Deformation and fracture of porous sintered ferrous alloys

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ABSTRACT. The mechanical properties of porous materials produced by Powder Metallurgy (PM) depend on density. The residual porosity causes strain localization and reduces the load bearing fraction and this results in a decrease of both strength and ductility with respect to the corresponding pore free materials. Nevertheless PM steels are increasingly used for the production of structural parts, since the effect of porosity on mechanical properties is well established. On the other side, high density processes and low alloy ferrous powders have been developed in the last years, which lead to mechanical properties comparable to those of many structural steels.

Porosity can be considered as a "controlled defect" well reproducible in the microstructure of the material. For a deep analysis of its influence on properties, the combined effect of pores and of the microstructural constituents (which sometimes are peculiar in PM steels) has to be taken into account. This presentation is an overview of the tensile behavior of PM steels. By considering the interaction between pores and microstructure, the peculiarity of the deformation and fracture behavior is discussed.

The elastic deformation shows an early deviation from linearity due to localized yielding, which is enhanced by a soft microstructure and an irregular porosity. After a few loading cycles, the elastic field stabilizes over a linear dependence and a method for the determination of the elastic modulus is proposed.

Yielding behavior is mostly influenced by the microstructural constituents. In the particular case of inhomogeneous microstructure containing Ni-rich areas (which are typical of most structural steels) a continuous yielding over a broad stress range is observed. Such a microstructure results in a multistage plastic field, as well, which does not follow the classical Hollomon model. Contrarily, carbon steels display the usual yielding and strain hardening behavior.

Fracture is strongly affected by the interaction between microstructure and porosity. Depending on the microhardness and on the pore amount and morphology, fracture can be either localized in the neck regions or spread over the bulk. This influences mostly ductility. Particular attention is paid to the case of hardened microstructures. In this case, ductility may be strongly depressed by porosity and it can be demonstrated that, over a given microhardness, pores act as pre-existing cracks. This microhardness threshold depends on the porosity.

In conclusion, the Weibull analysis is used to discuss the mechanical reliability of porous steels in comparison to alternative structural materials.

KEYWORDS. Mechanical properties; Density; Sintered steels.