Compression Fracture Analysis of a Pellet Press Shaft

When parts break unexpectedly, determining the root cause is an important step in avoiding future problems. SEM fractography and composition mapping are excellent ways to determine the reasons behind part failures. In this study, a shaft from a pellet press was examined after breaking during routine use. Figure 1 shows the broken shaft compared to an intact shaft. The shaft broke into seven fragments and there was a small black hole at the top center of the shaft. The head of the shaft had a small protrusion which fit into the hole. The shaft was likely connected to the head by a welding or brazing process.

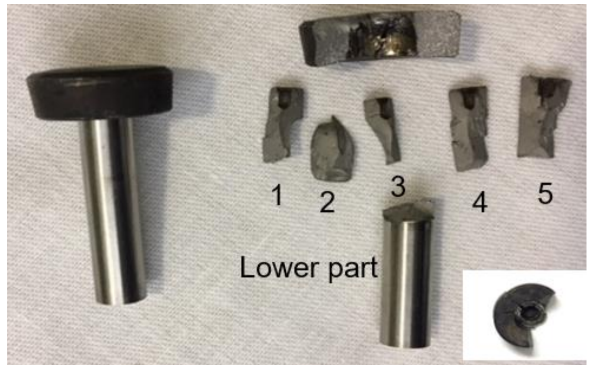

Figure 1. Intact (left) and fractured (right) pellet press shafts.

The composition of the shaft was analyzed by X-ray energy dispersive spectroscopy (EDS), the results of which are shown in Figure 2. The EDS spectrum indicates that the shaft was primarily composed of Fe, Cr, W, Mo and V, which are the most common elements used to create tool steels. The bright particles in the SEM image are W, Mo and V carbide particles added to inhibit crack propagation and increase the mechanical strength of the material.

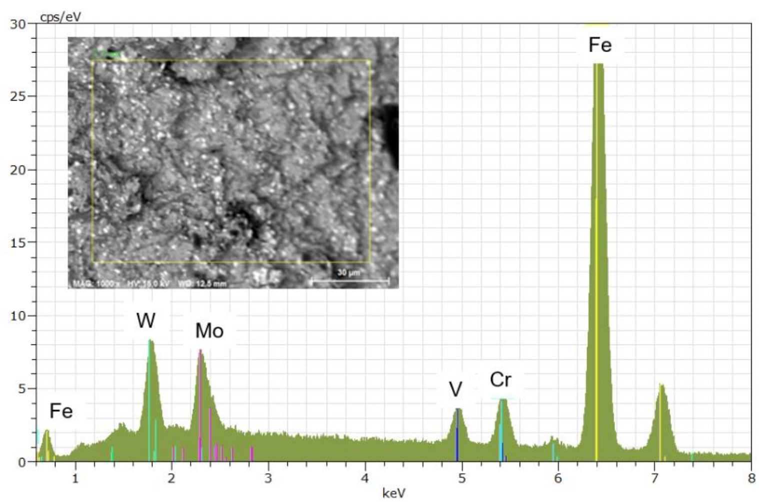

Figure 2. EDS spectrum of the fracture surface. Inset: SEM image of the corresponding area.

The microstructure of the compression fracture surface was investigated further using SEM (Figure 3). Figure 3a is the SEM image of fragment 5 from Figure 1. In fragment 5, chevron marks, or small lines, are visible which converge at the crack origination site. Chevron marks were not only observed in fragment 5, but also in fragments 1, 3, and 4. By tracing the chevron marks back, the fracture on fragment 5 originated from the bottom of the hole (red circle, Figure 3a). This location corresponds to the joint area between the shaft and the head, which is an area of high stress concentration. For this shaft fragment, several cracks initiated at the joint area, and the top part of the shaft broke into five pieces. After the crack initiated, the crack propagated downward at approximately 45º, which is the direction of highest shear stress. This also explains why fragment 2 had two slopes at about 45° angles (not shown).

