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Failure Analysis of Elastic Pad Under Railway Track

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Abstract

The elastic pad under the rail of a subway line cracked and shattered. A variety of characterizations were performed on the failed pad, such as: PY-GC/MS, FTIR, EDX, DSC, SEM observation of the surface and fracture, etc. Research shows that: the elastic pad belongs to fatigue cracking, mainly due to squeeze abrasion damage; the failed pad is slightly degraded; there are holes in the pad, which accelerates its fracture.

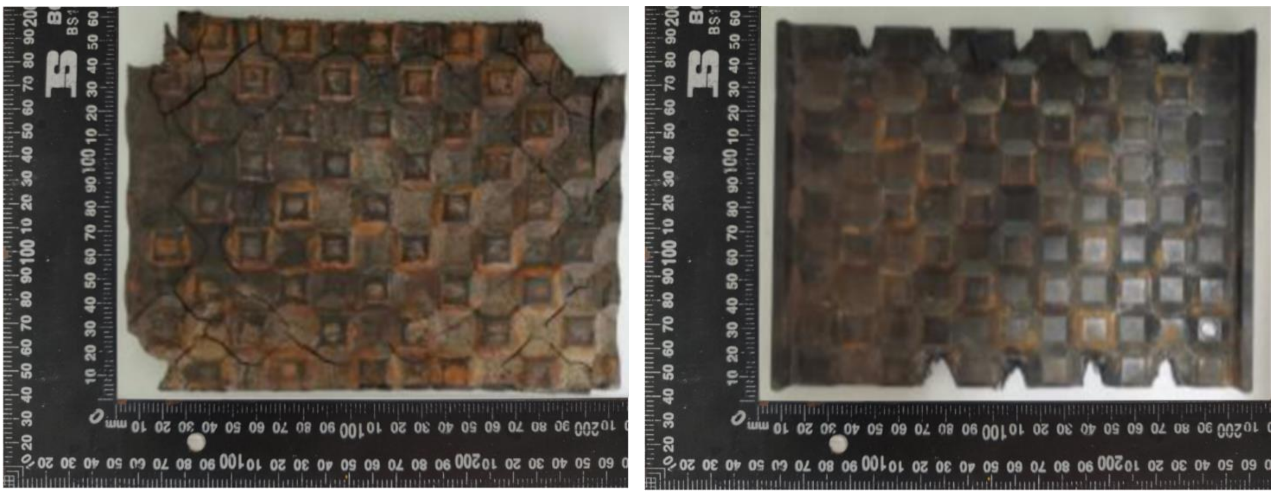
Keywords

Elastic Pad; Failure; Fracture.

1. Introduction

The elastic pad is particularly important for the vibration damping of the track, which can effectively attenuate the vibration and noise generated when the train is running. The elastic pad has a great influence on the working conditions of vehicles, rails, sleepers, etc. The failure of the elastic pad deteriorates the force state of the fasteners, and the fasteners are easy to loose; it also causes the track power imbalance, deteriorates the track working state, and affects the driving safety. In addition, the vehicle vibration will increase, and the saddle-shaped wear and wave-shaped wear of the rail will appear earlier. [1]

The elastic pads under railway track and the elastic pads under the iron pad made of thermoplastic polyester elastomer (TPEE) used in a subway line were found to be cracked and broken after 4 to 5 years of installation and service, which was far from reaching the designed service life.



(a) (b)

Fig. 1 (a) the failed elastic pad, (b) the normal elastic pad

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In this paper, the surface and damaged parts of the elastic pad under railway track Were inspected. scanning electron microscope (SEM) and energy dispersive X-ray spectroscopy (EDX) were performed on the surface and cross-section of the failed pad. Fourier transform infrared spectroscopy (FTIR), pyrolysis gas chromatography-mass spectrometry (PY-GC/MS), differential scanning calorimetry (DSC), etc were performed on the material of the failed pad. Through the above analysis and characterization, the failure nature of the elastic pad is determined and the cause of the failure is understood.

2. Results and Discussion

The photos of the failed and normal parts of the elastic pads under railway track are shown in Fig.1.

