Tribology International 70 (2014) 119–127

Contents lists available at ScienceDirect

Tribology International

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

Effect of double pressing/double sintering on the sliding wear of self-lubricating sintered composites

Gisele Hammes [a], Renan Schroeder [a], Cristiano Binder [a], Aloisio N. Klein [a], Jose Daniel B. de Mello [a,b,*]

[a] Laboratório de Materiais, Universidade Federal de Santa Catarina, Brazil
[b] Laboratório de Tribologia e Materiais, Universidade Federal de Uberlândia, Brazil

ARTICLE INFO

Article history:
Received 28 May 2013
Received in revised form
15 September 2013
Accepted 19 September 2013
Available online 16 October 2013

Keywords:
Solid lubrication
Self-lubricating composites
Powder metallurgy
Double pressing/double sintering

ABSTRACT

This work presents the effect of a double pressing/double sintering technique on the sliding wear of self-lubricating composites. The matrix composition was based on that of a Fe–Mo–C–Si alloy, and the solid lubricants were h-BN and graphite. Sliding tests were carried out first at a constant load. Subsequently, scuffing tests with loading steps of 7 N/10 min were also performed. The wear rates of both specimens and counter-bodies and the average friction coefficient were slightly affected by the compaction technique. DPDS specimens showed higher scuffing resistance. The scuffing resistance depends to a great extent on the mechanical support provided by the matrix. DPDS significantly reduced the sub-surface porosity and, as a consequence, the scuffing resistance.

1. Introduction

The production of high-performance self-lubricating composites containing second-phase particles incorporated into their volume is a promising technique for controlling friction and wear in modern energy-efficient mechanical systems [1–5].

Composite self-lubricating components have been used for several decades in household and light office equipment such as printers, electric shavers, drills and blenders. There are several possible manufacturing routes for producing such composites, in polymeric, metallic or even ceramic matrices [6–8]. The most frequently used metallic matrix materials are copper [9], nickel [10] and ferrous [11,12] alloys. Compounds such as MoS_2, WS_2, $MoSe_2$, NbS_2, $TaSe_2$, $MoTe_2$, h-BN, low-melting metals such as Ag, Sn and Pb, graphite and polytetrafluorethylene (PTFE) are most frequently used as solid lubricants [2,3,13,14]. The majority of the composites developed in the past contained a high percentage of solid lubricant particles (15–40%) to obtain a low friction coefficient. This resulted in a largely discontinuous metallic matrix that exhibited poor mechanical properties.

Fig. 1 presents a schematic drawing of the ideal microstructure of a self-lubricating composite. The microstructure must consist of a continuous matrix containing regularly dispersed solid lubricant particles and take into account the mean free path between them and the active area to be covered by each one of them.

For the development of metal-matrix composites, powder metallurgy (PM) is a competitive and attractive technique because of its low cost when applied to large-volume production and because of its great versatility due to the suitability of the technique for tailoring the microstructure according to the requirements imposed by a given application. The resulting high mechanical and tribological performance is a consequence of the combination of matrix mechanical properties and structural parameters such as the degree of continuity of the metallic matrix, the amount of solid lubricant added to the material and the size and the shape of solid lubricant particles. In addition, PM processes are very advantageous for developing complex shape parts or even small-size components, which have been increasingly required due to the miniaturisation of modern mechanical systems.

The high porosity of sintered components leads to reduced mechanical strength and load capacity when compared with those properties of fully dense materials [15,16]. However, sintered components have the potential to store lubricants that can be released during use [17,18]. Moreover, the pores can eventually play an important role in the removal of wear debris from sliding interfaces, as suggested by some authors [19]. In fact, similar to other tribological properties, the tribological behaviour is strongly dictated by the imposed tribological system, e.g., in some cases, pores might be useful and in other cases detrimental to the tribological behaviour [20,21].

In addition, it is clear that the development of high-quality composites demands improved mechanical resistance. Therefore, powder metallurgists are continuously searching for new alternatives and mechanisms to improve mechanical resistance and

* Corresponding author at: Laboratório de Tribologia e Materiais, Universidade Federal de Uberlândia. Brazil. Tel.: +55 34 3219 3771; fax: +55 34 3239 4273.
E-mail addresses: ltm-demello@ufu.br, d.mello@ufsc.br (J.D.B. de Mello).

0301-679X/$ - see front matter
http://dx.doi.org/10.1016/j.triboint.2013.09.016

load support. In this paper, special attention is given to the compaction step. Several compaction techniques, such as uniaxial die pressing, extruding, rolling, 3D prototyping and powder injection moulding, must be considered, depending on the geometry and properties desired for the composite material.

Uniaxial die-pressing, due to its low manufacturing costs, is still the most traditional processing route. It also produces the closest tolerances in the finished parts, thus nearly eliminating post-sintering operations such as machining [22]. A potential alternative for improving the mechanical strength of self-lubricating sintered composites is therefore the use of the double pressing/double sintering technique [23] developed by Hoeganaes [24]. The goal of this method is to increase the density of composites by two-fold pressing. According to German [25], reductions of 2–3% in porosity would result in up to a 20% increase in mechanical strength.

The literature does not report the use of double pressing/double sintering for the production of self-lubricating composites. On the other hand, there are a few papers that report its use in the production of sintered steels, and it is generally accepted that the technique induces higher densities and strengths. In fact, DPDS has been used by the automotive industry since 1990 s in highly demanding applications such as synchroniser hubs, crankshaft sprockets, steering column tilt levers and planetary gear carriers [26].

