mentioned approximations of displacements it is possible to reduce the order of the element in comparison with the approaches used by Bartelds and Ottens [2], Argiris and Sharpf [1], thus ensuring high accuracy of the solution.

When the method of coordinatewise descent is used, there is no need to form and store rigidity and weight matrices, and therefore the numbering of the nodes in discretization of the domain is arbitrary; this reduces considerably the required storage capacity of the computer. Since the MCD is a converging iteration algorithm, the errors of rounding off have a lesser effect on the accuracy of the final result.

The advantages of the suggested approach lie in the possibility of its realization in connection with three-layered structures with the aid of the internal computer memory alone.

LITERATURE CITED


VARIANCE METHOD OF CALCULATING THE DEFLECTION RATE OF A RECTANGULAR PLATE IN HIGH-TEMPERATURE CREEP CONDITIONS

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In examining the stress-strain state in the continuously cast slab formed in the roller zones of machines for continuous casting of billets (MCCB) it is necessary to determine the deflection of the skin of the shelled slab between tile rollers under the effect of the ferrostatic pressure of the liquid phase. In this work, we solve the problem of determining the deflection rate of the slab skin in high-temperature creep conditions. The skin is examined as a thin rectangular sheet secured around its perimeter and is subjected to the effect of a uniformly distributed load which is perpendicular to the plane of the sheet.

The relationship between the deflection rate of the rectangular sheet and creep has been studied by a relatively large number of Soviet and foreign authors (USA, West Germany, Japan, etc.). There are two main approaches used to solve this problem. The first approach is based on the assumption according to which the effect of restraint along the short sides (side edges) of the sheet is insignificant and affects only slightly the deflection rate in the center of the sheet. At the same time, the two-dimensional problem of the sheet is reduced to the unidimensional problem of calculating the deflection along the central line of the sheet [1, 2]. The second approach is based on the assumption according to which information on the tensor of the bending moments can be obtained from the solution of the corresponding elastic problem, and the deformation pattern in the sheet and the deflection rate can be calculated only after this stage using the creep law [3, 4].

The approach used in this work rejects both these assumptions. The following results were obtained in the calculations carried out for various exponents $\alpha$ in the creep law and for various ratios $\beta$ of the long and short sides of the sheet. If for the elastic sheet the
deflection in the center remains almost unchanged at $\beta > 2$ [5], the deflection rate in the center of the sheet subjected to creep stabilizes at considerably higher values of $\beta$ (Fig. 1). This shows that the problem is highly two-dimensional and that the stress-strain state of the crept sheet greatly differs from that of the elastic sheet. In other words, both assumptions greatly reduce the accuracy of the mathematical model. Excluding these assumptions, we can construct a corresponding mathematical model. For this purpose, as the initial equation we use the nonlinear equation in partial derivatives for the deflection rate of the sheet made of a homogeneous material which corresponds to the exponential creep law [6].

We use this equation to formulate the boundary-value problem for a sheet with restrained edges. The boundary-value problem represents the maximum condition for the variance problem. We solve this problem using Ritz's method [7]. The problem of finite dimension minimization formed in this case is solved by the gradient descent method.

The exponential law of steady-state creep in uniaxial tension has the form

$$\sigma = A \varepsilon^\alpha, \quad 0 < \alpha \leq 1,$$

where $\sigma$ is the stress, N mm$^{-2}$; $\varepsilon$ is the strain rate, sec$^{-1}$; $\alpha$ is the exponent; $A$ is a multiplier which characterizes quantitatively the creep of the material, N mm$^{-2}$ sec$^{-\alpha}$.

In the two-dimensional stress-strain state, this law is generalized as follows [6]:

$$\sigma_{xx} = \frac{4}{3} AE^\alpha \left( \dot{\varepsilon}_{xx} + \frac{\varepsilon_{yy}}{2} \right),$$

$$\sigma_{xy} = \frac{2}{3} AE^\alpha \left( \dot{\varepsilon}_{xx} - \frac{\varepsilon_{yy}}{2} \right),$$

$$\sigma_{yy} = \frac{4}{3} AE^\alpha \left( \dot{\varepsilon}_{yy} + \frac{\varepsilon_{xx}}{2} \right),$$

where $\sigma_{xx}$, $\sigma_{xy}$, $\sigma_{yy}$ are the components of the stress tensor; $\dot{\varepsilon}_{xx}$, $\dot{\varepsilon}_{xy}$, $\dot{\varepsilon}_{yy}$ are the components of the strain rate tensor.

Under these assumptions we can introduce the so-called generalized creep potential for the plate $U(w_{xx}, w_{xy}, w_{yy})$ which satisfies the conditions [6]

$$\frac{\partial U}{\partial w_{xx}} = M_{xx}; \quad \frac{\partial U}{\partial w_{xy}} = 2M_{xy}; \quad \frac{\partial U}{\partial w_{yy}} = M_{yy},$$

where $M_{xx}$, $M_{xy}$, $M_{yy}$ are the components of the tensor of the bending moments; $w(x, y)$ is the vertical component of the deflection rate of the sheet at the point with the coordinates $x$, $y$; $w_{xx}$, $w_{xy}$, $w_{yy}$ are the secondary partial derivatives of the function $w(x, y)$.

Using the generalized potential $U(w_{xx}, w_{xy}, w_{yy})$, we can describe the process of deflection of the sheet [6].

### TABLE 1. Values of $v_{\infty}$ and $R^{-1/\alpha}$ for Various Values of $\alpha$

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$v_{\infty}$</th>
<th>$R^{-1/\alpha}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1/4$</td>
<td>2.029</td>
<td>1.155-10^-2</td>
</tr>
<tr>
<td>$1/3$</td>
<td>3.474</td>
<td>1.188-10^-3</td>
</tr>
<tr>
<td>$1/2$</td>
<td>6.793</td>
<td>1.116-10^-4</td>
</tr>
<tr>
<td>$1/3$</td>
<td>14.112</td>
<td>1.017-10^-2</td>
</tr>
<tr>
<td>$1/5$</td>
<td>30.363</td>
<td>0.915-10^-3</td>
</tr>
</tbody>
</table>