2.1 FTIR analysis

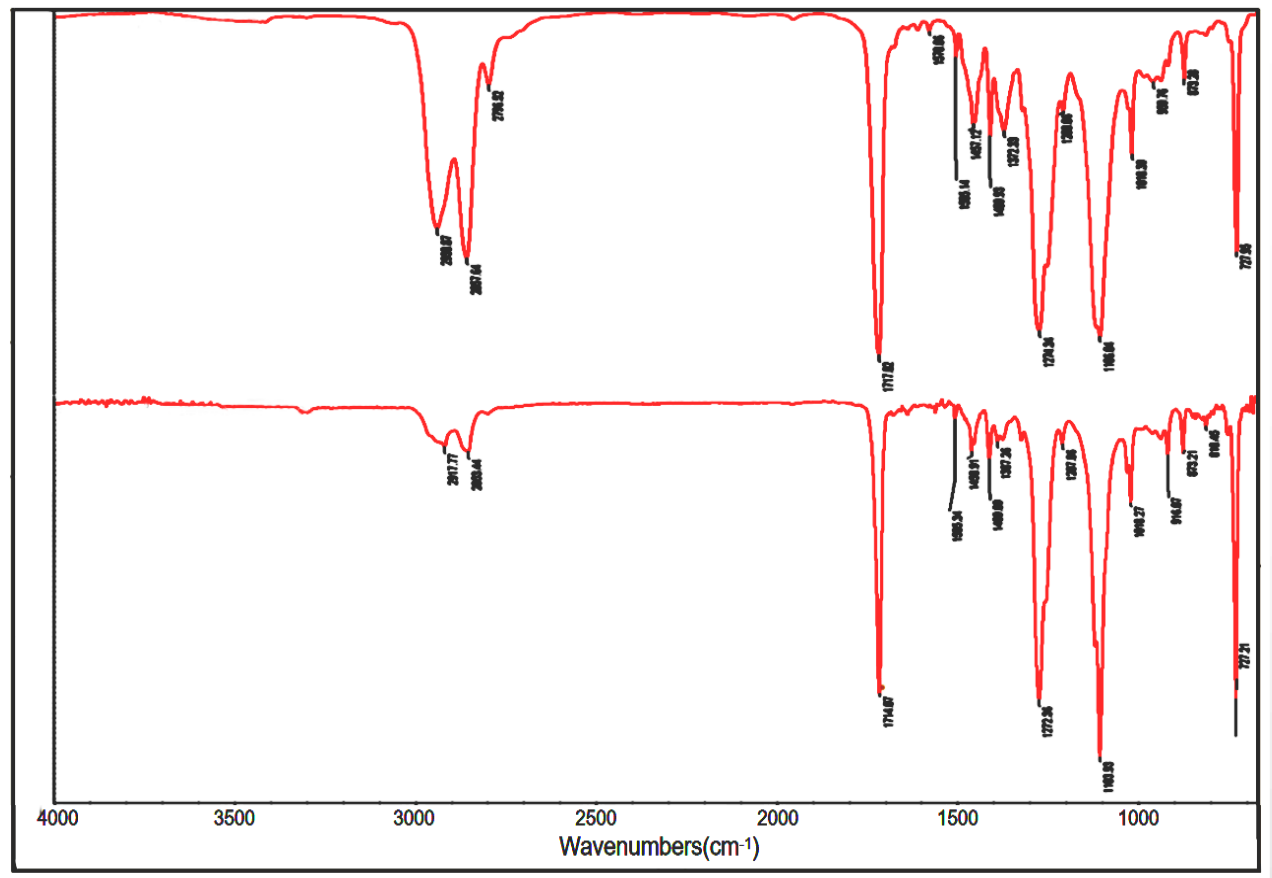

Fig. 2 FTIR of chloroform extract of the failed elastic pad (top) and the normal elastic pad (bottom)

FTIR was used to characterize the failed and normal samples, and the results are shown in Fig. 2. The characteristic absorption peaks of 2939cm^{-1} and 2858 cm^{-1} correspond to —CH_2. The characteristic absorption peak of 1717 cm^{-1} corresponds to C=O of ester. The characteristic absorption peaks of 1274cm^{-1} and 1106 cm^{-1} attributable to C—O. Compared with the normal pad, the infrared spectrum of the failed pad has no obvious change.

