Multibody Fatigue Assessment in Industrial Mechanisms Considering Wear in Revolute Joints

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EXTENDED ABSTRACT

1. Introduction

In the design of mechanisms and dynamic machines, fatigue life should be considered as a fundamental factor to ensure the reliability of their components. However, the fatigue life prediction models currently used in mechanical design do not take into account the effect of relevant factors, as wear and the evolution of clearances it produces, which undoubtedly influences dynamic loads. These changes can vary the load ranges in some components of the machine during its life and, consequently, modify the stress levels on them. In the field of multibody system dynamics, there are studies focused on the modeling of clearances and wear in the rotating joints of mechanisms [1,2]. However, few studies relate the dynamic effects of these phenomena to the loads that must be born by the components of the mechanism. A paper has recently been published in which a methodology to evaluate the effect of the evolution of wear clearances on the fatigue life of components is proposed [3]. That work shows, in a single case study, the relevance that this effect may have on the fatigue life of a specific component of the machine.

In this work, the methodology developed in [3] was applied to two industrial use cases. Multibody dynamics (MBD) simulation was employed to consider the effect of the evolution of wear clearances present in rotating joints in the dynamic behavior of the machines over the time. In this way, a much more accurate description of the fatigue behavior of the machine components and estimation of the service life of the mechanism can be obtained than applying the classical machine design methods. In particular, the behaviors of a railway pantograph and an industrial press have been studied, and relevant design recommendations have been drawn from the study.

2. Metodology

The analysis of the industrial mechanisms studied in the present work was carried out by means of a MBD simulation procedure that allows to simulate the evolution of the clearances during the life of a machine. For this purpose, a wear model was implemented whose parameters were experimentally validated through an in-house developed test bench. The forward-dynamics simulation of the mechanism provides the reaction loads that are then used to evaluate the stresses in the components through finite element (FEM) models. In this way, the critical points can be identified and the stress histories at them can be calculated. This process enables to evaluate the evolution of fatigue damage with greater accuracy than classical machine design methods as it considers the variation along the time of dynamic loads due to clearances. Two representative case studies are presented below, for which the effects of considering the growth of clearances in the fatigue life of the mechanisms are opposite.

2.1. Case study: industrial press

This case study considers the effect of a clearance in the rotating joint of an industrial press indicated in Figure 1a. The clearance does not grow uniformly, yet it grows more in the sector subject to the greatest efforts. As the size of the clearance increases along the time, the dynamic forces also increase, as illustrated in Figure 1b, which translates into a significant increase in stresses and, consequently, into a reduction of the fatigue life. Figure 2a shows the evolution of the clearance size along the work cycles of the machine, while Figure 2b plots the cumulative damage, which follows an exponential behavior. In fact, the model which takes into account the clearance effect predicts a premature break of the component.

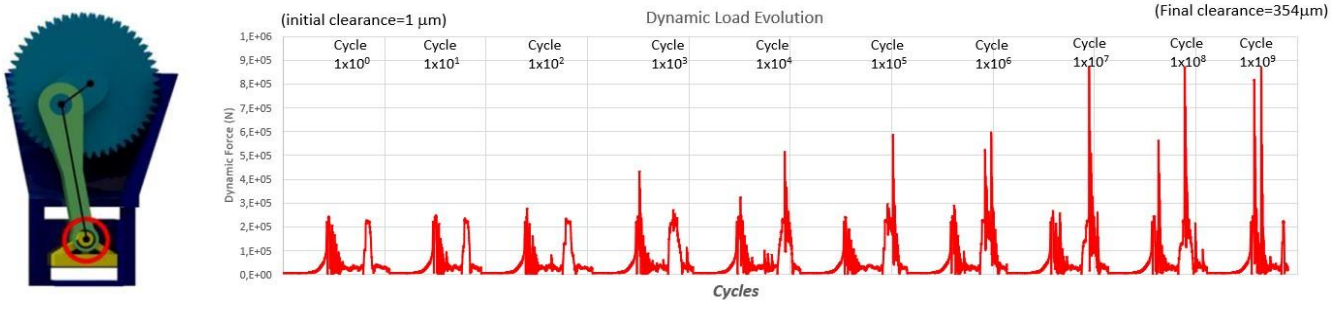

Figure 1: (a) Mechanism critical joint; (b) Dynamic load evolution due to the increase in the size of the clearance.

