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Investigation of roll calibration of continuous pipe welding machines

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ABSTRACT: This paper provides a calibration of rolls of continuous pipe welding machines

KEY WORDS: High frequency current welding, thermal deformation, calibration of rolls,weld

I. INTRODUCTION

High-frequency pressure welding with melting is carried out with preheating and local melting of the welded surfaces. The molten metal is removed from the zone of the joint during precipitation; the welded joint is formed between surfaces that are in solid state. This process is most widely used in the production of welded products and semi-finished products with a continuous seam of ferrous and non-ferrous metals.

Welded elements, have the same geometric dimensions and material and are located symmetrically relative to the vertical plane. At symmetrical current supply to the welded elements provides complete identity of heating. [1]

Both elements to be welded converge at an angle α, at some distance from the point of convergence and current is supplied to them by means of contact or induction systems, the edges are heated and melted, at the point of their convergence precipitation occurs. Heating and deformation of the welded elements occur sequentially. Physical contact between the surfaces, creation of active centers on them and prevention of the possibility of destruction of the formed knots of setting after removal of the precipitation pressure are necessary for welding. Fulfillment of these conditions is conditioned by the calibration of rolls of continuous pipe welding units. [2]

II. LITERATURE SURVEY

The whole variety of existing roll calibrations can be represented by five main types [3]:
1) single-radius;
2) bi-radius with edge bending;
3) bi-radius with flat center section;
4) double-radius with a bend in the center section;
5) oval according to the curves of the second order.
When selecting the type of calibration, the following criteria shall be used:
- for thick-walled pipes it is necessary to ensure good edge forming of the billet to obtain a quality seam;
- for thin-walled pipes it is necessary to ensure the absence of corrugation on the edges of the billet, which will exclude the weld not welded [4-5].

III. METODOLOGY

The scheme of strip deformation (forming) in a continuous forming mill is shown in Fig. 1.

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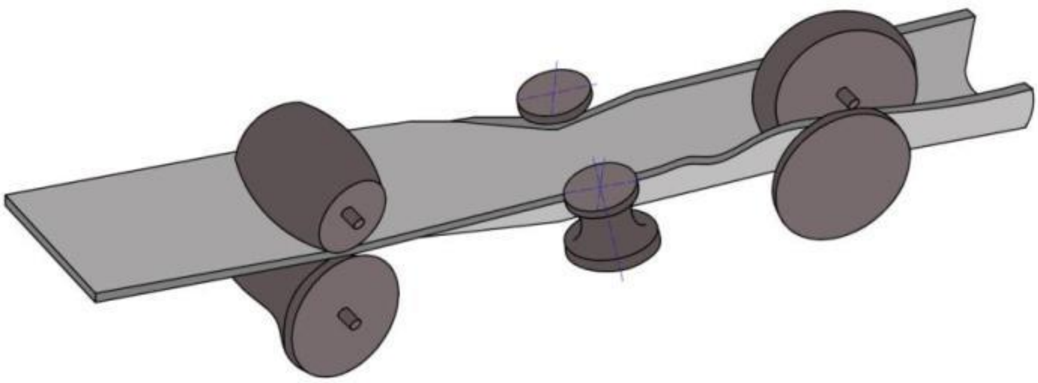

Fig. 1. Scheme of strip deformation in a continuous forming mill

Pipe billet forming schemes are shown in Fig. 2.

