Validation of the numerical procedure to calculate the fatigue life of welded joints using the Ansys computational package

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Abstract. The phenomenon of fatigue is highly complex and is present in most mechanical component applications. In this sense, according to Ruchert (2007), fatigue shows itself as the predominant cause in structural failures. Recognizing the importance of fatigue in engineering studies, the goal of this research is to gather information and data that may become relevant for the computational modeling and analysis of welded joints, as well as the calculation of fatigue life. Thus, was reproduced the modeling of a beam-column assembly, which is subjected to a transverse loading to the free section of the beam, performed previously by Moreira et al (2017). The ANSYS Finite Element software was used, specifically the Fatigue Tool module of the Ansys Workbench environment. The weld element on which fatigue life is evaluated is of the fillet type. The results obtained are compared with those presented by Moreira et al (2017) and showed agreement with each other. Thus, since the adopted procedure proved to be effective in the study of fatigue life, it is details are presented here as a contribution to the development of future works.

Keywords: fatigue, numerical analysis, fatigue life.

1 Introduction

Among the various causes of failure of mechanical components, the most common is due to material fatigue [7]. Currently, it can be said that the fatigue phenomenon is involved in at least 90% of mechanical failures [8].

The history of fatigue can be traced back to the year 1837, when Wilhelm Albert, then employed in the mining industry, checked and studied failures in conveyor chains used in mining, the results of his studies are part of the first known fatigue test. The term "fatigue", until then unknown in the field of mechanics, was used for the first time to describe a process in which the fractured material appeared to have become tired and brittle due to the application of loads over a certain period of time [5].

Fatigue is a process of gradual failure of a component under cyclic mechanical stress [4]. In this sense, a metal subjected to cyclic stresses breaks at a stress lower than that required to cause fracture due to the application of a static load [3]. Within this segment, for a real material, it is not possible to state that, even for stresses below the limit stress of the elastic regime, we have only elastic deformations [7].

In weld joints, the most dangerous type of failure is caused by fatigue, because the weld shows no signs prior to partial loss of functionality [2]. Therefore, it is necessary to analyze the weld as a mechanical component prone to failure by fatigue. In this sense, in order to meet the need to analyze the fatigue life of welded joints, the use of numerical modeling is important to estimate the possible fatigue failures [11]. The use of computational analysis tools during design decreases costs and product development time, even allowing designers to evaluate the effects of various parameters, such as geometry change and material choice, without the need to build physical prototypes [6].

The present work proposes to reevaluate a beam-column welded joint from Valle et al (2017). For this purpose, the software Ansys Student 2022 R1 and its fatigue tool module were used to determine the fatigue life. The cited authors produced a study on the fatigue life of the welded joint, in which it was found that the critical load was much lower than the result obtained using the analysis for static loading.

2 General objective

The present work aims to validate the numerical procedure under the use of the *Ansys* computational tool, starting from the comparative study between the results obtained by the present work and those presented by Valle et al (2017).

Thus, the procedures adopted in the simulation will be described in order to assist future research related to the study of fatigue life of welded joints.

2.1 Specific objectives

- Determine the fatigue life for the beam-column welded joint;
- Compare the results with the work of Valle et al (2017);
- Compare the results for fatigue life using aluminum alloy and structural steel as the weld material.

3 Applied methodology and description of the object of study

In the applied methodology, the *fatigue tool* was used, which belongs to the *Workbench* computational package of the *Ansys Student* 2022 R1 software. With this, using the *Workbench* computational package, a fatigue life study was developed for the beam-column welded joint. The numerical simulation results were compared with the work of Valle et al (2017).

For this, the materials used to model the beam, the column and the weld were structural steel and aluminum alloy. In this sense, for the reproduction of the beam-column joint, the material properties were described in Tab. 1.

Table 1. Properties of structural steel and aluminum alloy.

Properties	Structural Steel	Aluminum Alloy
Tensile Yield Strength	250 MPa	280 MPa
Tensile Ultimate Strength	460 MPa	310 MPa
Young's modulus	200 GPa	71 GPa
Poisson's ratio	0.3	0.33
Density	7850 kg/m^3	2770 kg/m^3

The problem geometry consists of a beam and a column, which were joined using a fillet weld. Fillet welds are typically characterized by a cross section formed by an isosceles triangle, with exceptions according to the project [1]. In Fig. 1, the typical geometry of the fillet weld can be seen.

