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The role of residuals in engineering steels*

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The very gradual rise in the residuals content of scrap (see papers by Westbrook and Hartley *et al.*, this symposium) is reflected in the levels of residuals found in engineering steels. A superficial survey of national standards and a few 'in-house' specifications shows considerable variation in the limits imposed on residual contents. The normal levels in U.K. steels are so high that for some specifications purer and more expensive raw materials must be used: this is reflected in the increased price of low-residual steels (figure 1).

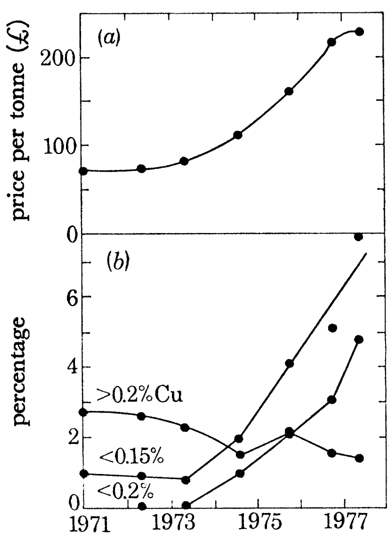

FIGURE 1. (*a*) Steel price for 080A35, En8A black bar (cold heading quality). (*b*) Extra cost (as percentage of price) for control of copper content.

One way of counteracting this trend is to restrict the demand for 'low residual' steels to applications where they are essential. The most serious detrimental effect is hot cracking and the incidence of surface defects. The critical contents of Cu and Sn depend on the process route and final application. In Melford's (1972) formula

$$Cu + 6\ Sn = 9/E,$$

E is an enrichment factor depending on heating cycles and furnace atmosphere. A superficial literature review suggests that *E* can vary between 10 and 26. Steel users should specify residual levels in line with the 'enrichment factor' applicable to their processing route.

Residuals may raise the flow stress at room temperature and thus increase tool loads and tool wear in cold working. Tool load measurements have shown a close correlation with hardness (Cooksey 1968; Pickering & Gladman 1963; Halley 1957; Rhinebolt & Harris 1951; G. T. Brown,

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personal communication) indicate that current melt-out levels correspond to a hardness increase of about 20 V.p.n. or an increase of 80 MPa in ultimate tensile stress. This justifies the demand for low residuals in material subjected to severe forming operations. However, steel users should give serious thought to the actual forming operation before specifying low residuals.

The effect of residuals on hardenability is beneficial. The engineering industry in the U.K. derives considerable benefit from the ability to obtain good mechanical properties by oil quenching what are officially classed as alloy steels. For example, calculated Jominy curves (J. Houseman, personal communication) suggest similar heat treatment responses for a low-alloy steel with low residuals (523A14 at £288 per tonne) and carbon steel (040A15 at £228 per tonne) with higher residuals.

To summarize, a number of steps can be taken over the coming years to cope with the rise in residuals: (1) contain the tonnage of low residual steels ordered; (2) restrict the use of low residual steels to special applications where they are really essential; (3) determine the 'enrichment factor' for particular processing routes and adjust specifications accordingly; (4) develop processing routes with a low 'enrichment factor'; (5) take full advantage of the higher hardenability bonus.

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