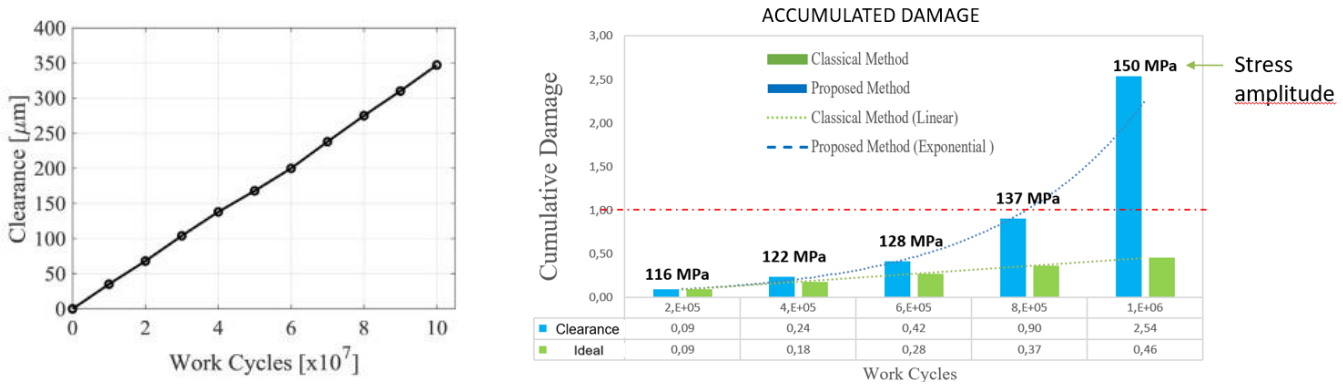

Figure 2: (a) Clearance Evolution. (b) Cumulative damage for the classical and the proposed approach

2.2. Case study: railway pantograph

This case study focuses on the mechanism of a railway pantograph. The mechanism is responsible for keeping the adequate contact force with the catenary cables that feed the towing vehicle. After applying the proposed fatigue life evaluation methodology, it turned out that the increase of clearances improved the fatigue resistance of the components, which would allow the use of tighter safety factors in the design. The results of this study are shown in Figure 3.

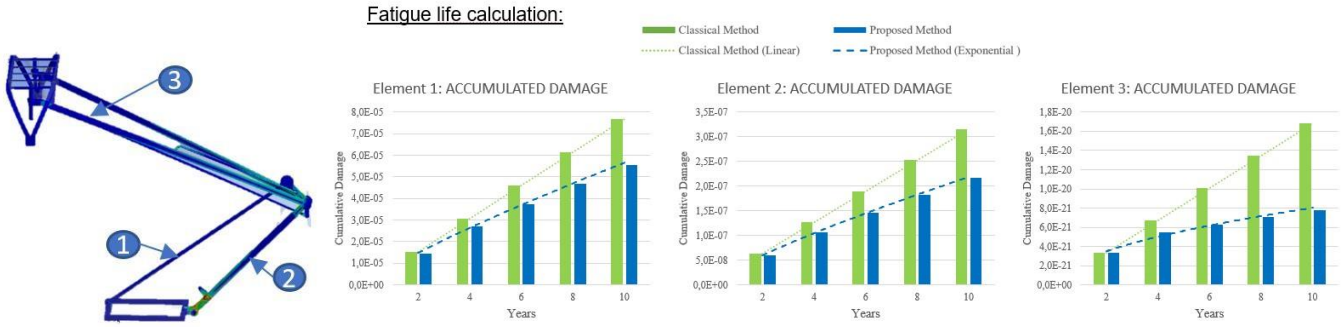

Figure 3: (a) Mechanism and components; (b) Cumulative damage in each component using the classical (green) and the proposed (blue) approaches.

3. Conclusion

The evolution of clearances due to wear has an important influence on the fatigue life of industrial machines and mechanisms. In addition, it is observed that this phenomenon may affect differently depending on the characteristics of the machine motion. The presence of clearances in cases with high dynamic forces involved causes these forces to increase, thus increasing the stresses, which in turn accelerate the accumulated damage, reducing the fatigue life. However, in certain mechanisms not subject to high dynamic loads, the clearances may slow down the accumulated damage due to the geometrical changes in the mechanism they cause, so that a less conservative safety factor could be applied in the design of the mechanism.

In order to improve machine design methods, we are currently working on a series of tools, based on MBD simulation, that seek to provide a better life prediction from the design stage. Furthermore, taking into account the force variations due to increased clearances allows the design of machines which can possess greater precision and greater structural and functional reliability. It is intended to develop design methodologies for joints that rely on predictions based on MBD simulation.

References

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