NATOLI METALLURGY
a division of Natoli Engineering Company, Inc.

Customer: ----------	Order Number: ----------
Tool for Evaluation: Lower punch core rod tools	Method of Evaluation: Visual/Metallographic
Material: DC-53	Tool Hardness: 63.2 HRC (+/- 0.2)HRC
Lab Report #: --------	Date: 2/18/2013

Summary:
---------- returned several lower punch core rod tools that fractured during production, to Natoli for evaluation

Examination:
Examination of the lower punches that were still intact or partially intact showed multiple fractures to the shoulder (Figure 1) that extended along the lower radius and up through the shoulder to the top. This allowed the shoulder to break away from the punch in pieces. One section of shoulder (Figure 2) exhibited a well worn area that was not seen on the other pieces.

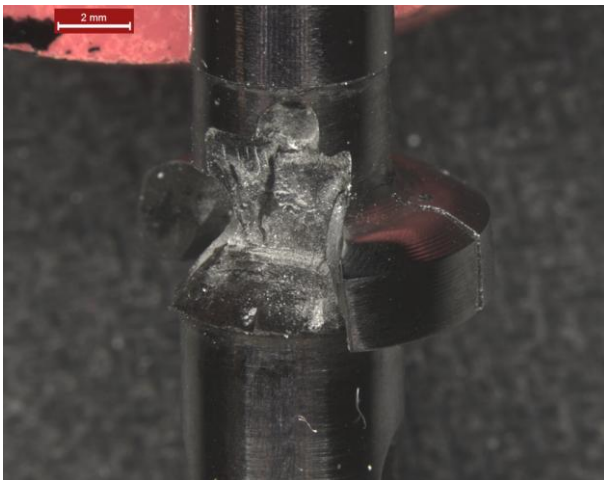

Figure 1 Lower punch core rod tool with fractured shoulder

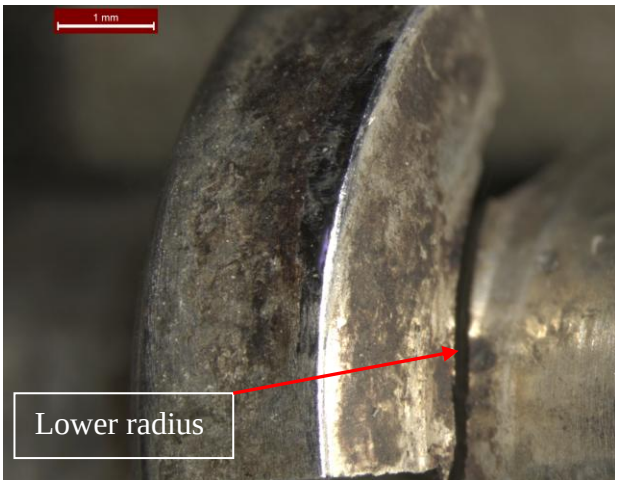

Figure 2 only observed section of shoulder with indication of wear

Beach marks (Figure 3) on the lower punch's fractured surface indicated that initiation occurred along the lower radius between the stem or body of the punch and the shoulder. The punches showed several origins of fracture along the lower radius of the shoulder as witnessed by the ratchet marks. Beach marks identify the defects origin by propagating in ever widening semi circles from the initiation point, similar to the marks left on the beach by advancing water. The ratchet marks are where two different sets of beach marks or crack propagations collide and the plane of fracture changes leaving a distinct upright line. Several sets of beach marks and ratchet marks (Figure 4) are visible on the fractured punches.

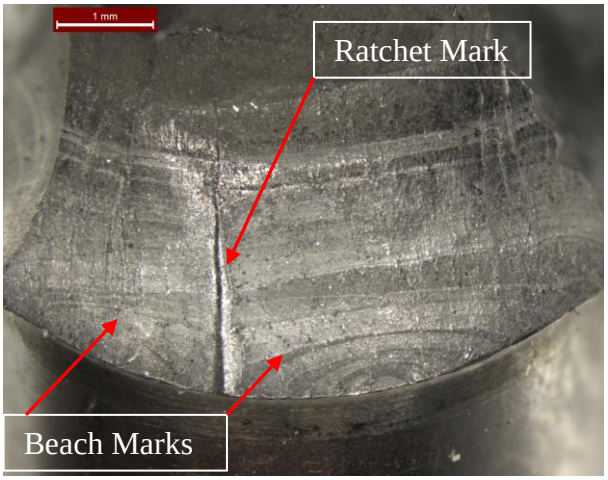

Figure 3 beach marks visible with ratchet marks

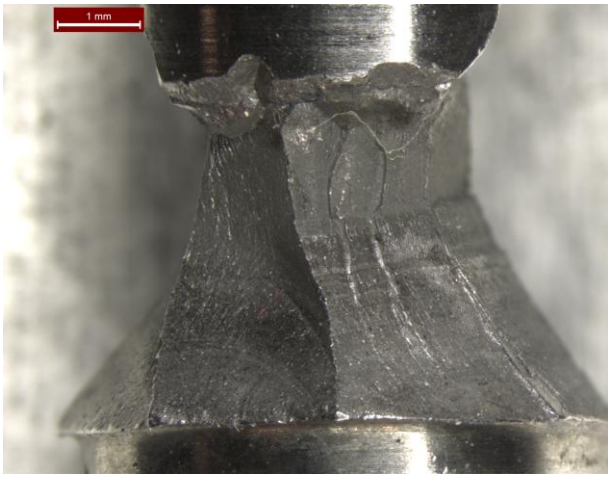

Figure 4 several sets of beach marks and ratchet marks

One punch was sectioned through the center of a beach mark (Figure 5) to help determine the source of failure. Metallographic examination of the lower radius was conducted in this area (Figure 6).

