressure vessel ASTM A533B steel. It was observed that at very low test temperatures, fracture toughness is controlled by the average carbide size, whereas at higher test temperatures fracture toughness is controlled by coarser carbides. Therefore, the effect of temperature on changing carbide sizes suitable for nucleation of microcracks is a significant factor in the crack formation process, since the coalescing mechanism is facilitated by the proximity of the microcrack's nucleus.

In conducting the studies on weld joints with mechanical dissimilarities, with SE (B) samples, based on slip-line theory and 3D numerical analysis, Hao, Schwalbe and Cornec (2000) noted the occurrence of crack side of the more resistant material, evidencing a preferred path, that is, a plastic strain guideline in the direction of the material of least resistance.

Wang et al. (2011) used the finite element method (MEF) based on the Gurson-Tvergaard-Needleman (GTN) model to investigate the unique behavior of ductile crack growth in an SE (B) specimen of a dissimilar welded joint composed of four materials in the system of nuclear power plants. The authors observed that initial cracks at different locations in the JSD obtained different tenacity values and growth paths. Thus, when the initial crack was located at the Nickel Base Base weld 182 and Nickel-Base Base 83 weld center, the plastic strains and damage at the tip region of the crack are symmetrical, and the crack growth is almost in line along the initial plane of the crack. However for cracks at the interface between the materials and in the vicinity of the crack interface, the plastic strains and damage at the crack tip region are asymmetrical, and the crack growth trajectory obtained a significant deviation into the material with the lower limit of between the two interface materials.

ALVES et al. (2016) conducted a study on crack behavior in JSD. The researchers identified a behavior pattern of plastic strain, which suggests a future crack trajectory to be developed, independently of the dissimilarity presented by the welded joint. It was recorded in the studies analyzed by ALVES et al. (2016) (Fig.1) a preferred plastic flow is the lower strength material.

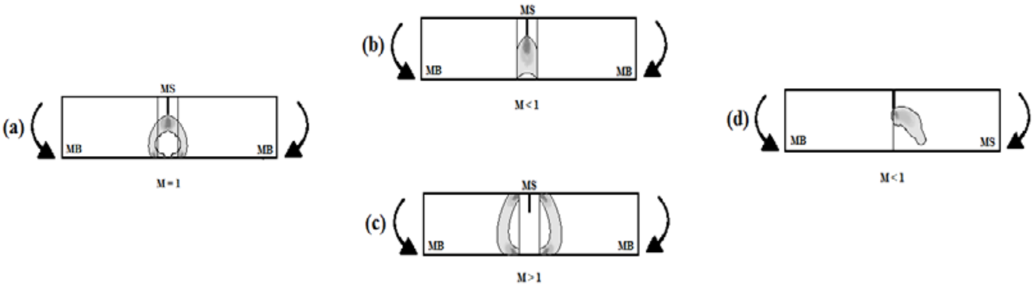

Figure 1. Variation of the strain field: (a) Homogeneous specimen; (b) and (c) dissimilar specimens with crack in the weld; (d) dissimilar specimen with crack at the interface.

Coules et al. (2016) proposed a technique of incorporating measured stress and residual elastic strain data into a finite element elastic-plastic fracture simulation. Residual tensile stress and strain in three-point flexural fracture test specimens were measured using neutron diffraction and an iterative method was used to generate an estimate of the total residual stress field. The interaction between the residual stress and the external load was observed. The Model showed good agreement with the corresponding measured data and consistency with experimental results of fracture test. All fracture samples failed in a fragile manner and the residual stress had a substantial effect on the fracture toughness detected.

This work seeks to qualitative analyze the behavior of the crack tip zone, from the perspective of fracture mechanics, located in a dissimilar welded joint used in the union of pipes present in the offshore oil production lines, in order to identify a phenomenon of preferential flow presented by Almeida (2014). For this, a numerical approach was used as a tool to predict the behavior of the stress fields generated from a given mechanical request system.

