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## Abstract

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## HYDROMECHANICS


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# RESISTANCE TO CAVITATION EROSION OF POLYMER PLASTICS

*(Presented by Academician P. Ya. Kochina, 26 I 1961)*

A clear representation of the erosion resistance of certain metals is given by the scale of relative resistance (Table 1), compiled

**Table 1**

| Material | Brinell hardness | Erosion resistance | Material | Brinell hardness | Erosion resistance |
|---|---|---|---|---|---|
| Rolled aluminum alloy | 48 | 1 | Chromium-nickel steel 18—8, welded by electric welding | 218 | 280 |
| Cast iron | 171 | 11 | The same, rolled | 405 | 5000 |
| Wrought iron | 105 | 36 | Alloy Co65, Cr30, Va4 | 486 | 8000 |
| Bronze | 153 | 44 | | | |
| Bronze | 165 | 163 | | | |
| Fluoroplastic | 3—12 | | | | |

by us from data of tests of specimens by the method of flow cavitation ([1]). The resistance to erosion is expressed as the ratio of the weight loss due to erosion of a specimen of the weakest material (aluminum) to the weight loss of a specimen of the given material. Other scales of relative resistance to cavitation erosion of metals are also known, but such data are entirely lacking for polymer plastics. Meanwhile, polymers possess physical and mechanical properties that differ from those of metals, namely properties that can have a great influence on erosion resistance: fine-grainedness and homogeneity of structure, high impact toughness with low mechanical strength, etc. (Table 2).

**Table 2**

| Material | Specific weight, $\gamma$ | Elastic modulus, $E$, kg $\cdot$ mm$^{-2}$ | Tensile strength, $\sigma_{\text{br}}$, kg $\cdot$ cm$^{-2}$ | Brinell hardness $H_B$ | Impact toughness, $a_k$, kg $\cdot$ m $\cdot$ cm$^{-2}$ |
|---|---|---|---|---|---|
| Sheet aluminum | 2.6 | 7000 | 1150 | 23 | 2.5 |
| Alloy -437 | 8.2 | 19 700 | 9600 | 315 | 12 |
| Rod bronze | 8.5 | 11 200 | 6000 | 140 | 4—6 |
| Plexiglass | — | 13000—28000 | 400—540 | 20 | 0.08—0.12 |
| Polystyrene | — | — | 900 | 14 | 0.15 |
| Fluoroplastic-3 | 2.0—2.16 | — | 300—400 | (10—13) | 0.20—0.30 |
| Fluoroplastic-4 | 2.1—2.3 | 3850—4550 | 140—250 | (3—4) | 1.00 |
| Fluoroplastic-4 | | | | 8 | |

Our experiments with several polymers and metals were carried out in hydrodynamic tube No. 3 of the Institute of Mechanics of the Academy of Sciences of the USSR in the working

**Fig. 2.** Photographs of erosion on flat specimens of various materials after 100 hours of testing:
*a* —aluminum, *b* —Plexiglas, *v* —polystyrene, *g* —fluoroplastic-3, *d* —fluoroplastic-4.

**Fig. 3.** Photographs of erosion on cylindrical specimens:
*a* —alloy EI-437B after 50 hours, *b* —alloy EI-437B after 75 hours, *v* —bronze after 50 hours, *g* —fluoroplastic-4 after 25 hours, *d* —fluoroplastic-4 after 75 hours, *e* —fluoroplastic-3 after 100 hours.

chamber of cross section $12 \times 50$ mm$^2$ (Fig. 1), at the same velocity along the longitudinal axis of the chamber $v = 20$ m $\cdot$ sec$^{-1}$, and at a constant length of the cavitation zone $\lambda = l_k/d = 2.5$, where $d$ is the diameter of the model

Fig. 1. Scheme for testing specimens for resistance to cavitation erosion: 1 —walls of the working chamber, 2 —circular-profile model, also a cylindrical specimen, 3 and 4 —plate specimens

Figure 1: Fig. 1. Scheme for testing specimens for resistance to cavitation erosion: 1 —walls of the working chamber, 2 —circular-profile model, also a cylindrical specimen, 3 and 4 —plate specimens

—a circular cylindrical cavitation exciter. This length of the cavitation zone corresponds to the maximum erosion intensity ([2]). The water temperature in the experiments varied within the range $13 \div 28^{\circ}$, but this circumstance should not have affected the experimental results, since the cavitation stage, its length $\lambda$, was maintained constant by regulating the pressure independently of the flow velocity in the working chamber. The maximum duration of specimen testing was set at 100 hours.

