1. INTRODUCTION

With excellent properties of light weight, damping, heat conductive, electromagnetic shielding and so on, Magnesium alloy is known as green material of resources and environment sustainable development in the 21st century [1, 2]. Currently, cast products are prevailing in the applications of magnesium alloy structural materials because of their good surface quality, high productivity and accredited dimensional precision [3–6]. Nevertheless, wrought alloy products preponderate over cast products in strength and ductility. Recently, a novel severe plastic deformation (SPD) method which combines traditional extrusion with the equal channel anger pressing (ECAP) named Extrusion-Shear (ES) has been developed by Hu et al. [7]. From researches results on microstructures and textures evolution and mechanical properties of ES-processed AZ31 magnesium alloys, it has been found that there are homogeneous and fine microstructures [8–10]. In addition, ES extrusion processes for magnesium alloy have been simulated by utilizing finite element method (FEM) in some reports [11, 12].

There seems to be limited published papers on the wear behaviors of magnesium alloys produced by severe plastic deformation methods. Researches on the tribological properties of magnesium alloys almost focused on influences of alloy elements and magnesium matrix composites and surface modified magnesium alloys on wear behaviors of magnesium alloy [13–23]. Among them, Huang et al [9, 13] investigated the fretting wear behavior of AZ91 and AM60B magnesium alloys by using a reciprocating tests. Chen et al. [24] have researched the wear behavior of thio-formed (TF) and permanent mould cast (PMC) AZ91D magnesium alloys under dry reciprocating sliding conditions. Researches results of dry sliding wear tests on an ECAP-processed AZ31 magnesium alloy showed that the wear depth and wear volume loss decreased with increase of ECAP passes [25].

In this present work, fraction and wear behaviors of ES-processed AZ31 magnesium alloys fabricated by ES process and direct extrusion respectively have been investigated and compared under dry reciprocating sliding conditions. EFM simulations have been also employed in this study to predict the stress states in ES-processed and direct extruded AZ31B magnesium alloys.

2. EXPERIMENTAL AND SIMULATION PROCEDURE

2.1. Materials and Specimens

The material employed in this study is a wrought AZ31B (Mg–3% Al–1% Zn, wt %) magnesium alloy. The billets have been extruded by ES and direct extru-
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DRY SLIDING WEAR BEHAVIOR

sion, respectively. The structure diagram of ES die is shown in Fig. 1. For the extrusion process, the billets have been heated to the temperature 370°C and then held for 2 hours before extrusion. Meanwhile, both of the ES extrusion and direct extrusion dies have been heated to 350°C. Subsequently, the billets have been extruded on 500 tonnage horizontal extruder with extrusion speed of 20 mm/s, and the container diameter of which was 85 mm. The extrusion ratio for the two extrusions was 12 and the extrusion corner for ES extrusion was 120°. Mechanical properties of the different extrusion specimens are list in Table 1 [11].

The wear test specimens have been machined into rectangles with dimensions 20 × 15 × 8 mm³. For microstructure analysis, specimens have been prepared by the metallographic standard procedure and etched by using picric acid based etchant (5.5 g picric acid, 100 mL alcohol, 5 mL acetic acid and 10 mL distilled water). The microstructures have been observed by metallographic scope and image analyzer (OLYMPUS made in Japan). AD5000X X-ray diffract meter has been employed to research the phase composition of the material. The microhardness measurements have been conducted by HVS-1000 Digital Micro indentation Tester with a normal load of 100 g.

2.2. Wear Test

Dry sliding wear tests of extruded specimens have been conducted by utilizing a HSR-2M High-speed reciprocating friction tester at room temperature. A GCr15 steel sphere with a diameter of 3.0 mm has been chosen as friction pair of AZ31B. The rectangle specimens have been finished by 200, 400, 600 # SiC paper in dry condition and 800, 1000 # SiC paper in water, respectively. Then all the specimens would be cleaned using acetone and dried by air blower. The wear tests have been performed in reciprocation frequencies of 2, 4, 6, 8, 10 Hz with applied load of 5 N and testing duration 10 min and stroke length 10 mm.

The volumetric wear losses have been examined in different portions on the worn surface by using NanoMap500LS surface scanning contourgraph. The values of volumetric wear loss for both ES and direct extruded alloys have been obtained. The morphologies of worn surfaces have been observed by JSM-6460LV style scanning electoral microscope.

2.3. Simulation Conditions

The DEFORM™3D finite element software is selected to simulate the stress and strain evolutions of ES-processed AZ31B alloy during wear tests. The finite element method (FEM) numerical model for dry reciprocation sliding wear of ES-processed specimens is illustrated in Fig. 2. The model includes two objects, i.e. the specimen and the counterpart. Simulation parameters including FEM element numbers and mesh methods are listed in Table 2.

3. RESULTS AND DISCUSSION

3.1. Microstructures Observations

The microstructures in cross sections of the extruded rods at extrusion temperature 370°C with direct extrusion and ES extrusion respectively can be seen in Fig. 3. There are almost equiaxed grains in ES