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Progress Report

HOT-HARDNESS OF MnSe

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ABSTRACT

The hardness of manganese selenide (MnSe) was determined up to 900°C (1650°F). Although harder than MnSe at ambient temperatures, iron is softer than MnSe at high temperatures. This accounts for the globular shape of MnSe inclusions in free-machining steels. This is in contrast with MnS inclusions which deform more than the surrounding metal matrix. It represents a favorable feature for the use of selenium in free-machining steels.

HOT HARDNESS OF MANGANESE SELENIDE (MnSe)

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Previous work by Chao, et al.[1] provided a comparison between the hot-hardness values of MnS inclusions and unalloyed ferrite in steel. Those data covered the temperature range of 20° to 960°C (Figure 1a). The data were interesting because the relative hardnesses of the two phases have a significant effect upon inclusion deformation and fracture.[2,3,4] Subsequent work by Riewald[5] showed that the hardness of MnSe was less temperature sensitive than MnS in the -70° to 135°C range. Although softer than MnS at ambient temperatures (Figure 1b), an extrapolation of Riewald's data indicated to Aborn[6] that MnSe would be harder than MnS at steel-rolling temperatures. He proposed this as an explanation for the more globular shape of selenide inclusions than of sulfide inclusions in commercial steels. While plausible, the authors of this note felt that the extrapolation values should be replaced with experimental data.

Hardness data were rerun for ferrite (Ferrovac-E) and manganous sulfide (MnS) from 20° to 800°C. Data were also obtained for manganous selenide (MnSe) from 20° to 900°C. The present hot hardness testing apparatus utilized the same furnace as Chao[1] used. It was evacuated and backfilled with purified argon to restrict sample oxidation. Titanium "getters" were used in the furnace to scavenge any oxygen leakage. Improvements were made in the load application. Specifically the Vickers machine was replaced by a dead-weight load counter balance over ball-bearing pulleys. Depending on the temperature, loads were chosen between 1200 gms and 200 gms with sensitivities to less than 1%. The hardness was calculated[7] according to

$$DPH = \frac{1.85\ L}{d^2}$$

where L is the load in kilograms, and d is the average length of the diagonal of the impression in millimeters.

The results are shown in Figure 2. In general the data corroborated the previous work by Chao, et al.[1]. There is a slight modification of the high temperature hardness of iron. The current data are preferred in view of the insensitivity of the Vickers machine used by Chao to the light loads required for the higher temperatures. While there is some evidence that larger loads reduce the calculated hardness values a few percent, other unidentified variables are equally if not more important.

Figure 3 shows the lines of central tendency for the hardnesses of ferrite, MnS and MnSe from the present data, plus the $\alpha \rightarrow \gamma$ hardness shift detected by Chao. The crossover of the MnS and MnSe curves predicted by Aborn[6] was observed. Thus his hypothesis still remains plausible, - specifically that the globular selenide and the elongated sulfide inclusions shapes are a consequence of the relative hardnesses of these two phases compared to the hardness of the iron phase. Caution should be used, however, in applying this conclusion to most steels since selenium-bearing steels usually contain high chromium contents. Kiessling[8] has shown that chromium affects the hardness of the selenide phase, and of course, chromium will harden the metal phases by solid solution.

