Design and Fabrication of Portable Block on Ring Tribometer and Its Application to Evaluate Wear of SS-201 Steel

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Abstract. Wear is phenomenon of material loss that arises because of interaction of solid surfaces which mechanically loaded and in relative motion. Understanding wear phenomenon is important in teaching and learning process for subjects related to engineering materials. A tribometer is a typical tool utilized to characterize wear of materials. This work is intended to design and fabricate a portable block on ring wear tester to characterize various material's wear for laboratory demonstration as well as research tool in Mechanical Engineering Program, Faculty of Engineering, University of Muhammadiyah Surakarta. SS201 steel was employed as cylinder material and Mild Steel was employed as Disk material to evaluate the functionality of designed tribometer. The test was conducted under dry sliding contact with load of 2 kgf and 4 kgf gram. Rotational speeds were varied at 300 rpm, 600 rpm, and 900 rpm respectively. The speed and load show effect to wear of SS-201 sample. Three wear evaluation method were employed to compare their significance in evaluating wear results, i.e. wear depth, wear scar length, and weight loses methods. The highest wear observed at 4 kgf load and 900 rpm sliding speed and the lowest wear observed at 2 kgf of load and 300 rpm speed sliding speed. It is concluded that evaluation of wear is better performed by using weight loss method for this apparatus. Moreover, symptom of adhesive wear dominantly observed on the wear surfaces. This mechanism is accompanied by fatigue and abrasion mechanisms.

Keywords: tribometer · wear

1 Introduction

In a mechanical system, contacts between the surfaces of component are commonly occurred to during motions. Friction and wear are two phenomena typically occurs between machine component due to their relative motion. This phenomenon can be found in bearings, internal combustion engine, gearing systems, hinges, bolts, etc. Wear is incident of gradual material losses that arises as a result of surfaces interaction that moving relative to each other and experience loading. Understanding wear phenomenon is important in teaching and learning process for engineering materials subject.

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A tribometer is a typical tool utilized to characterize wear of materials. Various tribometer has been introduced and commercially available. These tribometer mainly attempt to simulate real contact interaction and conditions of mechanical elements with different contact geometry and configuration [1]. Performing wear test basically meant to provide data for several engineering applications, which generally employed to expand component's life, maintenance cost, cost reduction, and reliability [2]. Moreover, several standard testing methods to quantify friction and wear have been published by ASTM international.

The concept of friction and wear of materials are typically introduced in engineering materials or other subject related to surface engineering. Block-on-ring wear test is one of standardized testing method to determine the resistance of materials to sliding wear [3]. This test utilizes a block-on-ring to rank pairs of materials according to their sliding wear characteristics under various conditions. This testing configuration typically simulate line contact situation between two solid surfaces. An important aspect of this test is that this testing configuration is very flexible where any material that can be fabricated into blocks and rings can be tested. Thus, the potential materials combinations are endless.

In this work, a testing apparatus to simulate sliding friction and wear is meant to be built. This work is intended to design a portable block on ring tribometer to characterize various material's wear for laboratory demonstration as well as research tool in Mechanical Engineering Program, Faculty of Engineering, University of Muhammadiyah Surakarta.

2 Methods

2.1 Design Selection

In this work, an apparatus that capable to simulate sliding friction and wear is meant to be constructed. Several contact geometries such as point contact, line contact, and area contact, have been considered. Line contact geometry which typically represent contact mode in roller bearing and gears was finally selected. A block on ring configuration is one of several testing configurations represent this type of contact mode. Prior to the designing process, several criteria such as simplicity of construction, manufacturing cost, structural stability, and assembly process were employed to select final design of the apparatus. The apparatus also required able to test various material pair lubricants, rotational speed, and load to simulate various service conditions requirements. Final design of the apparatus is shown in Fig. 1. In this apparatus, the driven rotor shaft is placed inside the frame for operational safety. L-angle made of mild steel is used as frame material and lever mechanism is employed to apply the load. An AC-Motor of 1 HP is employed as motor driver and installed at the top side of the frame structure. This driver is transferring power a driven shaft which connected to ring or disc specimen through belt connection. This motor is controlled by a variable-frequency drive (VFD) is to control the torque and rotation of the driver motor.