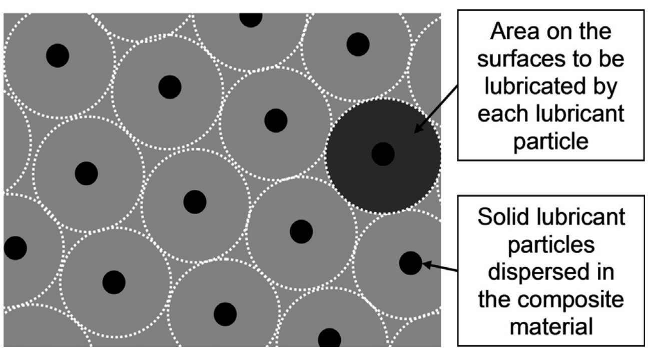

Fig. 1. Microstructural model of an ideal self-lubricating composite.

This work presents the effect of a double pressing/double sintering (DP) technique on the tribological behaviour (sliding wear and scuffing resistance) of iron-based self-lubricating composites. The matrix composition was based on that of a Fe–Mo–C–Si alloy, and the solid lubricants were h-BN and graphite. Composites submitted to single pressing/single sintering (SP) and produced at medium and high compacting pressures (500 MPa and 700 MPa) were also analysed as reference materials.

2. Experimental procedures

The matrix of the composites developed in this work was based on a Fe–1.5Mo–1.0Si–0.8C alloy, and 2.5% wt graphite + 5.0% wt hexagonal boron nitride (h-BN) were added as solid lubricants. The purpose of using two solid lubricants is associated with the tribological behaviour of the lubricants in different environments: graphite is very well known for its improved lubricity effect in wet atmospheres, whereas h-BN is suitable for high-temperature applications [27,28].

Commercially available powders (Höganäs Astaloy Mo – d = 109 μm; Osprey Sandvik Fe45Si – d50: 10 μm; Nacional Grafite – d50 = 32 μm; Momentive 6028 h-BN, d = 125 μm) were first mixed according to the nominal composition of the composite. The powders were mixed for 45 min in a Y-type mixer, rotating at 35 rpm. The powder mixtures were uniaxially pressed using a double-action press with a floating die.

Three different processing routes were applied to obtain discs (65 mm diameter/5 mm thickness) and samples with the same chemical composition for tensile tests (MPIF standard 10 [29]). The first two routes were processed by single pressing/single

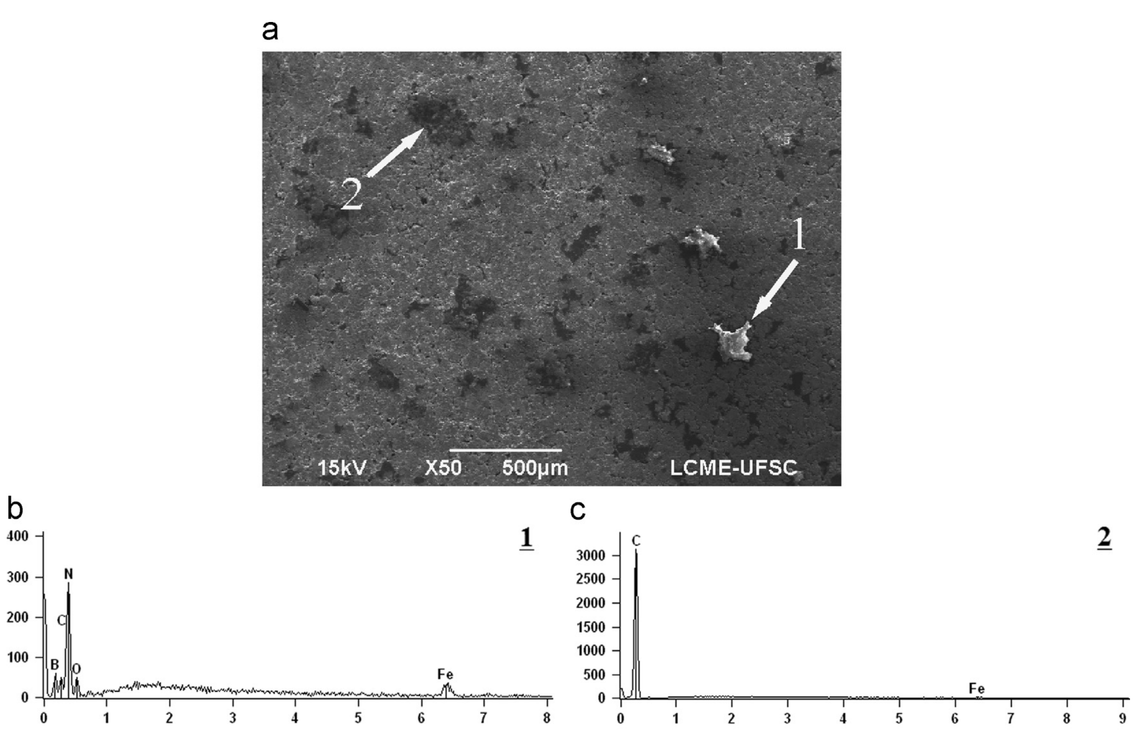

Fig. 2. SEM-EDS analysis of the surface of the composite SP-700. (a) BSE image showing reservoirs of solid lubricants dispersed in the metallic matrix. (b) EDS spectrum of point 1. (c) EDS spectrum of point 2.