Study on hardness and wear resistance of shot peened AA7075-T6 aluminum alloy

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Abstract

AA7075-T6 aluminum alloy samples were shot peened at various shot peening pressures in the range of 10-70 psi to study their mechanical and tribological properties under dry and mineral oil lubrication conditions. The surface roughness of the shot peened AA7075-T6 samples apparently increased with increased shot peening pressure. The best bearing surface was obtained when the shot peening process was carried out at the highest shot peening pressure of 70 psi. It was found that the increased shot peening pressure increased the hardness and decreased the wear of the shot peened samples. The shot peened samples tested under the mineral oil lubrication condition also had lower wear for higher shot peening pressures due to the combined effects of their higher surface wear resistance and better bearing surfaces. The results clearly showed that using the mineral oil lubricant during sliding apparently decreased the wear of the shot peened samples as a result of the lubricating effect of the lubricant. It could be deduced that the tribological properties of the shot peened AA7075-T6 samples under the dry and lubrication conditions were affected by the shot peening pressure.

Keywords: AA7075-T6; Shot peening; Mineral oil lubricant; Friction; Wear

1. Introduction

High strength aluminum alloys, such as AA7××× series, are commonly used in aerospace applications, such as aircraft fittings, gears and shafts, fuse parts, meter shafts and gears, missile parts, regulating valve parts, worm gears, and so on, due to their lightweight and high strength [1, 2]. AA7075 aluminum alloy mainly remain the baseline with a good balance of properties required for aerospace components [2]. However, fatigue fracture, fretting fatigue, and wear of AA7075 aluminum alloy exposed to cyclic loading under applied stress and prolonged rubbing against other materials may bring failure risk to whole components made with it in service, and the major failures mostly originate at surface defects, for example, fatigue cracks, etc. [1-3]. Therefore, mechanical surface treatments are necessarily applied to AA7075 aluminum alloy to advance its longevity and efficiency [3, 4].

Shot peening process is a widely used treatment for mechanical surfaces to improve fatigue, corrosion, and wear resistance of metallic components because the process induces compressive residual stress fields in subsurface layers to impede initiation and propagation of micro-cracks [3, 4]. The shot peening modifies properties and microstructures of metallic components [3, 4]. Therefore, the shot peening surface treatment is successful in applying on gears, cams, shafts, springs, rods, gearwheels, drills, blades, and so on [4]. It was reported [5-7] that the shot peening of aluminum alloy enhanced their fatigue strength. In addition to the fatigue strength, the shot peening improved the wear resistance of metallic materials such as steel [8]. Although most researchers have found an improvement in the wear resistance of shot peened metallic materials, there are controversial reports on improving the wear resistance of metallic materials with shot peening probably owing to the complex nature of the shot peening process [3, 4, 8]. It is therefore important to understand the effects of shot peening on the mechanical and tribological properties of AA7075 for successful applications. The influence of shot peening pressure on the mechanical and tribological characteristics of AA7075 should be focused because the shot peening pressure is one of the most important shot peening process parameters affecting the surface properties of shot peened metallic materials [4]. The tribological properties of shot peened AA7075 have not been comprehensively reported yet. Therefore, there is a lack of comprehensive and systematic studies on the tribological characteristics of AA7075 after shot peening.

In this study, AA7075-T6 samples were shot peened at various shot peening pressures in the range of 10-70 psi. Since an improvement in the wear resistance was usually associated with an increase in the hardness [4], a variation in the hardnesses of the shot peened AA7075-T6 samples with shot peening pressure was studied with Vickers hardness measurement. The shot peening apparently modified the surface roughness of shot peened metallic materials, which in turn changed their tribological behavior [4]. The surface roughesses of the shot peened AA7075-T6 samples were therefore measured with respect to shot peening pressure using surface profilometry. Then, ball-on-disc triboogical test was used to systematically evaluate the tribological properties of the shot peened AA7075-T6 samples under the dry and mineral oil lubrication conditions.

2. Sample preparation

2.1. Sample preparation

Commercial AA7075-T6 samples with 6 mm thickness were used in this study. The shot peening of the AA7075-T6 samples was carried out at a large range of shot peening pressures from 10-70 psi (68.9-482.6 kPa). Before the process of shot peening, commercial AA7075-T6 samples were first polished in ethyl alcohol using 1200 grit papers at the final stage. Shot peening intensities were defined with various shot peening pressures of 10-70 psi using standardized Almen test strip A. The arc height of the Almen strip was measured with Almen gauge to plot its maximum arc height with respect to exposure time using PA^2 software in order to find out the shot peening level

[4]. Then, the AA7075-T6 samples were mounted in the same fixture to get shot peened under the same conditions. The AA7075-T6 samples were shot peened for 20 s that was longer than the time required to reach a saturation point where the arc height of the Almen strip was stabilized. The shot peening was conducted using Progressive Surface Robotic Shot Peening Machine 1938 with a nozzle diameter of 14 mm. A series of tests were carried out to examine the effects of the shot peening pressure on the intensity of the shots. It was found that there was a linear increase in the shot peening intensity from 6.1 A to13.4 A with increased shot peening pressure from 10 to 70 psi as reported in Fig. 1.

For the shot peening process, S110 steel shots (the inset of Fig. 1), which had a mean diameter of roughly 300 μm and hardness of 500±30 Hv, were used. The spherical steel shots had an uniform size distribution and smooth surfaces.

2.2. Characterizations

The surface and wear morphologies of the samples were captured by using Scanning electron microscopy (SEM, JEOL-JSM-5600LV). Optical microscopy (OM, Zeiss Axioskop 2, JVC color video camera) was used to study the surface and cross-sectional microstructures of the samples. To prepare for the microstructural examination, the specimens were first molded with epoxy resin.Then the molded samples got polished with chemical-mechanical polishing (CMP) process with a DiaPro solution containing diamond particles with a size of 9 μm, and an OP-S suspension solution containing 0.04 μm colloidal silica particles (Struers). In the end, the mirror-like surfaces of the polished samples were etched using an etchant for aluminum alloy (5 ml of 40% hydrofluoric acid).

The samples' surface and wear topographies were captured by surface profilometry (Talyscan 150) with a diamond stylus (4 μm in diameter). To obtain average three-dimensional (3D) parameters of surface roughness, three measurements per sample were carried out: such as arithmetic average (S_a) and root mean squared (S_q) surface roughnesses, maximum peak height (S_p), maximum valley depth (S_v), and surface skewness (S_{sk}) and kurtosis (S_{ku}).

The samples' hardnesses were determined by Vickers micro-indenter (Future-tech FM-300e) under a 0.49 N (50g) load. Twelve indentation measurements per sample were carried out to get an average hardness.

The tribological properties of the samples were measured against 6 mm 100Cr6 steel balls with or without mineral oil lubricant in a circular path of 2 mm in diameter for 20000 laps at a sliding speed of 3 cm/s under a 1 N normal load. A ball-on-disc micro-tribological test (CSM) that conformed to DIN50324 and ASTM G99 was used for three measurements on each sample to get average tribological results. The width and depth of wear tracks were measured to calculate the specific wear rate based on the equation:

$$k = \frac{V}{(F * s)}$$

where"*V*" was the wear volume, "*F*" was the normal load, and "s" was the sliding distance. The laboratory grade mineral oil lubricant (ACROS) was used.

3. Results and discussion

Fig. 2 shows the surface topographies and morphologies of the as-polished AA7075-T6 sample and shot peened AA7075-T6 samples at various shot peening pressures. Comparison of Figs. 2a and b shows that the shot peening at 10 psi roughens the surface of the AA7075-T6 sample by forming dimples on it compared to the relatively smooth surface of the as-polished sample. In Figs. 2b-f, surface dimples of the shot peened samples become larger and deeper with higher shot peening pressure as a result of the higher impact energy of the shot peening [4]. The shot peened samples exhibit a full coverage of dimples on their surfaces.

Fig. 3 shows the S_a, S_q, S_p, and S_v values of the shot peened AA7075-T6 samples at various shot peening pressures. The S_a and S_q values of the as-polished sample are about 0.07 and 0.09 µm, respectively. The shot peening of the AA7075-T6 sample at 10 psi gives rise to the larger S_a and S_q values of about 2.22 and 2.78 μm, respectively. Raising the shot peening pressure to 70 psi increases the S_a and S_q values of the shot peened samples to about 10.24 and 12.6 μm, respectively, denoting that the more severe shot peening causes higher surface roughness of the shot peened samples by creating deeper dimples on their surfaces [4, 9, 10].

The S_p and S_v values of the shot peened AA7075-T6 samples increase from about 10.7 and 8.65 to about 44.03 and 34.27 μm, respectively, with raising the shot peening pressure from 10 psi to 70 psi while the S_p and S_v values of the as-polished sample are about 0.51 and 0.3 μm, respectively. The deeper valleys and higher peaks on the surfaces of the shot peened samples at higher shot peening pressures (Fig. 3) result from the formation of deeper dimples on their surfaces (Fig. 2) [4, 9].