2.2 Functional Testing

Functional testing of the designed apparatus was performed by using SS-201 steel (82.7 HRB) as cylinder/block specimen and mild steel (84.1 HRB) as ring/disc specimen. Both steels are typical materials for general structural applications. The cylinder/block specimens fabricated with size of 6- mm in diameter and 25-mm in length and the disc/ring specimen was fabricated with size of 52- mm and 20 mm width. The samples were loaded with 2 kg and 4 kg load, rotated at rotational speed of 300, 600 and 900 rpm respectively for ½ hours. No lubrication applied during the testing.

To study significance of the measurement method to wear results, three methods are employed to determine wear of the samples, *i.e.* weight loss method, the wear length method and the wear depth method. The weight of the samples was measured by a digital scale with 0.001-g level of precision and the length of samples measured by a digital caliper with 0.01-mm level of precision.

2.3 Morphology Analysis

Surface morphology of the worn sample is an important feature to understand tribo-interaction wear mechanism between the solid and solid in condition dry sample. Wear surface that was generated on the surface of samples were observed by an optical microscope under magnification of 50x.

3 Results and Discussion

In tribology, friction and wear are considered as system properties hence various parameter such as load, speed, lubrication, sliding distance *etc.* will take influence on these properties [4, 5]. In this work, the effect of load and speed is evaluated under dry sliding motion by wear depth, wear scar length, and weight loses method. Figure 1 show the wear depth and Fig. 2 shows the effect of speed and load to wear of SS-210 block. It can be observed that incremental of load under similar sliding speed has small effect on the wear, however the incremental of sliding speed shows significant effect to wear depth. Figure 4 shows the wear scar length and Fig. 5 shows the effect of sliding speed and load to wear scar length measurement. The load shows lesser effect on the wear

