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Short Communication

Effects of surface texturing and kind of lubricant on the coefficient of friction at ambient and elevated temperatures

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ABSTRACT

Tribological tests were conducted using a pin-on-disc tester in unidirectional sliding under starved lubrication. A specimen of 25.4 mm diameter with a hardness of 50 HRC and a counter-specimen of 5 mm diameter with a hardness of 40 HRC were made from 42CrMo4 steel. Specimens were textured by abrasive jet machining. An average depth of oil pockets was 10 μm, a mean diameter was 0.5 mm and a pit-area ratio was 17%. Tribological behavior of sliding pairs with textured and untextured (polished) discs were compared. Friction tests were conducted at normal loads of 10, 20, 30, 40, 50 and 60 N increased in a stepwise manner, a sliding speed was set to 0.6 m/s. Friction behaviors were evaluated at room temperature and at elevated temperature (80 °C). The tested assemblies were lubricated by different oils. Surface texturing always led to beneficial performance of sliding pairs. However the best effect of surface texturing was observed at smaller loads and elevated temperature. Under these conditions, the effect of kind of oil on tribological behavior was negligible.

1. Introduction

Surface texturing is a well-known approach to improve tribological behaviors of sliding surfaces. Dimples act like additional lubricant reservoirs and wear debris traps, therefore their presences can improve tribological properties of sliding elements in starved lubrication [1,2]. A lubricant storage to prevent seizure was the probably the earliest understanding of the beneficial effects of surface texturing. Therefore the cross-hatched structure of honing grooves appeared with an oil capacity being one of the most important roughness parameter [3,4]. Surface texturing of bronze block specimens led to a considerably longer lifetime of a block-on-ring assembly [5]. Dimples are also able to generate an additional hydrodynamic lift. The effects of surface texturing in conformal contacts under full film lubrication conditions are lower than those observed under mixed lubrication [6]. However, a reduction in friction resistance owing to surface texturing is possible. Henry et al. [7] studied experimentally textured and untextured hydrodynamic thrust bearings. The results showed a decrease in the friction force owing to surface texturing up to 30% only under low loads. A similar reduction in the friction force was achieved due to texturing of honed cylinder liners under full fluid lubrication [8]. Borghi et al. [9], Greiner at al [10]. and Gramesh et al. [11] obtained the friction reduction of about 80% for laser textured samples under mixed lubrication. Apart from the beneficial results cases for which surface texturing was detrimental under mixed lubrication were also reported. For oil dimples with a lower area density, an increased coefficient of friction compared to the reference sample was observed [12]. Galda et al. [13] found that presence of dimples could decrease a seizure resistance.

In mechanical systems, consistent performance demands highly efficient lubricants. These lubricants include synthetic or mineral oils that consist of extreme pressure additives such as sulfur, chlorine, and phosphorus [14]. During operation, the lubricants are often exposed to elevated temperatures. In starved lubrication, a high temperature typically reduces the oil viscosity and the mechanical strength of the lubricant film [15], leading to increased friction and wear. High temperature also promotes tribochemical reactions on the contact surfaces that can be detrimental (e.g. causing corrosion) or beneficial (e.g. forming a stable tribofilm) to wear behavior [16]. Tribological tests were conducted on a steel plate against a steel ball under lubrication by oils containing no additive package [17]. The friction force was proportional to oil temperature, because a decreased oil viscosity at higher temperature caused collisions of surface summits. Smaller coefficients of friction under boundary lubrication of assemblies with untextured surfaces were obtained for high viscosity oils [18,19]. These differences are due to the thinner oil film thickness in tests with lower viscosity lubricant (a thinner fluid film leads to worse lubrication). In specific application, like gross

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fretting, low viscosity oils were more effective at suppressing friction than high viscosity oils due to easier penetration into the contact area [20].

Higher viscosity lubricants tend to reduce friction when test were carried out with textured surfaces under boundary lubrication [6]. The effect of laser surface texturing on lubrication regime transitions in unidirectional sliding was experimentally investigated using a pin-on-disc machine [18,19]. Surface texturing expanded the range of the hydrodynamic lubrication for both high- and low viscosity lubricants. However, under a boundary lubricated regime, the coefficients of friction obtained for sliding pairs with both textured and untextured samples were smaller when tests were conducted with a high viscosity lubricant. Hu et al. [21] studied the tribological behavior of laser-textured Ti-6Al-4V discs under mixed lubrication. A fourfold friction reduction and an improved wear behavior due to laser texturing resulted from a combined effect of the increased oil capacity, the reduced flow ability of highly viscous oils from the oil pockets and the excellent pressure-viscosity coefficient of these lubricants. Andersson et al. [22] found that textured surfaces with low dimple densities and small aspect ratios combined with a high viscosity oil considerably increased the oil film lifetime. However textures with high densities showed beneficial effects for low viscosity oils and small sliding speeds. Hu et al. [23] obtained the beneficial effects of surface texturing for a pit-area ratio of 8.5% as well as a small oil viscosity combined with a small load and a high viscosity combined with a high load. The tribological performance of steel sliding pairs under mixed lubrication was studied using a pin-on-disc experiment; a pin was textured [24]. By reducing oil temperature from 100 to 50 °C the optimum dimple diameter increased from 40 to 200 μm. Change of the oil viscosity with temperature is the probable reason of that performance.