The values of S_{sk} of the shot peened AA7075-T6 samples at 10, 20, 30, 40, 50, 60, and 70 psi are 0.17-0.23, 0.26-0.27, 0.23-0.38, 0.12-0.42, 0.15-0.43, 0.31-0.43, and 0.15-0.57, respectively. It is known that the surface has a lot of peaks if $S_{sk} > 0$. It means that the increased shot peening pressure results in the increased number of peaks on the shot peened surfaces due to the increased surface roughness [4, 8, 9]. The values of S_{ku} of the shot peened samples at 10, 20, 30, 40, 50, 60, and 70 psi are 2.9-3.3, 2.6-3.2, 2.9-3.1, 2.7-2.9, 2.7-2.8, 2.7-2.8, and 2.6-2.8, respectively. Since the surface has a broad height distribution of peaks if $S_{ku} < 3$, it can be seen that the shot peened AA7075-T6 samples have a broad height distribution of peaks on their surfaces [4, 8, 9]. In addition, the smaller values of S_{ku} of the shot peened samples at higher shot peening pressures are indicative of their surfaces with the broader height distributions of peaks. The broad height distribution of peaks on the surface produces a bearing surface for an effective lubricating effect of a liquid lubricant during sliding [4, 8, 9]. The surface roughness results therefore show that increasing the shot peening pressure improves the bearing surfaces of the AA7075-T6 samples by broadening the height distribution of their surface peaks. The S_{sk} and S_{ku} values of the as-polished

AA7075-T6 sample are 0.42-0.52 and 3.5-4, respectively. The as-polished sample has a significant number of protruded asperities above the surface and a narrow height distribution of asperities. It is clear that the shot peened samples have better bearing surfaces than the as-polished sample. It can be deduced that the as-polished sample and the shot peened sample at the highest shot peening pressure of 70 psi posses the worst and best bearing surfaces for the least and most effective lubricanting effects of a liquid lubricant, respectively.

Fig. 4 presents the surface microstructures of the as-polished AA7075-T6 sample and shot peened AA7075-T6 samples on which pits formed during the polishing are found as black spots. The shot peening at various shot peening pressures does not give rise to any apparent difference in the surface microstructures of the treated samples.

Figs. 5a and 5b show the cross-sectional microstructures of the shot peened AA7075-T6 samples at 20 and 70 psi, respectively, on which dimples can be seen. The deeper dimples can be found on the cross-sectional microstructure of the shot peened sample at the higher shot peening pressure of 70 psi as a result of the more energetic bombardment of shots. At the higher magnification, the shot peened sample at the higher pressure of 70 psi consistently has much larger and deeper dimples on its cross-sectional microstructure compared to the one at 20 psi as found in Figs. 5c and d. Herein, the black spots on the cross-sectional microstructures of the AA7075-T6 samples are also pits formed during the polishing.

Fig. 6 shows a variation in the hardnesses of the shot peened AA7075-T6 samples with shot peening pressure. The hardness of the shot peened samples increases from about 231 Hv to 444 Hv with increased shot peeing pressure from 10 to 70 psi while the hardness of the as-polished sample is about 205 Hv. The hardnesses of the shot peened samples are apparently higher (12.7% increment for 10 psi and 116.6% increment for 70 psi) than that of the as-polished sample because the shot peening causes the cold work hardening of the samples [4, 10]. Since the cold work hardnening effect becomes more significant with the more energetic bombardment of shots, the increase in the shot peening pressure is responsible for the increased hardnesses of the shot peened AA7075-T6 samples.

Fig. 7a illustrates the trends of friction coefficient versus shot peening pressure of the shot peened AA7075-T6 samples tested against steel counter balls under dry and mineral oil lubricantion conditions. Under the dry condition, the increased shot peening pressure from 0 to 70 psi results in the increased friction coefficient of the samples from 0.57 to 0.65 via the increased mechanical interlocking between two rubbing surfaces associated with the increased surface roughness [4, 11-13]. However, the shot peened samples show a decrease in their friction coefficients from 0.21 to 0.12 with increased shot peening pressure from 0 to 70 psi under the mineral oil lubrication condition. Comparison of the trends of friciton coefficient versus shot peening pressure obtained under the dry and mineral oil lubrication conditions (Fig. 7a) clearly reveals that the shot peened AA7075-T6 samples have apparently lower friction coefficients under the lubrication condition than under the dry condition. It can be deduced that the mineral oil lubricant effectively reduces the friction of the shot peened samples during the sliding contact via its lubricating effect as the improved bearing surfaces of the shot peened samples associated with the broadened high distribution of their surface peaks support the mineral oil lubricant to be more effective [14-18]. Therefore, the further improved bearing surfaces of the shot peened AA7075-T6 samples with increased shot peening pressure can be correlated to their decreased friction under the lubrication condition.

Fig. 7b illustrates variations in the friction coefficients of the shot peened AA7075-T6 samples at various shot peening pressures with respect to the number of laps under the dry condition, from which the as-polished AA7075-T6 sample and shot peened AA7075-T6 sample at the highest pressure of 70 psi exhibit the lowest and highest friction coefficients during the entire dry sliding. In addition, the increased friction coefficients of the samples with the increased number of laps are found in Fig. 7b, which are indicative of their increased wear during the prolonged dry sliding. Such increases in their friction coefficients with the increased number of laps are not found under the mineral oil lubrication condition as shown in Fig. 7c. Instead, the samples exhibit relatively stable friction coefficients throughout the wear tests with the mineral oil lubricant because an existence of the oil lubricant between two rubbing surfaces during the sliding contact gives rise to the stable wear of the samples. Obviously, the trends of friction coefficient versus laps of the samples are lower under the lubrication condition (Fig. 7c) than under the dry condition (Fig. 7b) as a result of the effective lubricating effect of the mineral oil lubricant. Under the lubrication condition (Fig. 7c), the shot peened samples at higher shot peening pressures consistently show lower friction coefficients during the entire sliding so that the shot peened sample at the highest shot peening pressure of 70 psi has the lowest trend of friction coefficient versus laps.

The influence of shot peening pressure on the specific wear rates of the shot peened AA7075-T6 samples under the dry and mineral oil lubrication conditions can be seen in Fig. 8. The specific wear rate of the as-polished AA7075-T6 sample tested dry is about 158×10^{-14} m^3/Nm. The shot peened AA7075-T6 sample at 10 psi has a higher specific wear rate of 177.6×10^{-14} m^3/Nm than the as-polished sample under the dry condition. The reason is that the higher roughness of the shot peened sample at 10 psi probably gives rise to its higher wear via higher vibration of the sliding system [4, 10, 11]. However, the increased shot peening pressure to 70 psi through 10 psi reduces the specific wear rate of the shot peened samples so that the specific wear rate of the shot peened sample at 70 psi under the dry condition is about 108.4×10^{-14} m^3/Nm (which is 31.4% lower than that of the as-polished sample) because of its increased surface wear resistance associated with its increased surface hardness [4, 10, 11]. The wear results show that the shot peening at shot peening pressures of more than 50 psi results in the better surface wear resistance of the shot peened AA7075-T6 samples compared to that of the as-polished sample. This finding is similar to the one in Ref. [4].

The specific wear rate of the as-polished AA7075-T6 sample under the lubrication condition is about 3.6×10^{-14} m^3/Nm that is much lower (97.7% less) than that of the same sample under the dry condition, indicating that the mineral oil lubricant used in this study is effective to lubricate the AA7075-T6 samples [16-18]. The shot peening of the AA7075-T6 sample at 10 psi further lowers its specific wear rate to 2.2×10^{-14} m^3/Nm while the increased shot peening pressure to 30 psi results in a continueous decrease in the specific wear rate of the shot peened sample to about 1.2×10^{-14} m^3/Nm under the lubrication conditioin due to the combined effects of its increased surface wear resistance and enhanced bearing surface. As a result, the specific wear rates of the shot peened AA7075-T6 samples at shot peening pressures of more than 30 psi are not measurable.

The wear topographies of the shot peened AA7075-T6 samples tested under the dry and mineral oil lubrication conditions are presented in Fig. 9 with respect to shot peening pressure. The as-polished AA7075-T6 sample has a smaller wear track than the shot peened AA7075-T6 sample at 10 psi under the dry condition as found in Figs. 9a and 9c. However, the wear tracks of the shot peened samples become smaller with higher shot peening pressure as shown in Figs 9c, e, g, i and k, which are consistent with the trend of specific wear rate versus shot peeing pressure of the shot peened samples tested dry in Fig. 8.

The wear tracks of the shot peened AA7075-T6 samples under the lubrication condition become smaller with higher shot peening pressure up to 30 psi (Fig. 9b, d, f and h) and more than that, the wear tracks of the shot peened samples are not measurable as shown in Fig. 9j and l. It is clear that the wear tracks of the shot peened AA7075-T6 samples tested with the mineral oil lubricant (Fig. 9a, c, e, g, i and k) are apparently smaller than those of the ones tested dry (Fig. 9b, d, f, h, j and l).

Fig. 10 shows the wear morphologies of the shot peened AA7075-T6 samples tested dry. The shot peened samples have lower wear for higher shot peening pressures. Abrasive lines are more apparently found on the wear tracks of the shot peened samples at lower shot peening pressures due to their more severe abrasive wear [18-23], which infer that the higher shot peening pressure gives rise to the higher abrasive wear resistance of the shot peened samples under the dry condition. Tribolayers are found on the wear track of the shot peened sample at 70 psi (Fig. 10d) because its highest surface wear resistance allows compaction of wear debris to form the tribolayers on its wear track during the repeated sliding [18-23].