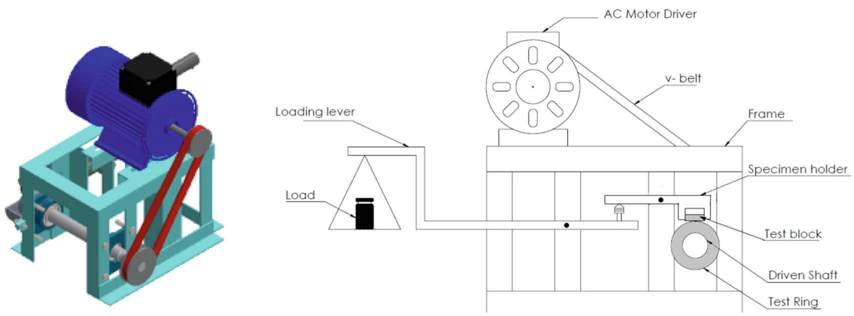

Fig. 1. Design of the apparatus

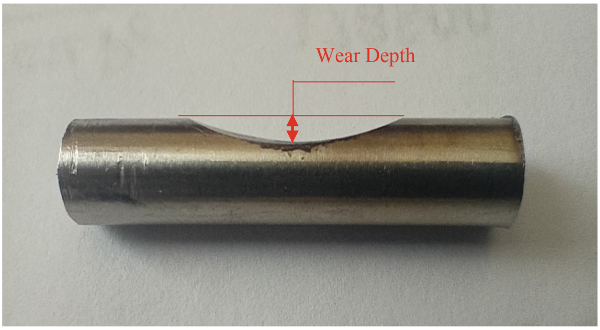

Fig. 2. Wear depth of the wear test sample

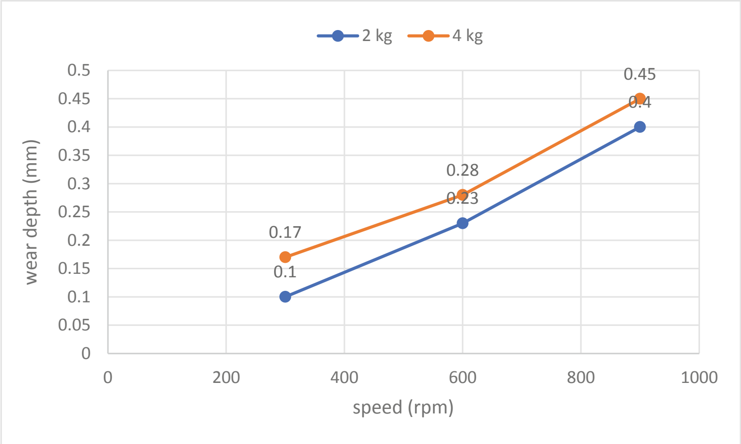

Fig. 3. Plot of wear depth of SS-210 block vs speed at various load

scar length compared to wear depth method. The sliding speed also shows effect to wear length measurement, but significant changes observed at the highest sliding speed and load (900 rpm, 4 kgf). Figure 6 shows the effect of effect of speed and load to weight loses of the sample. Both of load and sliding speed shows effects to wear of cylinder sample, but significant weigh loses observed on sample experiences high load and high speed. So can be concluded that wear quantification using this method provide better results compared to the previous methods. This occurrence possibly related to contact geometry and wear mechanism. These result is basically in accordance with the basic law of wear which indicates that wear is a function of load, hardness, running time or sliding distance [6–9]. Therefore, the apparatus is considered capable to simulate line contact wear conditions (Fig. 3).

Figure 7 shows morphology of worn surface of the block sample at 4 kg load at various sliding speed examined by using optical microscope. It can be observed, the wear was dominantly taken place by adhesion mechanism. At sliding speed of 300 rpm (Fig. 7(a)), combination of adhesion and fatigue can be observed. Indication of adhesive wear can

Fig. 4. Wear scar length of the wear test sample

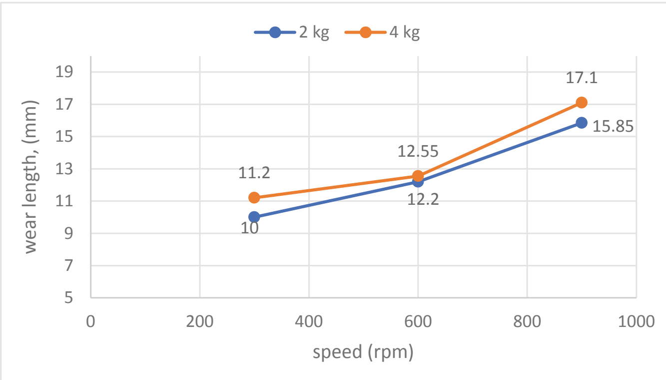

Fig. 5. Plot of wear length of SS-201 block vs speed at various load

be seen from layered layers on the surface while fatigue wear represents by microcracks. This mechanism getting intense when the speed increased while maintaining the load. Combination of adhesion, fatigue and abrasion marks can be observed on the worn surfaces of sample ran at 600 rpm speed (Fig. 7(b)). The trace of abrasive can be observed from plowing marks on the surfaces. When the speed increased to 900 rpm, the adhesion mechanism become dominant to form delamination layer. This mechanism accompanied with spalled layer which indicates fatigue wear also dominantly taken place. Adhesion wear mechanism is considered as typical wear mechanism that occurs on low carbon steel where it's probably related to the tendency of low carbon steel to experience strain hardening via structural grain refinement [10].

