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The Influence of Different Manganese-iron Ratios on the Friction and Wear Properties of Al-10Mg2Si Alloy

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Abstract

The study investigated the effect of different manganese-to-iron ratios on the friction and wear performance of Al-10Mg_2Si alloy. The results showed that the as-cast α-Al in the Al-10Mg_2Si alloy without manganese and iron phases was relatively coarse, and its eutectic Mg_2Si morphology was mostly in the form of long needles and needle-like flakes. When the manganese-to-iron ratio was 0.5, the manganese-iron phases were polygonal and fine granular. As the manganese-to-iron ratio continued to increase, the morphology of the manganese-iron phases became polygonal and nearly spherical, with particle sizes of about 10-12μm, showing a clear coarsening phenomenon. Under the conditions of a load of 40N, a rotation speed of 200r/min, and a wear time of 30min, the alloy not treated with ultrasonic had the least wear scar volume when the manganese-to-iron ratio was 0.5, which was 2.635mm^3, showing the best wear resistance relatively, and the worn surface exhibited abrasive wear accompanied by slight adhesive wear.

Keywords

Al-10Mg_2Si alloy; Varying Manganese-To-Iron Ratios; Friction and Wear Performance.

1. Introduction

Al-Mg-Si alloy has good mechanical properties, wear resistance and corrosion resistance, and is widely used in aerospace and automotive fields. The addition of alloying elements to Al-Si and Al-10Mg_2Si composites can form intermetallic compounds with Al, Mg, and Si to improve the mechanical properties of the material [1]. At present, Mn and Fe as important alloying elements have been widely studied and applied in Al-Si alloys. According to the existing research reports, the Mn / Fe ratio has a significant effect on the microstructure and properties of Al-Mg-Si alloys [2]. The results show that with the increase of Mn / Fe ratio, the grains in the alloy gradually become fine and round, and change from dendrite to equiaxed crystal. The addition of Mn can promote the transformation of acicular β-AlFeSi phase to skeletal, granular or blocky α-Al (FeMn) Si phase in aluminum alloy [3].This transformation helps to refine the grains and improve the comprehensive properties of the alloy. However, there are few reports on the mechanical properties of Mn / Fe ratio in hypoeutectic Al-Mg_2Si alloy at home and abroad. Considering the market potential and application prospect of Al-Mg_2Si composites in automobile and other fields, it is necessary to explore and make Al-Mg_2Si materials more widely developed [4]. In this paper, the effect of different manganese-iron ratio on the friction and wear properties of Al-10Mg_2Si alloy was studied [5], and the friction and wear morphology of the alloy with different manganese-iron ratio was investigated, aiming to promote the better application of manganese-iron in Al-10Mg_2Si alloy.

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2. Test Materials and Methods

2.1 Testing Material

In this experiment, industrial pure aluminum (99.7 %), crystalline silicon (99.5 %), pure magnesium (99.8 %), Al-10 % Fe alloy and Al-10 % Mn alloy were used.

2.2 Test Method and Process

In this experiment, the Fe content was 0.8wt %, and the required alloy ingredients were weighed for later use. Then the weighed ingredients are put into the crucible and placed in the well-type crucible resistance furnace to heat up to 750 °C and keep warm for 1h, so that the alloy can be fully melted. Then, 0.6 % hexachloroethane, a paper-wrapped degassing agent, is put into the bell jar. The bell jar is pressed into the bottom of the liquid metal and the liquid metal is slightly stirred for the first degassing. Until no gas escapes, the bell cover is lifted, and the scum is removed with a leaky spoon. Then the crucible is put back into the furnace and allowed to stand for 2 min. The temperature in the furnace is reduced to 700 ° C.After the dried pure magnesium block is wrapped with aluminum foil, it is pressed into the bottom of the molten metal with a bell cover and allowed to stand for 5 min. The temperature in the furnace was raised to 740 °C, kept for five minutes, the crucible was taken out, and the bell cover was lifted for the second degassing until no gas escaped. The scum was removed with a leaky spoon (hexachloroethane was used, wrapped in aluminum foil paper and stirred in the solution until smokeless). Put the crucible into the furnace, keep it at 740 °C for five minutes, and then cast it into the metal mold which is preheated at about 300 °C. The Al-10Mg2Si alloy bar was cut into 30 × 6.5 × 7.5 mm friction and wear samples by using the numerical control wire cutting machine. Two experimental materials were used in each group. The two ends of each alloy bar were polished with grinding wheel.

