Sumitomo Drive Technologies

AN OVERVIEW OF FRETTING WEAR

SANDEEP V THUBE SR.
RESEARCH AND DEVELOPMENT ENGINEER
SUMITOMO MACHINERY CORP. OF AMERICA
CHESAPEAKE, VA

US.SUMITOMODRIVE.COM

Contents

Introduction

Fretting is considered as a type of wear that occurs in presence of a small movement between machine components [1] [2]. The small movement could be observed in parts that are not intended to move, and also parts where limited movement is allowed by design. Bolted joints, hollow bore-shaft mating area, keyways, turbine blade roots, bearing races, shrink fitted and press fitted parts are examples of where unintended movement occurs. And flexible coupling, splines, cams, leaf springs are components that area allowed to have limited internal movement.

Fretting can be elaborated with one of above examples- hollow bore and solid shaft arrangement. Two equipment are connected by this arrangement, as shown in Figure 1, where a solid shaft of an equipment is inserted into a hollow bore of another equipment in order to transmit rotational motion. Fretting is commonly observed at contact surface due to its unintended movements in radial and axial directions. Reasons for those movements could be traced back to the design, manufacturing tolerance and/or installation of the components. Red color stained area with some debris (fine red powder) is an evidence of a fretting condition. As a consequence of this condition, the mating surfaces lose their geometric tolerance, to create misalignment between components. Often, it becomes impossible to separate the solid shaft from the hollow bore at the time of maintenance, or replacements.

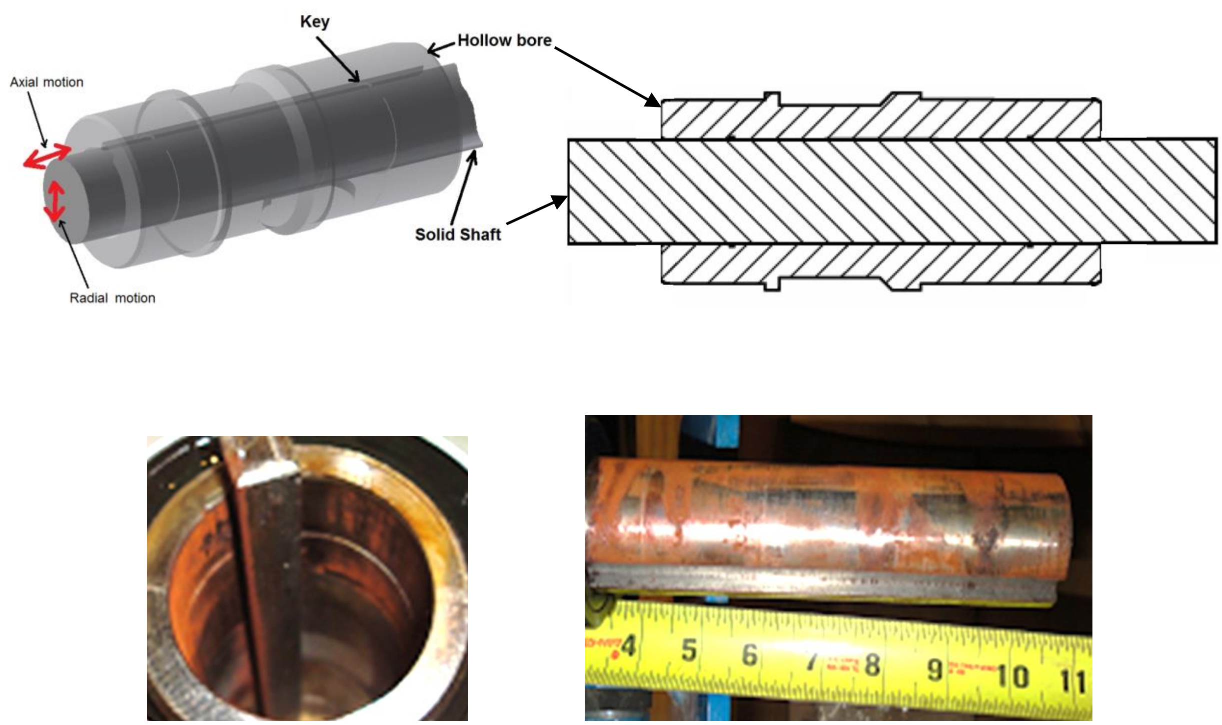

Figure 1: Fretting condition example. Staining is an evidence of fretting occurrence.

