Tribology International 53 (2012) 68–75

Contents lists available at SciVerse ScienceDirect

Tribology International

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

Initiation and growth of gaseous cavity in concentrated contact in various surrounding gases

Takefumi Otsu [a,*], Hiroyoshi Tanaka [b], Joichi Sugimura [b]

[a] Department of Mechanical Engineering Science, Graduate School of Engineering, Kyushu University 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan
[b] Department of Mechanical Engineering, Kyushu University 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan

ARTICLE INFO

Article history:
Received 31 August 2011
Received in revised form
15 April 2012
Accepted 16 April 2012
Available online 30 April 2012

Keywords:
Cavitation
Elastohydrodynamic lubrication
Gas
Dissolution

ABSTRACT

This paper describes an experimental study on the initiation and growth of gaseous cavity in EHL. Lubricated point contact sliding tests and separating tests were conducted in various different gas environments. Gases used were air, helium, argon and carbon dioxide. In the sliding tests, length of a cavity rapidly increased with time in the initial stage after its generation, and the speed of the increase was the same in all of the gases. The cavity length gradually increased after that at different speeds depending on the solubility of gas in the lubricant as reported in the previous study. In the separating test, changes in the size and the shape of the cavities were the same for all of the gases. This implied that the growth of cavity in the initial stage did not depend on dissolved gas in the lubricant. It is shown by a simple numerical analysis that the initial growth of the cavity depends on the rapid evolution of negative pressure at the outlet of the conjunction.

1. Introduction

Cavitation occurs in lubricated contacts of many machine elements, *e.g.* in journal bearings [1], piston ring and cylinder liners [2], seal surfaces [3], EHL conjunctions [4–6] and those with micro asperity [7]. Cavitation largely affects lubrication performance in both negative and positive ways.

One negative effect is the inlet starvation of the film that leads to a breakdown of the lubricating films. Cavity formation at the diverging gap between the two surfaces in sliding or rolling contacts causes starvation of the lubricant causing a decrease in the film thickness in some conditions. Nishikawa et al. reported the effect of starvation on film thickness in reciprocating EHL and cyclic squeezing tests, in which the cavity affected film formation in the next stroke [8,9]. Leonard et al. reported that gaseous cavity affected fretting wear under grease lubrication conditions [10]. Izumi et al. simulated changes in film thickness in reciprocating motion [11], and showed that the decrease in the film thickness in the next cycle depended on the time for the cavity to disappear [12].

The outlet cavity also causes inlet starvation in unidirectional rotating conditions, particularly in grease lubrication [13] and in the cases with a small amount of oil. Pembertom and Cameron reported that an opened cavity, *i.e.* an opened air cavity, affected the length of the meniscus at the contact inlet [14]. This suggests that oil is not replenished completely into an opened cavity area before the next contact, and it leads to a decrease in the meniscus length. In contrast, an enclosed cavity does not cause oil starvation, because oil is fully replenished into the track. Hence, whether a cavity is opened or enclosed greatly affects the amount of oil at the inlet.

On the other hand, a positive effect of cavitation is that cavities can reduce viscosity resistance force. Etsion et al. reported that a micro texture on the surface of a thrust bearing and a piston ring reduced friction force, and the magnitude of the reduction of the friction force decreased depended on the location of the textured area [15,16]. Yagi et al. reported that the shape of cavities and thus the friction coefficient, depended on the alignment of micro pits in the ring-on-ring sliding experiments [17]. In their work on radial lip seals, Sato et al. reported that micro-cavitation occurred due to surface roughness of the rubber surfaces and contributed to the decrease in the friction coefficient [18].

Cavitation in lubricating films occurs either by the vaporization of the lubricant itself or the release of dissolved gas in the lubricant [19]. Oils generally contain about 10% of dissolved air by volume [20], and the saturation pressure for the release of the dissolved gas is higher than that of the vaporization of the oils [21]. Therefore, we usually observe a gaseous cavity. However, although the gaseous cavitation is generated from the dissolved gas in the oil, the relationship between cavitation and the dissolved gas has not yet been studied in detail. The kind and the amount of dissolved gas change by surrounding gas, and the change may

* Corresponding author. Tel.: +81 942 35 9364.
E-mail addresses: otsu@mech.kyushu-u.ac.jp, otsu.takefumi@kyudai.jp (T. Otsu).

0301-679X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.triboint.2012.04.013

greatly affect the behaviour of gaseous cavitation. One of the most important issues for the design of machines to operate in various surrounding gases other than air is to investigate the effects of surrounding gas on lubrication.

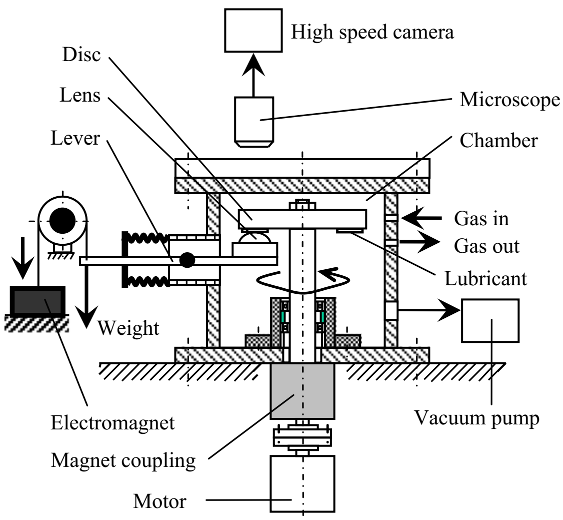

Fig. 1. Cavity growth in two stages in the sliding test.

