Advanced development of a probabilistic method for uniaxial fatigue sizing

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Abstract. This work consists in developing a probabilistic method for the prediction of uniaxiale fatigue behavior. This model is set up according to a probabilistic approach taking into account the dispersions of the various parameters used. The objective of this work is to study the effects of dispersion of the fatigue curves on the prediction of the fatigue behavior and then on the reliability of the fatigue strength. To do this, a developed probabilistic method is proposed for uniaxiale fatigue sizing.

Key words: Uniaxiale fatigue / Reliability / Probability / Sizing.

1 Introduction

The fatigue of mechanical structures is a phenomenon which reflects the application of one or more repeated or alternating loads over time, whose material and mechanical properties are known. The purpose of this is to estimate the number of cycles necessary for failure (Cazaud et al. 1969). The classic fatigue dimensioning is deterministic (binary forecast: cracking or not) (Ben Sghaeir et al. 2007), it does not really allow to quantify the risk of cracking. However, experimental investigations show that the fatigue phenomenon is characterized by significant dispersion of fatigue test results (Bathias and Bailon. 1997). A probabilistic approach is therefore necessary for the prediction of the fatigue behavior and consequently the reliability.

For this purpose, a developed probabilistic method is proposed for uniaxial fatigue sizing based on Wöhler's S-N curves and Haigh's diagram. The objective is to study the effects of dispersion of fatigue curves on the prediction of fatigue behavior and then on the reliability of fatigue resistance.

2 Sizing tools

Fatigue tests are generally carried out on specimens subjected to uniaxiale stresses at different stress levels. We, thus, the curve giving the evolution of the amplitude of the stress according to the number of cycles; it is the S-N curve. These curves are characterized by a significant dispersion (Schijve. 2001). This dispersion is due to several parameters. We will study the effect of sample size on reliability.

From the Wöhler curve we can draw the Haigh diagram since there is a relation of complementarily between the Wöhler curve and the Haigh diagram. The Haigh diagram represents the variation of the stress amplitude as a function of the average stress, for different number of cycles to failure. The dispersion of the Haigh diagram is used to determine the iso-probabilized Haigh curves (for Reliability 99%, 90%, 50%, 10%).

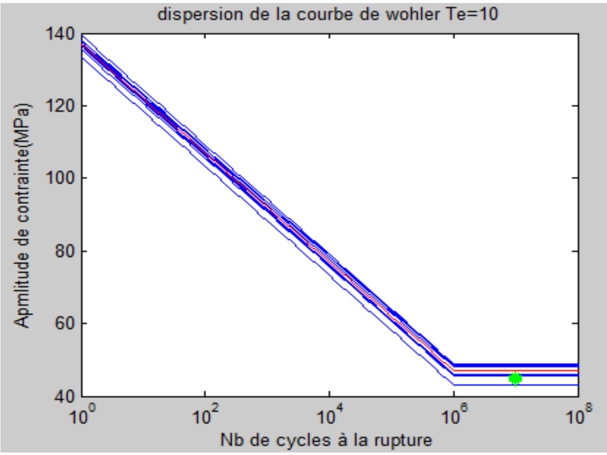
3 Reliability approach

In this part, we present a probabilistic approach for predicting fatigue behavior. The main response of the proposed model translated into the reliability of the fatigue behavior. The calculation of the reliability is performed based on the Monte-Carlo random draw numerical method. This probabilistic approach consists in taking into account the dispersions: (i) of the applied loading and (ii) of the parameters characterizing the material in the studied fatigue zones: the endurance limit in the fatigue zone for a large number of cycles and (a, b) the parameters which define the Wöhler curve in the fatigue life limited zone. The deterministic curve will be transformed into a bundle of lines, as well as the applied loading point. This approach makes it possible to predict, on the one hand, the iso-probabilized Wöhler and Haigh curves (PSN) of the material, and on the other hand, the prediction of the reliability of the fatigue resistance as a function of the applied cyclic stress and of its level of dispersions.

