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The Structure Sensitivity of the Effects of Pressure upon the Ductility of Fe – C Materials

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ABSTRACT. The effects of a superposed hydrostatic pressure of up to 24 kbars upon the ductility of a series of annealed and spheroidized Fe – C alloys ranging in carbon content from 0.004 to 1.1% are investigated. The effects of pressure upon ductility are found to be highly structure sensitive in terms of the presence, amount and distribution of the cementite. In the absence of cementite, or when the cementite is in spherical form in a ferrite matrix, the relationship between pressure and true strain to fracture is linear, with the slope decreasing with carbon content. When the cementite is in platelet form (pearlite), or in a continuous network along prior austenitic grain boundaries, the relationship between pressure and true strain to fracture is nonlinear, and varies considerably with carbon content and structure.

The relationship between pressure effects upon ductility and atmospheric pressure mechanical properties is examined. It is found that no single linear relationship or proportionality between pressure coefficient of ductility and strain hardening coefficient exists for the range of Fe – C materials investigated.

The effects of pressure upon macroscopic fracture appearance is described and discussed. The absence of a linear or continuous relationship between fibrous to total fracture area and pressure is demonstrated.

THE EFFECTS of high superposed hydrostatic pressure upon the mechanical properties, particularly ductility, of metals has been the subject of extensive investigation. Although the effects of pressure upon the ductility of numerous metals have been well documented, little information has been generated with regard to the mechanism or mechanisms responsible for the observed effects, or to why the pressure-ductility behavior varies so widely for different materials. Summarized herein are the results of the first phase of an investigation aimed at gaining a fundamental understanding of how and why pressure affects the ductility of metals. Considered particularly is the question of the structure sensitivity of the phenomenon in terms of the presence, amount, shape and distribution of a brittle second phase in a ductile matrix.

The flow characteristics and ductility of a variety of metals exposed to superposed pressures to in excess of 20 kbars have been measured by Bridgman (1–3). Although he examined a variety of materials, a significant portion of his work dealt with steels. His observations and conclusions concerning the effects of hydrostatic pressure on the mechanical properties, particularly of steels, were quite extensive. Those considered most pertinent to the subject of this current investigation will now be summarized.

Bridgman observed that the mechanical property most sensitive to pressure is ductility. To a first approximation, he found that the form of the true stress-true strain curve is unaffected by pressure; the principal effect of pressure being to extend that portion beyond maximum load (onset of necking). For the case of steels he found that the strain-hardening rate was effectively independent of pressure and remained nearly linear.

Although the rate of increase of ductility in terms of the true strain to fracture ($\ln A_0/A_f$) is a function of the material, Bridgman concluded that it is, in all cases, a linear function of the form

$$P = \alpha + \beta\epsilon_f \qquad \text{Eq 1}$$

where ϵ_f is the strain to fracture at some pressure P; β the pressure coefficient of ductility which is a function of the material; and α a material constant. He observed that, even in the case of steels, β varied widely between materials.

For steels, Bridgman proposed that the true stress-

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