impacting particle to be estimated from bending tests. It appears premature at the present time to attempt to predict volume removal in erosion from bending data alone. However, the analysis enables the relative erosion resistance of different materials to be assessed.

Acknowledgments

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DISCUSSION

I. J. Stewart[3]

Engineering knowledge of brittle materials and the controlled shaping of their surfaces is sparse. In particular, this field suffers from a dearth of substantial analytical investigations. Too few have apparently been willing to undertake the elemental poking and probing here that is required to establish a sound foundation of knowledge in any field. For doing just this, the authors are to be highly commended.

Such attempts to establish analytical-empirical agreement must be, at the present state of knowledge, relatively primative; many erroneous paths will be followed before the right one begins to appear. Both investigators and readers should be aware of the special implications of this. On the one hand, for example, commercially significant answers should not be expected by the latter group too soon; on the other hand, much care should be exercised by the former to avoid leading oneself and others into dead-end paths. Specifically, a somewhat broader-than-usual degree of experimental verification of any analytical hypothesis is necessary; a high degree of reporting candor is also most helpful.

Clearly, much thought and work have been expended on the analytical portion of this investigation, and it is most interesting. Aside from any question of validity, the thinking underlying it represents a valuable contribution toward advancing the state of knowledge of brittle materials.

Of course, the question to be asked by most practicing engineers does involve the validity of the analysis. This can only be answered by assessment of how well it corresponds to empirical results. Unfortunately, the authors have neglected to supply enough data to allow the reader to make an independent evaluation of the breadth of this correspondence. A critical question here is the degree of linearity, on log-log coordinates, between wear and the parameters particle size and particle velocity. The authors have not included experimental data, similar to those in Figs. 5 and 6 for glass and SiC grit, for the other four test materials when eroded by SiC, nor for any of the five test materials when impacted by steel shot. Nor does the summary of slopes in Table 2 impart any information as to the data scatter encountered here. Hence the reader is allowed to evaluate the hypothesized linearity for only two cases out of the sixteen studied. Nevertheless, the data reported for the combination glass-SiC would still constitute valuable, albeit limited, information. Un-

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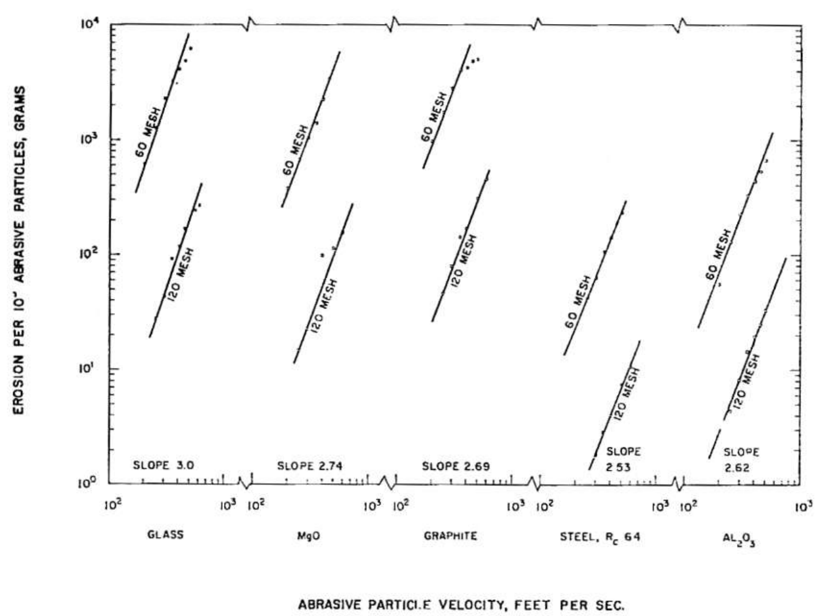

Fig. 8 Weight removal as a function of particle velocity for several brittle materials eroded by angular SiC grit of 60 and 120 mesh size and at a 90 deg impact angle

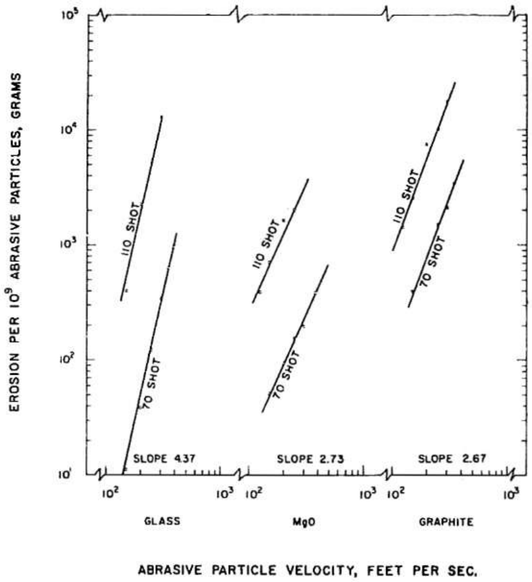

Fig. 9 Weight removal as a function of particle velocity for several brittle materials eroded by hardened spherical steel shot of No. 70 and 110 size and at a 90 deg impact angle