Firstly, the experimental parameters were set to 30 °C dry friction at room temperature. The load was 40N, the speed was 200r / min, and the experimental time was 30 minutes. The wear amount was calculated and the friction coefficient of the 9 samples was observed. The friction and wear coefficient was recorded in the test, and the wear scar width of the block sample after wear was measured. The average width of the wear scar was measured three times in the middle and both ends of the wear scar of the block sample as the test data. Then check the national standard of friction and wear wear scar width, and calculate the wear scar volume of the test block with Formula (1), as shown in Fig. 1.

$$V_k = \frac{D^2}{8} t \left[2\sin^{1} \frac{b}{D} - \sin\left(2\sin^{-1} \frac{b}{\mathrm{D}} \right) \right] \text{.......................... ......(1)}$$

In the formula :

V_k - volume wear, unit is cubic millimeter (mm^3)

D - test ring diameter in mm (mm)

B - Average width of wear scars in mm (mm)

t - width of test block in mm (mm)

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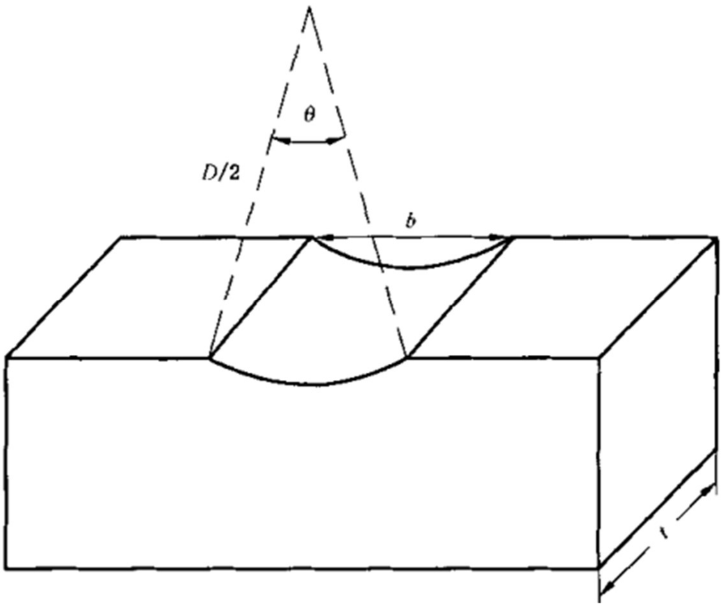

Fig. 1 Diagram of calculating volume wear

3. Experiment Results and Analysis

3.1 Phase Analysis

As shown in fig. 2, Mn / Fe = 1.4 is the XRD pattern of Al-10Mg_2Si alloy. In Al-10Mg_2Si alloy, when Mn / Fe ratio reaches 1.4, XRD pattern analysis reveals that the alloy is mainly composed of α-Al matrix phase, Mg_2Si strengthening phase, AlFeSi iron-rich phase and Al (FeMn) Si phase. As the main component of the alloy, the α-Al matrix phase is characterized by high diffraction peak intensity in the XRD pattern, while the Mg_2Si phase is distributed in the alloy in fine particles or blocks, which effectively improves the strength and hardness of the alloy. At the same time, AlFeSi phase, as a common iron-rich phase in the alloy, usually presents a needle-like or sheet-like morphology, which may adversely affect the plasticity and toughness of the alloy.