2. MATERIALS AND METHODS

This study involved a sample consisting of three different types of materials, so it is a heterogeneous sample as Fig. 2. The dissimilar welded joint consisted of the following materials: AISI 8630 M, ASTM A36 and INCONEL 625. The former acting as base metals and the latter, also used as a buttering of AISI 8630 M steel, operating as weld metal.

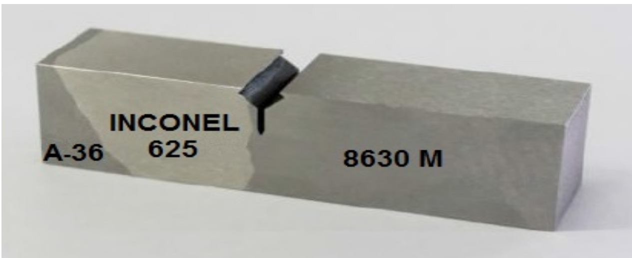

Figure 2. Specimen used by Almeida (2014).

The methodology adopted in the work was based on a numerical analysis using the finite element method to simulate the behavior of a dissimilar welded joint (JSD), with fatigue crack installed at 1 mm of the LF in the sense of MB, presented by Almeida (2014), according to Fig.3. The JSD analyzed is a welded joint used in the union of flanges and pipes present in offshore oil and gas production lines.

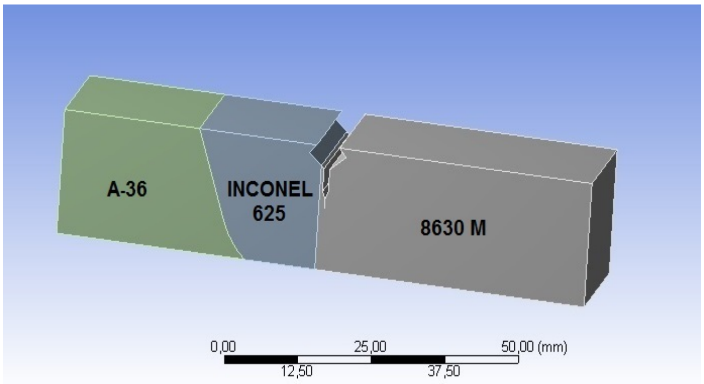

Figure 3. CAD Model.

An analysis of the stress state plane was performed. Therefore, a 2D model was constructed and due to the asymmetry of the sample, in the planes (XZ and YX), it was necessary to model all the geometry, shown in Fig.4.

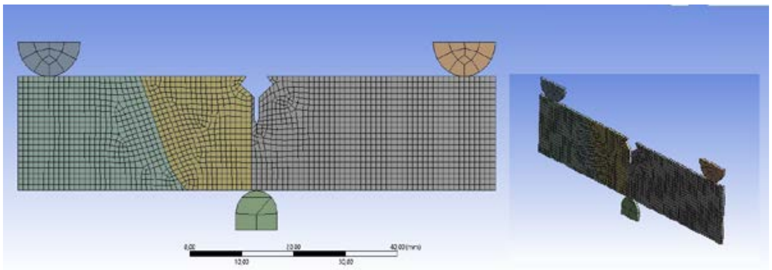

Figure 4. 2D CAD Model.

For the simulation, a three-point bending load was used according to the figure above (Fig. 4). This work was carried out at the Laboratory of Integrity and Inspection LabII / DEM / UFPB, with the support of the Laboratory of Mechanical Tests LEM / DEM / UFPB and the Solar Energy Laboratory LES / CEAR / UFPB, using the infrastructure and equipment.

3. RESULTS AND DISCUSSIONS

In Fig. 5 shows the behavior of von Mises stress in the flat stress state for a 2D sample. Due to the existing dissimilarity, asymmetric stress fields are observed in the specimen, where higher stresses are generated in the 8630M steel (yellow region) due to the constraints in the sample due to dissimilarity.