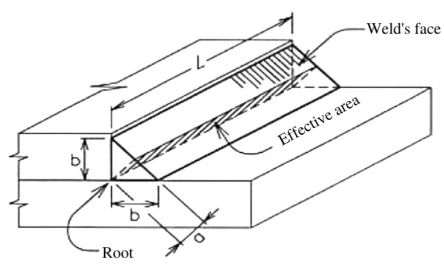
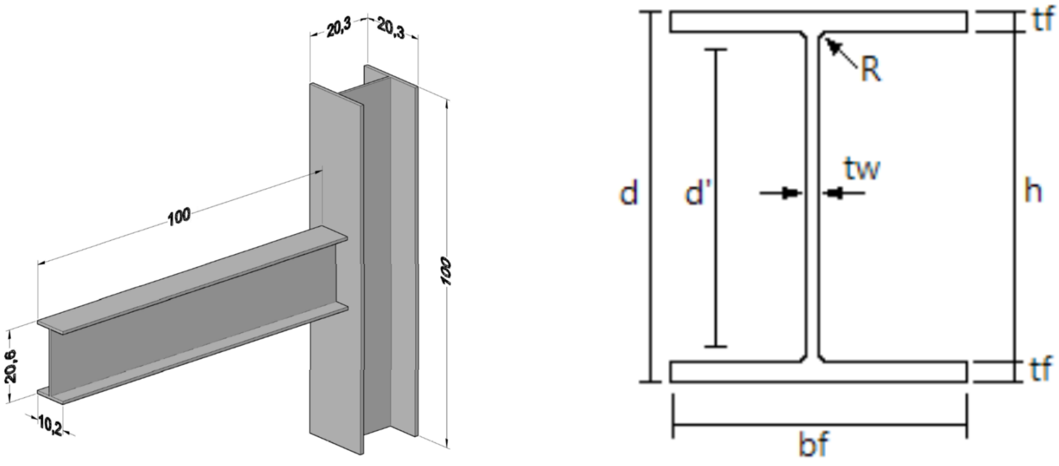


Figure 1. Fillet weld [1].

In Fig. 2 the beam-column assembly can be seen, as well as it is dimensions. It is also possible to observe the nomenclatures referring to the dimensions of the beam profile. The dimensions are defined in Tab. 2.



(a) **(b)**

Figure 2. Isometric view of the (a) beam-column assembly and it is (b) dimensions [11].

Table 2. Cross-section dimensions of the beam and column [11].

	d (mm)	bf (mm)	tw (mm)	tf (mm)	h (mm)	d’ (mm)
beam	206	102	6.2	8.0	190	170
column	203	203	7.2	11	181	161

At the free end of the beam, a harmonic force with constant amplitude equal to 6.7 kN was applied in the direction transverse to it. The beam-column assembly was discretized into 107393 nodes and 53505 elements.

In the first part of the simulation, the material assigned to the beam-column assembly was structural steel.

For the discretization, the *Patch Confirming Method* tool was used, in which it was chosen that the assembly would be discretized into tetrahedrons.

At the free ends of the column, the no displacement condition was applied. Thus, only the free end of the beam could move due to the applied force.

For the numerical simulation using aluminum alloy as weld material, the same procedures were used.

The Fig. 3 describes the procedures followed for the numerical simulation using Ansys Workbench.