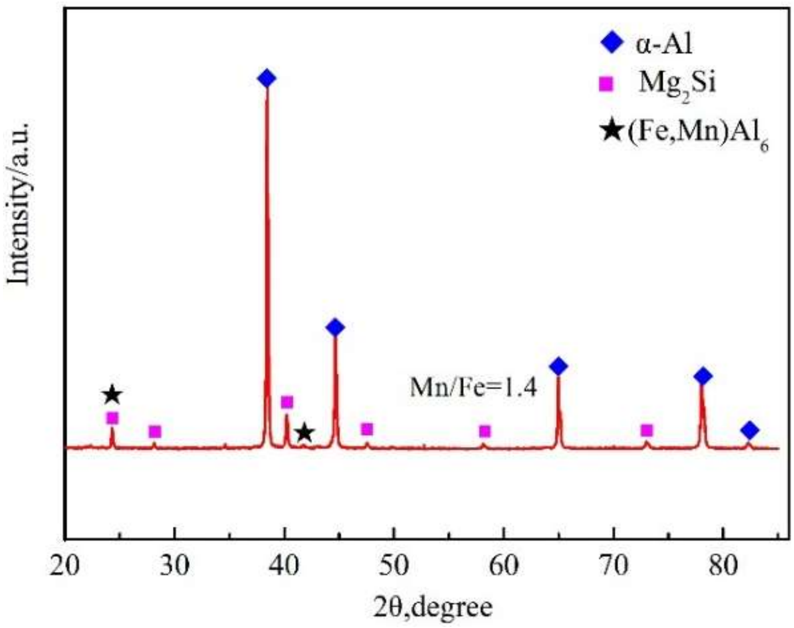

Fig.2 XRD patterns of Al-10Mg_2Si alloy with Mn / Fe = 1.4

3.2 Metallographic Structure

The microstructures of Al-10Mg_2Si alloys with different Mn / Fe ratios are shown in Fig.3 below.

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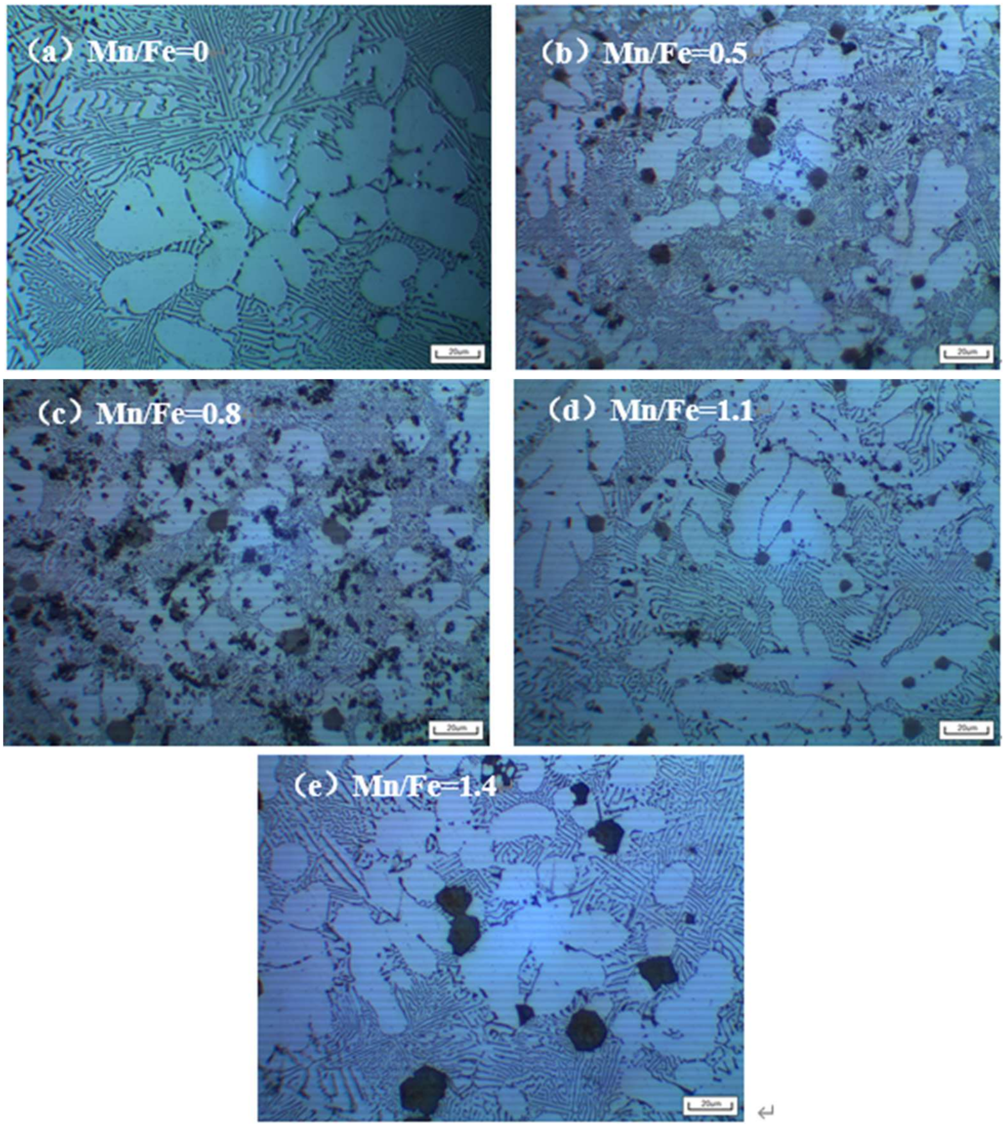

