Marek Szkodo
Gdańsk University of Technology, Department of Materials Science and Engineering, Gdańsk, Poland

ESTIMATION OF CAVITATION EROSION RESISTANCE OF MATERIALS

ABSTRACT

The paper presents an evaluation of 17 materials produced in Poland as to their cavitation resistance. In the paper new factor of cavitation erosion resistance of materials, representing some results from whole erosion test is proposed. New coefficient of cavitation erosion resistance R is a function of the incubation time, maximum volume loss rate v_{max} and time replying of v_{max} rate. This factor has been referred to the mean durability δ_{cav}, representing the results of the whole erosion test. The results indicate that there is very good correlation between cavitation erosion resistance represented by factor R and mean durability δ_{cav}.

Key words: *cavitation erosion resistance, estimation*

INTRODUCTION

The cavitation phenomenon consists in nucleation and evolution of gas or vapor bubbles in liquids and to their violent collapse. The cavitation may occur in liquid phases under pressure gradients in static as well as in dynamic conditions. The repeated cycle of cavitation near the surface of materials locally induces high tensile and compressive stress cycles which can lead to erosion of the surface because collapse generates a stress pulse ranging from a few hundred to over 1000 MPa [1]. The rapid repetition of the stress pulses would induce localized fatigue failure and subsequent material removal. Additionally as a result of cavitation lack of efficiency of the equipment, vibration and noise can occur. Cavitation erosion is the cause of costly damage to various equipment parts in pumps, hydraulic turbines, motor engines, impellers, valves, seals and bearing surfaces.
In the cases when the elimination of cavitation by appropriate design of the construction is not possible, a reduction of cavitation erosion rates may be achieved by application of the materials of higher erosion resistance. But there is a problem how to define erosion resistance of materials. Existing standards have been recommending to evaluate of cavitation erosion resistance of materials by comparison of their erosion curves i.e. volume loss and volume loss rate in time, under cavitation loading in the same conditions. But this evaluation is a relative and a qualitative and depends on the intuition and experience of researcher. In literature the single-value parameters defined

on the base of adduced curves are met [2-6]. But there is no consent which factor ought to be measurer for material estimation. Nevertheless these factors are very useful, because they lets to classify materials in the precise way. Among factors characterising the cavitation erosion resistance of materials have been proposed such as:

- incubation time t_{inc} (the massive loss of the material is immeasurable or confined to very small value defined a priori),
- total volume loss after defined time,
- maximum volume loss rate v_{max},
- maximum damage penetration rate MDPR,
- mean erosion depth after defined exposition period,
- estimator of mean value of the erosion depth,
- mean durability δ_{cav} defined as:

$$\delta_{cav} = \frac{1}{T}\int_0^T \left(\frac{d(\Delta V)}{dt}\right)^{-1} dt \qquad (1)$$

where: T – exposition period,
ΔV – volume loss,
t – time.

This last factor in the best way reflects cavitation erosion resistance of materials because it is representing the results of the whole erosion test. But this coefficient is difficult to calculate because there is no mathematical model describing, in the precise way, cavitation erosion of materials.

The values of adduced factors have been used by Reymann and Steller [2] as the basis for arranging the materials according to their resistance to erosion. Obtained results indicate that the evaluation of materials depends on the discriminating factor taken into account and that highest deviations from the coefficient δ_{cav}, occur for t_{inc} used as the basis of materials arranging. On the other hand, the response of the material to cavitation loading in the incubation period is very important and decisive for further development of the erosion. For designers and constructors of fluid flow machines operating under cavitation loading, incubation period lets calculate minimum repair-to-repair time if cavitation intensity is known.

EXPERIMENTAL PROCEDURE

In the work [2] cavitation erosion tests of 45 materials produced in Poland were presented. The tested samples were subjected to cavitation loading at the rotating disk facility [2]. The cavitation was generated there by cylinders situated in the disk surface on the circle which diameter equaled 300 mm. Test specimens were inlaid in the disk, downstream of the cavitator. Their rotation speed stand for 3000 r.p.m. Resulting mean gauge pressure was 155 kPa. The water which temperature equaled 20°C was used as an active medium. The tests were performed for 1200 min in total. From among of investigated alloys 17 materials to calculate of cavitation erosion resistance were chosen.

RESULTS AND DISCUSSION

Table 1 presents some results of cavitation erosion test [2]. On the base of these results new factor R of cavitation erosion resistance of materials was defined as:

$$R = \frac{t_{inc} + t_{v\max}}{v_{\max}} \tag{2}$$

Values defining of cavitation erosion materials (R rate) are presented in Fig. 1. How results from Fig. 2 there is no relationship between incubation time as well as time replying of v_{max} rate and mean durability δ_{cav}. In Fig. 3 relationship between mean

Table 1. *Results of cavitation erosion test*

material	t_{inc}	v_{max}	t_{vmax}	δ_{cav}	R
1H13	140	0,628	285	3,03	676,7516
2H13 (a)	154	0,47	330	3,69	1029,787
2H13 (b)	145	0,29	230	6,91	1293,103
2H13 (c)	241	0,073	500	18,72	10150,68
0H18N9	208	0,392	310	4,58	1321,429
1H18N9T	202	0,39	310	5,36	1312,821
23H12MNF	190	0,027	700	40,87	32962,96
ES24-18	159	0,19	350	6,55	2678,947
ES18-8	118	0,176	175	8,42	1664,773
ES18-8-6	261	0,198	420	8,39	3439,394
ES18-8-2	210	0,045	1050	15,86	28000
ES13Cr	172	0,026	700	33,79	33538,46
EStelCoWL	281	0,026	700	37,68	37730,77
Stellit	150	0,015	900	67,18	70000
S10	142	0,182	600	6,23	4076,923
S30	155	0,023	750	60,88	39347,83
G20	183	0,013	800	83,55	75615,38