This article dives into the reasons of this failure, its consequences and mitigation methods. The article also discusses about the life prediction of components. First, we will have to understand the fretting failure mechanism.

Failure Mechanism

Technically speaking, the fretting wear can occur when a pair of structural elements are in contact under normal load while cyclic stress and relative movement are forced along the contact surface.

The localized 'relative' movement between two ferrous materials, which is small and oscillatory, is defined as 'slip amplitude'. The slip amplitude is a peak-to- peak amplitude of the relative motion, and it could be as small as 0.25 microns [3]. In this mechanism, pressure and sliding initialize material adhesion. It is also described as 'micro-welding' in the literature. That leads to the material transfer from one surface to the mating one (Refer Figure 2. Later, the transferred material oxidizes, and its dislodging forms red oxide powder (Fe_2O_3), called Hemitite, as shown in Figure 3. The powder is formed in presence of oxygen, at room temperature. This powder does not carry magnetic property. Generated particles of the powder are extremely hard, and act as abrasive.

Generation of the powder leads to more clearance between the mating surfaces, and consequentially more intense relative movement. Again, closing the loop, it would increase the rate of powder generation.

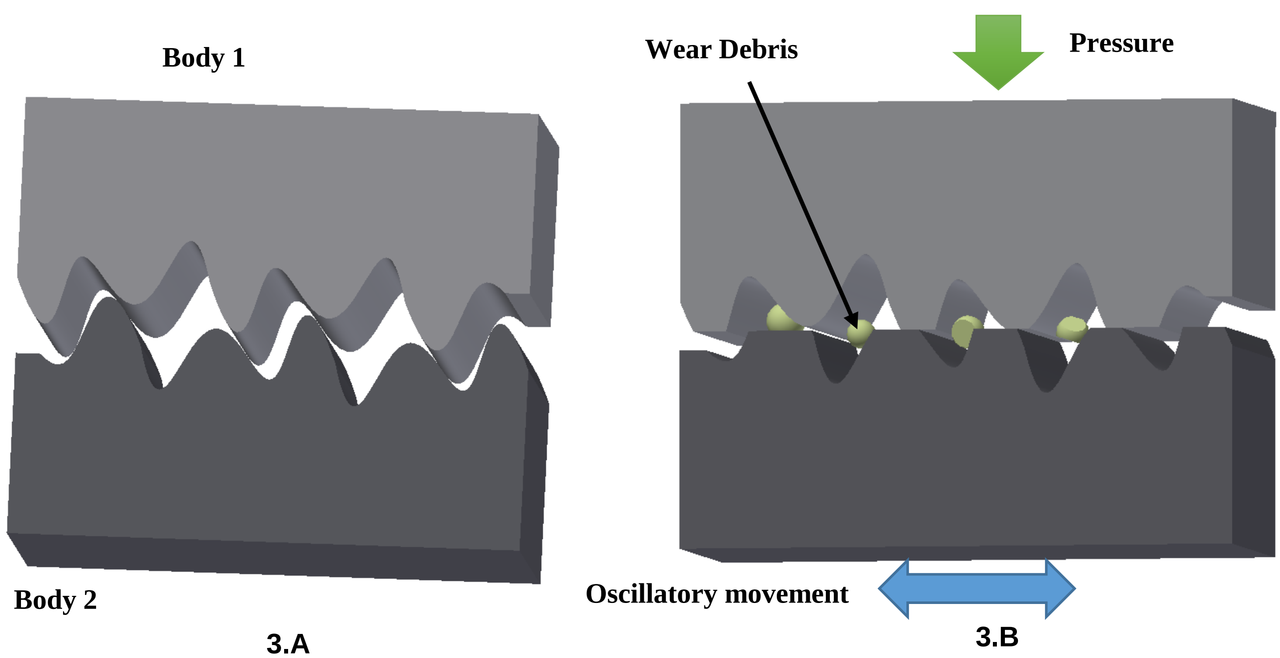

Figure 2: Microscopic surface asperities of two bodies before making contact (2.A) Pressure and movement brake asperities to form wear debris (2.B)