2.2 Composition analysis

Through FTIR, PY-GC/MS, Chloroform extract GC/MS, the composition of normal pad and failed pad were compared. The polymers of the normal pad and the failed pad are thermoplastic polyester elastomer (TPEE, polybutylene glycol- polybutylene terephthalate (PBT-PTMG) copolyester) and polyethylene (PE). The organic additives are bisphenol A (BPA) and 4,4'-bis (phenylisopropyl) diphenylamine.

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The failed pad sampled at the fracture site and the normal pad cut into pieces and then leached in chloroform for 16 hours, and then analyzed. The results are shown in Table 1. The results show that there is no obvious difference between the qualitative analysis of the chloroform leachables of the failed parts and the normal parts. The content of chloroform eluates (small molecular substances) of the failed parts is slightly higher than that of the normal parts, indicating that the failed parts are slightly degraded.

Table 1. Chloroform dissolution of the normal pad and failed pad

Qualitative and quantitative	Chloroform insoluble matter	Chloroform dissolved matter
Failed pad	Mainly TPEE and PE, the content is 62 (wt%)	Mainly small molecule TPEE, BPA and 4,4’-bis (phenylisopropyl) diphenylamine, the content is 32 (wt%)
Normal pad	Mainly TPEE and PE, the content is 64 (wt%)	Mainly small molecule TPEE, BPA and 4,4’-bis (phenylisopropyl) diphenylamine, the content is 30 (wt%)

The EDX tests of the normal pad and the failed pad show that the inorganic substances are carbon black and ash containing O, Ti, Ca, Si, Mg, A1 and other elements (see the following-Table 2-3). The results show that there is no significant difference in the content of each component.

Table 2. Distribution of ash elements of normal pad after burning in a muffle furnace

Element		O	Mg	Al	Si	S	Ca	Ti	Fe
Mass percentage (%)	1	44.34	3.70	3.06	7.91	1.12	11.12	27.23	1.51
	2	47.57	2.82	2.82	9.77	1.35	7.52	27.30	0.83
	3	45.39	1.34	2.21	9.02	1.50	12.63	26.75	1.16
	Average	45.77	2.62	2.70	8.90	1.33	10.42	27.09	1.17

Table 3. Distribution of ash elements of failed pad after burning in a muffle furnace

Element		O	Mg	Al	Si	S	Ca	Ti	Fe
Mass percentage (%)	1	39.33	2.27	4.34	8.07	2.72	10.92	30.92	1.43
	2	41.47	6.74	4.02	9.57	1.92	10.36	25.14	0.79
	3	44.94	5.36	1.34	10.92	4.13	13.64	17.25	2.43
	Average	41.91	4.79	3.23	9.52	2.92	11.64	24.44	1.55

2.3 DSC analysis

According to GB/T 19466.3-2004/ISO 11357-3: 1999 Plastics—Differential scanning calorimetry (DSC)—Part 3: Determination of temperature and enthalpy of melting and crystallization, DSC tests were performed on the normal pad and the failed pad. The results are shown in Fig. 3, Fig. 4 and Table 4. The results show that the melting point of the failed pad of polyester elastomer (TPEE) was lower than that of the normal pad, indicating that the failed pad was slightly degraded.

Table 4. Melting point of normal pad and failed pad

Sample	Melting point
Failed pad	125.1℃(PE);180.5℃(TPEE)
Normal pad	124.9℃(PE);197.7℃(TPEE)