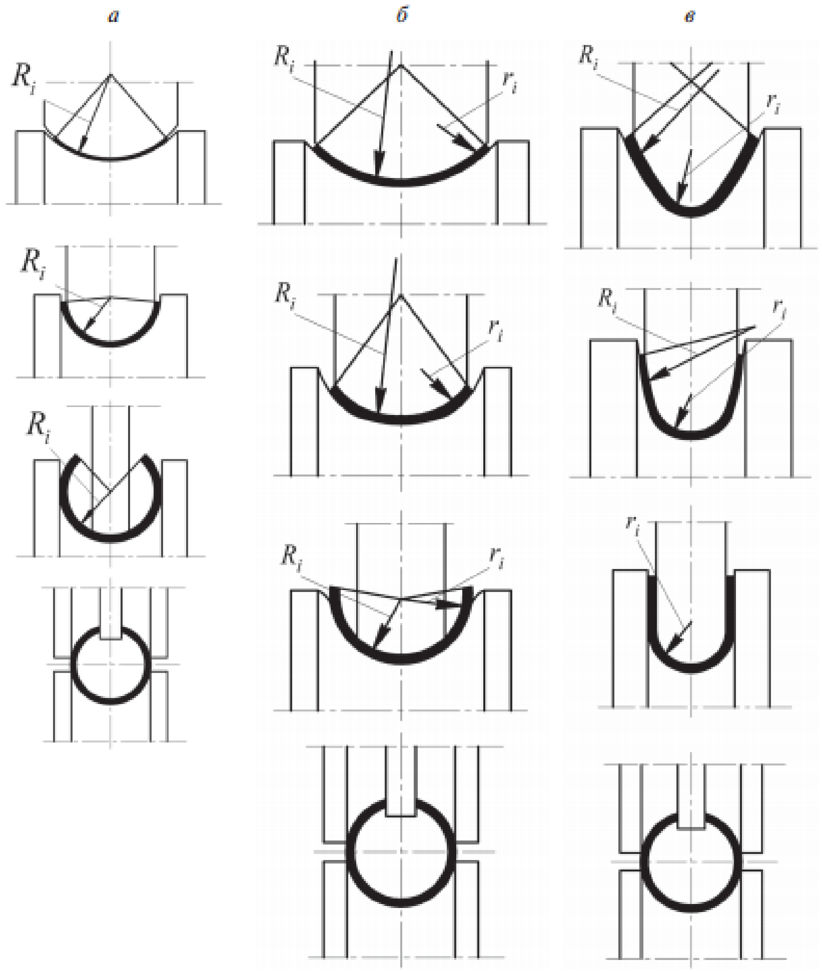

Figure 2. Schemes of tube billet forming on roll forming mills:
a - single-radius gauges; b, c - double-radius gauges

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Single-radius calibration of rolls. It is used for pipes with diameter D = 4...600 mm and wall thickness S = 0,2...20 mm. Calibration principle: the profile of the caliber is built with one radius gradually decreasing from the stand (Fig. 3.13). “Flower” of forming - profile of the neutral layer of the strip at different stages of the forming process.

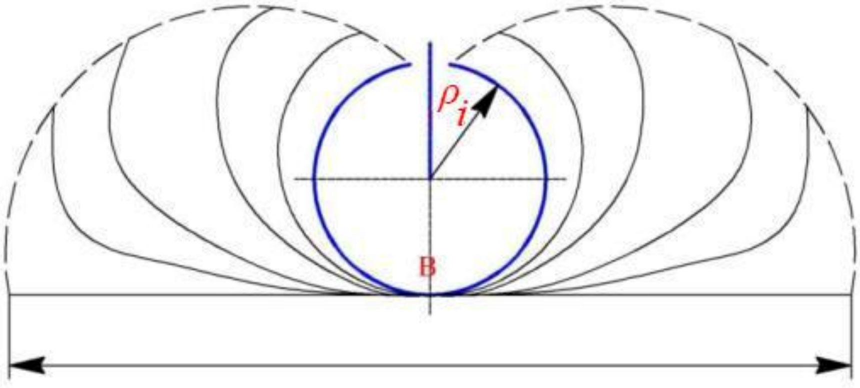

Figure 3. Forming profile for single-radius calibration

The caliber profile in the I-stand (Fig. 4) is determined by the parameters ρi, φi , which are related by the following relation:

$$\rho_i \varphi_i = B, \tag{1}$$

where ρi - bending (forming) radius of the neutral layer of the strip; φi - forming angle, rad.; B - strip width.

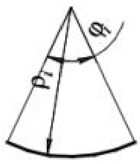

Figure 4. Profile of the caliber of the i-th stand

Advantages of calibration:
- simplicity of manufacturing of gauges;
- possibility to use one set of rolls at the beginning (at φ< 180º) of the forming mill for forming pipes of different but close diameters.

