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Technical Note ·

New Intermediate Phase in Burnt Tungsten Steels

by Kehsin Kuo

DIE steel with 1.47 pct C, 0.42 pct Mn, and 8.22 pct W contains Fe_3C and WC in the annealed state and WC embedded in a martensitic matrix in the hardened state (quenched from 800°C). The presence of a large amount of undissolved angular WC carbide particles makes this steel extremely wear-resistant.

However, the WC carbide begins to dissolve in the austenite when the heating temperature is raised above 1000°C, but this solution process is still not complete at 1250°C although partial melting has already taken place at the austenite grain boundaries. At 1325°C, this steel contains austenite and liquid metal but no WC carbide, Fig. 1. On quenching into brine, the liquid metal solidifies into a constituent which etches differently from the austenite-martensite matrix. This constituent appears lighter than the matrix at the 1250°C stage when etched with 2 pct nital but darker in Fig. 1 when etched with Murakami's reagent. Such a constituent has also been found in burnt tungsten high speed steels.

This constituent has been isolated from the matrix by anodic dissolution in a 5 pct HCl electrolyte and was found by the X-ray powder method to be isomorphous with β-manganese, Table I. The agreement in line intensity between these two phases indicates that there is no ordering in this new phase. The calculated cube edge of this phase is 6.395Å, somewhat larger than that of β-manganese (6.30Å).

Besides this phase, the anodic residue also contains free carbon from the matrix and amorphous WO_2, although the X-ray powder pattern of the residue shows the presence of only this phase. This makes it impossible to determine directly the composition of this phase from the residue. Attempts to prepare an alloy containing only this phase have hitherto been fruitless. The following experiments serve to show that this phase can only be obtained by drastic quenching from the liquid state and that its tungsten and carbon contents must be lower than those in the Fe_3W_3C carbide.

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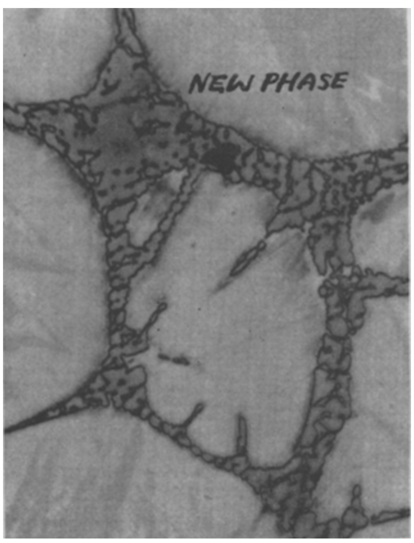

Fig. 1 — Die steel containing 1.47 pct C, 0.42 pct Mn, and 8.22 pct W was heated at 1325°C for 5 min and water quenched. Micrograph shows new phase into which the liquid metal solidified on quenching. Etched with Murakami's reagent. X1200. Area reduced approximately 10 pct for reproduction.

Table I. X-Ray Diffraction Data for the New Phase*

HKL	$\sin^2\theta_{obs.}$	$\sin^2\theta_{calc.}$	$I_{obs.}$†	$I_{\beta\text{-}Mn}$[1]
111	0.0432	0.0436	VW	2.7
210	0.0724	0.0727	W	9.1
211	0.0877	0.0872	VW	1.6
300, 221	0.1307	0.1308	VS	272
310	0.1454	0.1453	S	163
311	0.1599	0.1598	MS	89.6
321	0.2036	0.2034	M	28.8
411, 330	0.2621	0.2615	M	30.5
420	0.2900	0.2906	M	28.6
332	0.3194	0.3197	W	5.1
510, 431	0.3783	0.3778	S	142.2
511, 333	0.3922	0.3923	W	25.3
520, 432	0.4217	0.4214	S	127.2

* CuKα radiation.
† Letters represent: VS, very strong; S, strong; MS, medium strong; M, medium; W, weak; and VW, very weak.

On air cooling from 1325°C, the liquid metal solidifies into a eutectic consisting of austenite and the Fe_3W_3C carbide. The nature of this dark-etching Fe_3W_3C has also been ascertained by X-rays. This eutectic becomes coarser on furnace cooling. The solidification of a specimen cooled for 5 min from 1325° to 1200°C and water quenched is still not complete and the fine eutectic is formed during the quenching. Since this new phase can be replaced by a eutectic of austenite and the Fe_3W_3C carbide, its composition must lie somewhere between the latter two phases. The special features of this phase are: 1—it can only form directly from the liquid state by drastic quenching and 2—it is a ternary phase of iron, tungsten, and carbon.

The β-manganese structure of this phase is also interesting. In the Periodic Table, iron and tungsten lie on opposite sides of manganese; a certain combination of these two elements, in the presence of carbon, may have average properties similar to those of manganese. It has already been established that the χ phase, a ternary one of iron, chromium, and molybdenum, has the α-manganese structure.[2-4] A similar phase has also been found in the ternary system Fe-Cr-W[5] and in the following binary systems: Re-Cb, Re-Ta, Re-Mo, and Re-W.[6]

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