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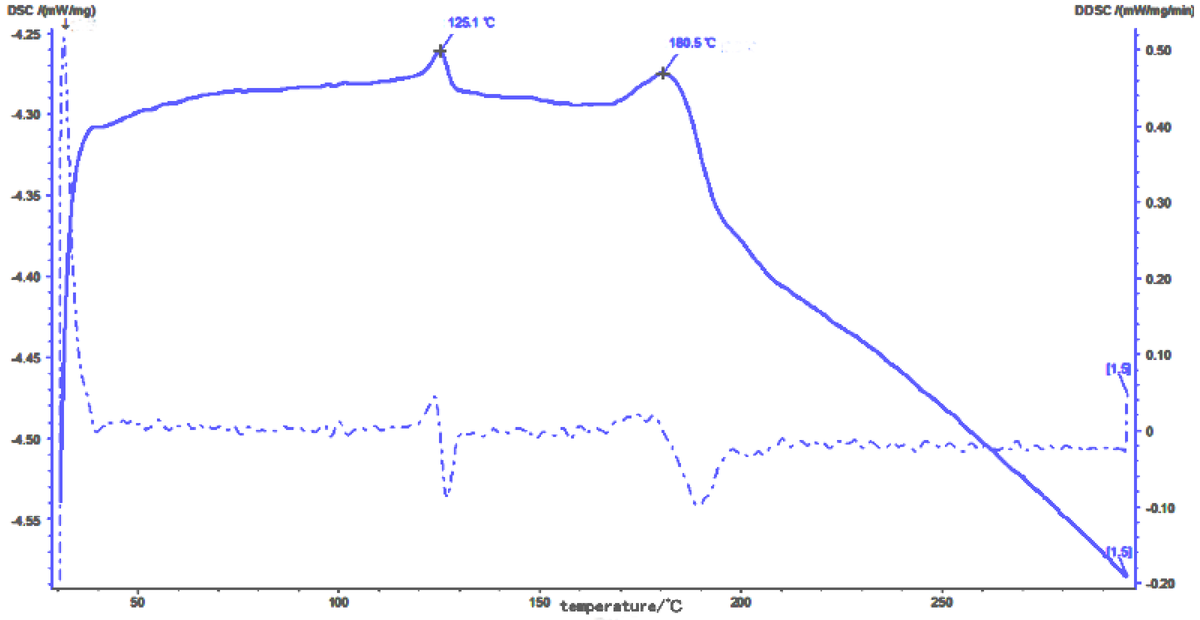