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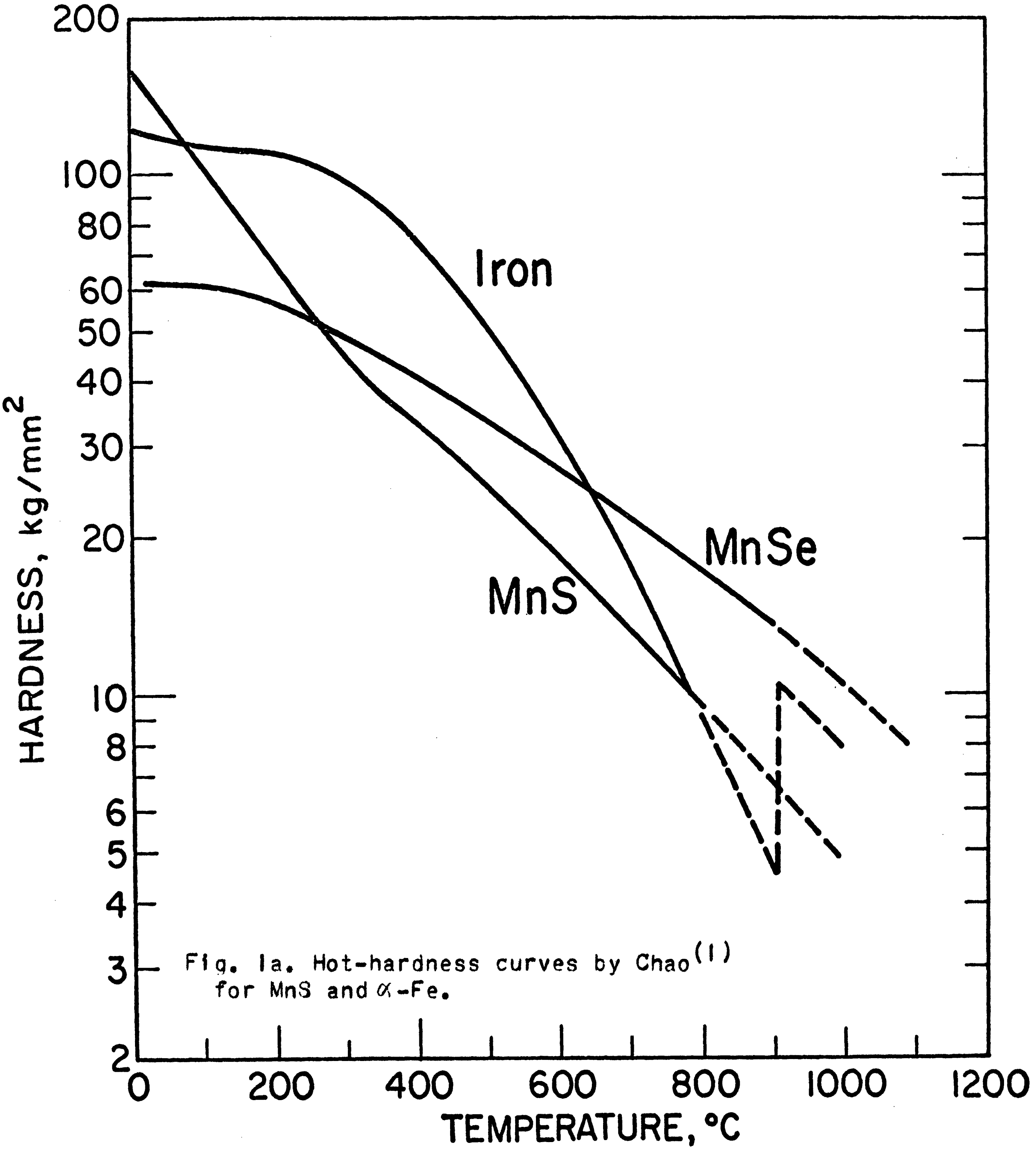

Fig. 1a. Hot-hardness curves by Chao[1] for MnS and α-Fe.