Fig.3 Metallographic structure of Al-10Mg_2Si alloy with different Mn / Fe

It is clearly observed from Fig. 3 (a) that in the Al-10Mg_2Si alloy without Mn and Fe, the primary α-Al is coarser, and the morphology of eutectic Mg_2Si is mostly long needle-like and needle-like. When the manganese-iron ratio is 0.5, as shown in Fig.3 (b), it can be observed from the figure that the eutectic Mg_2Si begins to refine, from the original coarse long needle-like and needle-like morphology to short rod-like, and worm-like morphology appears in some areas. The light gray polygon is fine granular manganese iron phase. It can be clearly seen from Fig. 3 (c) that when the ratio of manganese to iron is 0.8, the morphology of eutectic Mg_2Si in Al-10Mg_2Si alloy is fine worm-like and short rod-like, and the primary α-Al is equiaxed crystal. The number of light gray ferromanganese phase particles increases significantly, and the size is different, and the shape is polygonal and near-spherical. When the ratio of manganese to iron is 1.1, the morphology of primary α-Al in the alloy does not change significantly, but the size is slightly coarse, and the eutectic Mg_2Si changes from small short rod-like and worm-like to slender needle-like and Chinese characters-like, as shown in Fig. 3 (d). The morphology of gray ferromanganese phase did not change significantly, and it was still fine granular. Fig.3 (e) shows the metallographic structure of Al-10Mg_2Si alloy with a manganese-iron ratio of 1.4.Compared with Fig.3 (c), the morphology of primary α-Al and eutectic Mg_2Si phases did not change significantly, but coarse eutectic Mg_2Si and ferromanganese phase particles appeared in the matrix. The morphology was polygonal and nearly spherical, and the particle size was about 10-12 μm.

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3.3 Wear Resistance

Dry friction at room temperature, the load is 40 N, the speed is 200r / min, the wear time is 30 minutes, the friction and wear test is carried out, and the friction and wear coefficient is obtained as follows.

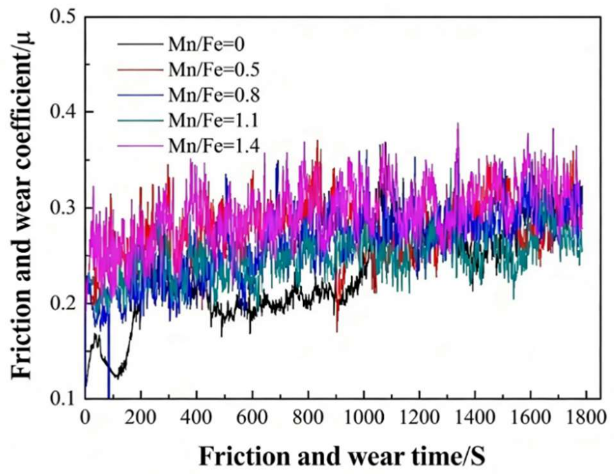

Fig.4 The friction and wear coefficient curves of different manganese-iron ratios under load of 40N, speed of 200r / min and wear time of 30 minutes.

Fig.4 is the friction and wear coefficient curve of Al-10Mg_2Si alloy with different Mn / Fe content under the load of 40N, the speed of 200r / min and the wear time of 30 minutes. With the increase of wear time, the fluctuation of friction and wear coefficient of Al-10Mg_2Si alloy with different Mn / Fe content is weakened, and finally maintained in a stable range. With the increase of the ratio of manganese to iron, the friction and wear coefficient decreases first and then increases. When the ratio of manganese to iron is 1.1, the friction and wear coefficient reaches the minimum and the fluctuation degree is the lowest, and the stable friction state takes the least time and the wear resistance is the best. When the ratio of manganese to iron is 1.4, the friction and wear coefficient is the largest, and it takes a long time to enter the stable process and the fluctuation degree is more intense, and the wear resistance is reduced.

