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Fretting fatigue behavior and life prediction of automotive steel bolted joint

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ABSTRACT

Fatigue tests of bolted joints of SAPH400 automotive steel plate were carried out. Effect of groove on fretting fatigue strength was investigated by introducing various geometries of grooves at contact edge. The fretting fatigue strength was improved by introducing groove: the fatigue strength increased with increasing groove depth. As the next step, the applicability of the tangential stress range–compressive stress range diagram to the bolted joints was investigated using the tangential stress range–compressive stress range diagram obtained from conventional laboratory-type SAPH400 steel specimens. The result showed that the fretting fatigue strength of actual component, i.e. the bolted joint could be successfully predicted based on the tangential stress range–compressive stress range diagram.

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1. Introduction

Fatigue strength can be significantly reduced by a process known as fretting fatigue. So fretting fatigue is one of the serious problems in engineering applications, where two components are in contact and subjected to cyclic loading [1]. Examples of fretting fatigue failure appear in gas turbines, steam turbines, wheel shafts, bolted plates, wire ropes, springs and so on [2–4]. From an engineering perspective, a huge number of research works have been reported on fretting fatigue over several decades and a standard fretting fatigue test method has been also published [5–8]. A number of papers have been published on fretting fatigue based on the parametric study [9–13], such as effects of contact pressure, relative slip, variable stress amplitude. These studies have provided wide knowledge on fretting fatigue and helped to understand the importance of this damage phenomenon in engineering. On the other hand, due to the complicated mutual interaction among these phenomenological parameters, it has been difficult to fully characterize the fretting fatigue behavior by such a parametric study. Therefore, contradictory conclusions have been reported, in some cases depending on experimental conditions.

Wheels are one of the most critical parts in automotive industry and they are designed to have a fatigue life longer than the expected life of the vehicle. Premature failure of the wheel initiating at the wheel/hub connection has been often reported in literature [14]. Most of the wheel/hub connections are bolted joints, which are susceptible to fretting fatigue damage. Since these parts are classified as safety components, it is necessary to pay more attention to avoid failure accidents by accomplishing improved design and proper strength prediction.

So far a number of fretting fatigue strength prediction methods have been proposed based on strength of materials approach, fretting wear approach, fracture mechanics approach, and etc. [15–20]. However, most of these methods were developed based on the result of fretting fatigue tests carried out using simple laboratory-type specimens. The applicability of these methods to wide range of application, i.e. to the actual components has been limited. A method for predicting fretting fatigue strength of actual components based on these results of laboratory-type tests has not yet been developed and established. Therefore, it is of importance to develop a method for predicting fretting fatigue strength which can be applied to both laboratory-type specimens and actual components.

It is well known that stress distribution at the contact edge (i.e. the tangential stress and the compressive stress) plays a dominant role in influencing fretting fatigue strength [21–26]. From this point of view, in the previous study, a fretting fatigue strength prediction method based on the tangential stress range–compressive stress range diagram has been developed and discussed for Ni–Cr–Mo–V steel [27].

In the present study, as one of practical fretting fatigue problems, fatigue tests of the bolted joints of SAPH400 automotive steel plates were carried out. Effect of groove on fretting fatigue strength was also investigated by introducing various geometries of grooves at contact edge. Stress distribution as well as tangential stress range and compressive stress range at the contact edge of bolted joints were evaluated by finite element analysis to discuss effect

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