Disadvantages of calibration:
- relatively large dimensions of the roll compared to other calibrations, so this calibration is used for small pipe diameters;
- uncontrolled transverse displacement of the strip in the caliber is possible, because the constant radius of the caliber does not prevent its displacement, only friction forces prevent transverse displacement of the strip;
- high load on the cut washer in the seam guiding stand;
- non-parallel convergence of strip edges, which leads to the formation of the “roof” defect (Fig. 6).

The formation of this defect is inadmissible when welding pipes with high frequency currents, when there is no preforming - compression with disk electrodes. At uneven edge convergence, due to the proximity effect, the inner corners of the edges are heated first of all. This increases the height of the internal grout and worsens the quality of the seam.

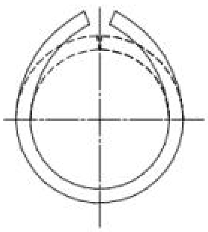

Fig. 5. Non-parallelism of strip edge convergence - “roof” defect

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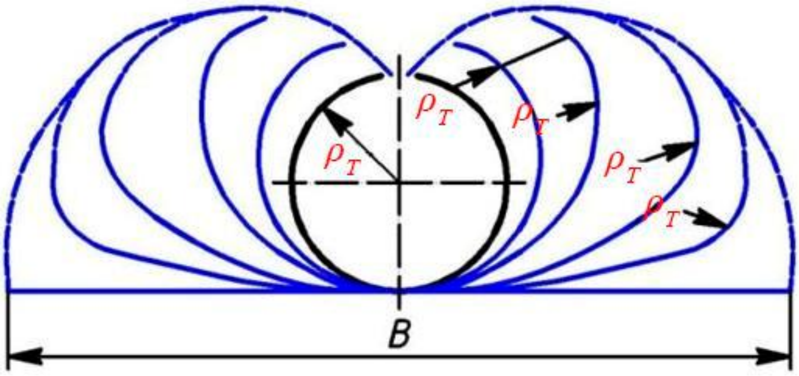
Double-radius roll calibration (with edge bending) is used for pipes with diameter D= 4...600 mm and wall thickness S= 0.2 ...20 mm. It is most common for pipes of small and medium (up to 168 mm) sizes.
Calibration principle: bottom and edges are formed starting from the first stand. The edge bending radius is constant, equal to the pipe radius. The bottom radius is variable, decreasing from stand to stand and becoming equal to the pipe radius.
For double-radius roll calibration, the forming profile is shown in Fig.



7.

Figure 6. Forming profile for double-radius calibration

The caliber profile in the i-th stand (Fig. 8) is determined by the parameters ρi,φi, ρT, αi, which are related by the following relation:

$$\rho_i \varphi_i + 2\rho_T \alpha_i = B \tag{2}$$

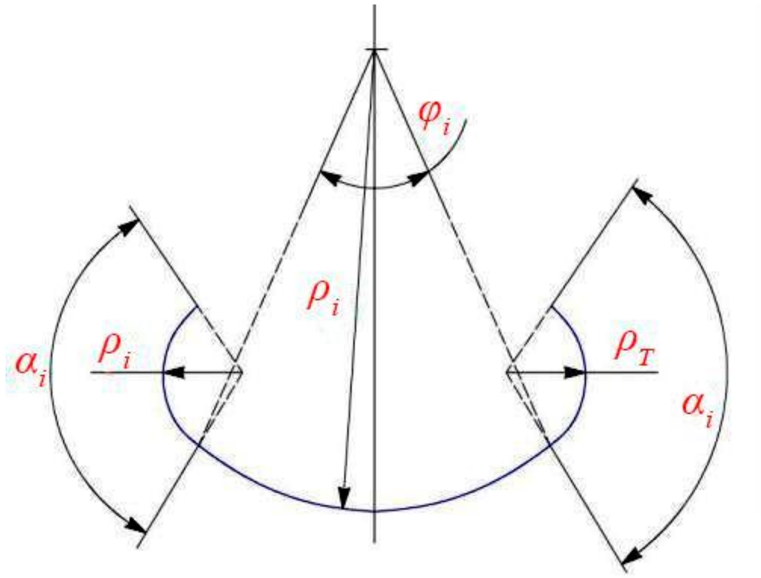


Figure 7. Caliber profile in stand I for double-radius calibration

Advantages of calibration:
- good edge forming, no "roof" defect formation;
- transverse displacement of the strip in the caliber is excluded.

