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ORIGINAL ARTICLE

A new fretting fatigue testing machine design, utilizing rotating–bending principle approach

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Abstract Fretting fatigue is a phenomenon which occurs when two parts are contacted to each other and one of those parts or both are subjected to cyclic load. Fretting decreases fatigue life of materials drastically by half or even more. Therefore, investigation of fretting fatigue life of materials is an important subject. Fretting fatigue tests are usually performed using universal hydraulic testing devices. In this work, a rotating bending apparatus for fretting fatigue test is introduced in which the cyclic load is provided by an adjustable eccentric load. The apparatus called RBFF machine which is the abbreviation of rotating bending fretting fatigue. The eccentric load is measured by load cell. The coefficient of friction and fretting load are measured by foil strain gauges using a Wheatstone bridge configuration. The performance of the machine is verified with doing a comparison between fatigue lives of a number of AL7075-T6 alloy samples on a Shimadzu rotating bending fatigue testing machine and RBFF. The results shows very close assent between the operations of the two testing rigs. The main privileges of RBFF are its simplicity with respect to universal devices, cheapness and, coefficient of friction (between pads and specimen) evaluation during the test. The RBFF also has the capability of being used for any other soft and hard metals. It can be advanced further for high and low temperature.

Keywords Fretting fatigue · Al7075-T6 alloy · Rotating bending fatigue

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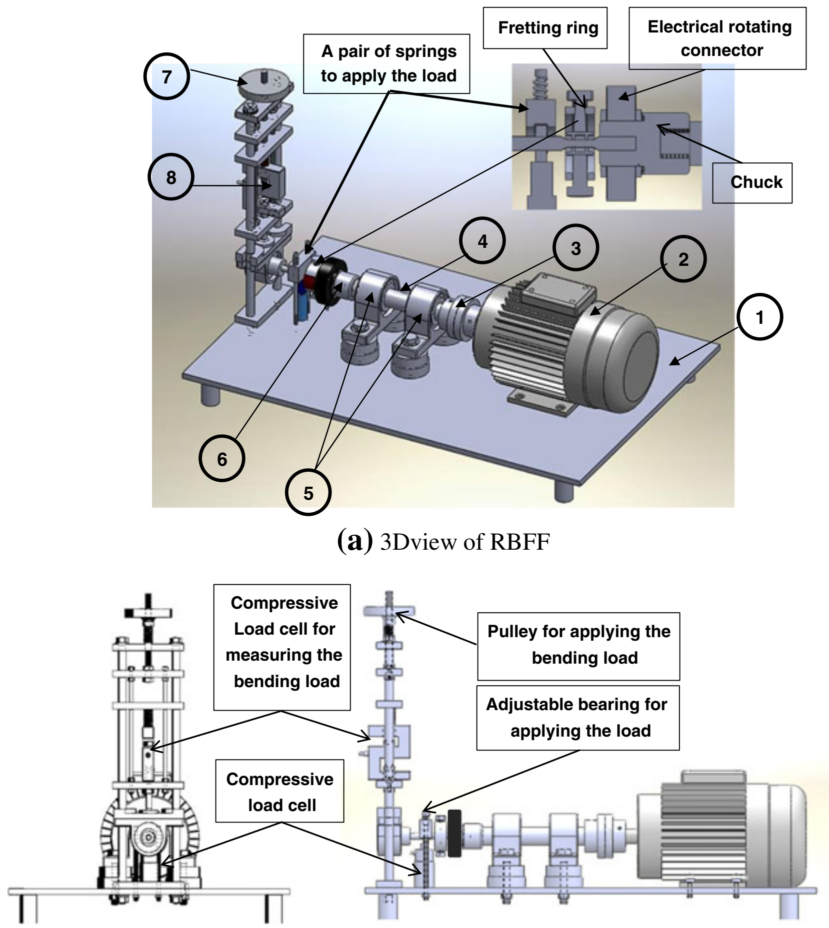
1 Introduction