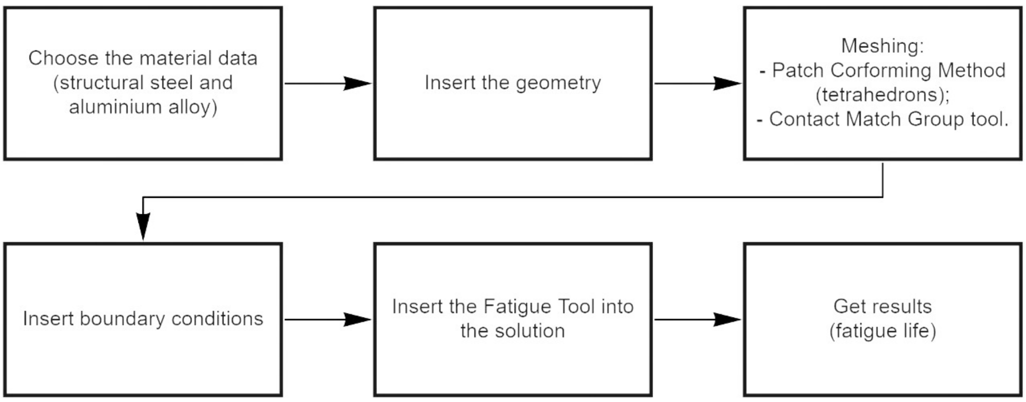
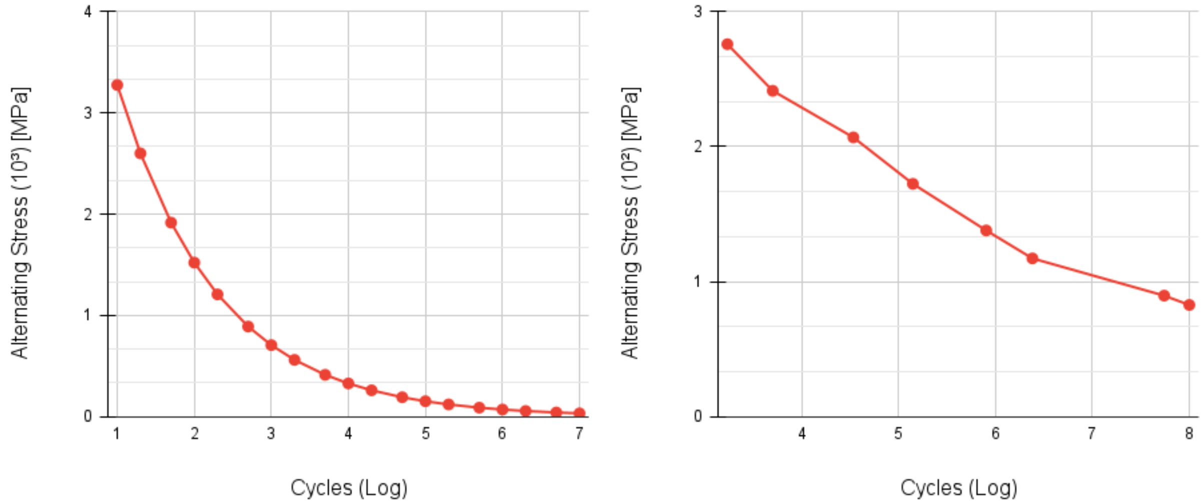


Figure 3. Procedures for fatigue life simulation in *Ansys Workbench*.

Keeping in mind that the data related to the mechanical properties of structural steel are available in the Ansys library, only the data regarding the S-N curve used by Valle et al (2017) were changed, which can be seen in Fig. 4. It is worth noting that it is necessary to do this procedure so that the final results are equal.



(a) **(b)**

Figure 4. S-N curve used in the simulation for fatigue life. (a) S-N curve of structural steel. (b) S-N curve of aluminum alloy.

4 Results and discussion

4.1 Fatigue life for structural steel weld joint

The S-N method, also called Stress-Life method, is used when the stress levels are much lower than the yield strength of the material [9]. Using this method, it is possible to estimate the number of cycles required for the material to fail, based on the applied alternating stress.

For the S-N curve presented by Valle et al (2017) in Fig. 4, which was used as the basis for the fatigue life simulation in this paper, the structure will fail after 20913 cycles, with the red region representing the point at which fatigue life will be minimal. The result can be seen in Fig. 5.

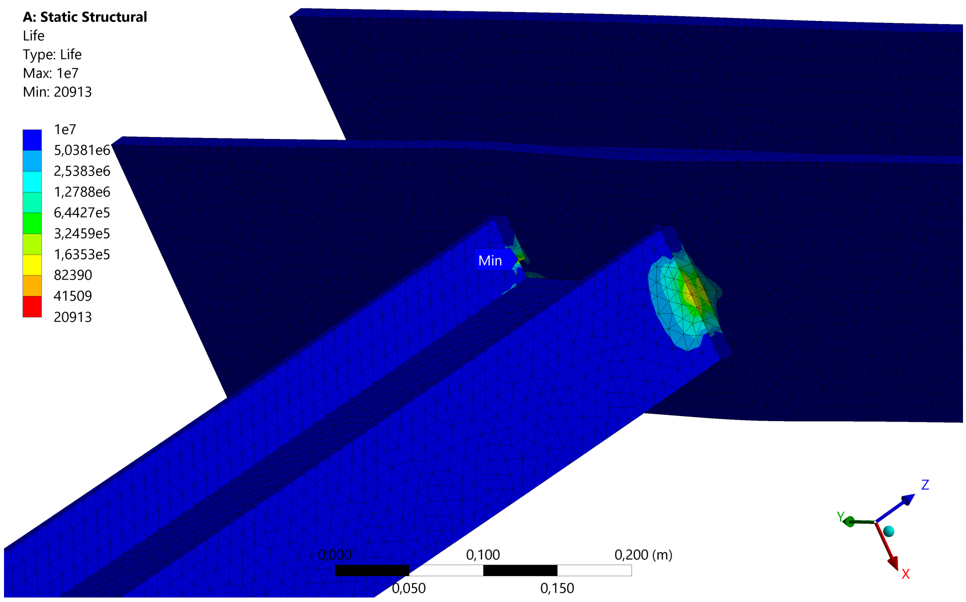


Figure 5. Result for fatigue life obtained in *Ansys Workbench*.