Fig. 11a shows an overview of wear debris accumulated from the wear track of the shot peened AA7075-T6 sample at 70 psi on which wear particles and flakes are found. The wear particles result from the abrasive wear of the shot peened sample while the wear flakes are probably produced by the detachment of tribolayers (Fig. 10d) formed on its wear track. Fig. 11b shows the EDX spectrum of the wear debris on which Al, Zn, and O peaks are mainly detected for this study. The O peak on the EDX spectrum indicates oxidation of the wear debris [18-23].

The wear morphologies of the shot peened AA7075-T6 samples tested under the mineral oil lubrication condition are shown in Fig. 12. The as-polished sample (Fig. 12a) and shot peened sample at 10 psi (Fig. 12b) have apparent wear tracks, but the wear track of the shot peened sample is smaller and less apparent as shown by the comparison of Figs. 12a and 12b. The wear tracks of the shot peened samples at shot peening pressures of more than 30 psi are not measurable as found in Figs. 12c and 12d. In Fig. 12d, the repeated sliding of the steel ball wears out only the protruded asperities of the shot peened sample at 70 psi. Comparison of Figs. 10 and 12 confirm that the samples have much lower wear under the lubrication condition than under the dry condition.

Fig. 13 shows the EDX spectra of the as-polished AA7075-T6 sample and shot peened AA7075-T6 samples determined on their tested and untested areas. In Figs. 13a, d, g, and j, the as-polished sample and shot peened samples exhibit similar EDX spectra for their untested areas on which Al, Zn, and O peaks are commonly detected. However, the shot peened samples at shot peening pressures of more than 30 psi have additional Fe peaks on their EDX spectra (Figs. 13g and j), which mean that the shot peening at higher pressures than 30 psi results in the wear of steel shots in the course of impacting on the samples [12]. The EDX spectra determined on the wear tracks of the samples tested dry (Figs. 13b, e, h, and k) have similar Al, Zn, and O peaks to those on the EDX spectra measured on their untested areas (Figs. 13a, d, g, and j). The O peaks (about 12 at.%) detected from the wear tracks (Figs. 13h and k) are stronger than the ones (about 6 at.%) from the untested areas (Figs. 13g and j), especially for the higher shot peening pressures, indicating that the higher friction of the shot peened samples at higher shot peening pressures (Fig. 7a) induces a more severe oxidation process via generation of higher frictional heat during the dry sliding [18-23]. The as-polished sample and shot peened samples exhibit stronger O peaks (about 38 at.%) on the EDX spectra of their wear tracks under the lubrication condition (Figs. 13c, f, i and l) than under the dry condition (Figs. 13b, e, h, and k). It is supposed that the sliding of the steel balls on the AA7075-T6 samples under the lubrication condition causes an interaction between the mineral oil lubricant and samples to form oxide layers on the sample surfaces [24].

Figs. 14a and 14b show the wear morphologies of steel balls slid on the as-polished AA7075-T6 sample and shot peened AA7075-T6 sample at 70 psi, respectively, under the dry condition, on which the steel ball rubbed on the shot peened sample exhibits higher wear. The reason is that the improved wear resistance of the AA7075-T6 sample associated with the shot peening promotes the wear of its counter steel ball [20-24]. At the same time, the rough surface of the shot peened sample serves as an abrading surface to cause the higher wear of its counter steel ball during the dry sliding compared to the smooth surface of the as-polished sample [4].

The steel balls slid on the as-polished AA7075-T6 sample and shot peened AA7075-T6 sample at 70 psi exhibit much lower wear under the lubrication condition (Figs. 14c and d) than under the dry condition (Figs. 14a and b). Comparison of Figs. 14a-d shows that the steel ball slid on the shot peened AA7075-T6 sample at the highest shot peening pressure of 70 psi under the lubrication condition (Fig. 14d) has the lowest wear due to the most effective lubricating effect of the mineral oil lubricant on the best bearing surface of the shot peened sample. It is clear that the shot peening pressure has a significant effect on the wear of the AA7075-T6 samples and their counter steel balls under the both dry and lubrication conditions.

4. Conclusions

The tribological properties of shot peened AA7075-T6 samples under the dry and mineral oil lubrication conditions were systematically investigated with the following conclusions.

- The surfaces of the shot peened AA7075-T6 samples became rougher with higher shot peening pressure. But, the best bearing surfaces of the AA7075-T6 samples were found at the highest shot peening pressure of 70 psi.
- The hardness of the shot peened AA7075-T6 samples increased with increased shot peening pressure due to their enhanced cold work hardening.
- The friction of the shot peened AA7075-T6 samples increased with increased shot peening pressure under the dry condition. However, the shot peening of the AA7075-T6 samples at higher shot peening pressures resulted in their lower friction under the mineral oil lubrication condition due to their better bearing surfaces for the more effective lubricating effect of the mineral oil lubricant. For all the shot peening pressures, the AA7075-T6 samples exhibited lower friction coefficients under the lubrication condition than under the dry condition as a result of the lubricating effect of the mineral oil lubricant.
- The wear of the shot peened AA7075-T6 samples tested dry decreased with increased shot peening pressure because of their increased surface hardness. The shot peened AA7075-T6 samples consistently exhibited a decrease in their wear with increased shot peening pressure even under the mineral oil lubrication conditioin. The wear results clearly showed that the mineral oil lubricant introduced during the sliding apparently lowered the wear of all the shot peened AA7075-T6 samples.

- Under the dry condition, the steel balls rubbed on the shot peened AA7075-T6 samples at higher shot peening pressures had higher wear because of the higher surface wear resistance and roughness of the samples. Under the mineral oil lubrication, the steel balls slid on the shot peened AA7075-T6 samples at higher shot peening pressures, however, exhibited lower wear as a result of the better bearing surfaces of the samples.
- It could be inferred that under the both dry and lubrication conditions, the shot peening pressure used in the shot peening process had a major effect on the tribological characteristics of the shot peened AA7075-T6 samples.

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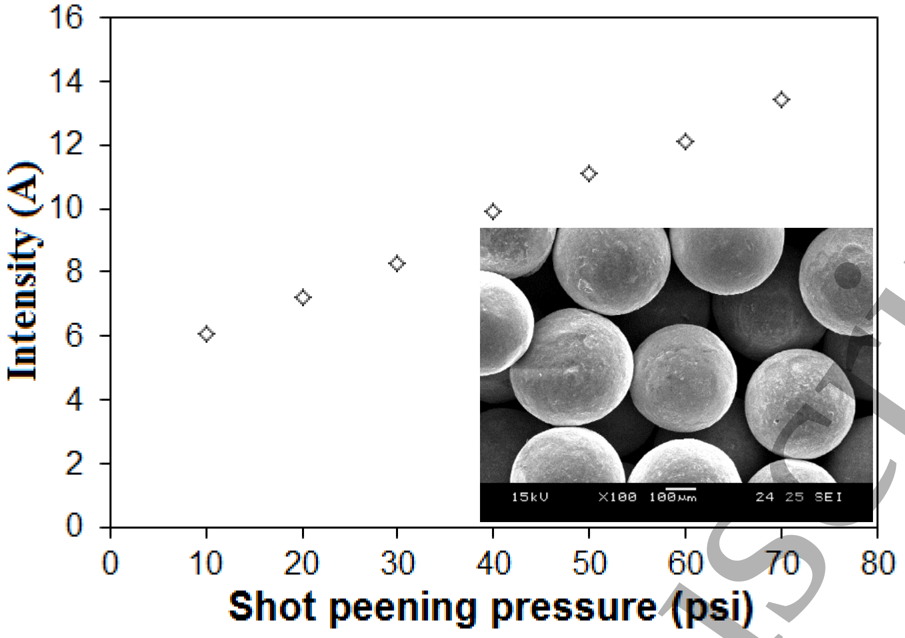


Fig. 1: Shot peening intensities measured at various shot peening pressures. The inset shows an overview of S110 steel shots.