Fretting is the surface damage that occurs when contacting surfaces between mating bodies experience an oscillatory motion of small amplitude. When fretting occurs under fluctuating loading condition, the process is termed fretting fatigue. Fretting fatigue increases the tensile and shear stresses at the contact surface producing surface defects which can act as stress concentration sites [1]. Fretting fatigue is a common occurrence in multitude of components or structures involving riveted joints, bolted joints, wire ropes, and dovetail joints of gas turbine engine [2–4]. Fretting decrease fatigue life of materials drastically. When fretting is applied on the surface of materials, the stress concentration at fretting region is increased and micro crack appears and starts to grow. Cracks may assert in some cases, while in others, they may propagate, eventually causing failure. Regions such as in the dovetail joint in a turbine engine, where the blade and disk are in contact and undergo vibratory stresses, are especially susceptible to fretting fatigue and have been subject of studies for a number of years [5, 6]. Structural members at macro- or micro-size scales by design or default involve contact between similar or dissimilar materials. Normally, the contacting surfaces are pressed together by a normal load, P and when one of the contacting bodies is subjected to an externally applied cyclic load, σ_a a small amount of relative displacement takes place at the contact interface and induces frictional force, f_f at the contact zone. The combination of normal load, frictional force, and cyclic axial load develops a localized stress field at the contact interface, which leads to early nucleation of micro-cracks. The process of crack initiation at the contact interface with fretting due to the cyclic axial loading is termed as fretting fatigue. The fretting has been observed in riveted and flanged joints, steam and gas turbines, wire ropes, biomedical implants, micromechanical devices, ball bearings, and springs [7, 8]. Arora et al. [5, 9] designed a fretting fatigue test rig in such a



(a) 3Dview of RBFF

(b) Front and side views of RBFF

Fig. 1 Schematic of rotating–bending fretting fatigue test machine from different views. **a** 3Dview of RBFF. **b** Front and side views of RBFF

way that the initiated small cracks at the contact edge could be directly observed and the crack propagation could be recorded using the video microscope. The fretting fatigue test jig is mounted on an 810 MTS material test system of 100 kN capacity. On the loading jig, two frictional force load cells are mounted. Normal force to the specimen–pad interface is applied through the normal force load cell by turning the loading bolt [10, 11] studied the crack growth in a shrink-fit assembly subjected to rotating bending. They observed a significant reduction in the fatigue crack propagation life, up to 50 %, as compared to an equivalent pure bending case. Rajasekaran and Nowell [12, 13] developed a biaxial fatigue experiment capable of simulating the loading experienced by a dovetail blade root in an aircraft gas turbine. The device can simulate the effects of centrifugal loading, disk expansion force, and blade vibration [14]. Ebara and Fujimura [15–17] used a fretting fatigue specimen with bolt-tightened shoe on both sides of the plate. The contact load was gained from the strain measured by a strain gauge fixed at the bolt center. A fretting test apparatus has been designed at Purdue University in USA to study fretting fatigue at elevated temperature. The fretting fatigue specimen is clamped between two contact pads and then loaded with a remote cyclic load that leads to eventual specimen cracking and failure. The main motivation behind the development of this device was to determine conditions that cause fretting-induced cracks to form in advanced turbine engine materials

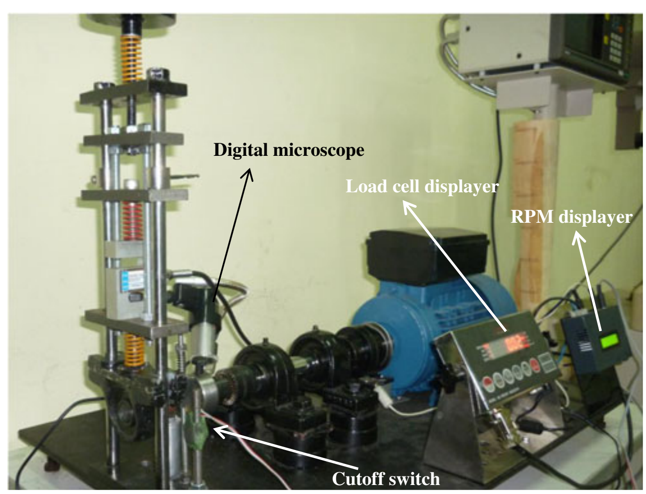


Fig. 2 Rotating bending fretting fatigue test machine