Disadvantages:
- Complexity of manufacturing of calibers;
- necessity to have a complete set of rolls for each pipe size.

In the process of calibrating rolls with a flat center section (bottom), when forming the strip, the bottom remains flat, and the peripheral sections are bent with a radius equal to the radius of the pipe. The angle of the peripheral sections increases from stand to stand.
For this roll calibration, the molding profile is shown in Figure 10.
The caliber profile in the i-th stand is determined by the parameters Bi, ρT, αi, which are related by the following relationship:

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$$B_i + 2\rho_T \alpha_i = B \quad (3)$$

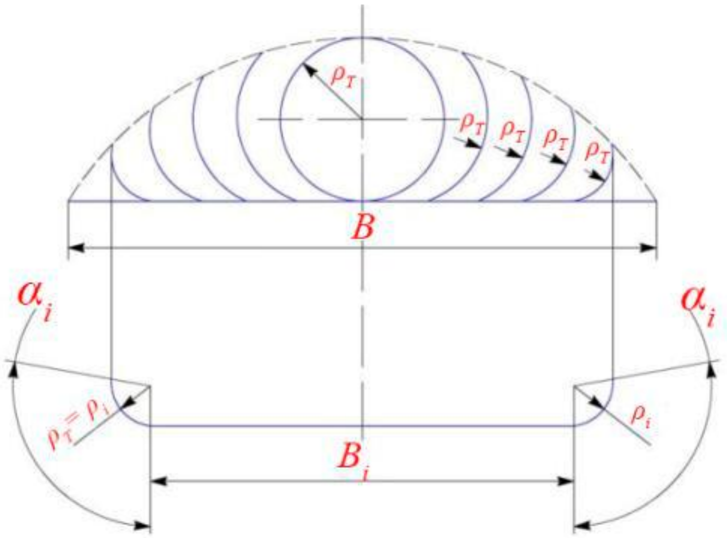

Figure 8. Forming profile and i-stand profile for roll calibration with flat center section

Advantage of calibration: Smaller roll dimensions, as there is no lifting of the strip edges above their convergence point.
Disadvantages of calibration:
- Difficulty in manufacturing the calibrations;
- necessity to have a complete set of rolls for each pipe size.
At double-radius calibration of rolls with bending of the central section, the bottom is formed with a radius equal to the radius of the finished tube, and the periphery - with a larger radius, which is gradually reduced from stand to stand. The φi width of the center section gradually increases, while the angle αi of the peripheral sections decreases.
For this roll calibration, the forming profile is shown in Fig. 12.

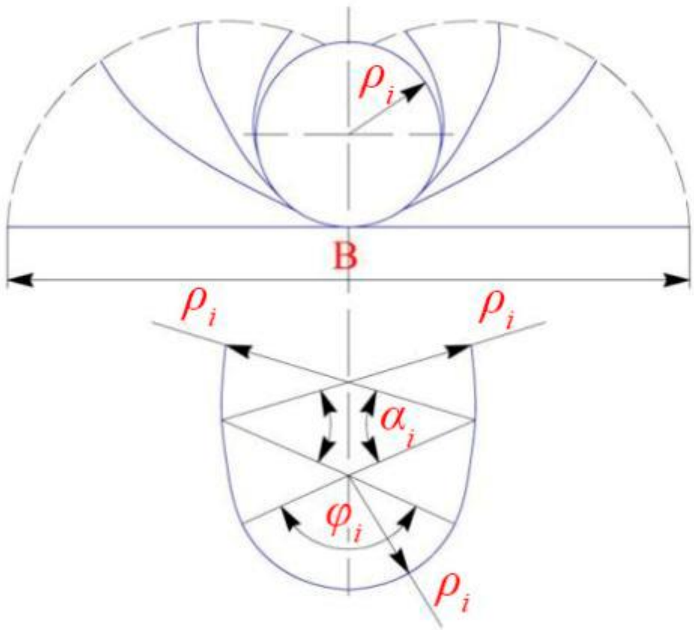

Figure 9. “Flower” molding and profile of i-th caliber for double-radius calibration with bending of the central section