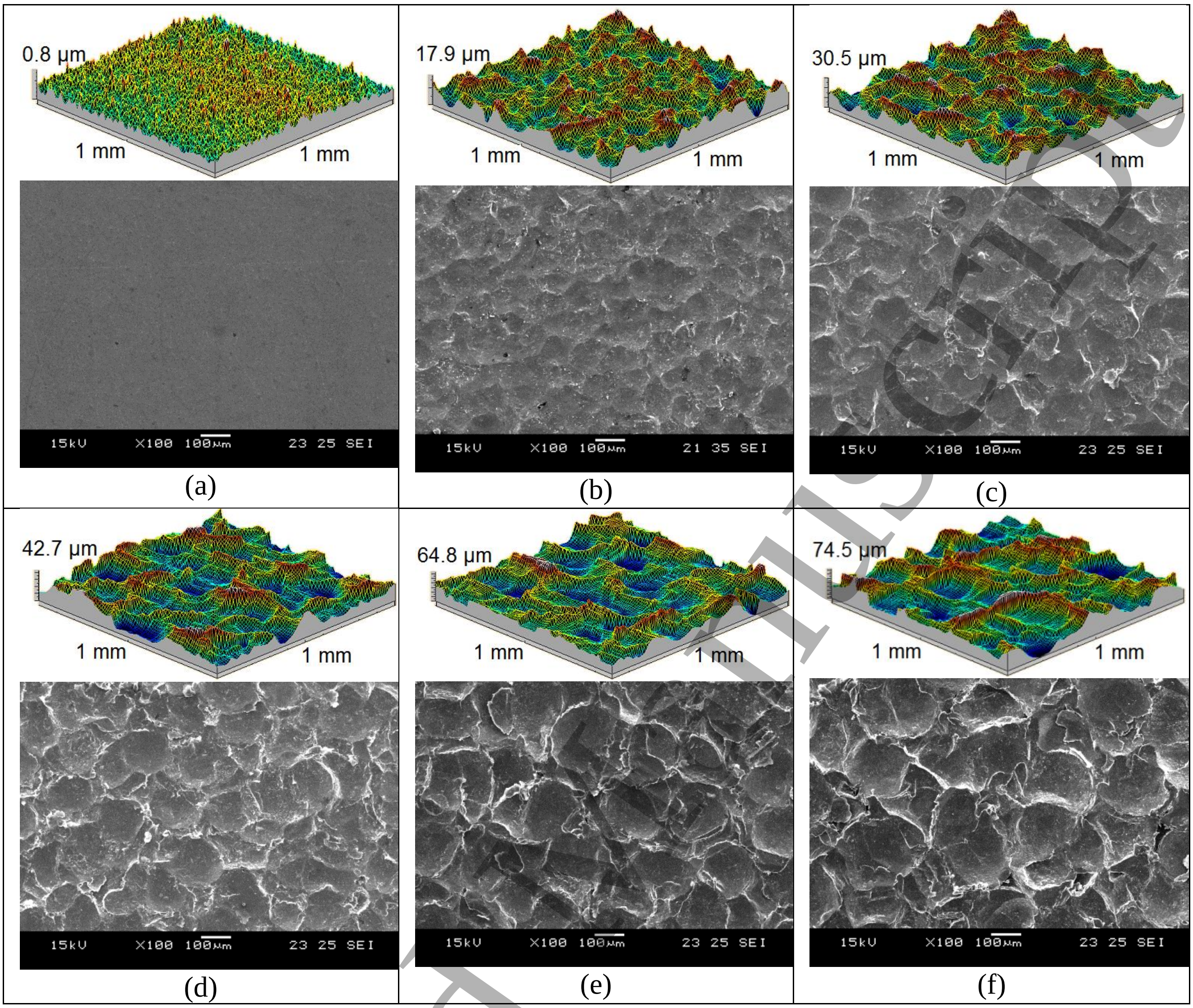


Fig. 2: Surface topographies (above) and morphologies (below) of (a) as-polished AA7075-T6 sample and (b, c, d, e, and f) shot peened AA7075-T6 samples at shot peening pressures of (b) 10, (c) 20, (d) 30, (e) 50 and (f) 70 psi.

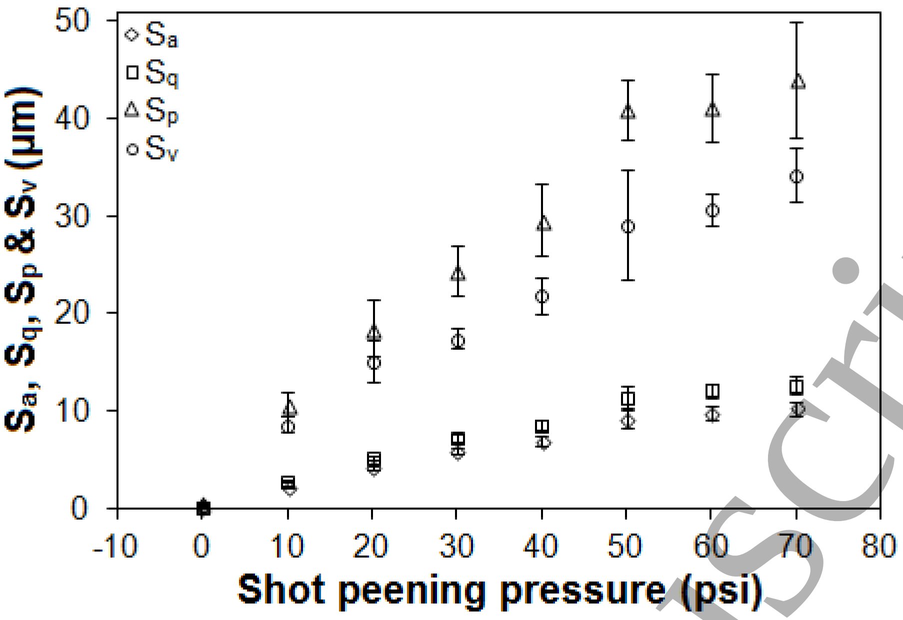
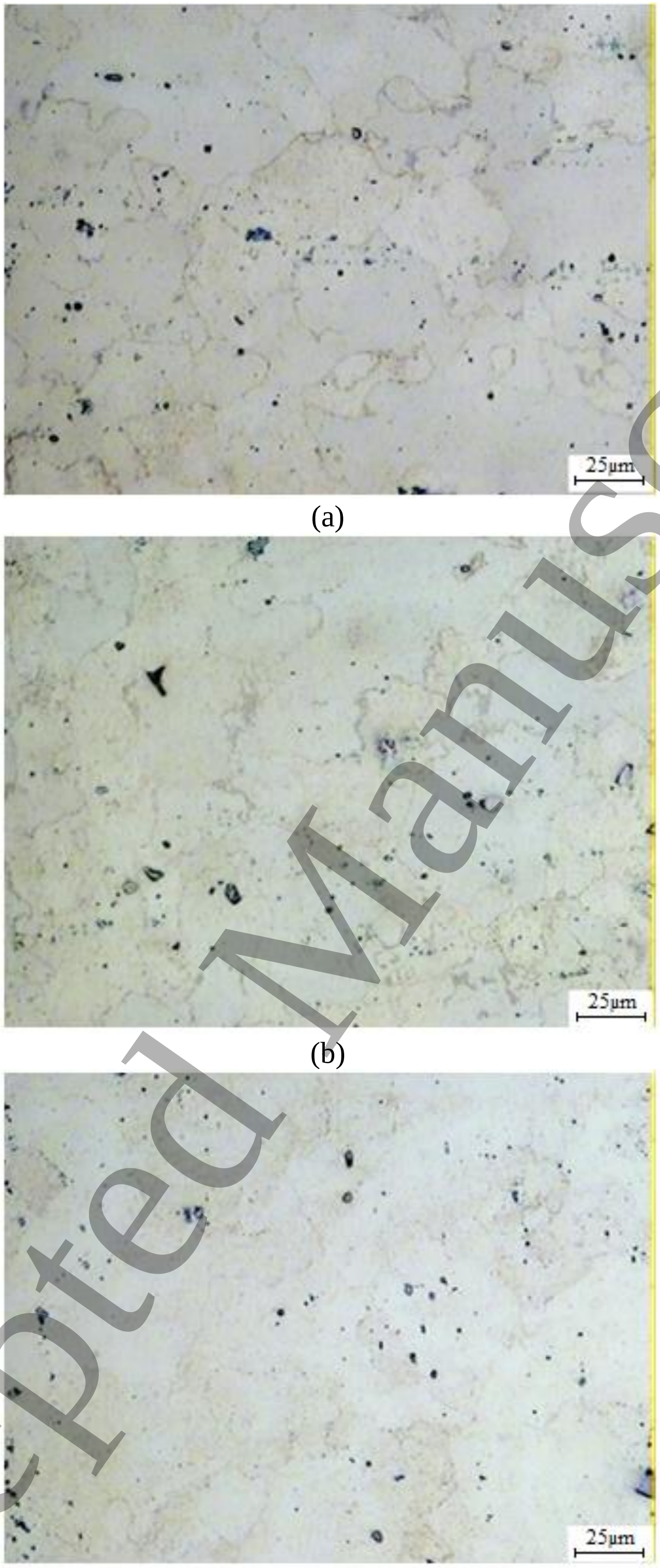


Fig. 3: S_a, S_q, S_p and S_v values of as-polished AA7075-T6 sample and shot peened AA7075-T6 samples at various shot peening pressures.

