MAXIMUM BURSTING PRESSURE OF RUPTURE DISKS

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Many factors exert an effect on the magnitude of the bursting pressure of rupture disks; therefore up till now there have been no theoretical or even practical principles which make it possible to guarantee disk failure within a range from p to 1.25 p [1] under fixed, specific operating conditions (here p is the maximum permissible pressure).

The use of experimental graphs is recommended in the foreign literature for determining bursting pressure. Thus, in instructions for installing rupture disks [2] a graph is given for determining the bursting pressure of disks 25.4 mm in diameter, made of certain pure metals, upon brief static loading with a neutral medium and at normal temperature. The scatter of possible disk bursting pressure is guaranteed within limits of ±5%. To determine the bursting pressure of disks whose diameter differs from 25.4 mm, the instructions recommend using the empirical formula

$$p = \frac{K\delta}{d},$$

where δ is the disk thickness, in mm; d is the disk diameter in mm; and K is an experimental coefficient.

In the All-Union Scientific-Research Institute of Safety Technique in the Chemical Industry an experimental check has been made of the bursting pressure of disks fabricated from domestic materials. This check showed that the coefficient and the pressure scatter differ considerably from those indicated in [2]. Thus, when 100 disks of A-2 aluminum having a diameter of 25 mm and a thickness of 0.07 mm were

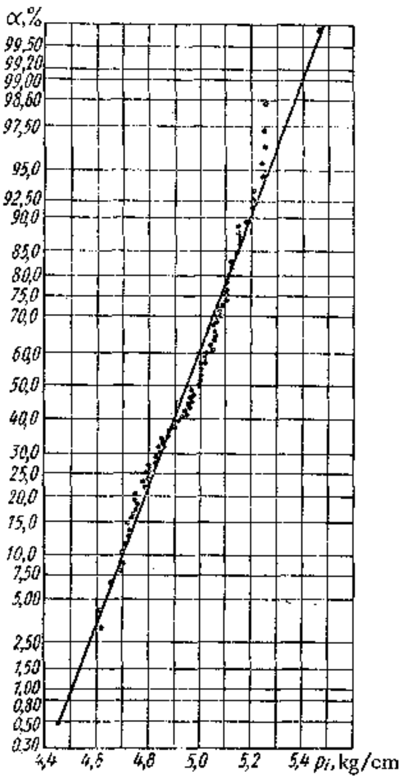

Fig. 1. Results of testing aluminum disks, plotted on a normal probability grid (α is the reliability coefficient and p_i is the bursting pressure).

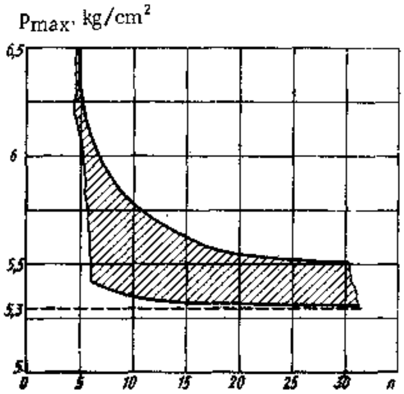

Fig. 2. Distribution field of maximum bursting pressures as a function of number of tests: – – –) actual maximum pressure.

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TABLE 1

Material	n	$p_{n\,av}$, kg/cm²	s_n, kg/cm²	p_{max}, kg/cm² calculated, α=95%		actual
				α=95%	α=99%	
Aluminum	2	4,68	0,050	7,88	25,50	5,33
	5	4,80	0,124	5,52	6,22	5,33
	10	4,81	0,142	5,34	5,70	5,33
Stainless steel	2	42,00	0,425	69,20	219,00	46,20
	5	42,30	0,820	47,10	51,70	46,20
	10	43,00	0,970	46,50	48,80	46,20
Nickel	2	16,80	0	16,80	16,80	18,90
	5	19,98	0,564	20,25	23,40	18,90
	10	16,84	0,455	18,48	19,50	18,90

Notes: n is the number of experiments; $p_{n,\,av}=\frac{1}{n}\sum_{i=1}^{n} p_i$ the mean value of disk bursting pressure from n experiments; i is the ordinal number of an experiment; $s_n=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(p_i-p_{n,\,av})^2}$ the mean squared deviation of disk bursting pressure from $p_{n,\,av}$; $p_{max}=p_{n,av}+\varepsilon\gamma s_n$ [3]; $\varepsilon=2$ at $\alpha=95\%$; $\varepsilon=2.6$ at $\alpha=99\%$; γ is determined from Table 2; ε and γ are coefficients which take into account, respectively, the fortuitous deviations of bursting pressure and the number of disk tests performed.