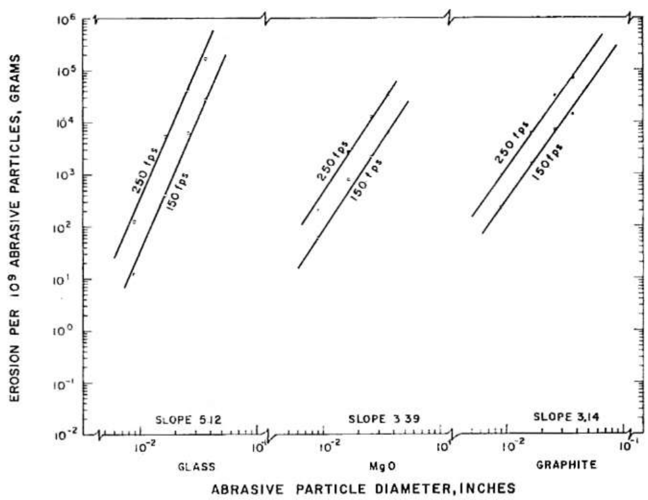

Fig. 11 Weight removal as a function of particle diameter for several brittle materials eroded by hardened spherical steel shot at 250 and 150 fps impact velocity and at a 90 deg impact angle

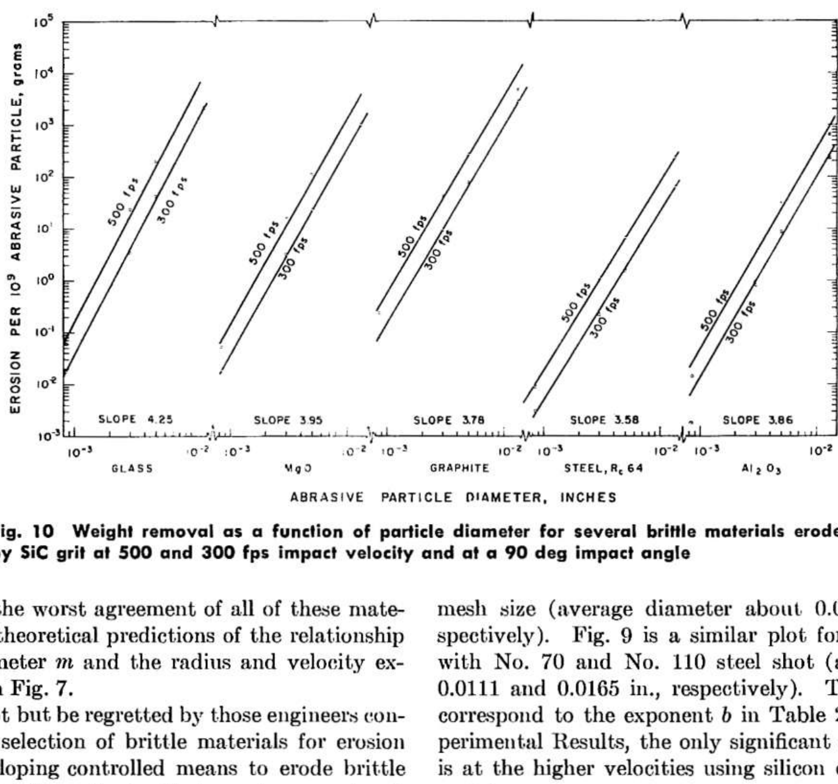

Fig. 10 Weight removal as a function of particle diameter for several brittle materials eroded by SiC grit at 500 and 300 fps impact velocity and at a 90 deg impact angle

happily, glass exhibits the worst agreement of all of these materials with the authors' theoretical predictions of the relationship between the flow parameter m and the radius and velocity exponents, as is evident in Fig. 7.

Such omissions cannot but be regretted by those engineers concerned with either the selection of brittle materials for erosion resistance, or with developing controlled means to erode brittle surfaces. It is hoped that the authors will choose to present such data to the technical community at a later time, as well as to expand upon the very interesting work begun here and in the companion paper (ASME Paper No. 65—WA/Prod-7, this issue, pp. 387–392).

Authors' Closure

The authors sympathize with Mr. Stewart's request for additional experimental data. Too often the space requirements for technical papers limit the amount of data which can be presented. Since writing the paper we have been able to condense some of the figures which show the data and we are including these as Figs. 8, 9, 10, and 11.

Fig. 8 is a plot of erosion wear in grams per 10^9 abrasive particles, for the five materials tested, versus the particle velocity. The abrasive particles were silicon carbide grit of 60 and 120 mesh size (average diameter about 0.0132 and 0.005 in., respectively). Fig. 9 is a similar plot for three materials tested with No. 70 and No. 110 steel shot (average diameter about 0.0111 and 0.0165 in., respectively). The slopes of these lines correspond to the exponent b in Table 2. As noted in the Experimental Results, the only significant deviation from linearity is at the higher velocities using silicon carbide grit on graphite and glass.

Figs. 10 and 11 show erosion as a function of particle diameter; the particle velocity being held constant at the values indicated. The eroding particles were again silicon carbide grit (Fig. 10) and steel shot (Fig. 11). The slopes of these lines correspond to the exponents a' and a in Table 2. Table 1 under the Experimental Results section of the paper summarizes the range of the particle sizes and velocities used in all these tests. This latter group of data is seen to fall in fairly straight lines for all the materials tested.

As Mr. Stewart points out, glass exhibits the worst agreement of the materials tested. Further work has shown that including the constant σ_u in the analysis considerably improves the prediction for the erosion of glass but has relatively little effect on the prediction for other materials. This work will be reported at a later date.