The circular-profile model, $d = 12$ mm in diameter, was installed between two parallel Plexiglas walls of the chamber and flush with them. At first, plates placed on the chamber walls opposite the ends of the model and the cavitation zone, and set into the walls flush with their surface, served as specimens; later the model itself, which excited cavitation, began to be used for this purpose (Fig. 1). The indicator of resistance to erosion was the external pattern of destruction. Such a qualitative assessment was adopted in order to shorten the duration of the experiments and at the same time was sufficient to determine the position of polymers on a relative scale of resistance of materials to erosion.

**Fig. 1.** Scheme for testing specimens for resistance to cavitation erosion: 1 —walls of the working chamber, 2 —circular-profile model, also a cylindrical specimen, 3 and 4 —plate specimens

The following materials were tested: polymers—Plexiglas, polystyrene, fluoroplastic-3, fluoroplastic-4; and metals—sheet aluminum, nickel alloy EI-437B, and bar bronze.

The chemical composition of the materials is described in the corresponding handbooks and is not given here. A characterization of the mechanical properties is given in Table 2.

Cavitation behind the circular-profile model and its development by stages have been described in other articles ([3,4]). Here it is necessary to discuss the types of erosion observed on specimens of weak metals, since resistance to erosion was judged from the external pattern of damage to the specimens. On metal plate specimens, erosion of two types was observed: 1) behind the model—tail erosion, and 2) opposite the front end of the cavitation zone and located diametrically on the transverse axis of the model—front-side erosion (Fig. 2, *a*–*v*). On cylindrical specimens, erosion was located along the generatrices of the cylinder symmetrically, on both sides, in the plane of the lateral erosion of the plates—side erosion (Fig. 3).

In the initial stage, the side erosion of cylindrical specimens usually consists of round pits, visible to the naked eye and arranged along the generatrices one after another (Fig. 3 $v, g$). In a more developed stage of erosion, the individual pits, increasing in size, merge into a single groove, widening toward the ends near the boundary walls (Fig. 3a).

Let us compare the results of experiments with plates and with cylindrical specimens (Table 3, Figs. 2 and 3). Despite identical testing durations, aluminum metal was destroyed by cavitation to a greater depth and over a larger area than polymers of the same or lower hardness. Thus, for example, fluoroplastic-3 sustained very slight destruction in the form of barely noticeable roughness on polished specimens; on a polystyrene specimen, side erosion reached a depth of 0.5–0.6 mm, whereas tail erosion was observed only as slight roughness.

On the basis of a qualitative comparison of the resistance of the metallic model specimens (bronze and alloy EI-437B) and fluoroplastics, the latter

Table 3

| Material | Test duration, h | Erosion |
|---|---:|---|
| **Plates** | **Plates** | **Plates** |
| Sheet aluminum | 100 | Intense |
| Plexiglas | 100 | Intense |
| Polystyrene | 100 | Lateral—intense; trailing—barely noticeable traces |
| Fluoroplastic-3 | 100 | Trailing and lateral—traces |
| Fluoroplastic-4 | 100 | Lateral—traces; trailing—traces and dents |
| **Round cylinders** | **Round cylinders** | **Round cylinders** |
| Bronze | 50 | Lateral—deep pitting |
| Alloy EI-437B | 24 | Roughness at the ends |
| Alloy EI-437B | 50 | Lateral—pitting |
| Alloy EI-437B | 76 | Lateral—continuous groove |
| Fluoroplastic-4 | 25 | Lateral—small pits |
| Fluoroplastic-4 | 75 | Lateral and rear, elongated shallow dents in the direction of flow |

| | | |
|---|---|---|
| Fluoroplastic-3 | 100 | Lateral and rear, elongated shallow dents in the direction of flow and roughness |

···must be placed at least between lines 5 and 6 of the scale in Table 1, with a resistance index of not less than 200. To determine a higher limit of resistance, experiments must be carried out with specimens of steel 18–8. Nevertheless, from the experimental results the following conclusions may be drawn.

1. Among the polymers tested, fluoroplastic-3 and fluoroplastic-4 have the greatest resistance to erosion. The resistance of the fluoroplastics is higher than that of aluminum, bronze, and EI-437B.
2. Since the mechanical strength (tensile strength, hardness) of fluoroplastics is much lower than the strength of metals, the high resistance of fluoroplastics to cavitation erosion should be explained by their fine-grained structure, more homogeneous than that of metallic alloys.
3. Among polymers, those that combine higher hardness with high impact toughness have the greatest resistance to cavitation erosion.
4. Homogeneity of structure and high impact toughness should be the principal properties required of materials resistant to cavitation erosion.

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*Note: Figure translations are in progress. See original paper for figures.*