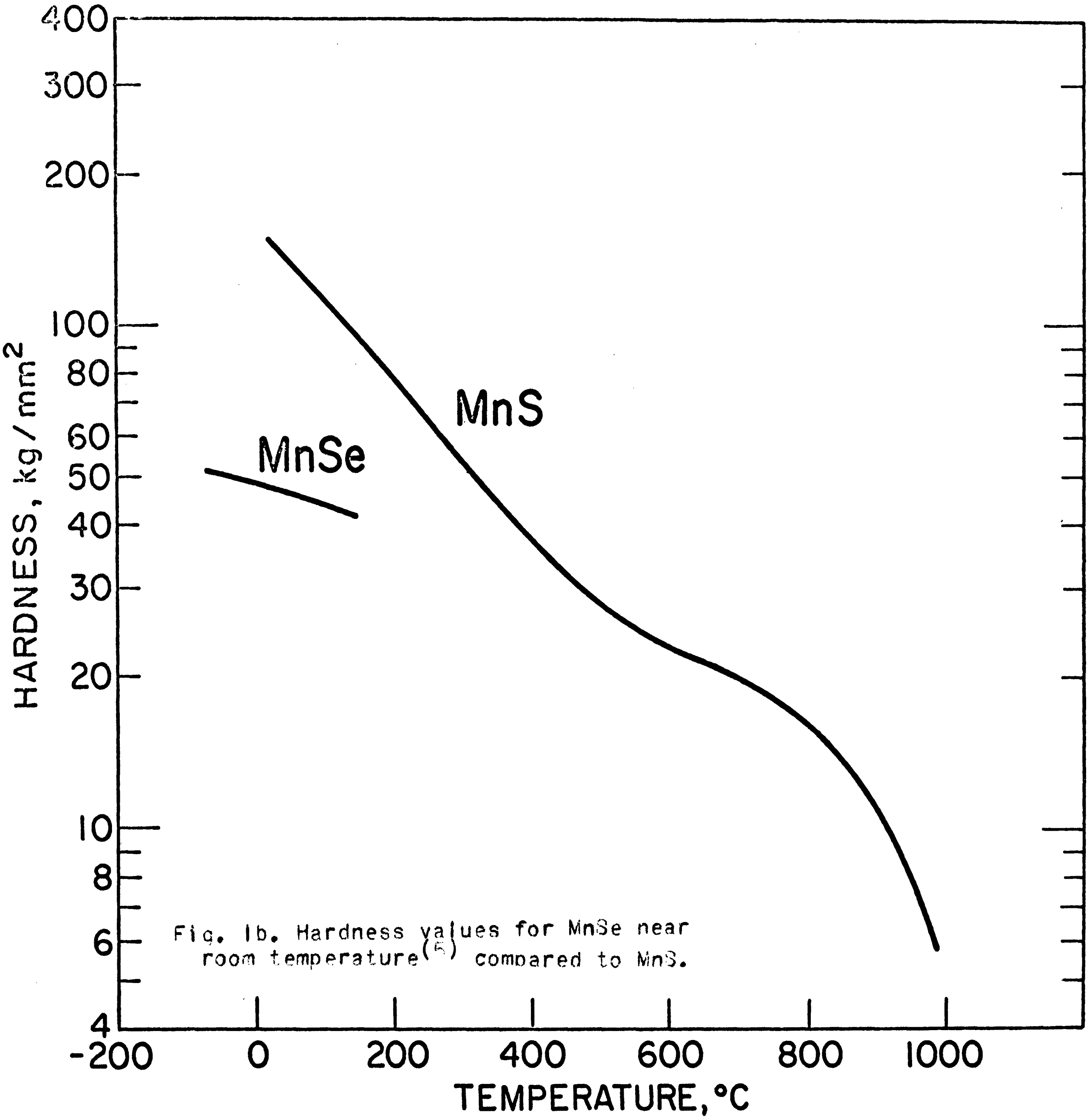

Fig. 1b. Hardness values for MnSe near room temperature[5] compared to MnS.