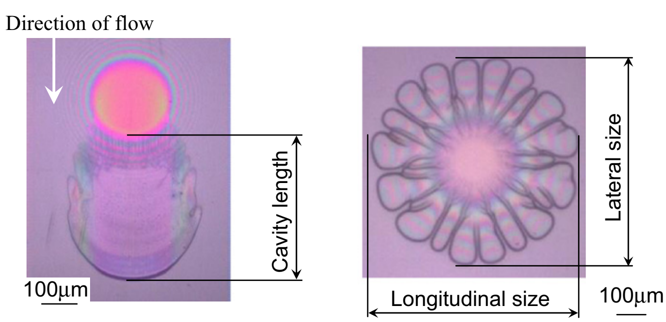

Fig. 2. Definition of cavity length and cavity size.

An example of the effect of gas on the refrigerant gas HFC-134a is given by Yamamoto et al., they discovered that the time to breakdown the lubricating film in HFC-134a gas was shorter than that in a nitrogen gas environment [22]. Suggesting that cavities formed in HFC-134a are larger and causes earlier starvation than those in nitrogen gas, and this is because of the higher solubility of HFC-134a [23].

Recently, the authors studied the growth of a cavity with time in a EHL-film in various gas environments [24]. It is probably the first time since Dowson [25], Archard and Kirk [4] reported that the cavities extended with time; little attention has long been paid to the phenomenon of cavity growth. The authors discovered that the cavity length was affected by the kind of surrounding gas, and was also related to gas solubility. They suggested that the gas dissolved in oil is released into a cavity with time, and the amount of released gas depended on gas solubility. While they focused on the cavity length from ten seconds to one hour after the start, the behaviour of a cavity soon after the initiation has yet to be investigated.

In this study, point contact EHL tests were conducted in some gases. The effect of the surrounding gas on the initial stage of cavity growth was studied. In addition to the sliding tests, cavities that were formed after the gap between two contact surfaces that increased with time were observed in separating tests. Their behaviours were compared with those in the sliding tests.

2. Experimental

2.1. Test apparatus

Fig. 1 shows a schematic of the test apparatus used in this study. The main part for the lubricated point contact sliding and separating tests was enclosed in a sealed chamber. The chamber had gas ports for supplying the arbitrary test gas and was also equipped with a vacuum pump.

A plano-convex glass lens was pressed against a glass disc by a lever while the disc was rotated by a motor in the sliding tests. In the separating tests, the lens was pulled downward by an electro-magnet after the contacts were set to touch. The disc and

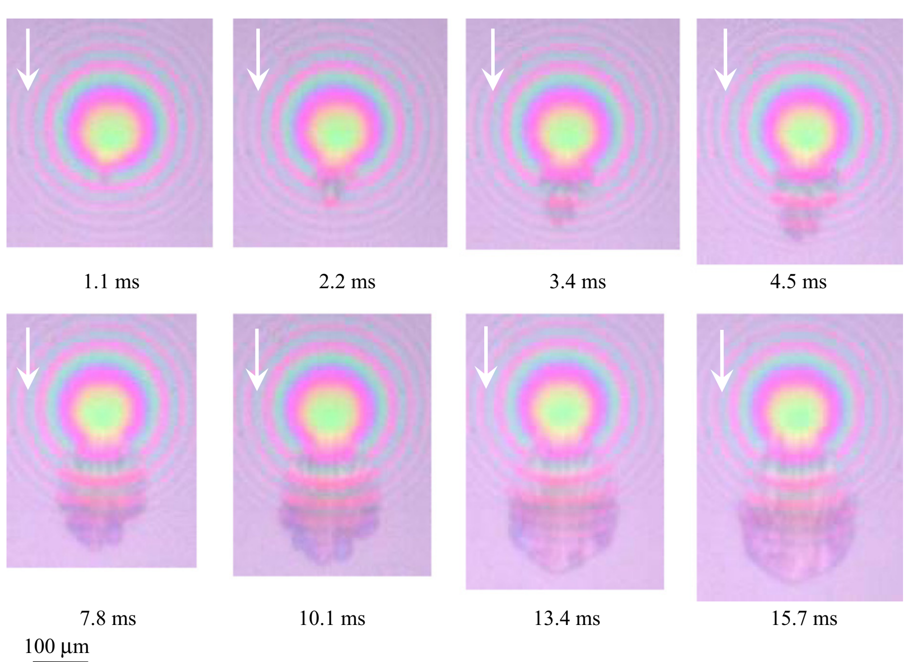

Fig. 3. Photograph of cavity upto 15.7 ms in the sliding test.