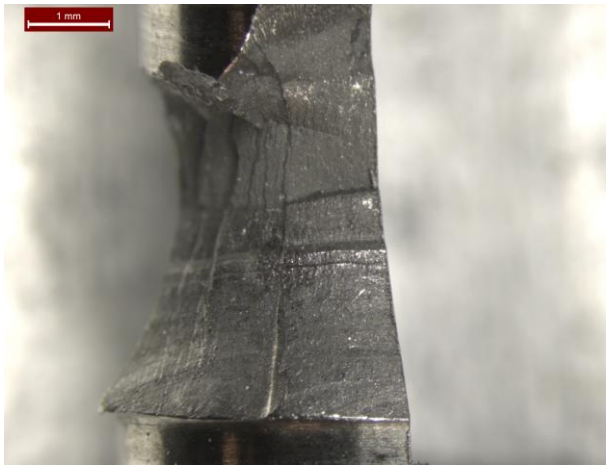

Figure 5 lower punch was section through crack initiation

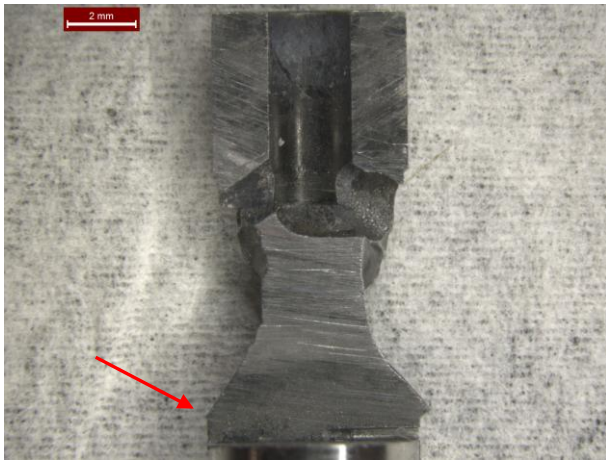

Figure 6 indicates area of micrograph

Metallurgical examination of the microstructure at the location of failure initiation showed a quenched and tempered martensitic microstructure with dispersed carbides, consistent with properly quenched and tempered DC53 steel. There was no indication of material defect.

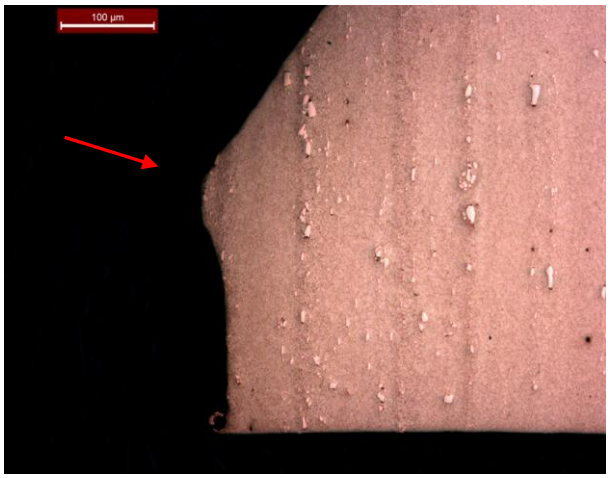

Figure 7 Microstructure of lower shoulder radius 200X Etched with 3% Nital

Figure 8 Microstructure of lower shoulder radius 1000X Etched with 3% Nital

XRF analysis of the punches showed the parts were made from DC-53 material.

Micro hardness measurements at the lower shoulder radius were 63.2 HRC (+/- 0.2) HRC.

Conclusion:
Lower punch core rod tools failed due to cracks initiating at the lower shoulder radius, where the radius acted as a stress concentrator. The microstructure of the material at this location contained no defects with hardness that was more than adequate to resist yielding and could be lowered to help improve toughness/resistance to cracking.

Beach marks and ratchet marks on the fracture surface of the punch show multiple points of origin along the lower shoulder radius, which suggests that failure was more dependent on geometry of the part than material.

Increasing the radius transition from the punch to the shoulder would lower the stress concentration at that critical location.

Reducing the material hardness would improve steel toughness and reduce the impact of stress concentrators.

Bill Cason
Metallurgical Engineer at Natoli Engineering
wcason@natoli.com
28 Research Park Circle,
St. Charles MO. 63304
(636) 926-8900 ext. 3119