



## HEAT TREATMENT OF TOOL STEEL FOR INSTRUMENT MAKERS

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**I**n the interest of accuracy the unintentional errors concerning the description of metallurgical changes occurring during the heat treatment of tool steel described in Ray Doer's paper (JAAMIM XV(4) December 1996, 26) cannot be left uncorrected. It appears to be generally true that plain carbon steels seem to give the best edge for wood cutting hand tools. The procedures described for hardening and heat treatment generally, together with the precautions necessary are generally correct. However, the explanations given are often in error and the constituents wrongly named. The problem arises through inaccurate teaching in "Trade classes" where process and final result are often more relevant than understanding.

For the present purpose a brief explanation of the metallographic changes taking place during the hardening of plain carbon tool steel might be helpful. While the "background" structure in the steel as it undergoes the various changes during hardening consists of a mass of crystals, each differently oriented, it is more correct to speak of them as grains because of their irregular shape due to impingement. The usual mental picture of crystals is one of regular mirror-like facets as seen in geological exhibits.

The changes that take place when tool steel is hardened depend on the fact that iron has two different crystal forms with greatly differing abilities to hold carbon dissolved in (solid) solution, at high and low temperatures. Both of these crystal types exist as close assemblies of grains. On heating or cooling slowly through a critical temperature, at

about 730°C, the crystal structure changes and one set of grains is replaced by a new set as the (phase) change takes place.

On heating, the grain size after the change is small but if the temperature is taken higher some grains grow absorbing others and the grain size is enlarged. With longer times held at these high temperatures the grain size increases. On cooling this size is preserved until on passing through the "critical temperature" new grains of the crystal structure stable at low temperatures form replacing those previously there. The new grains will be smaller than those they replace but not as small as they would be had the higher temperature grain size been small. One limits heating above the critical temperature to about 100°C when hardening.

Hammering (forging) above the critical temperature (and one can go well above to make it easier) results in a small grain size if the hammering is continued while cooling to just above the critical temperature. The working causes continuous recrystallisation so that grain growth does not occur at the higher temperatures unless the hammering stops.

The crystal structure stable at high temperatures can dissolve most of the carbon present in high carbon tool steels say about 50°C above the critical temperature. If the steel is cooled slowly, the carbon comes out of solution because the stable low temperature crystal structure can hold almost no carbon in solution. It does not come out of solution as carbon but combined with some of the iron as a compound called cementite. At ordinary rates of cooling the local dynamics of the change result in the microstructure called pearlite which is a fine "finger print" like mixture of iron with almost no carbon in solution and cementite which has all the carbon.

On very fast cooling, as in water or brine quenching, from the high temperature stable condition with all the carbon in solid solution, there is no time for the relatively slow separation of the cementite to form pearlite. Instead, because the change in crystal structure of the iron cannot be prevented, the carbon is forced to remain in solution in the low temperature stable crystal structure. This causes a great increase in hardness due to the distortion produced. The enormous stresses created now make the steel brittle and if left in this state cracking can occur (or the piece can shatter).