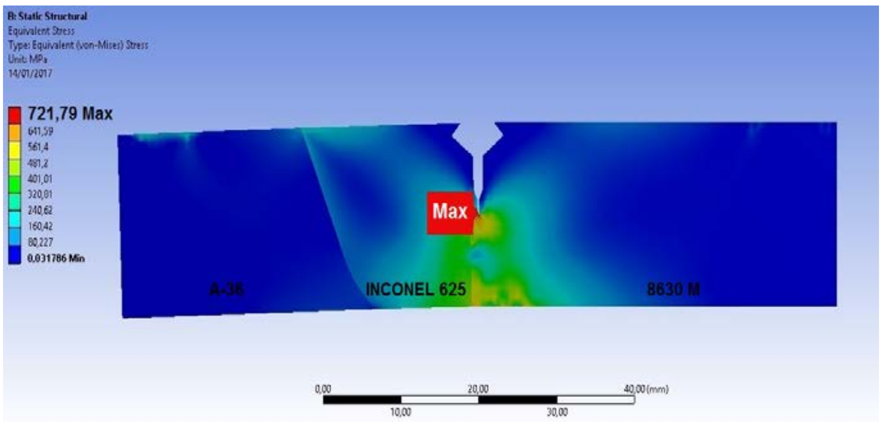

Figure 5. Stress distribution in the state of plane stress.

This nonsymmetrical stress profile is related to the elastic behavior of the materials. As already mentioned, the materials are arranged in ascending order of mechanical resistance, so the left side of the sample presents greater flexibility, that is, greater elastic phase, resulting in this case lower values of stresses when compared with the right side of the specimen.

With the presence of dissimilarity in the sample, the permanent strain will follow a preferential flow, being influenced by the present restrictions resulting from the heterogeneity of the specimen. In this way, fig.6 shows the preferred flow for the plastic strain in this case.

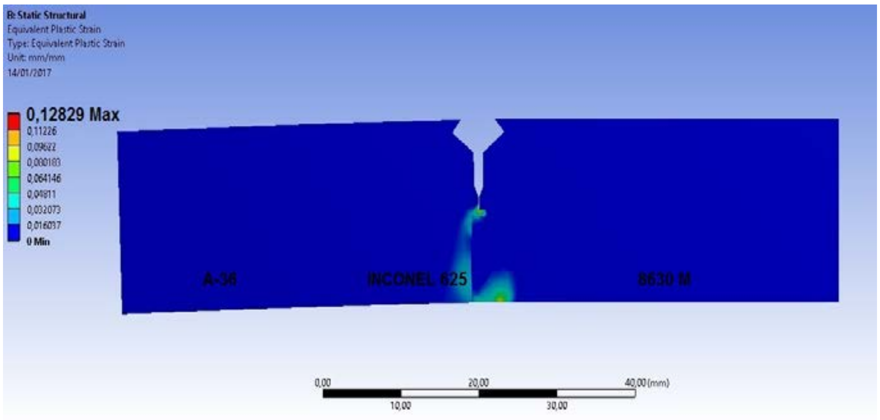

Figure 6. Preferential flow of plastic strain.

4. CONCLUSIONS

This work had the objective of numerical analysis of the behavior of a dissimilar welded joint used in offshore equipment with the presence of a fatigue crack. From the results obtained through the numerical analysis using commercial software based on the finite element method, it was concluded:

- It is evidenced the preference of the plastic strain flow, in the material direction of lower mechanical strength, that is, with lower drainage stress, due to the constraints generated by the existing dissimilarities.
- The combination of the stress field and the inherent constraints of each heterogeneous joint determined the deviation of the strain fields;
- Following the path that exerts less resistance to its advance, the triaxiality present at the crack tip is responsible for penetration into the body of the material.

The analyzes carried out took into account the type of dissimilarity and the location of the specific crack of this welded joint, being limited to a directional analysis of the crack based on the behavior of the strain and strain fields from a cracked sample.

For further study on this subject, some studies are suggested based on the degree of dissimilarity, width of the weld bead for example.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

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