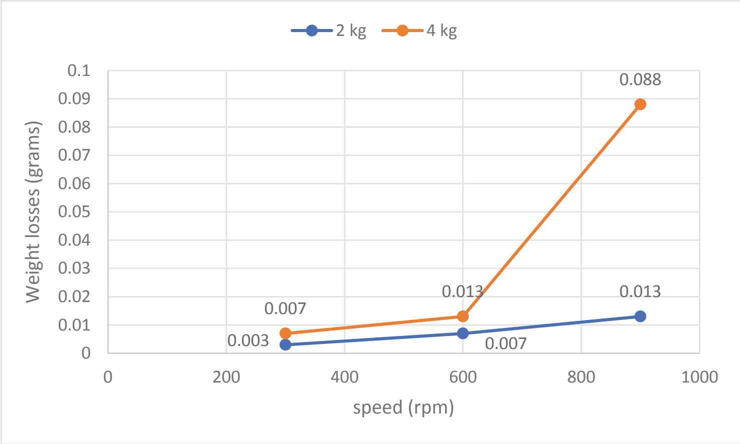

Fig. 6. Plot of weight loss of the SS-201 block vs. speed at various load.

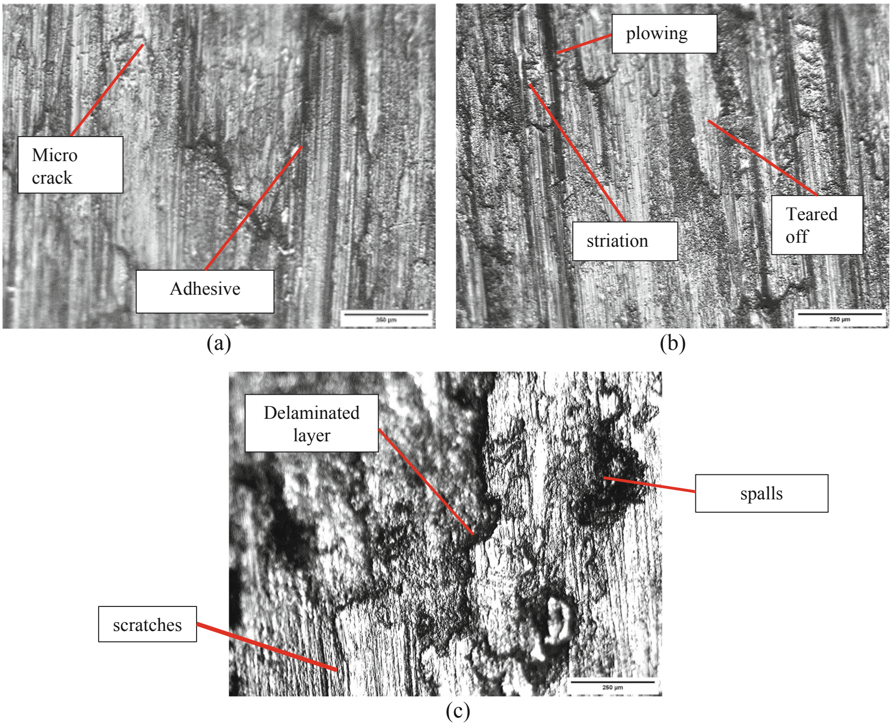

Fig. 7. Wear scar morphology of the SS- 201 samples at 4 kg load: (a) 300 rpm (b) 600 rpm, and (c) 900 rpm

4 Conlusion

A block on ring apparatus that capable to simulate sliding friction and wear was successfully constructed. This apparatus capable to simulate sliding of line contact geometry which typically represent contact mode in roller bearing and gears. Functional testing on the apparatus successfully simulates wear process under dry atmosphere. The results show influence of load and sliding speed to wear of SS 201 steel sample. From the three methods employed to determine wear, the weight losses method provide significant results compared to wear depth and wear scar length method. Wear morphology analysis indicated that the adhesion wear mechanism dominantly taken place and getting strong with increasing of load and speed. Moreover, this wear mechanism is accompanied by fatigue and abrasion wear.

5 Acknowlegment

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