2. Experimental details

Friction tests were conducted using a pin-on-disc tester in unidirectional sliding under starved lubrication. A specimen (large disc) of 25.4 mm diameter with a hardness of 50 HRC and a counter-specimen (small disc) of 5 mm diameter and a hardness of 40 HRC were made from 42CrMo4 steel. The counter-specimen, with a chamfer for oil gathering was fixed by a pin. This sliding pair ensured conformal contact between co-acting surfaces [25–27]. Before tests one drop of oil (0.04 ml) was supplied to the middle regions of the larger discs, without further addition during tests. This amount of oil was selected to obtain the most similar starting conditions for all tested sliding pairs and to prevent disproportions that would occur if the larger amount of oil would be supplied. In the latter case the amount of lubricant in the contact region between untextured counter-parts would decrease with time, leading to quick change from mixed to boundary lubrication, while for contact between textured specimen and counter-specimen oil would be accumulated in dimples so its reduction from the contact area would be slower. In addition one drop of oil was the smallest amount that could be supplied precisely at every test.

Surfaces of sliding elements were polished, the values of the Ra parameter were in the range: 0.05–0.07 μm. Large discs were textured by

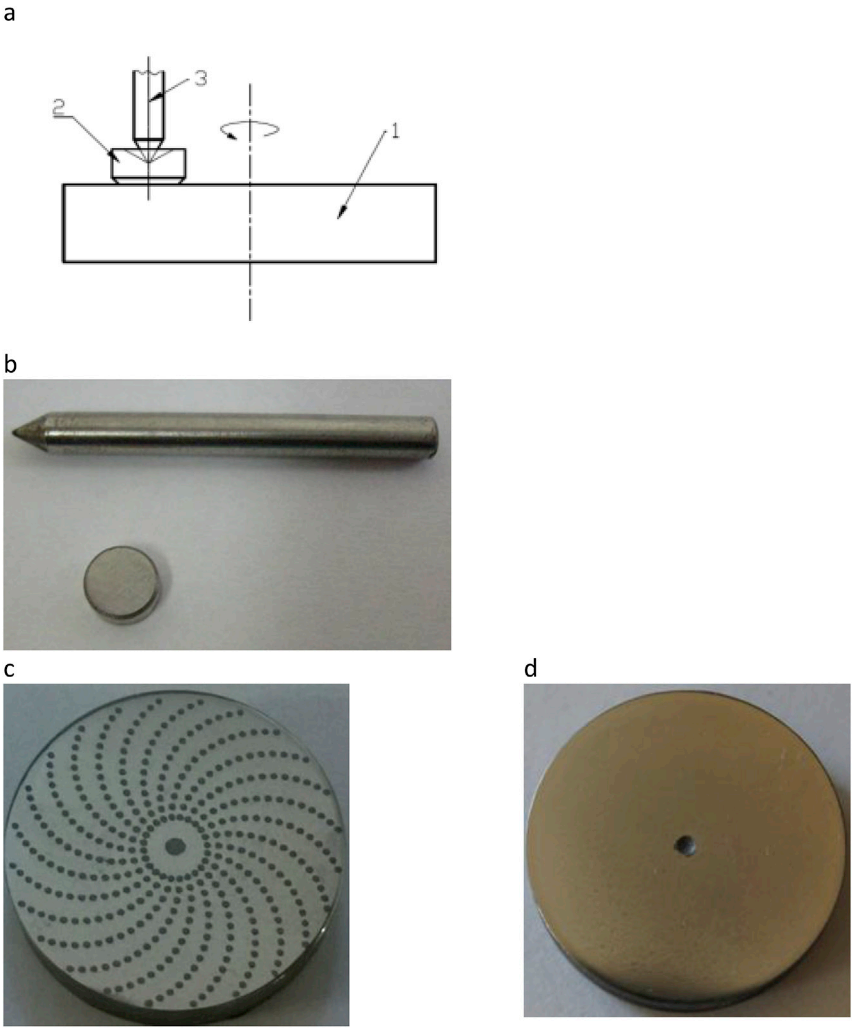

Fig. 1. Scheme of co-acting parts (a): 1 specimen, 2- self-aligning counter-specimen, 3–conical pin, counter-specimen with pin (b), textured specimen (c) and untexured specimen (d).