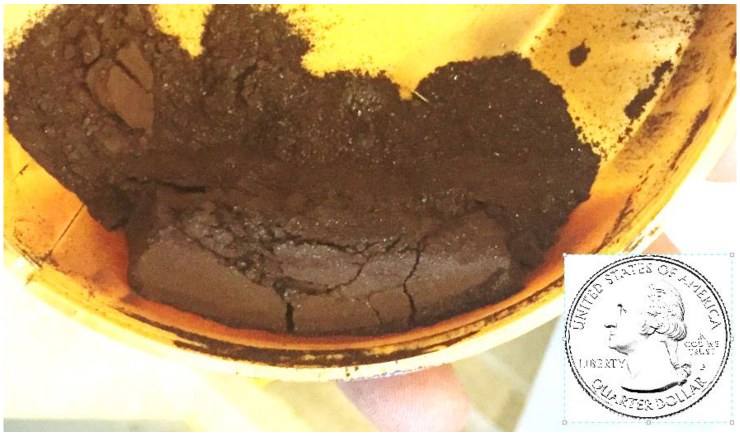

Figure 3: Fine oxide powder as a result of fretting

There are more than fifty parameters that influence the fretting fatigue process. Type of materials of the mating surfaces, their shapes, surface roughness, hardness, pressure in the contact zone, slip amplitude, frequency are some of them.

Influencing Factors

Contact pressure and displacement amplitude are generally considered the most important contributors in deciding the extent of fretting [4]. An increase in the magnitude of one or both of them correspondingly increases the surface damage. It is also proposed that the contact geometry greatly influence the extent of the wear [5].

Surface Hardness greatly influences the wear fatigue life of components. It has been documented that the contact surfaces with different hardness show less wear volume than the surfaces with the same hardness [6] [7]. When surfaces hardness are different, in general, the harder material wear debris from the harder surface is retained on the softer surface, protecting it from wearing out.

Elaborating the temperature effect, one study shows that the local hot spots at contact surfaces of AISI 52100 steel drive microstructural changes in materials [8]. These hot spots could reach above 1000 °C temperature, altering mechanical properties of the material.

Surface roughness impacts the coefficient of friction in the beginning of the surface interaction, influencing the fretting mechanism [9]. During wear process, the surface degradation changes the initial roughness. Depending on the material type, it has been reported that the initial roughness acts in favor or against the fretting wear.

The oxide wear debris also plays role in fretting wear. Depending on 'adhesion dominant' or 'abrasion dominant' fretting mechanism, the wear debris helps to accelerate or reduce the wear damage [10]. In the referred study, it was experimentally shown that the presence of the debris in bronze-on-steel contact added more wear damage, while in steel-on-steel contact, alleviated it.

Prediction:

Stresses are concentrated at edges of the contact, initiating crack at those locations. The concentration of stress can be calculated using numerical method- Finite Element Analysis (FEA) [11] [12]. Using critical distance theory, stress distribution under fretting condition can be calculated, and hence the fatigue life.

Laboratory testing that is capable of varying many influencing factors like slip amplitude, frequency, contact pressure [13].

Fretting mitigation:

Even though the occurrence and timing of the fretting phenomenon is not quite predictable, once occurred, it is still possible to address it, and avoid its further acceleration. Extra attention should be paid to constrain unwanted movements of components. The relative movement of the mating shafts, described in Figure 1, can be minimized by clamping shafts axially. As seen in Figure 4, clamping rings on both ends of the shaft help to align the components which each other, and arrest axial as well as radial relative (unwanted) motions.