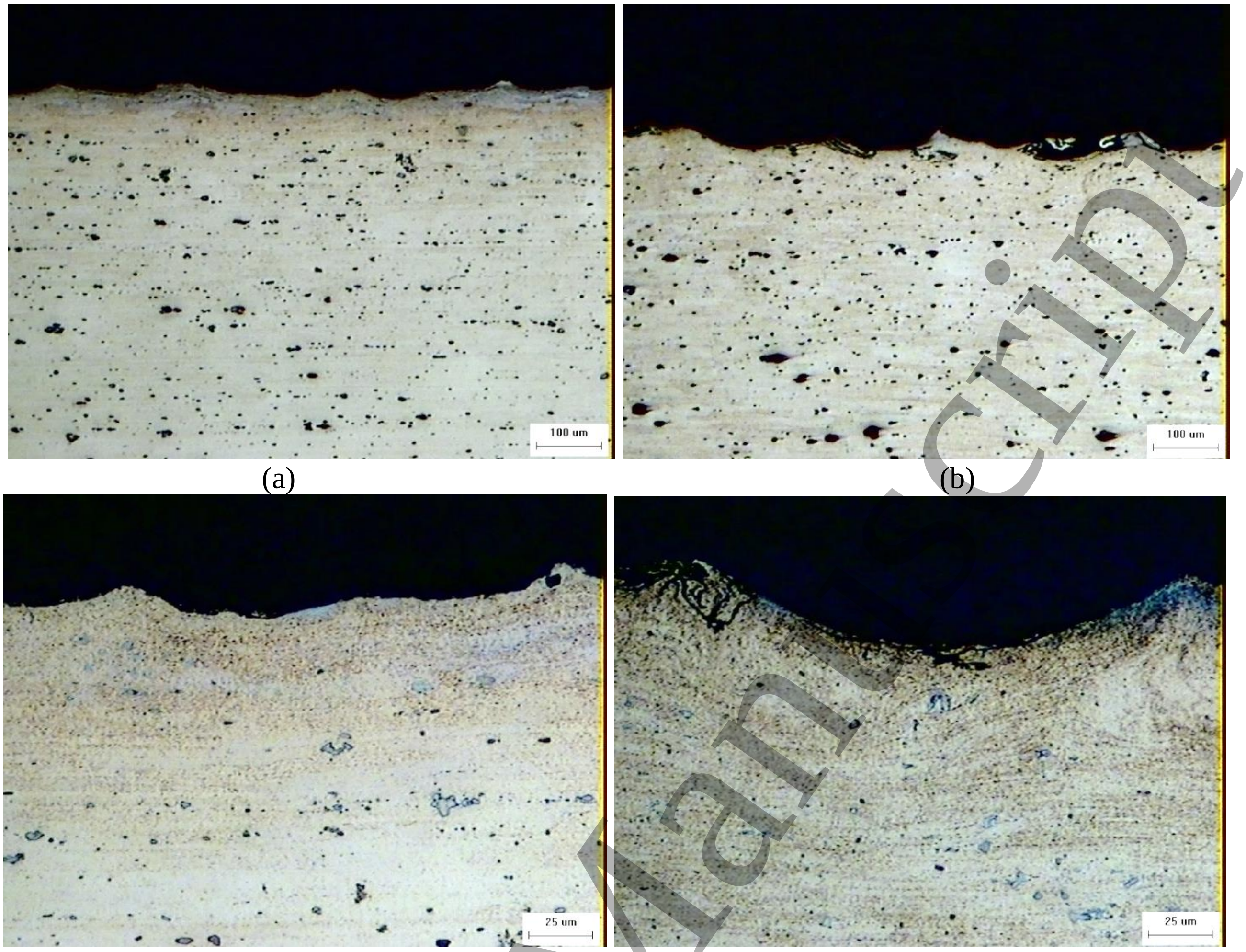


(a)

(b)

(c)

Fig. 4: Surface microstructures of (a) as-polished AA7075-T6 sample and (b and c) shot peened AA7075-T6 samples at shot peening pressures of (b) 10 and (c) 70 psi.



(a) (b)

(c) (d)

Fig. 5: Cross-sectional microstructures of shot peened AA7075-T6 samples at shot peing pressures of (a and c) 20 and (b and d) 70 psi observed at different magnifications.

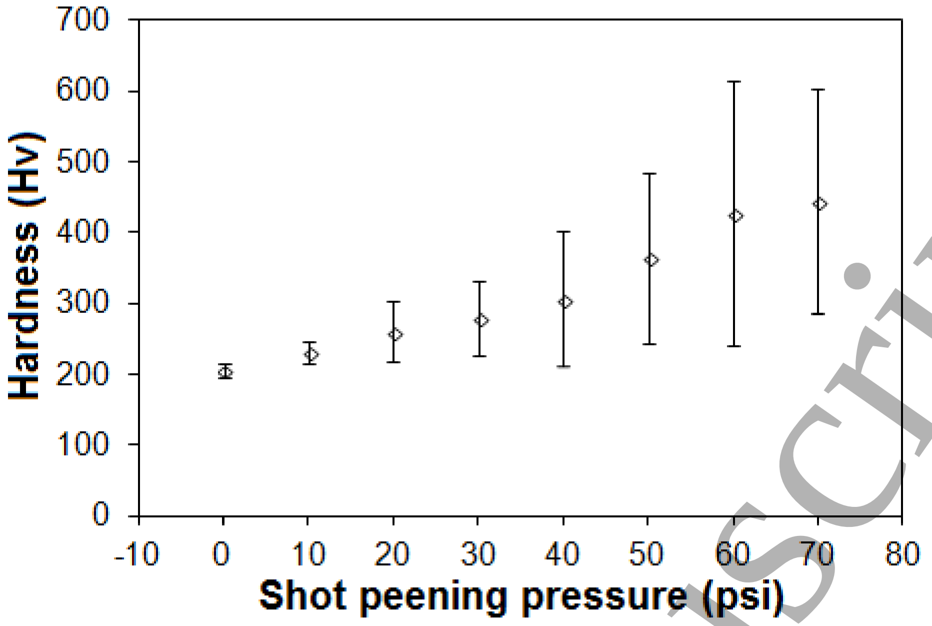
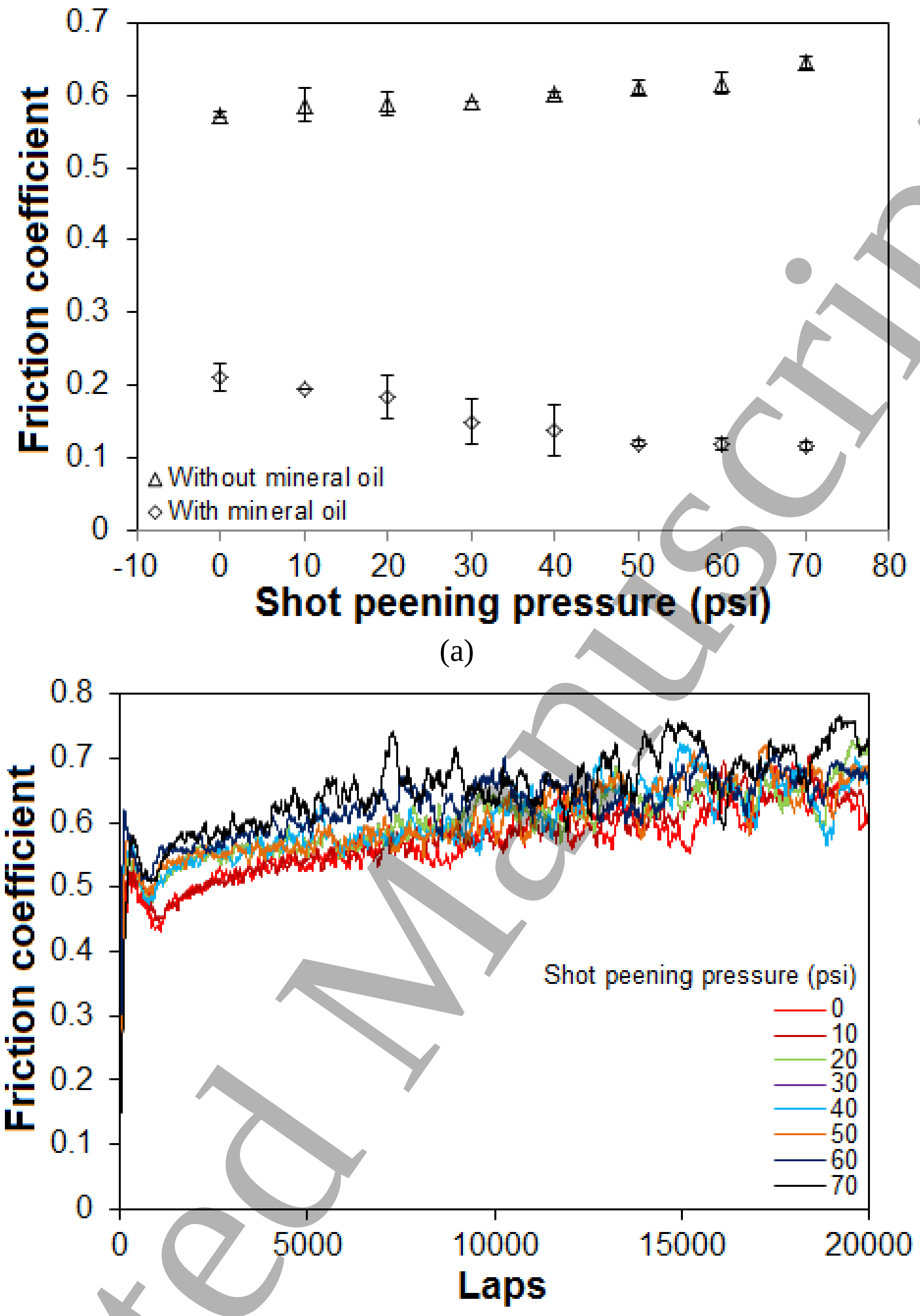
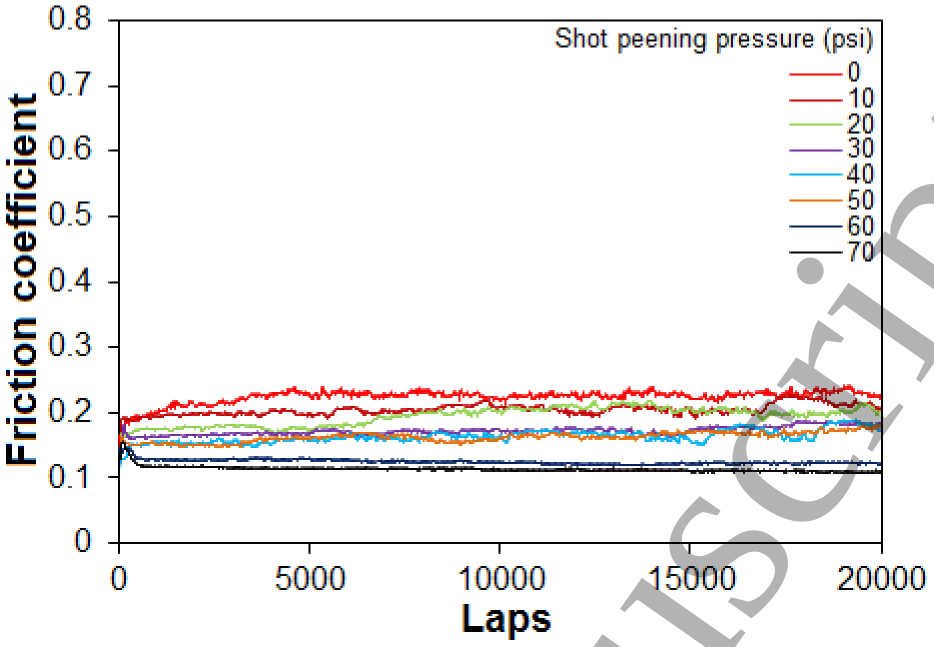


Fig. 6: Hardnesses of as-polished AA7075-T6 sample and shot peened AA7075-T6 samples at various shot peening pressures.