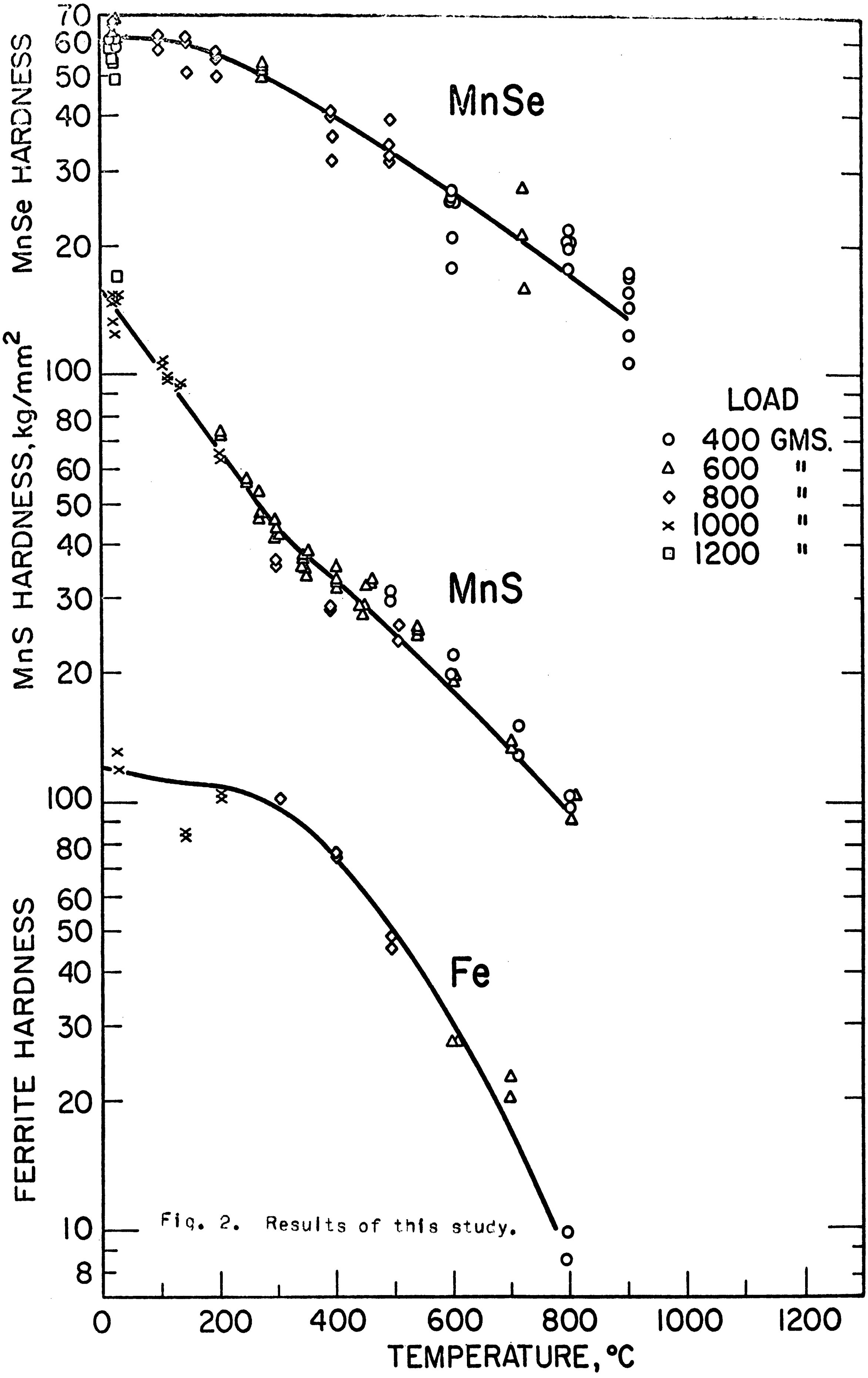

Fig. 2. Results of this study.