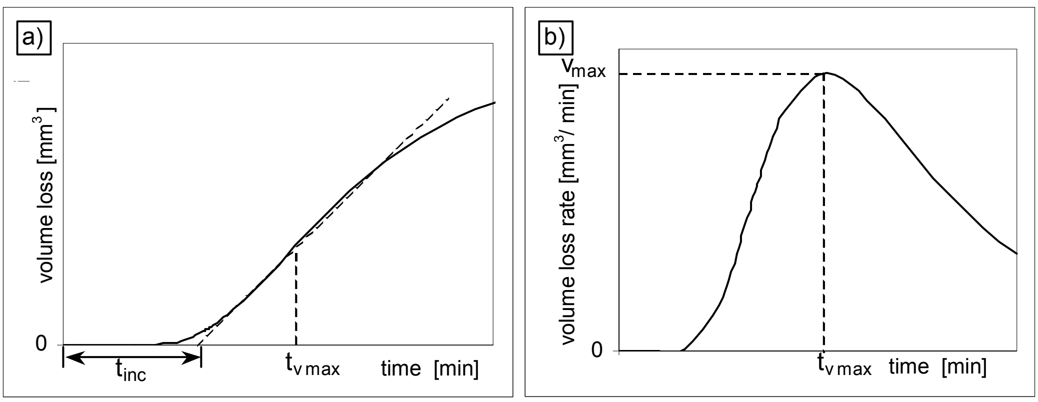

Fig. 1. Volume loss of eroded material – Fig. a) and volume loss rate as a function of cavitation time – Fig. b) and values defining of cavitation erosion of materials R

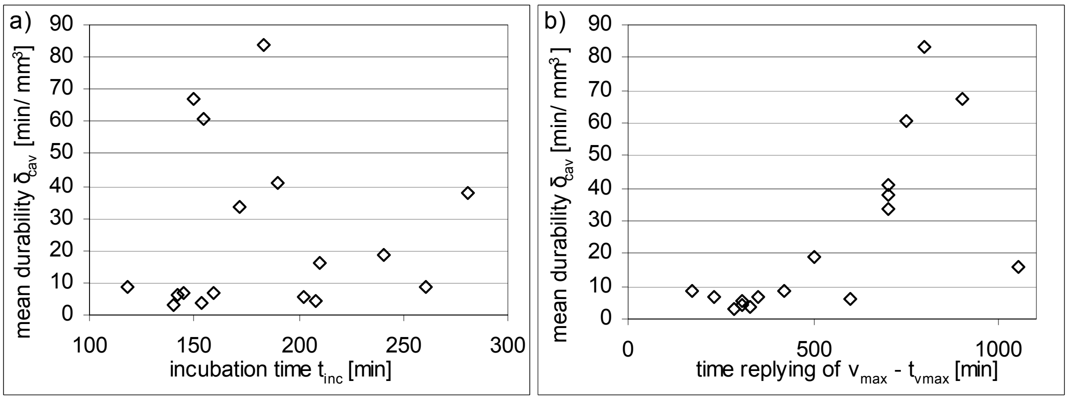

Fig. 2. Relationship between mean durability and incubation time – Fig. a) and time replying of v_{max} rate – Fig. b)

durability δ_{cav} of tested materials and R rate is presented. How results from this figure there is very good correlation between those coefficients. However R rate has two advantages. First, it is easier to calculation than mean durability and second, it depends on the incubation time too. Investigation of influence of mechanical properties of materials on the cavitation erosion resistance will be easier when R coefficient will be considered.

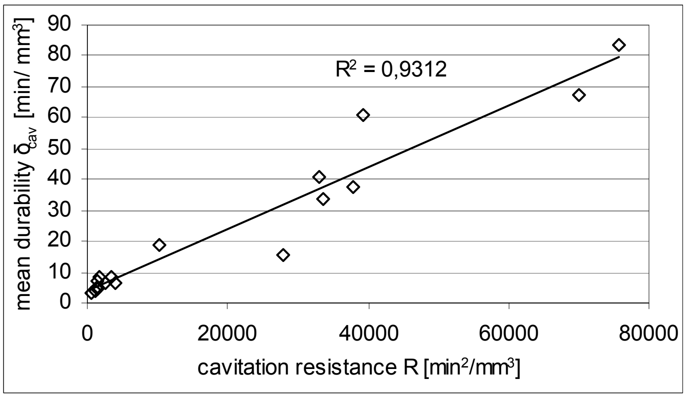

Fig. 3. Mean durability as a function of R rate

CONCLUSION

1. Results indicate that there is very good correlation between cavitation erosion resistance of materials represented by factor R and mean durability δ_{cav} representing results of the whole erosion test.
2. Incubation time can be used to calculate cavitation erosion resistance although there is no relationship between this factor and erosion resistance of materials.
3. Factor R is an easier to calculation than mean durability δ_{cav}.
4. The role of the mechanical properties of materials in the cavitational damage resistance can be easier to define if we will separately determine influence of these

parameters on the incubation time, maximal volume loss rate and time replying of maximal volume loss rate (t_{vmax}).

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