Surface & Coatings Technology 212 (2012) 1–13

Contents lists available at SciVerse ScienceDirect

Surface & Coatings Technology

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

New advances on maskless electrochemical texturing (MECT) for tribological purposes

J.G. Parreira [1], C.A. Gallo [2], H.L. Costa *

Tribology and Materials Laboratory, School of Mechanical Engineering, Universidade Federal de Uberlândia, Campus Santa Mônica, Bloco 5K, 38400902, Uberlândia, Brazil

ARTICLE INFO

Article history:
Received 22 February 2012
Accepted in revised form 18 August 2012
Available online 25 August 2012

Keywords:
Surface texturing
Electrochemical machining
Tribology

ABSTRACT

Surface texturing can be applied to improve tribological performance of mechanical contacts, in particular in the case of lubricated systems. The purpose of this work was to improve an alternative method for surface texturing based on electrochemical dissolution without previous masking of the workpiece named maskless electrochemical texturing (MECT). Electrochemical dissolution combines high speed, good reproducibility and high cost-benefit ratio, which are important factors when an industrial application of surface texturing is pursued. The use of electrical discharge machining (EDM) for the manufacturing of the MECT tools enabled different microtexture patterns to be produced. The cathodic tool was an AISI 430 ferritic stainless steel plate containing a pattern of microholes and covered with an insulating paint layer. The effect of important parameters such as the gap between electrodes, the applied voltage and the texturing time were evaluated. Different texturing patterns containing dots, trace-dots and chevrons were successfully obtained using a NaCl solution electrolyte. Tribological tests textured surfaces under starved liquid lubrication showed friction and wear reduction, when compared with a smooth surface.

1. Introduction

The controlled modification of surface topography, creating a uniform microrelief, known as surface microtexturing, may be used in many areas of engineering, promoting benefits such as improvement of adhesion between surfaces, generation of superhydrophobic surfaces, increase of light absorption, reduction of drag in aerodynamic applications, improvement of tribological properties, among others [1].

Surface texturing techniques for tribological purposes have been intensively studied in the last 15 years. The microtexture can, in dry sliding conditions, entrap wear debris and consequently reduce friction and wear between contacting surfaces [2–4]. In lubricated sliding conditions, the texture can, besides removing wear debris, act as microreservoirs for lubricant [4,5], and increase contact hydrodynamic pressure, consequently raising the load capacity of the component [6,7]. For example, measurements of film thickness showed a load capacity increase of up to 10% for textured surfaces in hydrodynamic regime when compared with smooth surfaces [6]. Rapoport et al. [8] evidenced a friction reduction of up to 40% in textured surfaces when compared with non textured components.

However, despite intense investigation regarding the effects of surface texturing under hydrodynamic and elastohydrodynamic lubrication conditions, where the contact is fully immersed in lubricant, less information is found for starved lubrication conditions. Under starved lubrication, the lubricant which passes through the contact and remains on the out-of-contact tracks on the rubbing two bodies is not, of itself, sufficient to refill the inlet. Within the inlet, all of the lubricant except that which passes through the contact, will be pushed to the sides. Some of this latter oil flows back into the track, driven by surface tension, and the lubricant which thus returns provides the required inlet reservoir [9].

In a recent paper, Mishra and Polycarpou [10] investigated the possibility of using surface texturing in air conditioning and refrigeration compressors under realistic operating conditions of starved lubrication. The textures were composed of regular arrays of pockets with diameters varying between 40 and 60 μm. The authors found an increase in scuffing life duration for all the textures investigated when compared with untextured surfaces and also reduction in wear. The present paper will investigate the role of surface texturing on the lubricant replenishment at the contact inlet under starved lubrication conditions using pocket diameters substantially larger than those used by Mishra and Polycarpou [10].

Many techniques can be used to create microtextures in surfaces. Costa et al. [11] have reviewed over 40 possible surface texturing

---

* Corresponding author. Tel.: +55 34 32394036.
E-mail addresses: jakeline.parreira@vse.com.br (J.G. Parreira), gallo@mecanica.ufu.br (C.A. Gallo), ltm-henara@ufu.br (H.L. Costa).

[1] Present address: VSE, Rodovia Presidente Dutra, km 138, 12247 004, São José dos Campos, Brazil. Tel.: +55 12 33212557.

[2] Tel.: +55 34 32394035.

0257-8972/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.surfcoat.2012.08.043

Table 1
Comparison of different surface texturing techniques.

	Laser	Photochemical	Masked electrochemical	Maskless electrochemical
Previous treatment		- - -	- - -	
Post treatment	- - -	- - -	- - -	
Speed	- - -	- - -	- - -	
Cost	- - -	- - -		
Material			- - -	- - -
Tool Complexity				- - -

Table 2
Test conditions.