4 Application

To study the effect of sample size Te on reliability on the Wöhler curve we added a sample size of Te = 10 and Te = 1000, respectively in Figure 1 and Figure 2, with identical loading parameters and for a coefficient of variation of 2%. For Figure 1 and Figure 2, the reliability is equal, respectively, to 80% and 88.5%. The results show that reliability increases as the sample size increases. As the sample size increases, the precision of the releability determination increases.
Next, we will compare the iso-probabilized Haigh curves for different reliability values. Figure 3 and Figure 4 represent, respectively for Cov values of : 1% and 5%, the Haigh curves for the following reliabilities: 99%, 90%, 50%, and 10%.

Figure 3 and Figure 4 show that as the applied level of loading increases the reliability decreases. The coefficient of variation influences the accuracy of the reliability determination. To have acceptable reliability (in the vicinity of 99%) for large dispersions (coefficient of variation of 5%) we must limit to low values of the constraints.



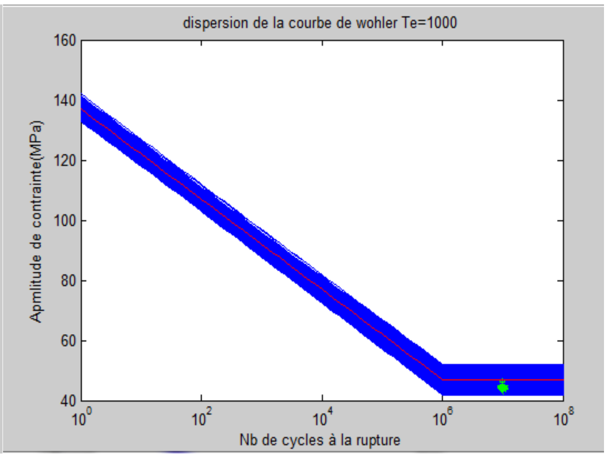
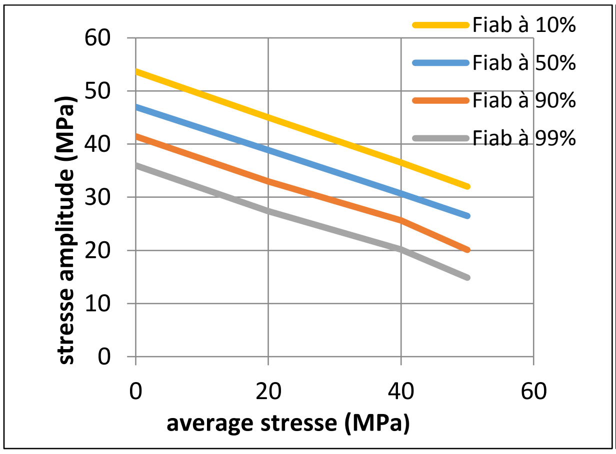


Fig. 1 Simulation of the model response for Te=10

Fig. 2 Simulation of the model response for Te=1000



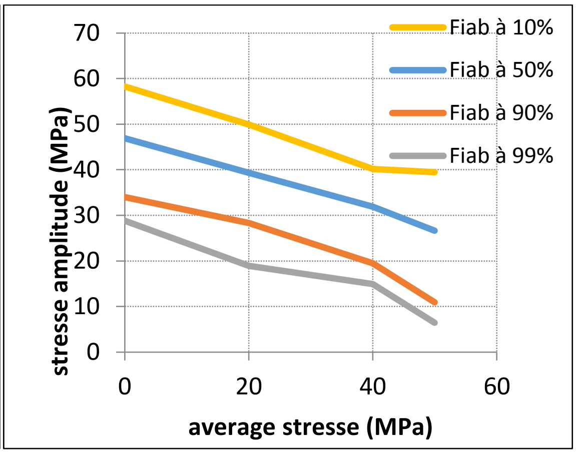


Fig. 3 Iso-probabilized Haigh curves for a 1% cov

Fig. 4 Iso-probabilized Haigh curves for a 5% cov

5 Conclusion

A probabilistic method has been developed to assess the reliability of the fatigue behavior of mechanical parts based on the Wöhler curve and the Haigh diagram.

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