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Failure Analysis of a Power Steering Torsion Bar

M. A. Neri-Flores, C. Carreño-Gallardo and I. Estrada-Guel.

Centro de Investigación en Materiales Avanzados (CIMAV), Miguel de Cervantes No. 120, C.P. 31109, Chihuahua, Chih., México.

A steering wheel is a metal bar usually cylindrical in shape and solid, that is used to support rotating components or to transmit motion by rotary or axial movement. Usually with tensile forces, but sometimes combined with bending and torsional forces, these particular characteristics can cause the failures of the material. The brittle fracture may thus be attributable to inappropriate choice of material, incomplete knowledge of operating conditions, but it may also be the result of abuse or misuse of the product under service conditions for which it was not designed.

A steering wheel made with SAE 4140 steel treated by plasma (ion) nitriding was used for this study. Visual examination, chemical analysis, stereoscopy examination, metallographic and, microhardness analysis, scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDS) were made to establish microstructural changes and the mechanism of failure.

The material under investigation was identificated visually. Figure 1, shows the position where the torsion bar was fractured, near to the zone where the diameter changes suddenly. The chemical analysis was performed in a section of the bar, in order to determine the content of C, Mn, P, S, Si, Cr and Mo according to the SAE standard for 4140 steel, the results are shown in Table I. A digital microhardness tester with two scales of hardness: Vickers and Rockwell "C" was used, in order to obtain the microhardness profile. Figure 2 present a graph of hardness profile vs. distance, as we can see in the figure, the hardness values decrease to the interior of the piece and the hardness value is constant at distances > 30μm.

In accordance with the results obtained by EDS analysis, we can say that there are not extrinsic elements in the chemical composition of the SAE 4140 steel in the fractured surface of the torsion bar, because we detected only C, Fe, Cr, Si, P, and S, and traces of Al, Zn, Cl, K and Ca.
In the micrographs taken at the fractured surfaces of the bar, specifically in the crack initiation sites, we did not find inclusions or other type of defects on it.

Also we find that the crack detected was of the radial type, and run from the external surface of the torsion bar, to the center of it Figure 3 shows the fractured surface. The chemical composition of the crack zone detecting by EDS, was: Fe (42.55%), Cr (38.85%), C (17.44%), Si (0.46%), P (0.25%), S (0.26%), and Al (0.27%). At higher magnifications we observed cracks oriented at 0° and 45° from the longitudinal axe of the bar, at the external surface of the fractured bar Figure 4 Both cracks initiate at the l surface of the ion-nitrided layer, where the state of stresses is maximum.

According to the previous results, we suppose that the fracture analyzed was of the brittle-type with minimal plastic deformation, and the cracks detected runs from the outer surface of the bar to the center of it, in a radial form. There is not evidence of extrinsic elements in the fractured surface of the bar, the brittle fracture was caused by a torsional overload, presenting cracks oriented at 45° from the longitudinal axe of the bar.

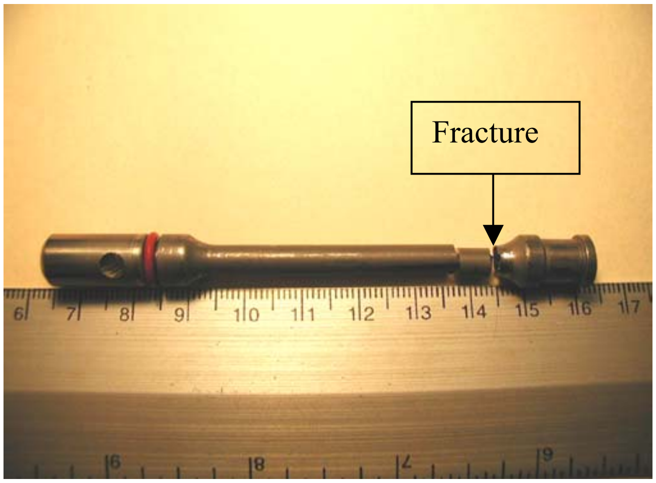

Figure 1.- Location where the torsion bar was fractured.