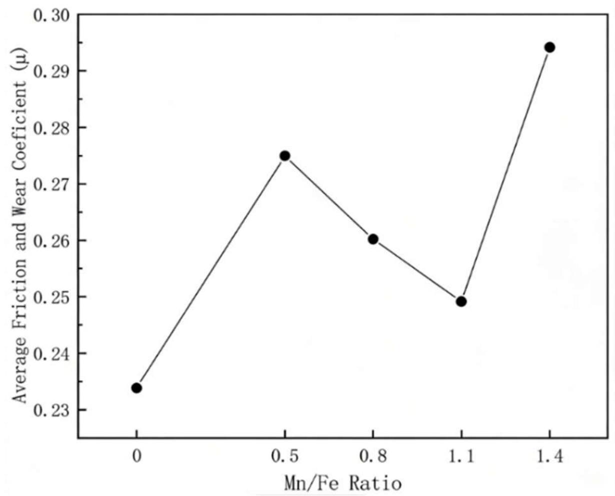

Fig. 5 Average friction coefficient of Al-10Mg_2Si alloy with different Mn / Fe ratio under load of 40N, 200r / min and wear time of 30min.

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Fig.5 shows the average friction and wear coefficient of Al-10Mg_2Si alloy with different manganese-iron ratios when the load is 40N, the speed is 200r / min and the wear time is 30min. It can be seen from Fig.5 that when Mn / Fe = 0, the average friction and wear coefficient is the smallest, which is 0.234. Then, with the increase of manganese-iron ratio content, it shows a trend of increasing first, then decreasing and then increasing. When the Mn / Fe ratio is 0.5, the average friction and wear coefficient of Al-10Mg_2Si alloy is about 0.276. With the increase of Mn / Fe ratio, when Mn / Fe = 0.8, the average friction and wear coefficient of the alloy is about 0.262. Studies have shown that an appropriate amount of Mn can promote the transformation of the acicular β-AlFeSi phase to the skeletal, granular or blocky α-Al (FeMn) Si phase in the aluminum alloy, which helps to refine the grains and improve the overall performance of the alloy. When the Mn / Fe ratio is 1.0, the alloy exhibits the best comprehensive mechanical properties, including tensile strength, elongation and hardness. However, when the Mn / Fe ratio is greater than 1.0, the mechanical properties of the alloy may decrease, because too much Mn may consume more Si in the alloy, thereby reducing the Si required to form the main strengthening phase Mg2Si, resulting in a weakening of the strengthening effect of the alloy.

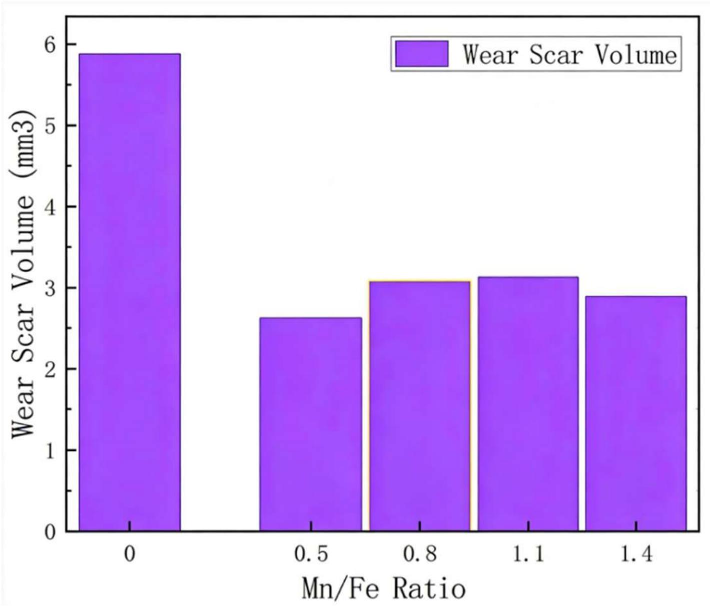

Fig.6 Wear scar volume of Al-10Mg_2Si alloy with different Mn / Fe ratios

Fig.6 shows the wear volume of Al-10Mg_2Si alloy with different manganese-iron ratios when the load is 40N, the speed is 200r / min and the wear time is 30min. It can be seen from Fig.6 that when Mn / Fe = 0, the wear scar volume of the alloy is the highest, which is 5.886 mm3, so the wear resistance of the alloy is the worst. Then with the increase of Mn / Fe ratio, the wear scar volume of the alloy increases first and then decreases. When the ratio of manganese to iron is 0.5, the volume of wear scar is the smallest, which is 2.635 mm3, indicating that the wear resistance of the alloy is better.

