Wear 332-333 (2015) 1185–1192

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

Interpretation of galling tests

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ARTICLE INFO

Article history:
Received 29 August 2014
Received in revised form
9 January 2015
Accepted 12 January 2015

Keywords:
Galling
Adhesive wear
Threshold galling stress
Tribotesting

ABSTRACT

Galling as defined by ASTM G40 [1] Terms and Definitions relating to wear and erosion, requires the formation of protrusion (excrescences) from a surface after rubbing contact. However, there are other forms of damage that can occur that can affect the serviceability of a tribosystem. For example, a couple in relative sliding may not form excrescences, but the wear rate can be so large that the test couple would be unsuitable for use. A similar situation can exist if adhesive transfer dominates on the rubbing surfaces.

This paper describes some of the standard galling tests and proposes interpretation of galling results using a multifaceted evaluation matrix that leads to a compatibility rating for a particular sliding couple. The ASTM standard test employs visual inspection of rubbed surfaces to determine if galling occurred. The proposed interpretation uses visual as well as low-powered binocular microscope examination.

The pros and cons of the existing standard tests (ASTM G 98 and G 196) are discussed and it is shown that the proposed rating system solves problems that arise with the present "gall" or not galled" rating system.

1. Introduction

The tendency for galling is a limiting factor in many tribosystems. It results in local spots of material rising up from a surface which impedes sliding against other surfaces. In conforming contacts it often results in seizure. In gears, it usually means localized roughening/scuffing at the pitch line on teeth. In the chemical process industry, it means stainless steel fasteners that break or seize before they seat. Industries that cannot adequately lubricate sliding surfaces because of contamination concerns, (sanitary systems, food processing, medical devices, clean rooms etc.) are very prone to galling problems, They often must use unlubricated metal-to-metal sliding systems The feature of galling that sets itself apart from other forms of wear is the severity and size of protrusions from the original surface that form during the rubbing process. Another common characteristic of galling is that it can occur in one pass of one surface on another. Seizure is the net result of galling in close-fitting tribosystems. Seizure means that parts that are supposed to slide on each other no longer do so. Motion is stopped. The large protrusions from the original surface that form during galling use up the running clearance and seizure are the net result. Fig. 1 shows a cylinder that galled inside of the tube that it was supposed to slide in.

Galling has been a problem since the inception of sliding systems, but it was not called "galling" until 1970 or thereabouts when Schumacher and others [2] published threshold galling stress data on various material couples. Ives et al. published a literature review on galling in 1983 [3] that indicated that Bowden and Tabor did work in this area in the 1940s using terminology such as wedge and prow formation. This same literature survey, mentioned that the official wear definitions used in Europe at the time (OECD-[4]) defined galling as:

> Galling, n. A severe form of scuffing associated with gross damage to the surfaces or failure.
>
> Note: The use of this term should be avoided. More detailed description of damage is desirable. See also scuffing and scoring.
>
> The Wear Control Handbook [4] definitions for scuffing and scoring are:
>
> Scuffing, n. Localized damage caused by the occurrence of solid phase welding between sliding surfaces without local melting.
>
> Scoring, v. The formation of severe scratches in the direction of rubbing.

A noteworthy part of this scuffing definition is the reference to solid phase welding. This is noteworthy because current definitions of galling do not mention the role of adhesion or solid state bonding between rubbing surfaces. Friction welding a commonly used commercial joining process that produces solid state welding of metals that are difficult to join using fusion processes. The mechanism is attraction of atomic species when separating films are displaced by the plastic deformation that is taking place at the rubbing surfaces [5]. Friction welding is commonly used to weld

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http://dx.doi.org/10.1016/j.wear.2015.01.022
0043-1648/

steel shafts to aluminium rollers and similar applications where fusion welding is troublesome. Galling may be related to the tendency for rubbing metal surfaces to bond as in the friction welding process.

Most tribologists agree that galling is a severe form of adhesive wear. Normally, adhesive junctions between rubbing surfaces are submicron is size and continued rubbing breaks them. However, some mating couples form large adhesive bonds during rubbing and a significant volume of metal forms from one member adheres to the other and it rises up from one or both surfaces. The term excrescence is used in the medical field to describe an outgrowth from a surface and it seems to fit what happens in galling. A large outgrowth is produced on one or both members of a couple. It is these outgrowths that form the criterion for deciding in a galling test if galling occurred or not. Microscopic excrescences are termed "incipient galling" in this paper and elsewhere [6] and the ASTM tests for galling disregards these and uses the formation of macroscopic protrusions from a surface as the criterion for galling.

