CREEP BUCKLING OF AN ECCENTRICALLY LOADED COLUMN

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ABSTRACT: A number of experimenters investigating the buckling of columns at elevated temperatures [1–3] have noted a significant scatter of the experimental values of the buckling time. Below, an attempt is made to account for this scatter in terms of eccentricity in the application of the load.

The tests were conducted on the apparatus previously described in [4] at 250 ± 1° C. The test pieces were made from grade D16T duralimin rods 14 mm in diameter in the as-delivered state. The

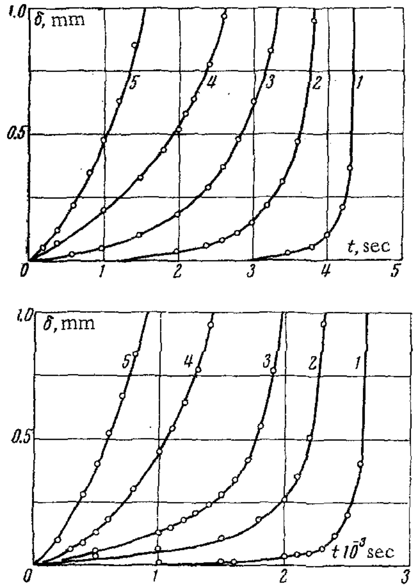

Fig. 1

test pieces, 7 mm in diameter with slenderness ratios from $\lambda = 35$ to $\lambda = 81$, had a regular cylindrical geometry, which was checked on a tool microscope correct to 0.001 mm. A hinged support was provided for the test pieces by means of steel adapters, a slot in which made it possible to vary the eccentricity from the minimum technically possible to 1.42 mm. The test piece, carefully measured under the microscope, was mounted in the testing machine on knife edges with an angle of 75° and a rounding radius of less than 0.01 mm. The knife edges were set up strictly along the loading axis. The displacement of the center of the test piece was transmitted through an invar lever and a quartz rod to a micron indicator and progressively registered by a RFK-1M motion-picture camera. The lever, with a reduction ratio of 5:1 and a cross hinge, was used to reduce the force exerted on the test piece by the indicator spring. The load was applied after heating for 20 minutes and was increased linearly at rates from 0.0045 to 4 kgf/mm^2 · sec.

Figure 1 shows typical deflection-time curves for test pieces with $\lambda = 70$ at a loading rate $d\sigma/dt = 3$ (upper part of figure) and 0.0045 (lower part) kgf/mm^2 · sec; the values of the eccentricity are given in the figures: 1) 0 mm, 2) 0.05 mm, 3) 0.15 mm, 4) 0.50 mm, 5) 1.42 mm. In fact, zero eccentricity corresponded to the smallest value that could be discriminated under a microscope with a resolution of 0.001 mm. The accuracy of placement of the test piece in the testing machine may also be judged from the fact that as the load increases deflection begins to develop at loads equivalent to 75–85% of the buckling load irrespective of the loading rate. Similar curves were obtained at other slenderness ratios and loading rates. As the buckling time we took the value corresponding to the point at which the deflection rate tended to infinity.

We note the following interesting experimental fact which is easily established from an examination of Fig. 1 and the analogous figures corresponding to other loading rates: for any fixed value of the deflection and eccentricity the ratios t/t_0^* and t/t_k^* remain almost constant, i.e., the $\delta = f(t)$ curves constructed in $\delta - t/t_k^*$ coordinates coincide. Notation: t is the variable time, t_0^* the time to failure at zero eccentricity and the fastest loading rate of the given series, t_k^* the time to failure for a test piece at zero eccentricity and some other loading rate corresponding to the subscript k. Similar constructions can also be made for $\lambda = 35.5$, 47, 57, 70, and 81. If the experimental data are plotted in the variables δ/λ and t/t_k^*, all the curves will be grouped about the curve corresponding to the given eccentricity, irrespective of the length of test piece and loading rate in the interval investigated. Hence it follows that the creep process that develops at low loading rates does not affect the qualitative picture of variation of deflection with eccentricity.

The eccentricity has a substantial influence on the value of the buckling load. This was previously noted by Karman [5] in connection with elastoplastic, eccentrically loaded columns with small and medium slenderness ratios. The same picture is observed in tests on columns subjected to longitudinal bending in the presence of creep. The buckling load is understood to be the load at the point at which the deflection rate tends to infinity. In this case, owing to the adequate elasticity of the testing machine, there is no decrease in load. If we construct a graph showing the relation between buckling stress and eccentricity, we obtain a series of descending curves, whose curvature in the region of small eccentricities decreases with increase in the length of the test piece. However, if we plot the experimental data in the variables σ/σ_{ik}^*, $-b/l$, where the asterisk indicates the value of the buckling stress at zero eccentricity for a test piece with slenderness ratio λ_i and a certain loading rate k, while b and l are, respectively, the eccentricity and the length of the test piece, they will all be grouped about the single curve shown in Fig. 2. In Fig. 2 the experimental points correspond to the conditions

	1	2	3	4	5
$l =$	82	102	122	82	122 mm
$d\sigma/dt =$	3.5	4.5	3.0	0.011	0.0045 kgf/mm^2 · sec.

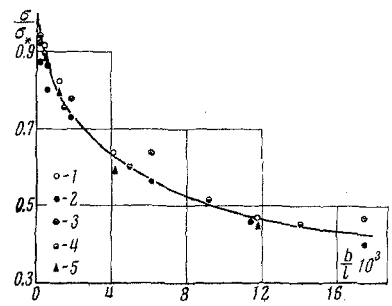

Fig. 2

It is clear from Fig. 2 that an error in centering the test piece of more than 2% leads to a reduction in σ/σ^* of more than 20%, which, in turn, means a substantial change in the life of the compression member. In [6] Hoff also noted that the buckling time is very sensitive to the value of the average applied compressive stress, and if the load falls from 90% to 75% of the Euler load, the buckling time is more than doubled at all values of the eccentricity. From this we may conclude that the organization of column buckling tests should not be less than first class, i.e., in particular, the deviation of the point of application of the load from the geometric axis of the test piece should not exceed 1% of the linear dimensions of its cross section.

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