

High-Speed Tool Steel.

NEARLY a quarter of a century has elapsed since a revolution in metal-machining practice was caused by the invention of the so-called high-speed cutting tools by Messrs. Taylor and White, of the Bethlehem Steel Company, U.S.A. This discovery was not an isolated one but was simply the last of a series of connected discoveries leading to this particular result. To a large extent it was empirical and in advance of the metallurgical theories of the time. It gave rise to various researches designed to explain the remarkable properties of these steels. Most of these have thrown some light on the properties in question, but none of them can be said to have provided a complete explanation of all the phenomena observed. The paper, therefore, by Messrs. Marcus A. Grossmann and Edgar C. Bain "On the Nature of High Speed Steel," presented at the autumn meeting of the Iron and Steel Institute, is to be welcomed in that it constitutes a further attempt to place on a scientific foundation a comprehensive theory of the mode of action of these steels.

The paper gives an account of the physical phenomena occurring from the time of casting the homogeneous melt to the production of the hardened tools. The authors emphasise the point that high-speed steel, far from being an alloy having wholly unique properties, merely possesses to an unusually marked degree certain of the tendencies which may already be discerned in other steels and alloys. They have availed themselves of the results of many of the methods of investigation applicable to metals, and the more recently developed conceptions of crystal structure and hardness constitute the foundation upon which the views offered have been built. They consider high-speed tool steel essentially as a binary alloy, of which one constituent is a solid solution of chromium in iron and the other the complex carbide containing tungsten, chromium, vanadium, and carbon. In the unhardened condition the finished bar is regarded as containing on an average 30 per cent. of carbide, but this is not evenly distributed. Rather more than half of it is in the form of fine particles which have been precipitated from solid solution, and, owing to "coring" in the original dendrites, it is never completely removed. There is a concentration gradient from the centres to the edges of the crystals. The remainder of the carbide is in comparatively coarse particles, which represent the plates of carbide in the original eutectic. These are still present in fairly pronounced streaks throughout the piece.

When this aggregate is heated to the hardening temperature (about 1300° C), the solubility of the carbide in the γ iron increases rapidly as the temperature rises, so that at the highest temperature nearly half the total carbide can be dissolved in the matrix. Owing, however, to the sluggishness of diffusion of the alloying elements, especially the tungsten, the amount dissolved never reaches the theoretical figure, and the austenite formed is far from homogeneous.

In addition, small regional concentration gradients are set up round the larger carbide particles, the solution of which is never complete. Incidentally, the particles of excess carbide exercise a very useful function in preventing grain growth at this high temperature, which would otherwise be so rapid as to render the steel useless on account of brittleness.

After being suitably heated, the steel is now quenched, and in this process a portion of the austenite is transformed into martensite, so that freshly quenched high-speed steel shows under a microscope grains consisting of a mixture of austenite and martensite, and distributed through them the excess carbide particles. A light etching reveals the austenite grains and the excess carbide particles, but suitable further etching shows the martensite quite clearly. The relative proportions of martensite and preserved austenite undoubtedly vary from place to place. The regions lower in carbide contain more martensite, while those richer in carbide contain more austenite.

A piece of freshly quenched steel is thus to be conceived as containing regions of austenite-martensite mixtures of widely varying stability. On heating at comparatively low temperatures, softening is considered to take place in the martensitic areas, and this low-alloy martensite resembles carbon steel martensite. The decomposition of this can be traced both in changes of hardness and of shrinkage. On heating to 600° C. the phenomenon of secondary hardness is observed, due to the conversion of the austenite regions to martensite or troostite. This reaction takes place throughout the tool. The total effective hardening may be considered, therefore, as representing the algebraical sum of hardening effect of the transformation of the various austenites and the softening of the various martensites.

The authors do well to emphasise the point that "secondary hardness" is by no means restricted to high-speed steel and that it is not the same as "red hardness." The retention of austenite on quenching is characteristic of many alloy steels on heating to sufficiently high temperatures. When this is reheated at low temperatures, secondary hardening sets in owing to the formation of minute crystals of α iron and the precipitation of fine carbide particles. Indeed, it is likely that if the tungsten of high-speed steel were omitted altogether, the remaining elements alone would be sufficient to cause the retention of the austenite and the appearance of secondary hardening. The special usefulness of high-speed steel, however, is due to the extent to which it exhibits the property of red hardness, and it is here that tungsten plays its rôle. The large, heavy, immobile atoms of this metal act by supporting the structure at these slightly elevated temperatures and prevent the diffusion and agglomeration of the carbide particles, which would otherwise take place with consequent softening.

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Isotopes and Spectra.

THE question of the spectroscopic evidence of the existence of isotopes, which has already been brought forward in our correspondence columns (see NATURE, March 29, May 31, August 16) is dealt with at length in two papers published in the *Japanese Journal of Physics*, vol. ii., Nos. 6-10,—the first by Nagaoka, Sugiura, and Mishima, on "The Fine Structure of Mercury Lines and the Isotopes," and the second by Nagaoka and Sugiura, on "Spectroscopic Evidence of Isotopy."

The assumption is made that the mercury atom consists of a central mass with a proton quasi-elastically connected with it. Vibrations of this system are conceived to give rise to spectrum lines. Thus, several mercury lines are known to have large numbers of closely adjacent satellites. It is thought that these are due to coupled vibrations of the nucleus owing to the stimulus given by the principal line which seems to be excited by the change of electron configuration according to Bohr's scheme. A number of facts are