EFFECTS OF OXIDATION ON THE MECHANICAL PROPERTIES OF CARBON/GRAPHITE*

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The mechanical properties of carbon/graphite are degraded by oxidation via mass removal and microstructural deterioration. Karcher et al. [1] showed that a 1% mass loss reduced the tensile strength by 15% and increased the pore density and the average pore diameter.

We investigated the mechanical properties of polycrystalline graphite (ATJS) and vitreous carbon [2] as functions of temperature, oxygen flow, and oxidation time. The reductions in ultimate tensile strength as a function of temperature are shown in Fig. 1. The effects of oxygen mass flow are shown in Fig. 2. Oxidation effects below threshold temperatures (~ 850 K for ATJS and ~ 1050 K for vitreous carbon) were within experimental error. These threshold temperatures for oxidation agree with those obtained from thermogravimetric analysis in air (~ 900 K for ATJS and ~ 1000 K for vitreous carbon). [3] The higher threshold temperature for vitreous carbon corroborates its higher oxidation resistance. [2, 4] Consequently, the strength reduction near oxidation threshold is caused by loss of mass.

At higher temperatures the reduction in strength of graphite/vitreous carbon is not compatible with mass loss alone (< 30% mass loss reduced tensile strength by 60% for ATJS and 76% for vitreous carbon). Optical and scanning electron microscopy show large-scale erosion; thus, pore enlargement and graphite component debonding are responsible for the enhanced loss in ultimate tensile strength at high temperatures. Presently, the relative contributions of mass loss and microstructure deterioration to changes in strength are undefined. However, the temperature at which the ultimate tensile strength starts to decline rapidly (~ 950 K for ATJS and ~ 1200 K for vitreous carbon) can serve as an indicator of the increased contribution from microstructure deterioration.

The oxidation effects on microstructure were investigated by scanning electron microscopy. The unoxidized ATJS graphite has a relatively smooth surface caused by the fine grain binder. The oxidized ATJS shows a rough surface with large protruding filler particles (~ 50 μm) having the appearance of being weakly bonded; the individual pores become large holes (~ 25 μm) interconnected with broad channels ~ 5 μm wide.

This difference of surface structure between the oxidized and unoxidized ATJS supports the hypothesis that the binder oxidizes at a faster rate than the filler and that during oxidation a partially oxidized filler particle can be removed from the surface as a particulate. [5]

The unoxidized vitreous carbon has an extremely smooth surface; grain structure and pore size appear as small dark pits at 1600X. The initial effects of oxidation cause a rapid increase in pore density as well as pore size. When oxidation becomes significant, the surface is filled with large circular depressions plus distinguishable grains (~ 2 μm). The high homogeneity in vitreous carbon produces a highly uniform oxidation effect on