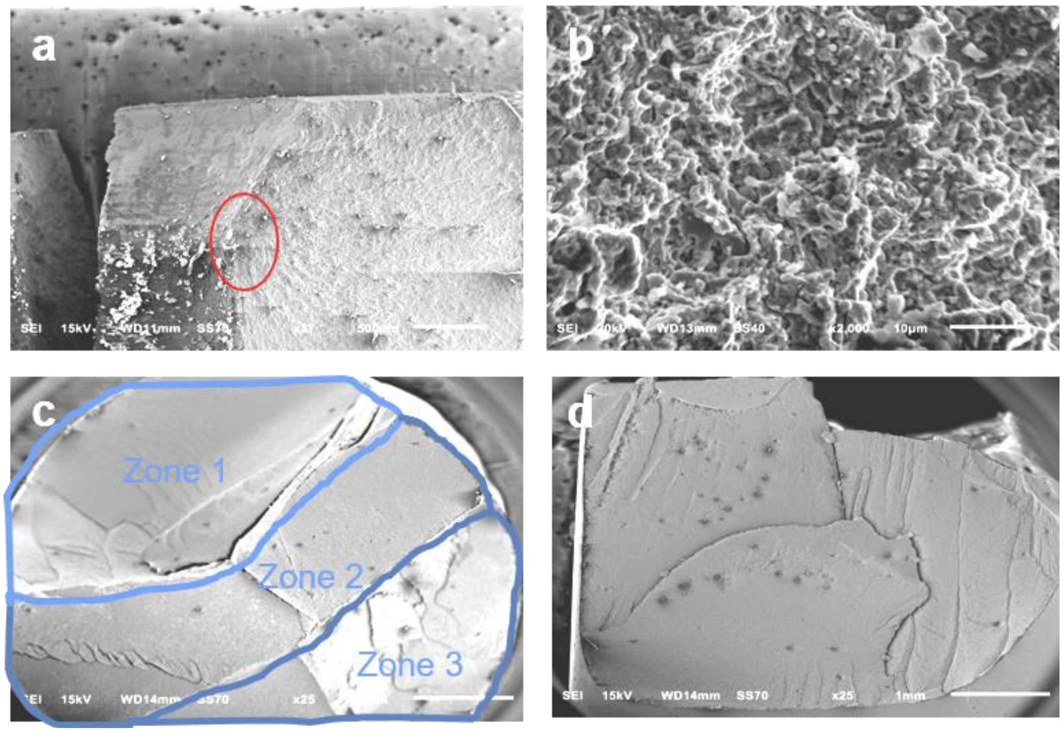

Figure 3. Fracture surface microstructures. a) SEM image of fragment 5, b) Typical microstructure of the fracture surface at 2000x, c) Top view of the fracture surface on the lower shaft, d) Zone 1 fracture surface.

A typical microstructure of the fracture surface at 2000X magnification is shown in Figure 3b. Pieces 1 through 5 and the lower shaft had similar uneven and dimpled fracture surfaces, characteristic of ductile fracture. Some carbide particles were also found at the base of these dimples. The top view of the lower shafts' fracture surface is shown in Figure 3c. Three unique areas were identified and labeled as zones 1, 2, and 3. Zone 1's fracture surface has a cliff shape (Figure 3d). As shown in Figures 3c and 3d, cleavage lines formed on the fracture surface, demonstrating the growth direction of the cracks. Reassembling the fragments, fragment 2 fitted into zone 1, fragments 1 and 3 fitted into zone 2, and fragments 4 and 5 fitted into zone 3. The slopes on the fragments demonstrated that the cracks grew due to shear stress.

Based on morphological analysis, the fracture was identified as a ductile compression fracture. The cracks initiated at the joint area between the shaft and the head, and grew along the highest shear stress direction. The size and distribution of the carbide particles were homogenous. No large carbide segregation was observed at the critical areas. The failure of the shaft was due to an overload of compressive force.