Fig. 3 DSC spectrum of failed pad

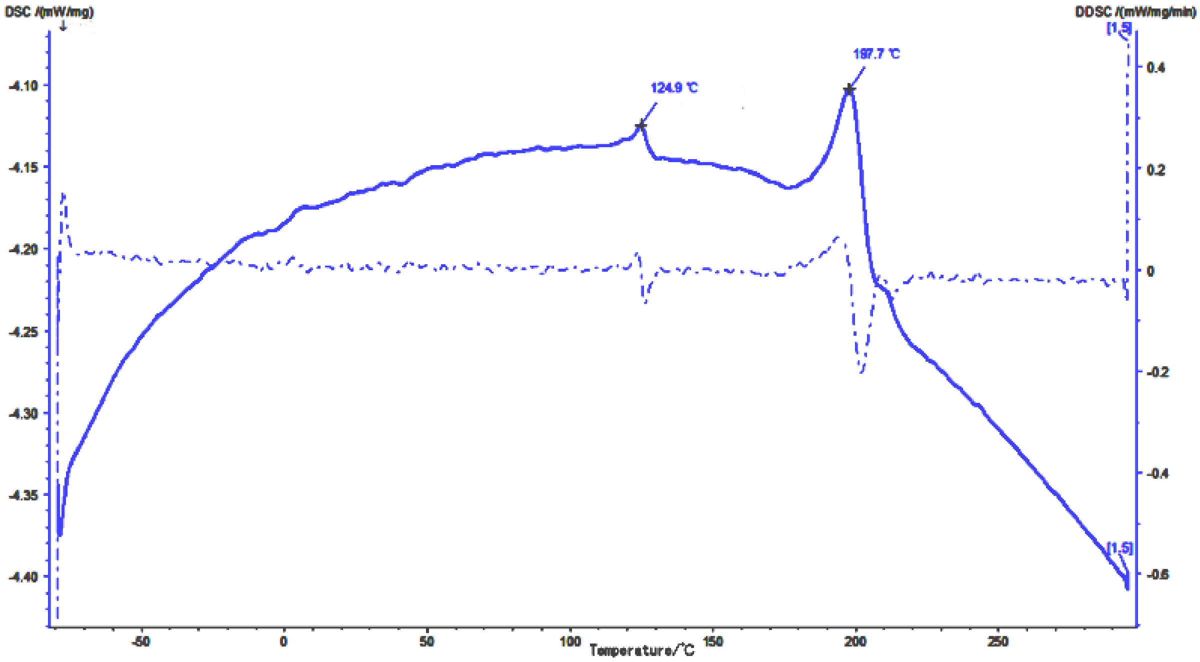

Fig. 4 DSC spectrum of normal pad

2.4 SEM analysis

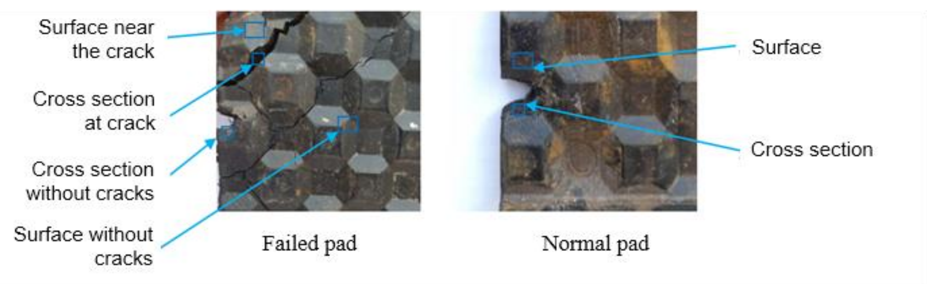

Fig. 5 The positions of SEM of the failed pad and normal pad

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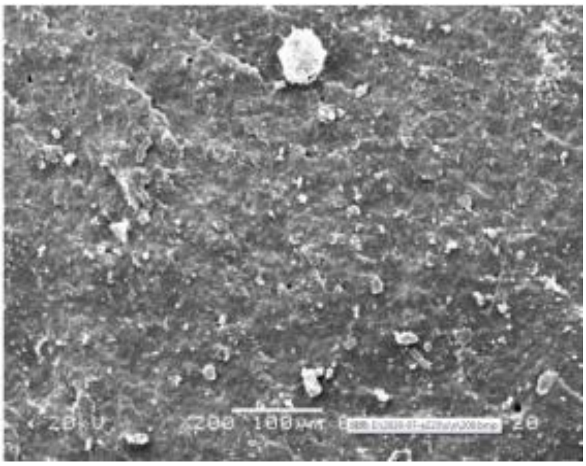
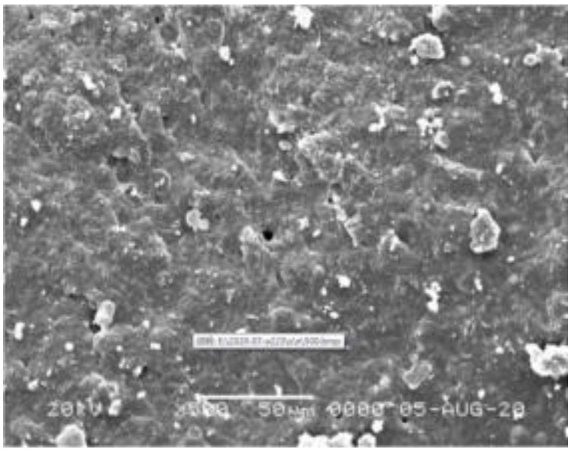
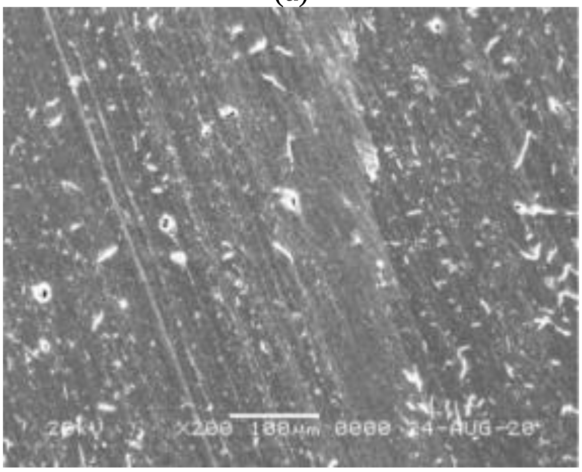