It is the purpose of this paper to describe the most commonly used tests for galling and how to interpret the data from these tests. The objective of this work is to have everybody who has to deal with galling agree on when rubbing damage is galling or something else. The format of the paper is to describe threshold galling stress, tests for threshold galling stress, possible galling results: burnishing, incipient galling, scoring, adhesive transfer, galling and seizure. The paper will conclude by discussing interpretation of galling test results and the use of a data matrix to glean more useful information from tests.

Fig. 1. Cylinder that galled on removal from a conforming cylinder.

2. Galling tests

In 2014, two international standard tests that were in common use: ASTM G 98 [7] and G 196 [8]. In 2014 there was a work item in ASTM to develop a standard test for the twist-compression test [9] which is a galling test usually used with lubricants. The three tests are shown schematically in Fig. 2.

There are other galling tests in use (10–12) but these are the ones most used in commercial testing laboratories. The G 98 and G 196 tests both measure the apparent contact stress when galling commences. The twist compression test uses the friction force of coefficient of friction (COF) as the measured parameter that indicates galling. In 2014 this standard is still in the balloting stage, so this paper will not go into the test details, we will only present general description. The other tests will be discussed in more detail.

2.1. Twist compression test

This test had been used for decades. It was developed in the 1970s [13] in response to a need to screen lubricants for sheet metal forming dies. When cans and the like are formed from sheet metals there is risk that the sheet metal will adhesively transfer to the tooling creating a build-up that can mar the surface of other parts made on the tooling. So the galling tribosystem is usually a soft sheet metal rubbing on hardened tool steel (usually 60 HRC or thereabouts). Adhesive transfer is almost certain on tooling unless the sheet material tools are lubricated in some fashion [14]. The major use of the twist compression test is to screen lubricants to prevent adhesive transfer to of the formed material to the tool. Type D2 tool steel is often used for the "tool" tribocomponent and the sheet material of concern is the counterface. The shape of the counterface is usually a piece of sheet metal about 50 mm square (the type and

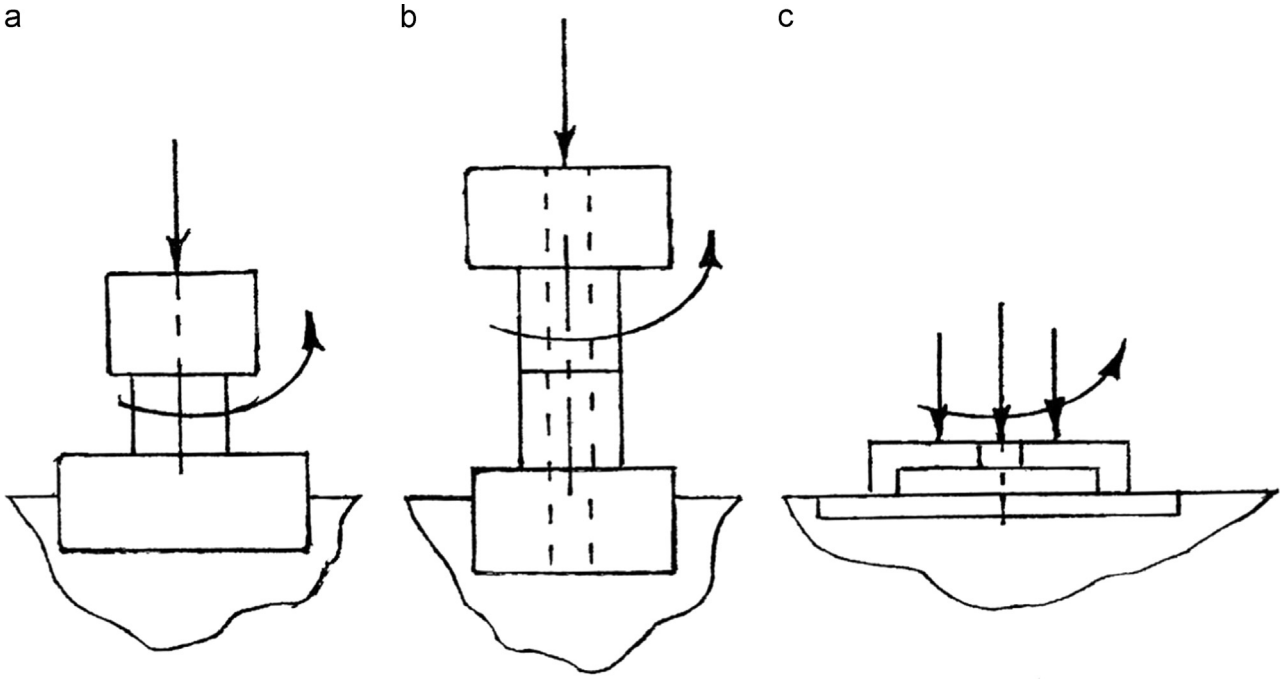

Fig. 2. Schematics of various galling tests: *a*=ASTM G 98, *b*=ASTM G 196, *c*=twist compression.