Test	Evaluated parameter	Variable conditions	Fixed conditions
1	Gap between electrodes	500 μm, 250 μm, 200 μm, 100 μm, 50 μm.	Concentration = 200 g/L Flow = 20 mL/s Voltage = 30 V Time = 30 s Pattern = dots
2	Voltage applied	10 V, 20 V, 30 V, 40 V, 50 V	Concentration = 200 g/L Flow = 20 mL/s Gap = 100 μm Time = 30 s Pattern = dots
3	Texturing time	10 s, 20 s, 30 s, 60 s, 90 s, 120 s	Concentration = 200 g/L Flow = 20 mL/s Voltage = 30 V Gap = 100 μm Pattern = dots
4	Texture pattern	Dots, dashed lines with dots, chevrons.	Concentration = 200 g/L Flow = 20 mL/s Voltage = 30 V Gap = 100 μm Time = 30 s

techniques. The methods were categorized according to their physical principals into four main groups:

Adding material: the pattern features are created by addition of material to the desired surface, creating small areas of relief.

Removing material: the features are created by removal of material of the surface, creating small depressions.

Moving material: the change in the surface structure is attributable to plastic deformation and redistribution of material from some parts of the surface to others.

Self-forming: since some researchers claim that once produced, a surface texture may not have sufficient mechanical resistance to survive in highly loaded systems [12,13], wear-resistant regions are formed on a surface, so that a texture develops through wear of the surface, with the wear-resistant regions being left standing above the surrounding material.

Major advances in microfabrication have driven the area of surface texturing. In principle, the majority of the methods used in the microelectronics industry could be adapted to surface texturing. However, many of these techniques are slow and expensive, which makes them inappropriate to produce a large number of cheap components, especially when texturing of large areas is required. For these applications, alternative texturing methods are needed, in order to make surface texturing cost-effective.

This paper investigates the use of micro-electrochemical machining to texture surfaces.

In electrochemical machining (ECM), metal dissolution allows the shape of the tool to be copied onto the workpiece surface. The main drawback with the usual techniques that use micro-ECM to texture surfaces is the need to mask each individual workpiece to be textured, which adds cost and time to the process [14,15]. To overcome this limitation, some work has focused on locating the electrical insulation that localizes the machining action at the surface of the cathodic tool, instead of applying a mask to each individual workpiece [16–18]. Costa and Hutchings [18] proposed a simple method for texturing metallic surfaces by electrochemical machining, termed 'maskless electrochemical texturing' (MECT). This technique can be regarded as an adaptation of jet ECM [19,20] to texture surfaces. However, in jet ECM, the process occurs at a single location, whereas MECT occurs with complete wetting of the surface sample, leading to the machining of a large number of areas in parallel. For MECT, machining localization is achieved with the use of a masked tool. This probably reduces the accuracy of the process due to stray currents away from the holes in the tool, but increases substantially the speed of the

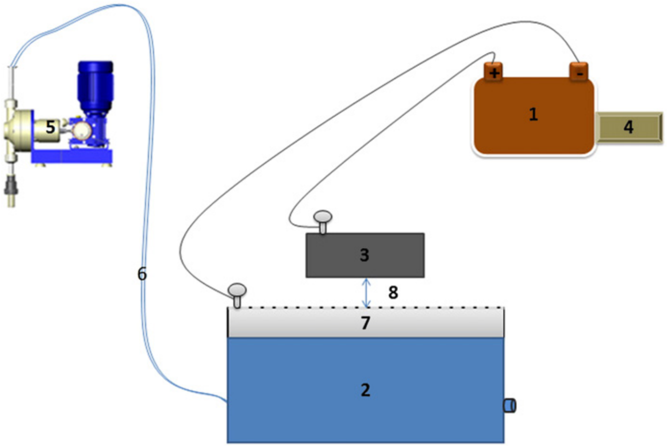

Fig. 1. Scheme of the experimental apparatus.

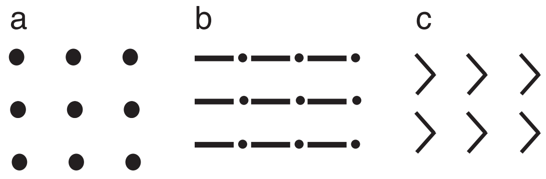

Fig. 2. Scheme of the textures produced; (a) arrays of circular dots; (b) dashed lines with dots; (c) arrays of chevrons.

Table 3
Lubricant properties.

Commercial name	SUNISO 3GS
Density at 20 °C, g/cm^3	0.906
Viscosity at 40 °C, cP	25.91
Viscosity at 100 °C, cP	3.86
Flash temperature, °C	182
Ignition temperature, °C	190
Dielectric strength, kV	60

Table 4
Normal loads in tribological tests and respective Hertz calculations.

Normal load (N)	Maximum contact pressure (MPa)	Contact width (μm)
2.94	631	94.4
12.74	1029	153.8
51.94	1643	245.7