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Technical Note

Heat Treatment of Titanium Generalized in Terms of Beta Prime

by Leonard D. Jaffe

THE data recently published[1-9] on heat treatment of titanium alloys have not been readily systematized into an overall picture. When the β titanium phase transforms isothermally at low temperatures, the hardness follows a typical age-hardening pattern, going through a peak as schematized by the "hardness" vs "time of isothermal transformation" coordinates of Fig. 1. As the temperature is raised, the peak will decrease in height and occur at shorter times; slowing must however take place as the β transus is approached.

The brittle microconstituent in the region of peak hardness has been termed β'. Its structure is still undetermined but it is clearly a transition stage from soft β to the $\beta + \alpha$ that is found at the right of the peak.

On continuous cooling, high cooling rates correspond to short times on Fig. 1; abscissa labeling has been added accordingly. Extremely rapid cooling will retain soft β; very slow cooling will precipitate soft α; intermediate rates give hard β'. Increasing distance from the water-quenched end of a Jominy hardenability bar corresponds to slower cooling (right on Fig. 1), but the range of cooling rates covered by a Jominy bar is only a small portion of that shown in the figure.

The β-stabilizing alloying elements retard the transformation process, moving the material to the left on Fig. 1. A lean alloy is harder water-quenched (β') than air-cooled ($\beta + \alpha$); a rich alloy is harder air-cooled (β') than water-quenched (β). Examples of the position of various compositions with respect to the curve, based on limited data in the literature, are given at the top of the figure.

Oxygen and carbon accelerate the transformation process, moving the material to the right on Fig. 1.

If an alloy quenched quickly enough to retain soft β is reheated below the β transus (tempered), it ages, going through a hardness maximum as time increases (moving right on Fig. 1). Material which after cooling from the β range lies on or right of the hardness peak, will move still further right on tempering, and so soften.

Since the rate of the tempering (aging) reaction increases with temperature, the figure also may be used to represent the variation in properties with tempering temperature, at short tempering times.

The simple picture given here neglects martensite transformation, as well as differences between decomposition products of β formed by direct isothermal transformation and those formed by quenching and tempering. It may nevertheless be of use as a guide for practical heat treatment and for further research.

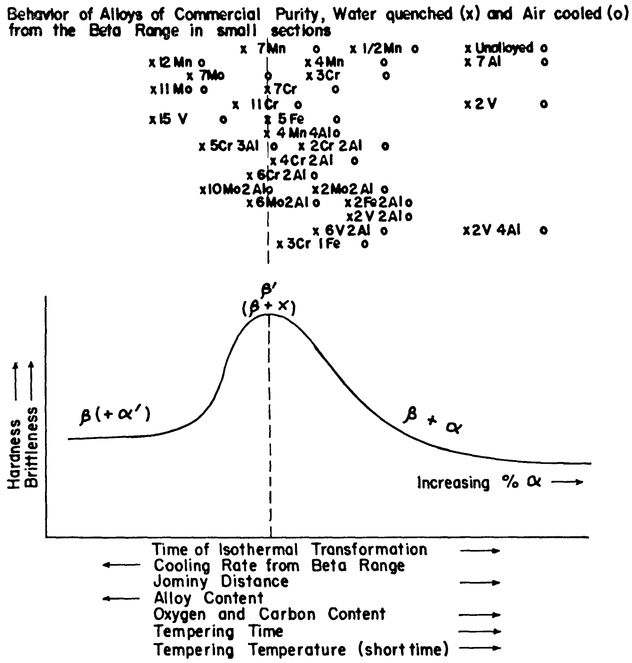

Fig. 1—Effect of variables upon properties of alloys first held in β range, schematic.

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