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«Plastic bending of the waveguide tubes with rectangular cross-section»

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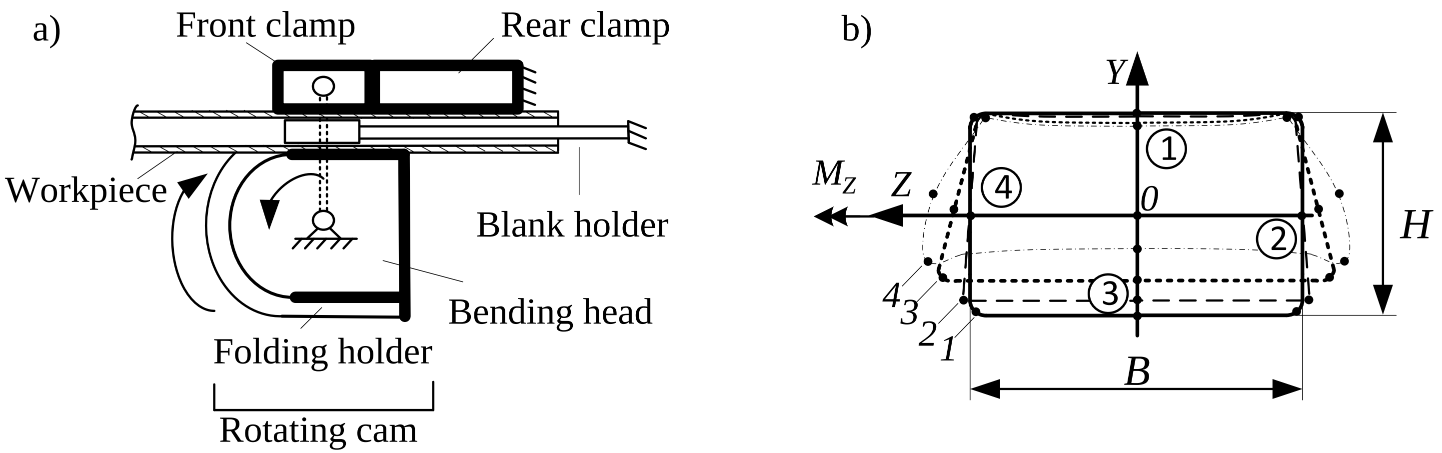
Problem statement

- Problems of manufacturing curved waveguide sections on the tube-bending machine:
- undesirable deformations of a cross-section;
- unacceptable thinning, cracks and wrinkles;
- limited angles and radii of bending.



Plastic bending process on the tube-bending machine

Solution methods

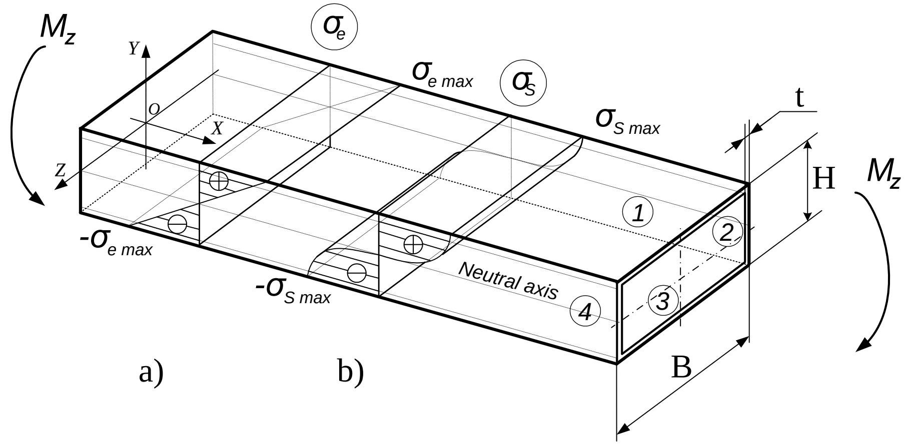
- Rectilinear waveguide is modelled by the theory of shells as composite construction which consist of 4 plates
- Complete system of the waveguide constitutive equations consists of 4 subsystems for each of its plates and have the form of nonlinear partial differential equations

- constitutive equations

$$\left.\begin{aligned}
&\frac{\partial^4\varphi_i}{\partial\alpha_i^4}+2\frac{\partial^4\varphi_i}{\partial\alpha_i^2\partial\beta_i^2}+\frac{\partial^4\varphi_i}{\partial\beta_i^4}=Et\cdot\left[\left(\frac{\partial^2\omega_i}{\partial\alpha_i\partial\beta_i}\right)^2-\frac{\partial^2\omega_i}{\partial\alpha_i^2}\cdot\frac{\partial^2\omega_i}{\partial\beta_i^2}\right];\\
&\frac{\partial^4\omega_i}{\partial\alpha_i^4}+2\frac{\partial^4\omega_i}{\partial\alpha_i^2\partial\beta_i^2}+\frac{\partial^4\omega_i}{\partial\beta_i^4}=\frac{1}{D}\left[\frac{\partial^2\varphi_i}{\partial\beta_i^2}\cdot\frac{\partial^2\omega_i}{\partial\alpha_i^2}-2\frac{\partial^2\varphi_i}{\partial\alpha_i\partial\beta_i}\cdot\frac{\partial^2\omega_i}{\partial\alpha_i\partial\beta_i}+\frac{\partial^2\varphi_i}{\partial\alpha_i^2}\frac{\partial^2\omega_i}{\partial\beta_i^2}\right].
\end{aligned}\right\}$$

- analytic solution

$$\left.\begin{aligned}
&\varphi_1=\beta_1^2\cdot\frac{M_Z}{J_Z}\cdot\frac{h'}{4};\quad w_1=\frac{h'}{2}-\frac{M_Z}{2\cdot EJ_Z}\left[\alpha_1^2+\mu\cdot\frac{h'^2}{4}\right];\quad \varphi_2=\frac{M_Z}{J_Z}\cdot\frac{\beta_2^3}{6};\quad w_2=0;\\
&\varphi_3=-\beta_3^2\cdot\frac{M_Z}{J_Z}\cdot\frac{h'}{4};\quad w_3=-\frac{h'}{2}+\frac{M_Z}{2\cdot EJ_Z}\left[\alpha_3^2+\mu\cdot\frac{h'^2}{4}\right];\quad \varphi_4=-\frac{M_Z}{J_Z}\cdot\frac{\beta_4^3}{6};\quad w_4=0.
\end{aligned}\right\}$$



Stress distribution by volume of the waveguide at bending

Conclusions

Results, implementation

- The most critical factor limiting the value of the minimum radius of bending from below is not stress, but the value of the maximum permissible deformation of the waveguide material .
- When using a filler the thinning of the waveguide wall increases by 30-50% .
- Heating increases plastic properties of the material only by 10%.
- Superplasticity is the best method to improve bending process.

Contacts

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