TABLE 2

Number of experiments	γ coefficient at indicated reliability coefficient		Number of experiments	γ coefficient at indicated reliability coefficient	
	95%	99%		95%	99%
2	32,0	160,0	12	1,7	2,1
3	6,3	14,0	13	1,6	2,0
4	3,7	6,5	14	1,6	1,9
5	2,9	4,4	15	1,6	1,8
6	2,5	3,5	16	1,5	1,8
7	2,2	3,0	17	1,5	1,8
8	2,0	2,7	18	1,5	1,7
9	1,9	2,4	19	1,5	1,7
10	1,8	2,3	20	1,5	1,7
11	1.8	2,2	25	1,4	1,6

tested under conditions like those indicated in [2], the K coefficient proved equal to 1750 kg/cm², and the scatter was ±8%, as opposed to 2350 kg/cm² and ±5%.

To study the effect of the number of sample test disks from a given lot on the reliability of determining bursting pressure, we tested about 100 disks of A-2 aluminum, NP-2 nickel, and Kh18N9T steel, 50 mm in diameter. To ascertain the bursting pressure distribution functions, the test results were plotted on probability grids of the most common statistical strength theories (normal distribution, logarithmically normal distribution, Weybull distribution, and Humbell distribution). Analysis of the graphs on the probability grids showed that the bursting pressure probability function of disks of aluminum, stainless steel, and nickel is rather close to a normal distribution function (Fig. 1).

However, it proved impossible to determine disk bursting pressure with an assigned reliability by using the distribution law directly. Actually, suppose it is required from data from the first 2, 5, or 10 tests to determine the greatest bursting pressure, p_{max}, for the remaining disks with reliabilities of 95% and 99% (complete conformity of the disk bursting pressures distribution function to the normal law is assumed). Results of a preliminary treatment of the experimental data are given in Table 1.

On the basis of the data given in Table 1, the following may be suggested: two experiments are not enough to judge the maximum bursting strength of a lot of disks; when $\alpha \geq 95\%$ and $n \leq 5$, the calculated p_{max} is greater than the actual p_{max}; but with increase in the number of tests and decrease in α, these values approach each other; the reliability coefficient is too low.

To verify these suggestions we analyzed a large number of samplings in the range $5 \leq n \leq 30$ from 100 experimental values of bursting pressure for disks of each material. All 100 values of bursting pressure were numbered in the order in which the tests were run.

Samplings consisting of n experiments ($5 \leq n \leq 30$) were taken in the following order. The first sampling consisted of n values taken in order, starting with the first number (1, 2, . . . , n); the second, starting with the second number (2, 3, . . . n + 1); etc., the last sampling consisted of the last experimental values (100−n, 100−(n−1), . . . , 100). For each sampling we calculated the maximum values of bursting pressure for aluminum disks (Fig. 2). Similar results were also obtained for the nickel and stainless steel disks. As is evident, the suggestions were confirmed. Moreover, from Fig. 2 it follows that, beginning with n = 20, the effect of the number of test samples on the scatter field of maximum bursting pressure is slight. Using the known empirical relationship, pd = const, for disks of the same material, plus the experimental results given above, a calculation of the maximum possible bursting pressure of disks for lots of 100 or fewer disks of aluminum, nickel, or stainless steel can be made with an error ±5% from data for 20 test samples by the formula

$$p_{max}=p_{20\,av}+Cs_{20},$$

where

$$p_{20\,av}=\frac{1}{20}\sum_{i=1}^{20} p_i;\quad s_{20}=\sqrt{\frac{1}{19}\sum_{i=1}^{20}(p_i-p_{20\,av})^2};$$

and C is a coefficient.

As a result of treatment of the experimental data, the following values of the C coefficient have been obtained: for aluminum disks, 3.4; for stainless steel, 4.6; and for nickel, 4.1. To determine the C coefficient for disks of other materials, it will be necessary to carry out similar investigations.

LITERATURE CITED

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