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The caliber profile in the i-th stand is determined by the parameters ρi,φi, ρT,αi, which are related by the following relation:

$$\rho_T \alpha_i + 2\rho_T \alpha_i = B \tag{4}$$

Advantage of calibration: this forming scheme requires fewer stands, so it is mainly used for large diameter pipes.
Disadvantage of calibration: poor edge forming.
At oval roll calibration (by second-order curves) the profile of the caliber is made by second-order curves with monotonically changing curvature - in open calibers the profile has the form of a hyperbola or parabola, in closed ones - the form of an ellipse.
The scheme of oval calibration is shown in Fig. 14.

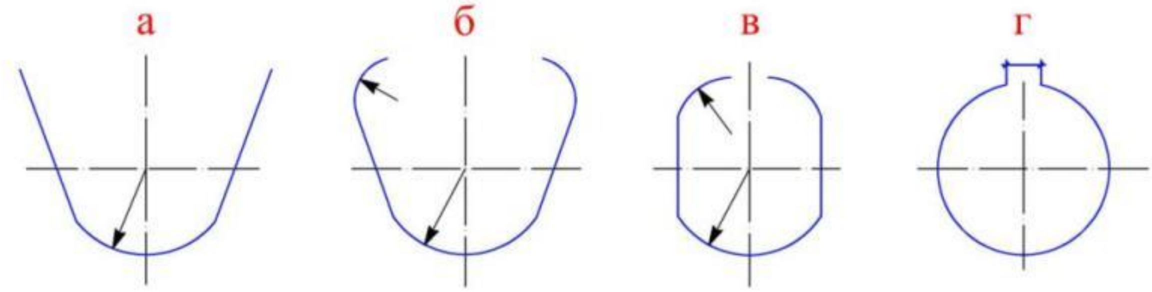

Fig. 10. Scheme of oval calibration:
a, b - open gauges; c, d - closed gauges

Advantages of calibration:
- effective for particularly thin-walled tubes, as it eliminates the formation of corrugations on the strip edges;
- four stands are sufficient for this forming scheme.

Disadvantage of calibration: complexity of manufacturing of gauges.
Technological efficiency of calibration is characterized by simplicity of mill adjustment and stability of the process of strip forming into a tube. Stability of the process is understood as the absence of transverse displacements of the strip in the caliber under the action of disturbing factors: non-parallel axes of rolls, different thickness and/or sickle-shape of the strip. Due to the load displacement (Fig. 15), asymmetric bending of the strip in the gauge occurs: φ1> φ2. When φ1 reaches the value of the friction angle, strip shear will occur.
In terms of manufacturability, the five types of calibrations discussed above can be characterized as follows. In type 1 calibration, the strip shear in the gauge is restrained only by frictional forces; in types 2-5, deformation is additionally required to shear the strip. Calibrations of types 2 and 3 have a constant radius of edge bending. If the strip is sickle-shaped, then there is unequal bending on the left and right. In type 5 calibration, the edge bending radius varies from stand to stand, which eliminates strip misalignment.

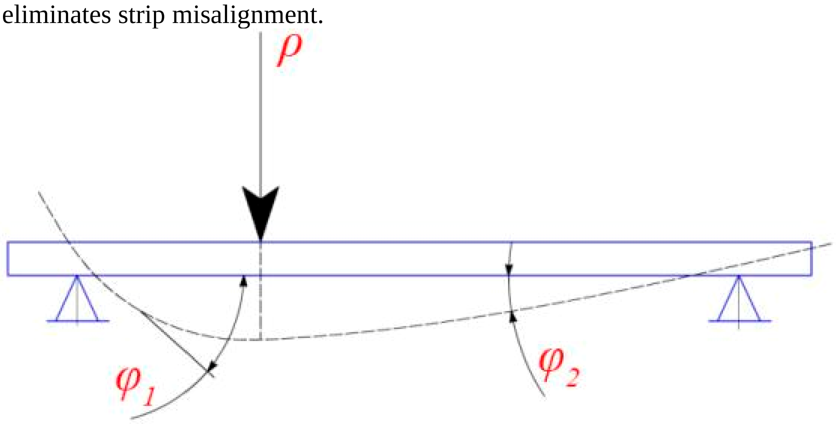

Figure 11. Schematic of strip bending

There are other criteria for selecting the type of calibration. One of the most important is the absence of corrugations on the strip edges during its forming.
As the strip moves through the forming mill, point a will move to position A along the straight line aA (Fig. 16).