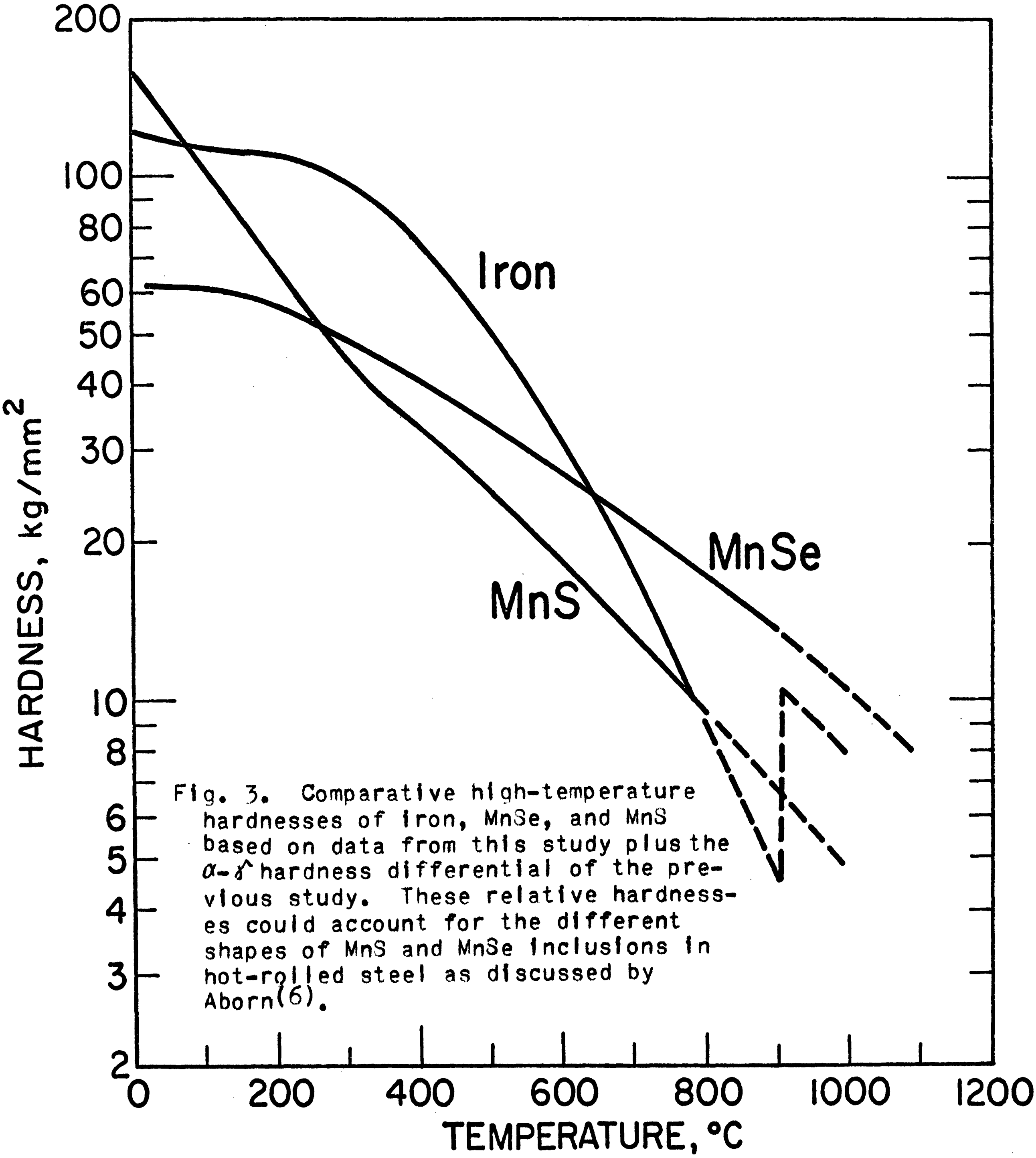

Fig. 3. Comparative high-temperature hardnesses of iron, MnSe, and MnS based on data from this study plus the α-γ hardness differential of the previous study. These relative hardnesses could account for the different shapes of MnS and MnSe inclusions in hot-rolled steel as discussed by Aborn[6].