Friction coefficient
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-10
0
10
20
30
40
50
60
70
80
Shot peening pressure (psi)
△ Without mineral oil
◇ With mineral oil
Friction coefficient
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5000
10000
15000
20000
Laps
Shot peening pressure (psi)
0
10
20
30
40
50
60
70

(a)

(b)



(c)

Fig. 7: (a) Friction coefficients of as-polished AA7075-T6 sample and shot peened AA7075-T6 samples at various shot peening pressures tested against 100Cr6 steel balls without and with mineral oil lubricant in a circular path of 1 mm in radius for 20000 laps at a sliding speed of 3 cm/s under a normal load of 1 N. (b and c) Friction coefficients of as-polished AA7075-T6 sample and shot peened AA7075-T6 samples at various shot peening pressures, tested (b) without and (c) with mineral oil lubricant under the same conditions as described above, as a function of the number of laps. The AA7075-T6 sample with shot peening pressure of "0 psi" represents the as-polished AA7075-T6 sample.

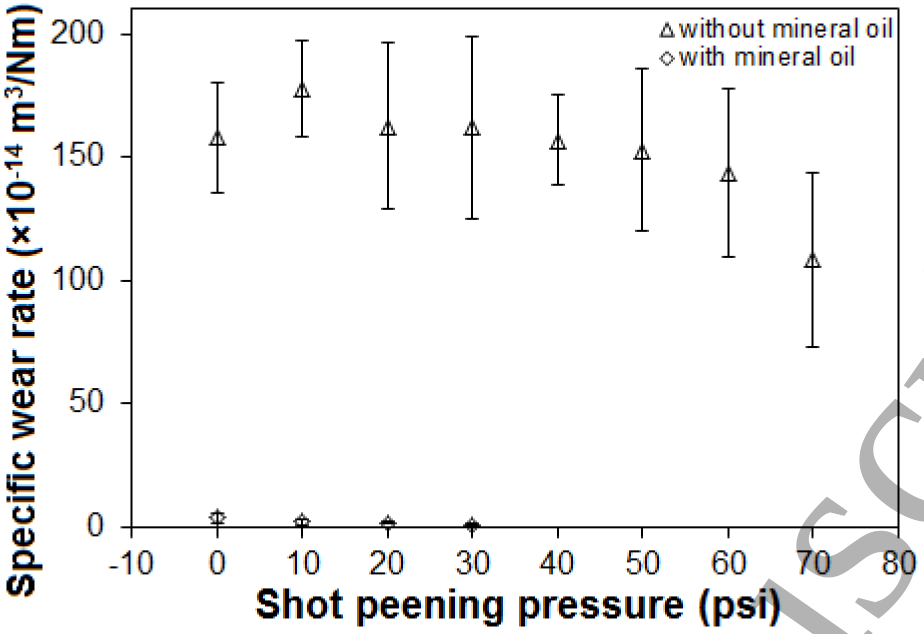


Fig. 8: Specific wear rates of as-polished AA7075-T6 sample and shot peened AA7075-T6 samples at various shot peening pressures tested under the same conditions as described in Fig. 7. The AA7075-T6 sample with shot peening pressure of "0 psi" represents the as-polished AA7075-T6 sample.

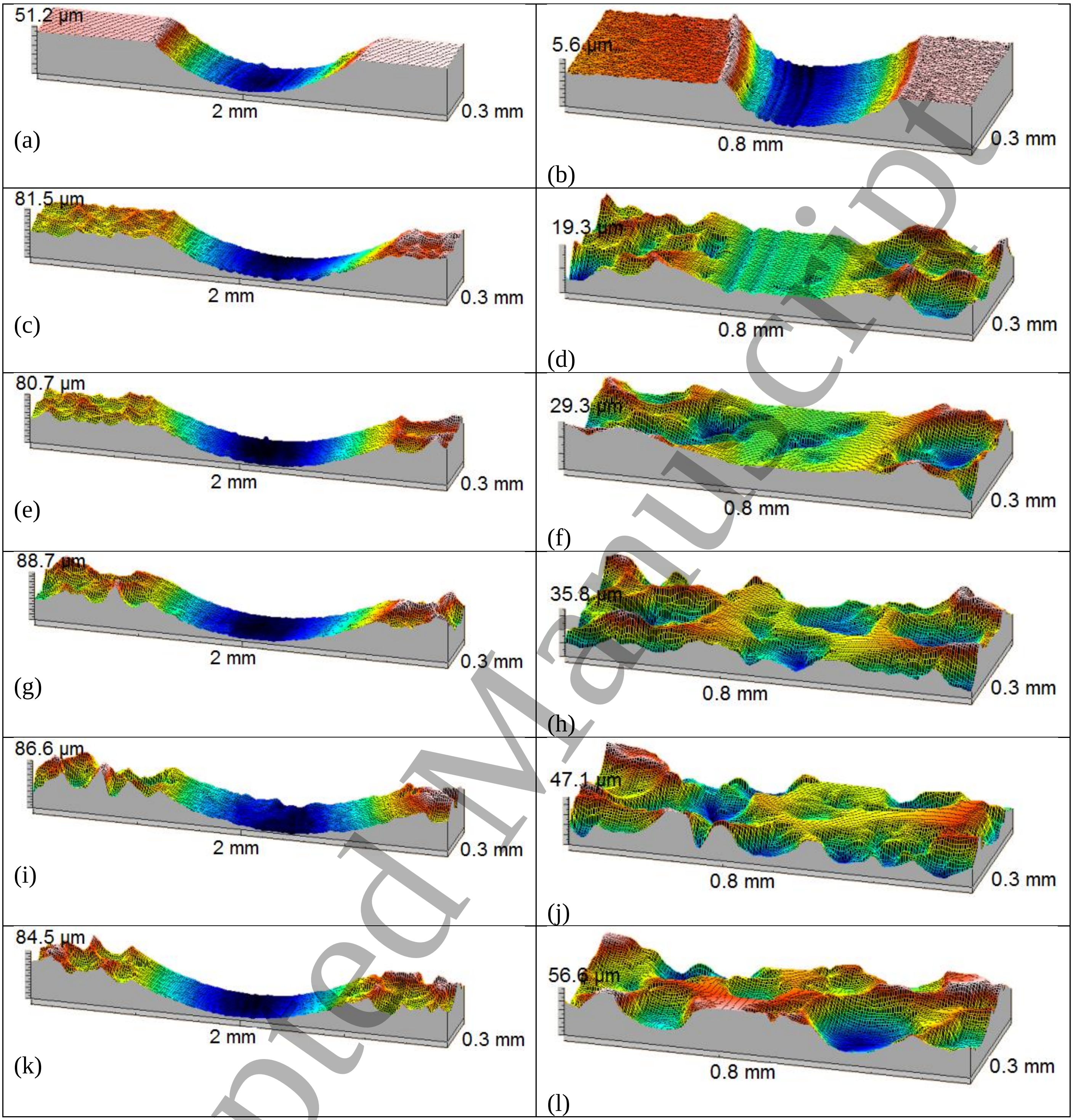
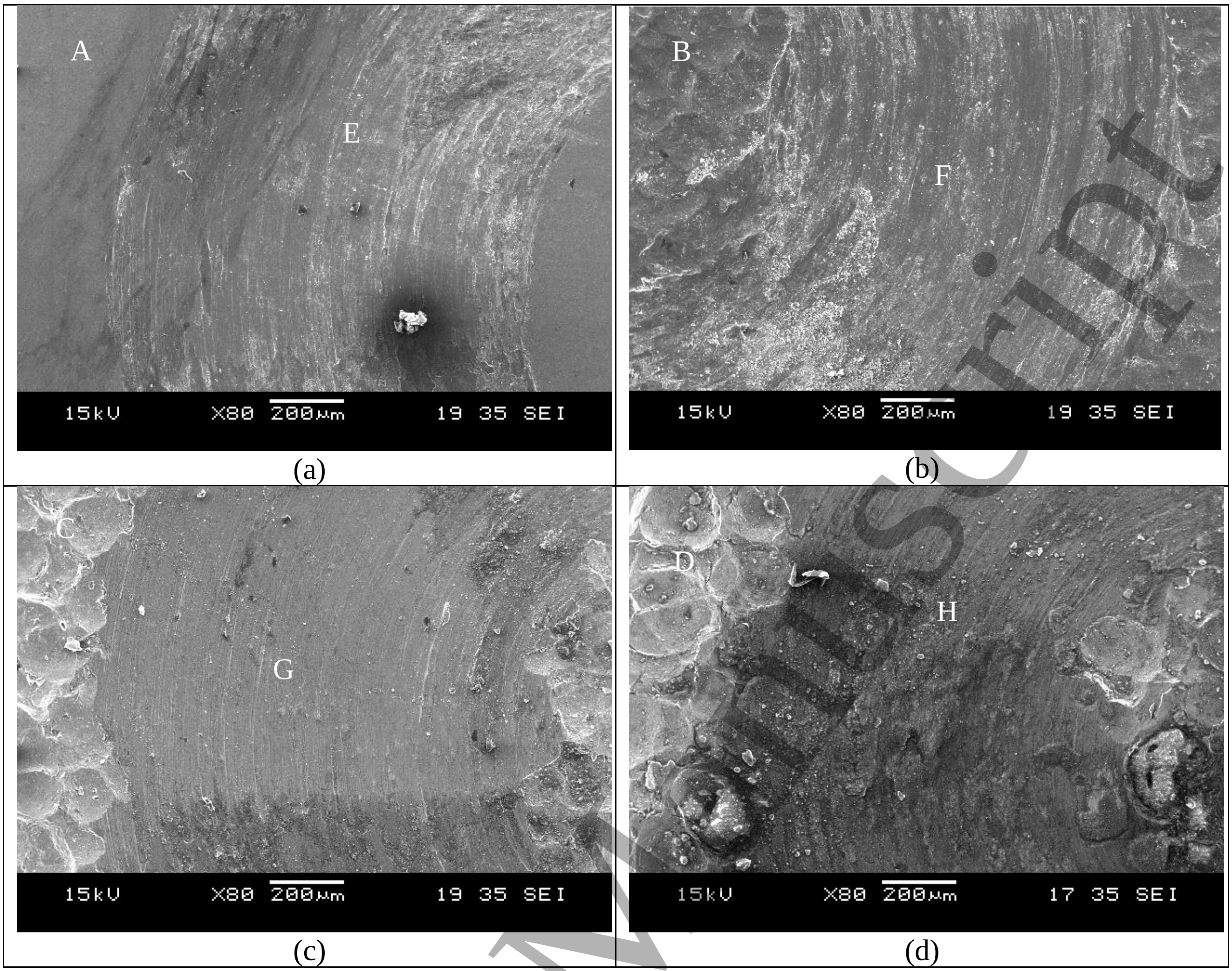
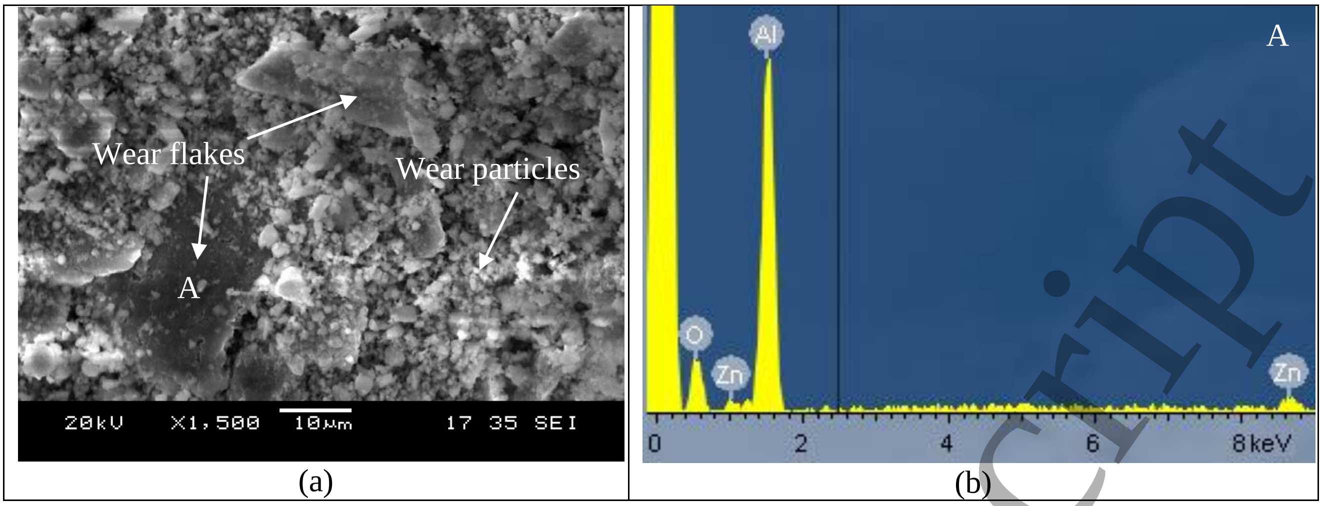