3.4 Analysis of Friction and Wear Morphology

Fig.7 (a) - (d) shows the wear morphology of Al-10Mg_2Si alloy with different Mn / Fe ratio under the load of 40N, the speed of 200r / min and the wear time of 30min. When Mn / Fe = 0.5, there is a small amount of peeling concave layer, and there is a clear pear groove on the grinding surface, which is mainly abrasive wear, but there are a small amount of adhesion marks, indicating that the surface is moving towards adhesive wear. When Mn / Fe = 0.8, a large number of large peeling pits are generated on the wear surface of the alloy, and the friction surface is oxidized. At this time, the wear surface shows delamination wear and oxidation wear morphology. As the Mn / Fe ratio continues to

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increase, at Mn / Fe = 1.1, fewer pear grooves and shallower exfoliated concave layers can be observed, accompanied by many small adhesion points. When Mn / Fe = 1.4, the friction and wear surface of the alloy sample appears peeling pits and pear grooves, mainly showing the peeling wear morphology.

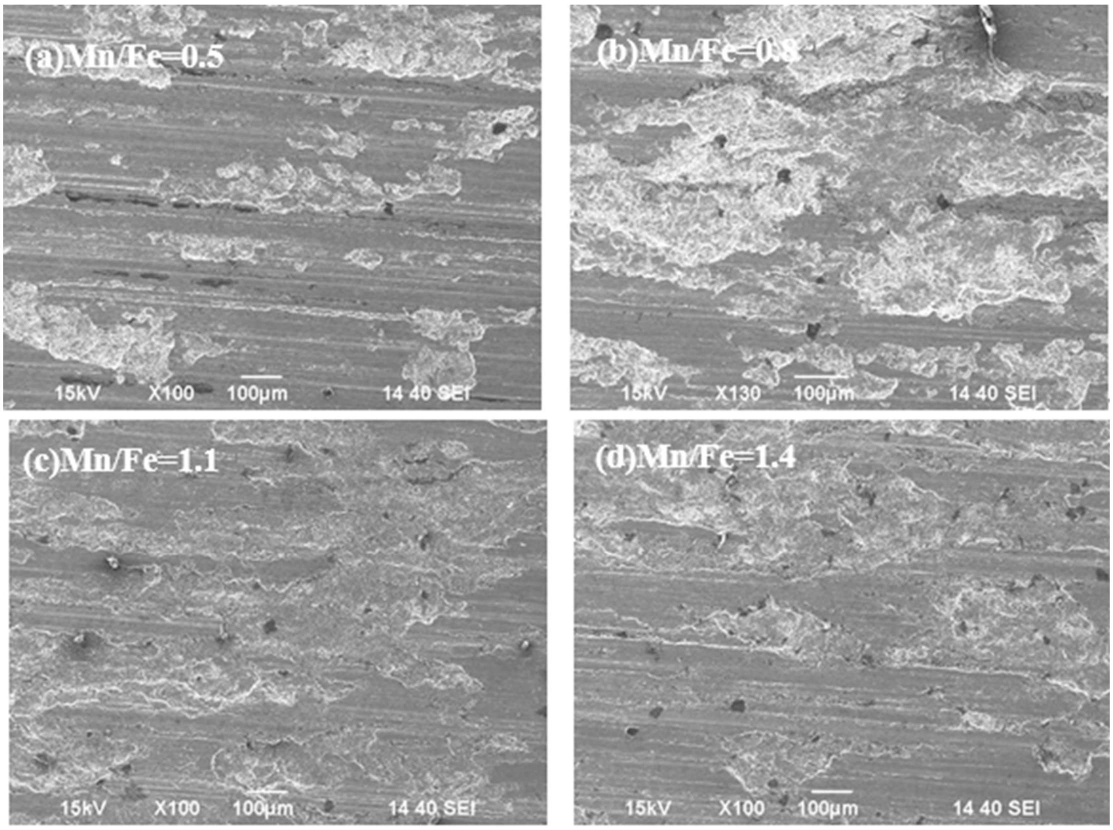

Fig.7 Wear morphology of different manganese iron ratio load 40N speed 200r / min

4. Conclusion

(1) The primary α-Al of Al-10Mg_2Si alloy without manganese and iron phases is coarse, and the morphology of eutectic Mg2Si is mostly long needle-like and needle-like. When the manganese-iron ratio is 0.5, the manganese-iron phase is polygonal and fine granular. As the manganese-iron ratio continues to increase, the morphology of the manganese-iron phase is polygonal and nearly spherical, the particle size is about 10-12μm, and the particle size is obviously coarsened.

(2) Under the condition of load 40 N, rotation speed 200 r / min and wear time 30 min, when the ratio of manganese to iron is 0.5, the wear scar volume is the least, which is 2.635 mm3, and the wear resistance is relatively the best. The wear surface is abrasive wear accompanied by slight adhesive wear.

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