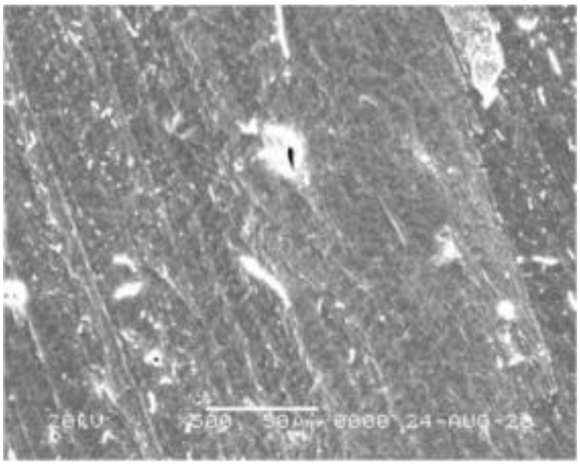
(a)



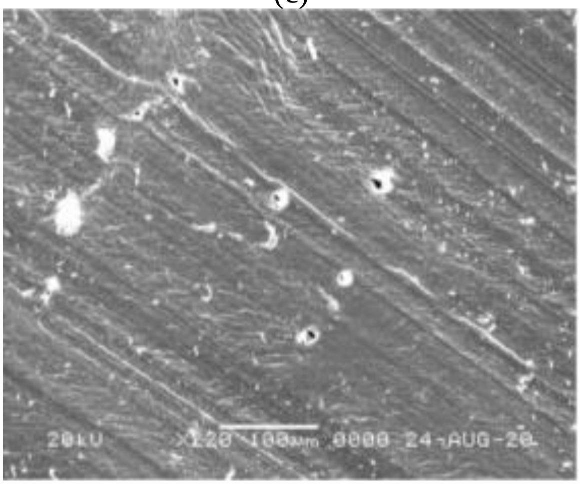
(b)



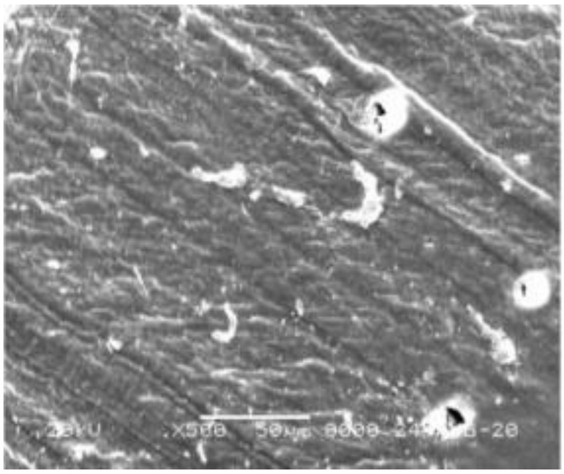
(c)



(d)



(e)
×200



(f)
×500

Fig. 6 SEM of the cross section of the failed pad (Fig. a and b at crack; Fig. c and d without cracks) and the normal pad (Fig. e and f)

The SEM pictures show that there are microcracks on the surface of normal and failed pad, indicating that they are all affected by fatigue. [2] The shape of the elastic pad is an asymmetric prism. Therefore, the edge area has the largest deformation, the molecular chain moves the most violently, and the crack originates from the edge. Two similar cracks merge and form a longer crack, accelerating the rupture of the backing plate. The broken section of the failed part is relatively rough, and a large number of polyester aggregates can be seen on the surface. Therefore, when the failed part is subjected to a large

