STATISTICAL PROCESSING OF TEST DATA IN TEMPERATURE DISTRIBUTIONS IN REINFORCED PANELS

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UDC 519.24:536.2

A method is given for statistical processing via the t test in estimation of the population mean and confidence limits for small samples.

The spread in the results from tests on temperature distributions in a structure is dependent on the following factors:

1) the spread in the characteristics of the specimens, which itself is dependent on any nonuniformity in the material, any variation in the blackness coefficient, variations in the contact thermal resistance between components, and so on;

2) errors in the equipment operation, which may be dependent on fluctuations in the line voltage to the heaters, and also variations in the characteristics of the individual heaters; and

3) errors in the measuring equipment, which are dependent on the errors in the transducers and recording equipment.

In order to obtain reliable parameters for the thermophysical properties it is necessary to test a fairly large number of specimens (about 100), which is followed by statistical processing; analogy with measurements on mechanical characteristics [1] leads us to suggest that the probability-density distribution for the logarithm of a quantity will be of normal type (strictly speaking, this hypothesis requires experimental confirmation).

We made measurements on the temperature distribution in 10 reinforced plates for τ = 3 sec; Table 1 gives the results.

For each point where the thermocouples were placed, we derived the arithmetic mean for the sample:

$$\lg T^i = \frac{1}{n}\sum_{i=1}^{n} \lg T_i^i$$

TABLE 1. Parameters of Temperature Distribution (°C)

N	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1	12,5	45	132,5	160	177,5	187,5	190
2	17,5	55	140	167,5	185	202,5	205
3	20	62,5	147,5	177,5	200	212,5	207,5
4	22,5	53	137	165	192,5	217,5	215
5	28	61	165	192	212	222	225
6	17	58	152	178	214	235	237
7	21	64	154	187	205	237	237
8	27	81	182	208	217	240	242
9	18	62,5	174	208	227	249	253
10	29,5	82	190	224	240	260	260

S. Ordzhonikidze Moscow Aviation Institute. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 29, No. 1, pp. 113-115, July, 1975. Original article submitted January 15, 1975.

TABLE 2. Determination of Confidence Limits for the Estimator for the Population Mean

j	$\sum_{1}^{n} \lg T_i^j$	$\left(\sum_{1}^{n} \lg T_i^j\right)^2$	$\sum_{1}^{n} (\lg T_i^j)^2$	$\lg \overline{T}_i^j$	$s(\lg T^j)$	T^j
1	13,148	172,87	17,408	1,315	0,1160	20,93°±3,39
2	17,885	319,87	32,043	1,788	0,0789	61,75°±6,80
3	21,941	481,41	48,167	2,194	0,0538	156,8°±11,9
4	22,687	514,70	51,490	2,269	0,0471	186,2°±12,4
5	23,141	535,51	53,564	2,314	0,0380	206,5°±11,0
6	23,526	553,47	55,364	2,353	0,0434	225,8°±14,1
7	23,545	554,37	55,453	2,354	0,0421	226,4°±13,5

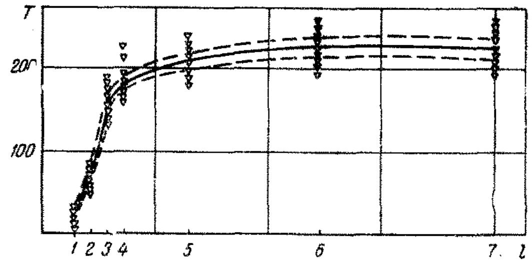

Fig. 1. Temperature distribution (T, °C) in a plate at τ = 3 sec; 1-7 are the positions of the thermocouples. The solid line is the population mean for the temperature distribution, the broken lines are the 90% confidence limits, and the points are from experiment.

and the standard deviation

$$s(\lg T^j) = \sqrt{\frac{1}{n-1}\left[\sum_{1}^{n} (\lg T_i^j) - \frac{1}{n}\left(\sum_{1}^{n} \lg T_i^j\right)^2\right]}.$$

The confidence range for a sample with an unknown mean and a standard deviation may be estimated from Student's [2]:

$$t = \sqrt{n-1}\left(\frac{\bar{x}-\nu}{\sigma}\right).$$

This t has a Student distribution with n − 1 degrees of freedom, and so for the probability 1 − (q/100) we can find the 2-percent limits $\pm tq_0 n - 1$ such that

$$p\left\{-tq,\ n-1 < \sqrt{n-1}\,\frac{\bar{x}-\nu}{s} < tq,\ n-1\right\} = 1 - \frac{q}{100},$$

i.e., the probability that t for the given sample will fall in the range (−tq, n − 1; tq, n − 1), this probability being 1 − (q/100). The latter equation can be put as

$$p\left\{\bar{x} - tq,\ n-1\,\frac{s}{\sqrt{n-1}} < \nu < \bar{x} + tq,\ n-1\,\frac{s}{\sqrt{n-1}}\right\} = 1 - \frac{q}{100}.$$

Consequently, by definition of the confidence range, the range

$$\left(\bar{x} - tq,\ n-1\,\frac{s}{\sqrt{n-1}} - \bar{x} + tq,\ n-1\,\frac{s}{n-1}\right)$$

will be the confidence range corresponding to the probability P = 1 − (q/100).

Table 2 gives results for the 90% confidence ranges for the estimator for the population means $\nu = \tilde{T}^j$; Fig. 1 does the same.

The middle of the confidence range was taken as the confidence value.

NOTATION

i, number of experiment; n, number of elements in sample; j, number of thermocouple point; ν, overall mean; σ, overall quadratic deviation.

LITERATURE CITED

1. E. I. Stepanychev, Plast. Massy, No. 2 (1962).
2. N. V. Smirnov and I. V. Dunin-Brakovskii, A Short Textbook of Mathematical Statistics with Engineering Applications [in Russian], Fizmatgiz, Moscow (1959).