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Effect of residual elements on the machinability of leaded free machining steels

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The machinability of a material can be defined in terms of the wear rate of the cutting tool used to machine the material. The lower the tool wear rate or the greater the tool life the better the machinability. The wear processes of cutting tools are complicated, but recent work has shown that cutting tool wear rates during machining can be directly related to tool material wear rates when rubbing in a modified crossed cylinder wear experiment (Mills & Akhtar 1975). The wear of cutting tools can be simulated by simple experiments. Here I present results on the effect of total residual levels in leaded low carbon free machining steels on the tool life of M2 high speed steel. The results will be discussed in terms of a simple wear model.

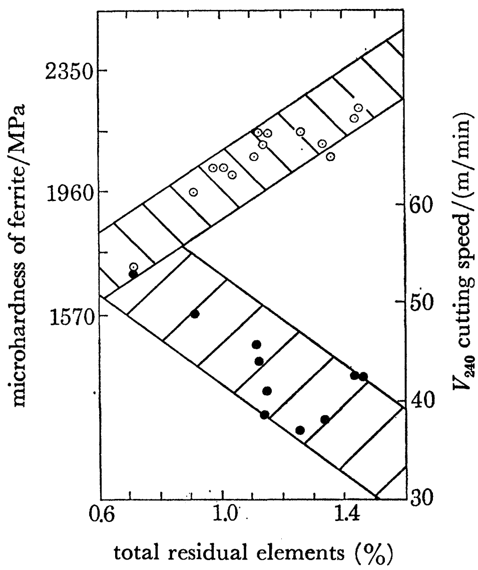

FIGURE 1. Effect of total % residual elements on ferrite hardness (⊙) and V_{240} cutting speed (●).

Figure 1 shows the V_{240} cutting speed (the speed to give a tool life of 240 min) plotted against the total level of residual elements for 14 steels. Also shown is the microhardness of the ferrite against total residual element level. It is clear from this figure that tool wear rate and ferrite microhardness increase with increase in the total level of residual elements. In the present steels the nitrogen and silicon contents are in the ranges 0.007 ± 0.003 % and 0.01–0.02 % respectively. The remaining residual elements, which were summed to obtain the total residual element level, are P (0.04–0.085 %), Cr (0.05–0.13 %), Ni (0.03–0.2 %), Mo (0.01–0.06 %), Cu (0.1–0.34 %) and excess Mn (0.42–0.74 %). All steels were given the same hot working and annealing treatment so that differences in ferrite hardness could not arise from this cause. The increase in microhardness of the ferrite with increasing residual element level is considered to be caused by solid solution hardening. Studies on the solid solution strengthening of Fe have shown that P, Si, Mn, Ni and Mo have a pronounced strengthening effect.

To explain the present results it is necessary to consider the way in which material properties influence the wear rate. The wear of the tool can be considered to occur mainly by an adhesive wear mechanism with perhaps a small contribution due to abrasion. Following Archard (1953), the wear rate, W can be written as $W = KL/H$, where K is a measure of the probability of an adhesion event leading to the formation of a wear particle, L is the load and H is the hardness of the softer material, in this case the free machining steel. On first inspection the relation suggests that the wear rate of the tool should decrease with increase in hardness of the workpiece. However, the normal load on the rubbing surfaces of the tool during machining increases with increase in yield strength (and hence hardness) of the workpiece. This latter influence must clearly be more important than that arising from hardness differences. It has been observed empirically (McLintock & Argon 1966) that the wear rate of a harder material (hardness H_h) rubbing against a softer material (hardness H_s) is given by an equation of the form $(H_s/H_h)^2$.

The present results give further support to the view that the wear rate is proportional to some power of the hardness ratio of the workpiece and tool material.

The present work has shown that a significant correlation exists between the wear rate of M2 high speed steel and the total level of residual elements in leaded low carbon free machining steels. The detailed way in which residuals affect mechanical properties in these commercial alloys is not well understood because of interactions with interstitial carbon and nitrogen. A previous Auger electron spectroscopy study of the swarf from the present machining experiments (Stoddart *et al.* 1975) showed that the surfaces were covered with a monolayer of lead which acted as an interfacial lubricant. It is clear therefore that the level of residual elements does not play a direct role on the interfacial conditions between the workpiece and tool but rather influences the mechanical properties of the workpiece during chip formation.

References (Mills)

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