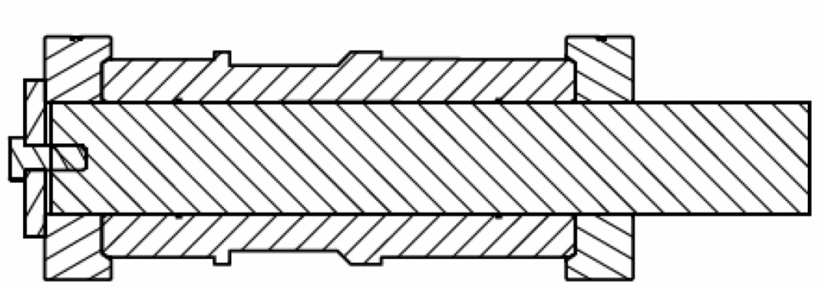

Figure 4: Constraining unwanted movements on fretted shafts to reduce further wear.

As mentioned before, fretting cracks are usually observed at high stress concentrations areas like shaft shoulders, steps, component edges etc. The stress concentration could be addressed in the design phase of the assembly or component. For instance, providing undercuts at contact ends of the hollow bore and solid shaft arrangement would help to alleviate the stress [3]. Applying lubrication between contact surfaces is one way of mitigating fretting. However, the lubricant use should not increase the slip due to reduction in coefficient of friction. If a thin oil is used, it needs to be replenished. It may not be so not ideal. Solid lubricant like molybdenum Disulphilde or zinc oxide are preferable to be utilized; however, for high fretting cycles, they may not be effective.

Surface treatment is considered to increase surface hardness, in order to improve fatigue strength. Other options, viz. Surface coating (chromium coating), use of PTFE material are also available to delay the effect of fretting wear [14] [15].

Summary:

Understanding of fretting wear is evolving, so as the solutions to counter it. This article briefly touches different aspects of this wear problem, including its mechanism, different influencing factors, and mitigation techniques.

Bibliography

[1] P. Hurricks, "The mechanism of fretting- A review," *Wear,* pp. 389-409, 1970.

[2] L. V. M. G. Y. Berthier, "Fretting fatigue and fretting wear," *TRIBOLOGY International,* p. Vol 22 No.4, 1989.

[3] J. Beard, "The avoidance of fretting," *Materials and Design,* pp. 220-227, August 1988, Vol. 9, No.4.

[4] S. S. O. Vinfsbo, "On fretting maps," *Wear,* pp. 131-147, 1988.

[5] S. P. A.R. Warmuth, "The effect of contact geometry on fretting wear rates and mechanisms for a high strength steel," *Wear,* pp. 491-500, 2013.

[6] K. G.Budinski, "Effect of hardness differential on metal-to-metal fretting damage," *Wear,* pp. 501-507, 2013.

[7] A. W. S. P. P. S. J.D. Lemm, "The influence of surface hardness on the fretting wear of steel paris- its role in debris retention in the contact," *Tribology International,* pp. 258-266, 2015.

[8] B. Podgornik, "Microstructual changes and contact temperatures during fretting in steel-steel contact," *Journal of Tribology,* pp. 670-675, October 2001, Vol.123.

[9] T. M. K.J. Kubiak, "Influence of roughness on contact interface in fretting under dry and boundary lubricated sliding regimes.," *Wear,* pp. 315-321, 2009.

[10] M. Varenberg, "DIfferent aspects of the rolw of wear debris in fretting wear," *Wear,* pp. 902-910, 2002.

[11] V. T. K. M. Y. Toshiho Hattori, "Fretting fatigue life estimations based on fretting mechanism," *Tribology International,* pp. 1389-1393, 2011.

[12] J. D. S. L. I.R. McColl, "Finite element simulation and experimental validation of fretting wear," *Wear,* pp. 1114-1127, 2004.

[13] R. R. R. R. Gnanamoorthy, "Fretting fatigue in AISI 1015 steel," *Bull. Mater. Sci, Vol. 25, No. 2,* pp. 109-114, April 2002.

[14] D. P. Kamani, "Forms of corrosion: Errosion-corrosion- Part 9," *Paint India*, pp. 97-101, January 2014.

[15] P. K. L. V. S. Fouvry, "Quantification of fretting damage," *Wear,* pp. 186-205, 1996.