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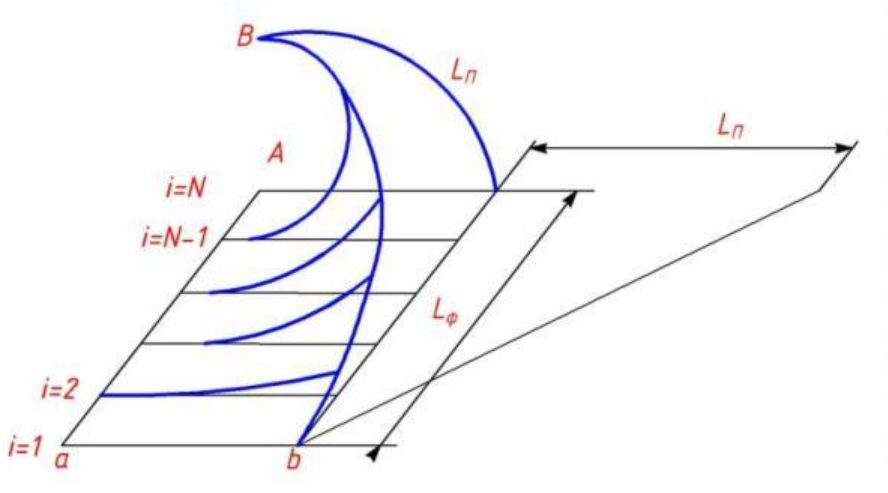

Fig. 12. Scheme of strip forming

The point b will move in space along the curve bB. The path bB is greater than aA, i.e. the edge of the strip experiences a tensile deformation:

$$\varepsilon_{\kappa p} = \frac{bB - aA}{aA} \quad (5)$$

where aA= LF is the length of the forming mill (up to the entrance to the seam-compression rolls);

$$bB \approx \sqrt{L_{\Pi}^2 + L_{\Phi}^2} \quad (6)$$

where LP is the length of the projection path bB of point b on the vertical plane, determined by the type of calibration of rolls of the forming mill (types 1-5).
If the tensile strain of the edge is inelastic, i.e. εkr> 0.002, residual compressive stresses will occur in it.

$$\int_l \sigma_x^{ocm} dl = 0 \quad (7)$$

condition of self-equilibration of residual stresses (Fig. 17).

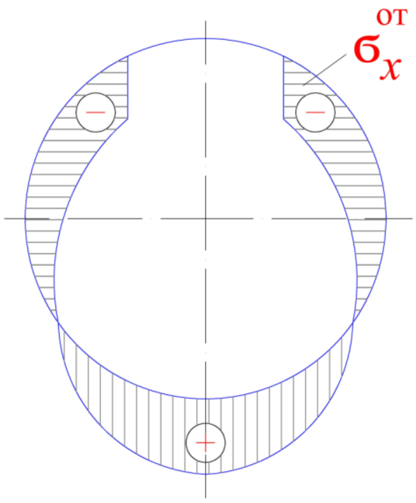

Fig. 13. Distribution of residual stresses in the strip during molding

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Residual compressive stresses on the strip edges can cause the appearance of corrugations by the mechanism of loss of stability of the Euler column.
To avoid loss of edge stability and the appearance of corrugations, the edge deformation should not exceed

$$\varepsilon_{кр} = \frac{\sqrt{L_{\Pi}^2 + L_{\Phi}^2} - L_{\Phi}}{L_{\Phi}} \le 0{,}002 \qquad (8)$$

From this inequality, the minimum length of the forming mill LF can be determined.

IV.CONCLUSION

By analyzing the types of roll calibrations: single-radius; double-radius with edge bending, with flat central section and with bending of the central section; oval by the curves of the second order, the optimal method of forming has been established, providing good proforming of the edges of the workpiece to obtain a quality weld seam

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