ENGINEERING METHOD OF CALCULATING A
CONICAL POWER DRUM

A. A. Fedorov

The engineering method of determining stresses in a conical power drum fastened by stringers and
frames and loaded by concentrated force factors which act both in the plane of its curvature and from its
plane (Fig. 1) is of practical interest in a number of cases. This method is especially necessary at the
initial stages of designing such structures.

At present not one of the principal central axes of inertia of the cross section of the "annular sys-
tem" of the design of the conical power drum being considered coincides with its plane of curvature. There-
fore, the deformations of the ring in its plane and from its plane should be interrelated. If the power drum
can be assumed cylindrical in the first approximation, there is no need to take into account this inter-
relation of deformations. Under these conditions the problem can be solved approximately by the method
proposed earlier [1], in obtaining which, however, constraint of warping of the cross section of the bar
in the fixed support during torsion by force factors acting from its plane and the effect of the rigid base to
which the drum was welded cantilever-fashion were not taken into account.

The effect of constrained torsion on the magnitude of stresses in the cross sections of the drum is
taken into account as a consequence of the fact that the power drum in the proposed method of calculation
is regarded as a statically indeterminate curvilinear thin-walled bar-shell with an open cross-sectional
profile. Here it is assumed that in conformity with [2] for a bar with an open cross-sectional profile the parameter

\[ K = \frac{I_{\text{min}}}{I_\ell} \leq 3, \]

where \( I_{\text{min}} \) is the minimum moment of inertia; \( I_\ell \) is the geometric torsional rigidity of a bar with an open
cross-sectional profile; \( I_\ell = \frac{\Sigma bh^3}{3} \).

The calculation model of such a drum is shown in Fig. 2.

We will show the course of calculation of a power drum by way of a numerical example. We decom-
pose the load acting on bow \( A' - A'' \) into symmetric and asymmetric. Then in the calculation we can con-
sider only one half of the bow. The static indeterminacy of the bow in this case is determined on the basis
of the system of canonical equations of the work method. This main system, consisting of two curvilinear
cantilevers loaded by given force factors and by five unknown force factors

\[ X_1 = Q_0; \quad X_2 = M_2; \]

\[ X_3 = M_2; \quad X_4 = P_0; \quad X_5 = M_0, \]

applied in the key cross section, is obtained by cutting the curvilinear bar along the axis of symmetry (at
point C).

The calculation of the auxiliary coefficients of the canonical equations of the work method is simpli-
fied considerably if we use the concept of elastic centers of a curvilinear bar [3]. The expressions of the
auxiliary coefficients in this case have the form

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The distance of the elastic centers from the line of the centers of gravity of the curvilinear bar is determined by the equations

\[ d = r \left[ \frac{2\alpha^2}{\alpha^2 + 1} \frac{\alpha}{A_{33}} (\alpha \sin \alpha \cosh \alpha \alpha - \cos \alpha) - 1 \right] \]

for the first elastic center;

\[ l = \frac{r}{\alpha^2 + 1} \left( 1 - \frac{\alpha \sin \alpha}{\sin \alpha \alpha} \right) \]

for the second elastic center.

We find the terms of the canonical equations (\( \Delta_{1p} \)) by the method of initial parameters if we take them for mutual displacements of the ends of the main system at the site of cutting under the effect of the given load; \( \Delta_{1p} \) is the mutual displacement of the points of application of forces \( Q \) along the vertical; \( \Delta_{3p} \) is the angle of mutual rotation of the end sections relative to the \( x \) axis; \( \Delta_{3p} \) is the angle of mutual displacement (twisting) of the end sections; \( \Delta_{4p} \) is warping of the end sections of the rod.

Since the load acting on the bow is decomposed into symmetric and asymmetric, we determine the displacement of any one part of the bow and double it. In this case displacements \( \Delta_{1p} \) and \( \Delta_{3p} \) are caused only by the asymmetric load, and \( \Delta_{3p} \) and \( \Delta_{4p} \) only by the symmetric. We calculate them so:

\[ \Delta_{1p} = 2(y_c + \theta_{ed}); \quad \Delta_{3p} = 2\theta_{ec}; \]

\[ \Delta_{3p} = 2(\theta_{ec} + \xi_{de}); \quad \Delta_{4p} = -2\xi_{ec}. \]

From the canonical equations of the force method we determine also the unknown force factors in the key section of the bar:

\[ X_1 = A_{11} \frac{\delta_{11}}{Gt}; \quad \delta_{11} = A_{11} \frac{r^3}{Gt}; \]

\[ \delta_{22} = A_{22} \frac{r}{Gt}; \quad \delta_{33} = A_{33} \frac{r^2}{Gt}; \quad \delta_{44} = A_{44} \frac{r}{Gt}. \]