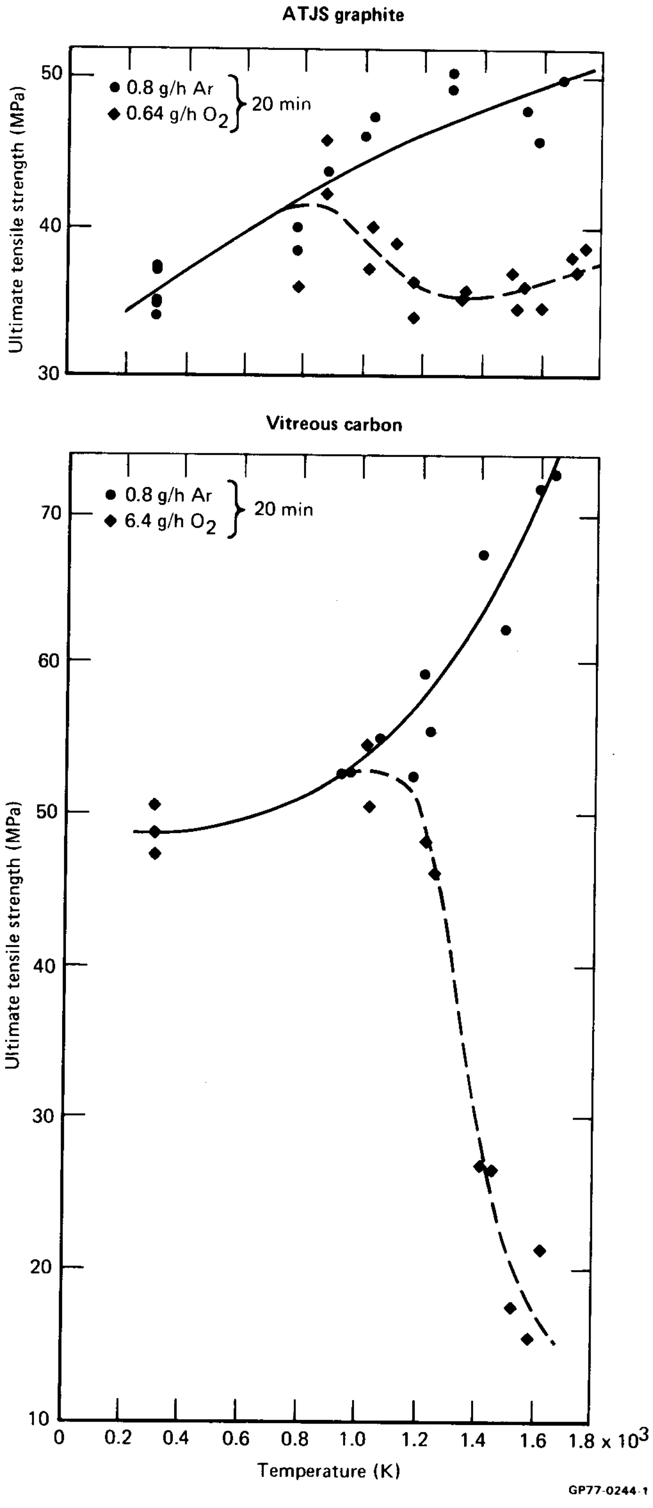

Fig. 1 Oxidation effects on ultimate tensile strength

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the surface with little evidence for particulate removal. Fine grain structures and homogeneous erosion provide two major reasons for the high oxidation resistance of vitreous carbon.[4]

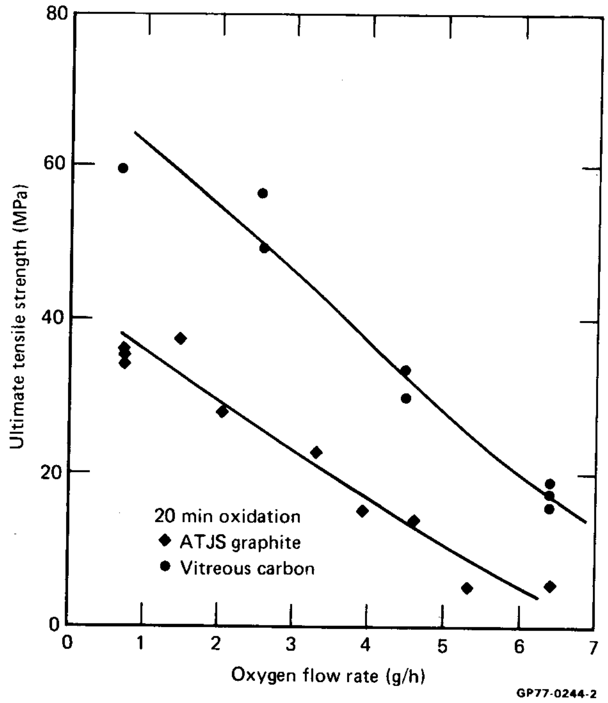

Fig. 2 Oxygen flow rate effects on ultimate tensile strength

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