Fig. 9: Wear topographies of (a and b) as-polished AA7075-T6 sample and (c, d, e, f, g, h, i, j, k, and l) shot peened AA7075-T6 samples at shot peening pressures of (c and d) 10, (e and f) 20, (g and h) 30, (i and j) 50 and (k and l) 70 psi tested against 100Cr6 steel balls (a, c, e, g, i and k) without and (b, d, f, h, j, and l) with mineral oil lubricant under the same conditions as described in Fig. 7.



(a) (b) (c) (d)

Fig. 10: Wear morphologies of (a) as-polished AA7075-T6 sample and (b, c, and d) shot peened AA7075-T6 samples at shot peening pressures of (b) 10, (c) 40, and (d) 70 psi tested without mineral oil lubricant under the same conditions as described in Fig. 7.



(a) (b)

Fig. 11: (a) An overview of wear debris accumulated from wear track of shot peened AA7075-T6 sample at a pressure of 70 psi tested without mineral oil lubricant under the same conditions as described in Fig. 7 and (b) EDX spectrum of the wear debris measured at location A in (a).

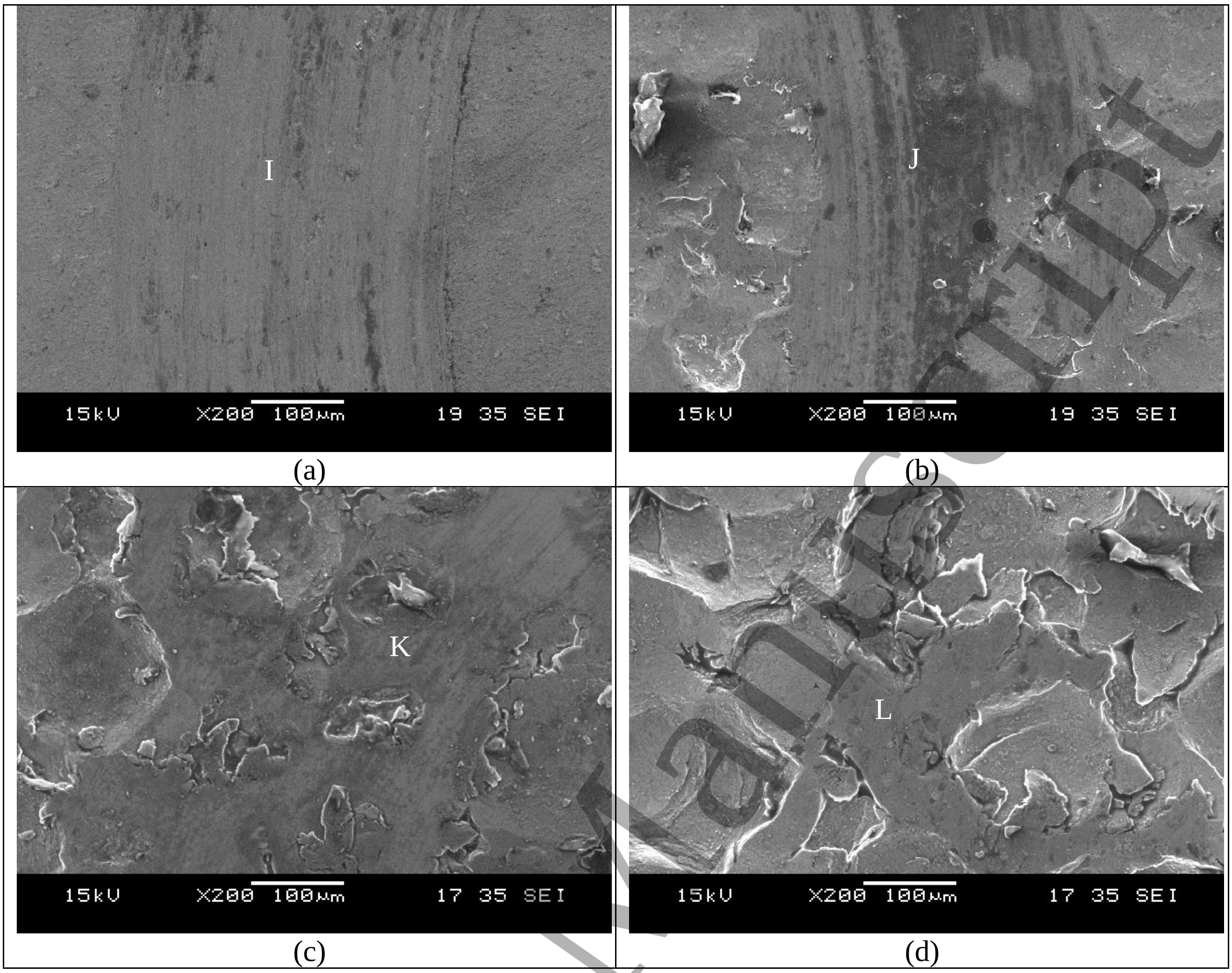


Fig. 12: Wear morphologies of (a) as-polished AA7075-T6 sample and (b, c, and d) shot peened AA7075-T6 samples at shot peening pressures of (b) 10, (c) 40, and (d) 70 psi tested with mineral oil lubricant under the same conditions as described in Fig. 7.