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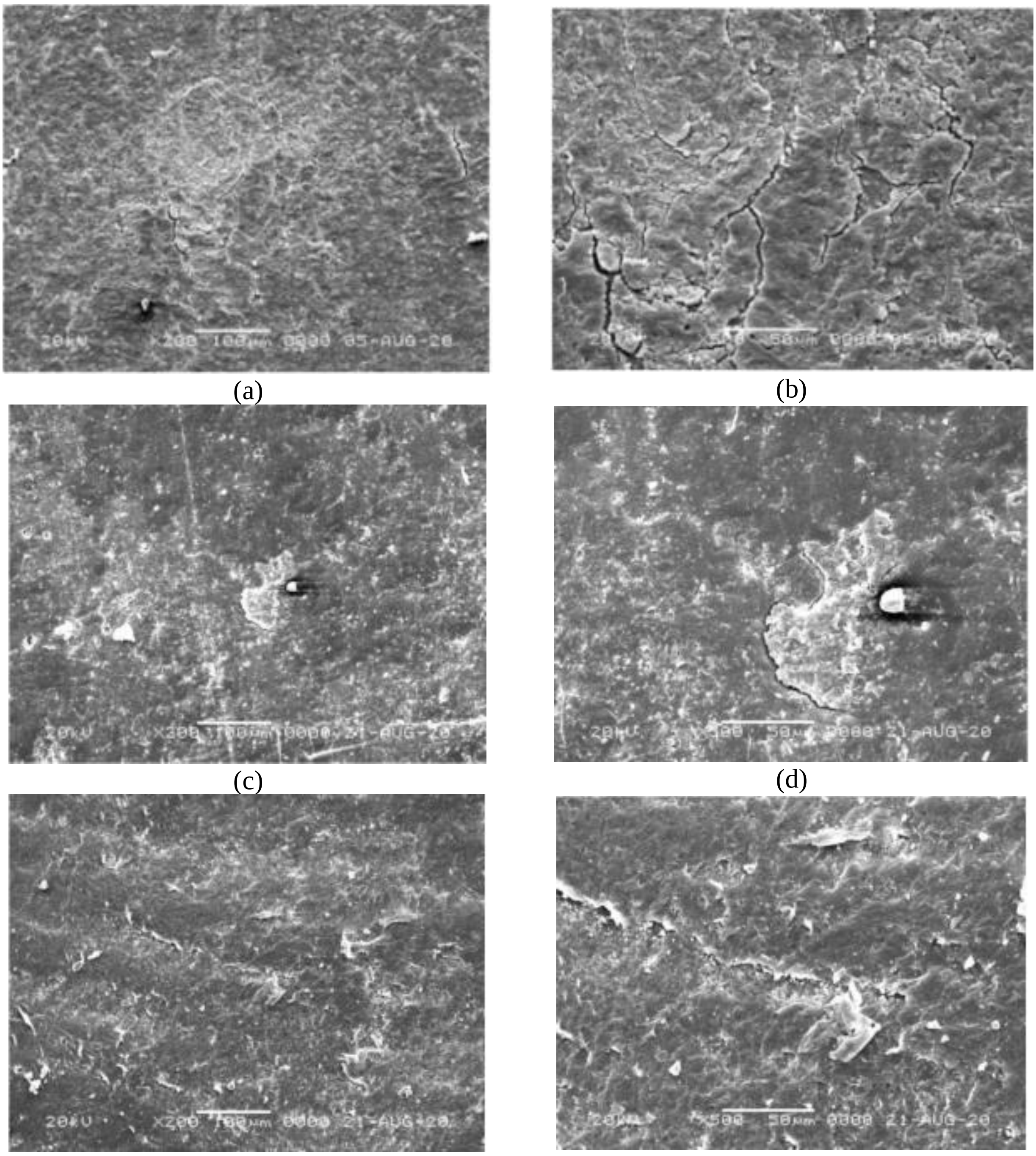
mechanical external force during service, severe friction occurs inside the elastomer and is accompanied by severe squeezing and abrasion. The external load causes the polyester matrix and additives to mix to form aggregates, causing cracks to grow instably. [3] In addition, there are relatively porous holes in the cross section, and microcracks are prone to propagate or break at the positions where there are holes in the material. This situation is more prominent when the sample is undergoing periodic deformation (i.e. fatigue). If the molecular chain is too late to relax when subjected to an external force, the strain lags behind the stress, so that the molecular chain is prone to breakage. When the molecular chain is torn off, micro-cracks will occur, and the micro-cracks will continue to expand under the external force until it breaks.



(a) (b)

(c) (d)

(e) ×200 (f) ×500

Fig. 7 SEM of the surface of the failed pad (Fig. a and b at crack; Fig. c and d without cracks) and the normal pad (Fig. e and f)

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3. Summary

(1) There is no obvious difference between the normal pad and the failed pad in the composition analysis, but the melting point of the failed pad is slightly lower than that of the normal pad, and the quantitative analysis of chloroform eluates shows that the failed pad have slightly more small molecules and the failed pad are slightly degraded.

(2) The cracking nature of the TPEE elastic pad is fatigue cracking, and the failure mode is mainly extrusion abrasion.

(3) The forming process of the elastic pad should avoid the generation of air bubbles inside the workpiece.

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