4.2 fatigue life for aluminum alloy weld joint

Initially, it was considered that the structure is composed of structural steel, including the welding fillets, and thus the result shown in section 4.1 of this paper was obtained. In practice, it is unusual to use such material to produce welded joints.

In order to bring this present study closer to real practices, fatigue life was determined for the same structure, considering now that the weld fillets are composed of aluminum, a metal commonly used in welded joints of vehicles [10]. Another advantage for choosing aluminum, is that the mechanical properties of the material are available in the Ansys library.

In Fig. 6 it can be seen that the value for fatigue life dropped considerably to 3339 cycles, much lower than the result presented for the steel welded joint. The result follows the expected pattern, since aluminum gives an S-N curve with stress values, for approximately the same number of cycles, lower than the structural steel curve.

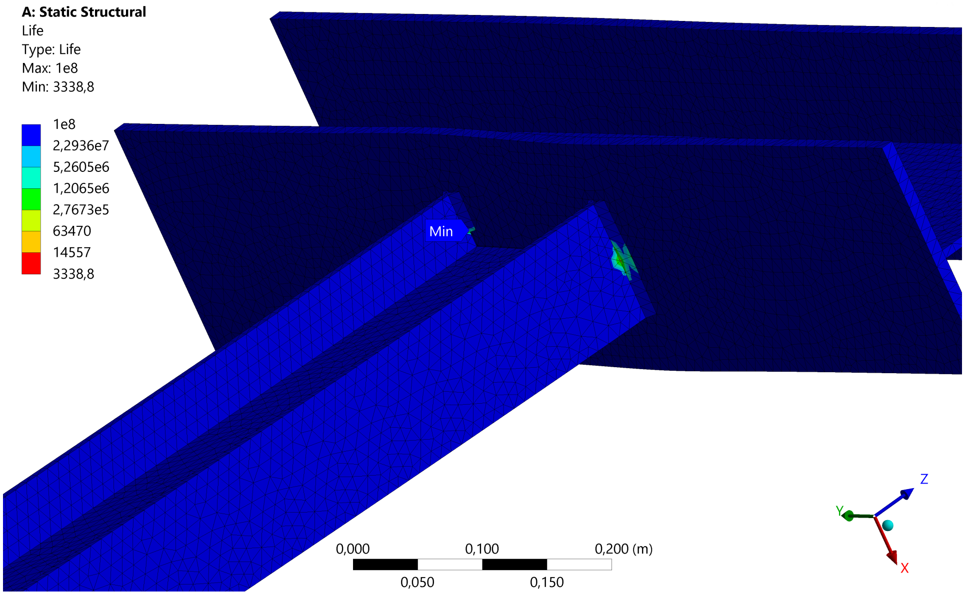


Figure 6. Result for fatigue life obtained in *Ansys Workbench*.

5 Conclusion

As demonstrated in this work, the procedure developed using the software Ansys Student 2022 R1, specifically the fatigue tool module, proved to be effective in the study of the fatigue phenomenon. In this sense, following the discussed script, it is possible to determine fatigue life for welded joints in a reliable manner.

When the welded joint material was changed to aluminum alloy, the procedures adopted also proved satisfactory. The fatigue life for the welded joint using aluminum alloy decreased considerably, as the material has lower fatigue resistance compared to the welded joint composed of structural steel.

The results obtained for fatigue life using structural steel as the material of the welded joints are in line with the values determined in the work of Valle et al (2017). The authors presented that for a constant amplitude loading equal to 6.7 kN, the minimum fatigue life will be equal to 20377 cycles. In this work, it was obtained, for the same loading value, that the minimum fatigue life will be equal to 20913 cycles.

It is worth pointing out that numerical simulation is an excellent tool for the initial analysis of complex designs, since the numerical experimentation phase can serve as a source of relevant parameters for the confection of physical prototypes, especially for the study of the fatigue phenomenon.

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Authorship statement. The authors hereby confirm that they are the sole liable persons responsible for the authorship of this work, and that all material that has been herein included as part of the present paper is either the property (and authorship) of the authors.

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