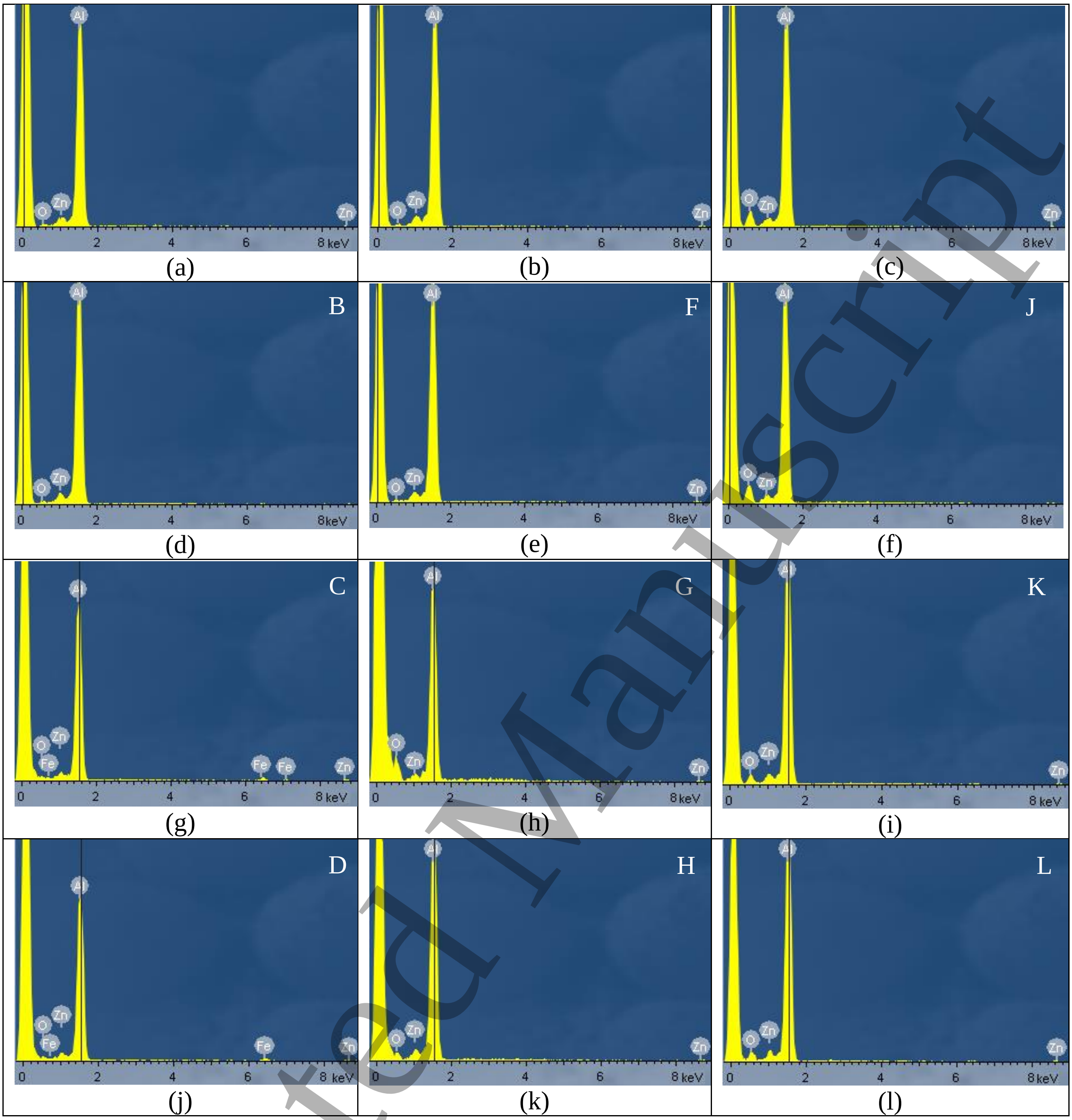


Fig. 13: EDX spectra of (a, b, and c) as-polished AA7075-T6 sample and (d, e, f, g, h, i, j, k, and l) shot peened AA7075-T6 samples at shot peening pressures of (d, e and f) 10, (g, h and i) 40 and (j, k, and l) 70 psi, tested without (b, e, h, and k) and (c, f, i and l) with mineral oil lubricant, measured on their (a, d, g, and j) untested and (b, c, e, f, h, i, k and l) tested areas at locations A and E in Fig. 10a, B and F in Fig. 10b, C and G in Fig. 10c, D and H in Fig. 10d, I in Fig. 12a, J in Fig. 12b, K in Fig. 12c and L in Fig. 12d.

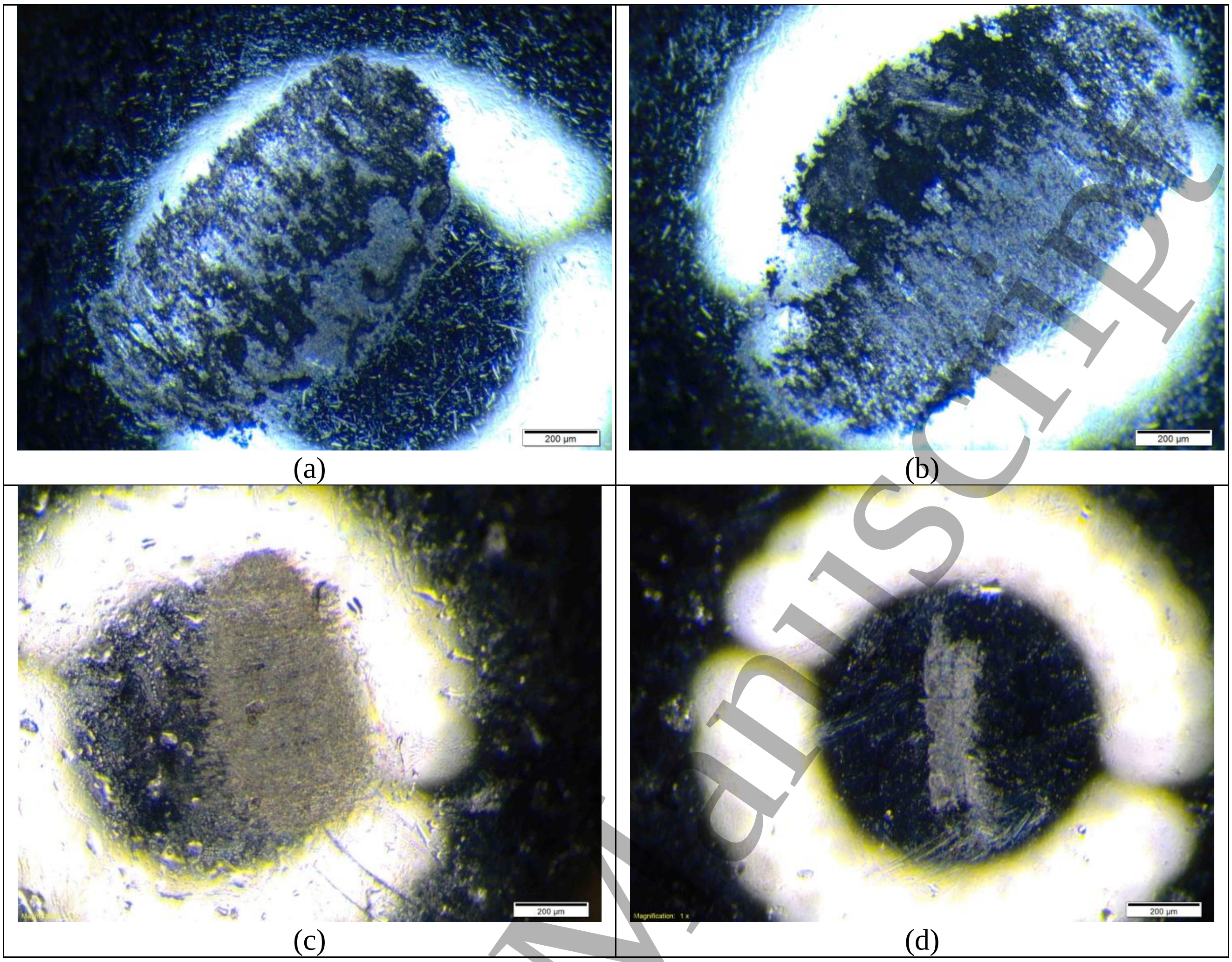


Fig. 14: Wear morphologies of steel balls slid on (a and c) as-polished AA7075-T6 sample and (b and d) shot peened AA7075-T6 sample at a shot peening pressure of 70 psi (a and b) without and (c and d) with mineral oil lubricant under the same conditions as described in Fig. 7.