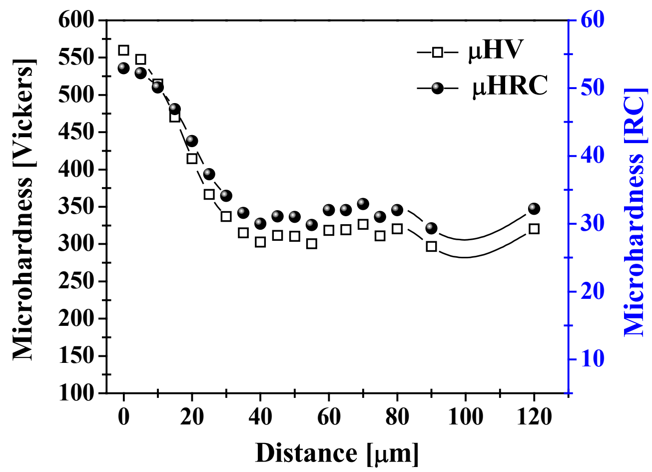

Figure 2.- Microhardness profile of the torsion bar.

Table I.- Are shown the results obtained in the analyzed sample, and the nominal value of the chemical composition of the SAE 4140 steel (in weight %).

Sample	C	Mn	P	S	Si	Cr	Mo
Nominal Value	0.40-0.53	0.75-1.0	0.04 max	0.04 max	0.20-0.35	0.80-1.1	0.15-0.25
Torsion Bar	0.2767	0.9201	0.079	N.D.	0.1411	1.1183	0.1946

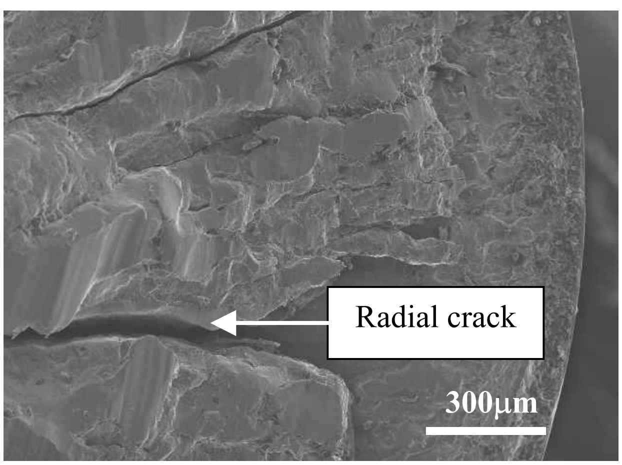

Figure 3.- Fractured surface of the torsion bar, showing a radial crack running from the surface to the center of the bar.

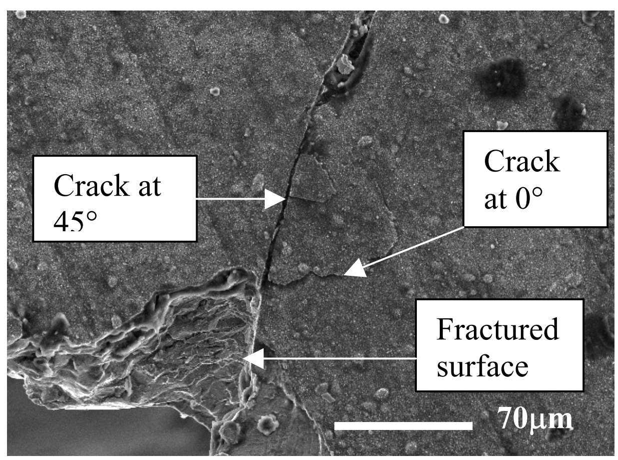

Figure 4.- External surface of the fractured torsion bar.

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