Analysis of skelp deformation zones for the down trajectory of electrically welded pipes forming

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Abstract. Deformation zones along the down trajectories of skelps forming using the forming mill TESA10-50 (Pipe Electrical Welding Unit) were considered. For pipes with 50×1.5 mm diameter, strained conditions for forming zones were identified for different options of down trajectories length with the as-formed skelp initial position upward gradient within the range of $H = 0 \div 50$ mm. It was determined that increase in the down trajectory length contributed to the decrease in longitudinal strain values, however, it could not provide for forming within the allowable values along the entire forming zone of the mill. Reduction in the skelp curvature by 8÷13 % resulted in the longitudinal strains decrease at the skelp edge along the entire forming zone length.

1 Introduction

Currently, multiple operations involving different equipment [1-3] with huge capacities, dimensions and weight are used for the production of pipes [4-7] of different size and grade range. The quality of finished pipes is affected absolutely by all the operations that are performed in a certain sequence starting from the initial skelp preparation to the finishing operations [8-11]. The regulated performance of multiple operations allows achieving the required parameters of skelps: from dimensions to mechanical properties, that shall determine the performance properties of the finished pipe [12-14].

A modern Pipe Electrical Welding Unit (TESA) is the process equipment arranged in series fitted with forming rolls that provide for continuous skelp forming, welding and pipe sizing. Forming mills are designed for roll forming of continuously moving skelps into the as-formed skelp, for subsequent welded pipes sizing along the outside diameter and minor straightening along the pipes' length.

It has been determined that the equipment configuration and the rolls contact action affect the skelp strained condition [15]. The forming mill configuration is determined by the number of opened, closed and edger stands and the inter-stand distance.

During the skelp forming, longitudinal stretching strains occur within the as-formed skelp forming zone [16, 17]. Determination of the most effective forming parameters and distribution of strains and stresses between the stands is the primary task. Strains and stresses along the entire as-formed skelp formation zone within the continuous forming

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sections are determined by the nature of the skelp geometry change in fixed fibers of the as-formed skelps for all roll passes [18].

Determination of the skelp strained condition between the stands [19] makes it possible to adjust the as-formed skelp dimensions within the deformed sections. Control of the strained condition through the dimensions of the forming zone (forming zone length, dependence of the change in curvature along the forming zone and the skelp trajectory) makes it possible to choose the best effective parameters for skelps forming [20, 21].

2 Equipment configuration and forming scheme

The effect of the down trajectory length and initial value of the as-formed skelp forming zone upward gradient on the strained condition of the pipe with 50×1.5 mm diameter is the subject of the research.

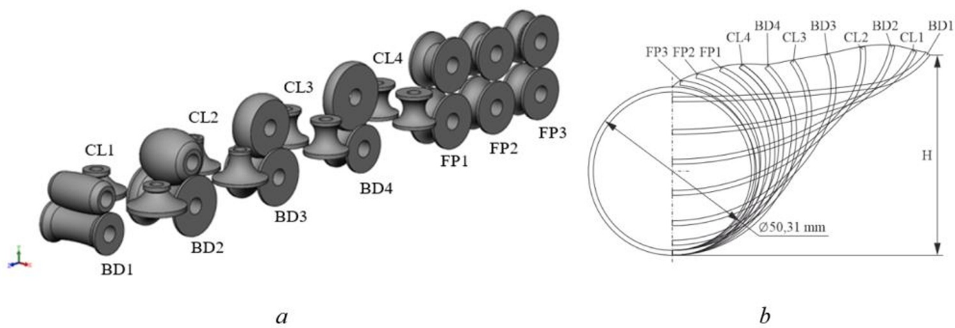

Fig. 1. Parameters of Pipe Electrical Welding Unit TESA 10-50: *a* – mill setup; *b* – flower pattern.

Fig. 1 shows parameters of TESA 10-50 [22, 23]. The forming mill configuration is as follows: four opened, three closed and four edger stands (Fig. 1*a*). The forming flower of the as-formed skelp with the down trajectory of the axial fiber is given in (Fig. 1*b*). The initial position of the as-formed skelp forming zone is determined based on the initial as-formed skelps upward gradient value (H). This article studies forming zones with various lengths of the as-formed skelps down trajectory, the length is within the following stands: BD1-CL1; BD1-FP1; BD1-FP2. The value of the as-formed skelps initial position upward gradient for each length of the down trajectory forming changes within the range of $H = 0 \div 50$ mm. The value of the as-formed skelps position upward gradient is calculated for each forming stand.

3 Determination and analysis of longitudinal strains of as-formed skelps

Fig. 2 shows results of longitudinal strains calculations along the as-formed skelps edge with the forming down trajectory within: BD1-CL4 (Fig. 2*a*); BD1-FP1 (Fig. 2*b*); BD1-FP2 (Fig. 2*c*). The area in charts highlighted in red corresponds to the longitudinal strains exceeding the allowable values ($e = 0.175$ %).

The analysis of results shows that within the zone of the down trajectory forming within the area of stands BD1-CL4 (Fig. 2*a*), the longitudinal strains in as-formed skelps edges at the area of opened stands when the upward gradient value is within $H = 0 \div 20$ mm, exceed the allowable value of ($e = 0.175$ %). While the values of longitudinal strains within stands

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BD1-BD3 when the upward gradient is within $H = 25÷50$ mm do not exceed the allowable values.

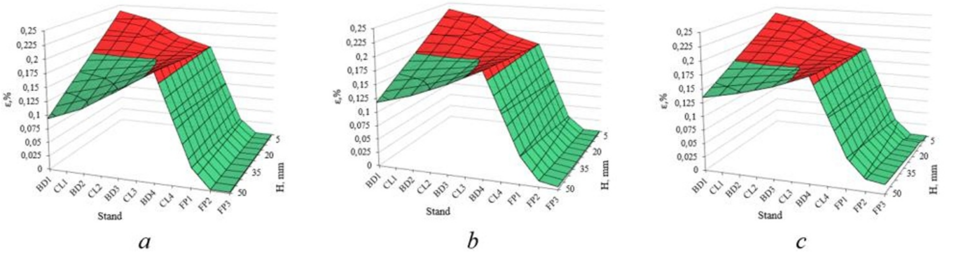

Fig. 2. Charts of longitudinal strains of as-formed skelps edges for the forming down trajectory within the area of stands: *a* – BD1-CL4; *b* – BD1-FP1; *c* – BD1-FP2.

As you can see in the chart given in Fig. 2*b*, the longitudinal strains in the as-formed skelps edges within the areas of opened stands when the upward gradient is within $H = 0÷25$ mm, exceed the allowable value. The values of as-formed skelps longitudinal strains within the area of stands BD1-BD3 when the upward gradient is within $H = 30÷50$ mm do not exceed the allowable values.

In Fig. 2*c* you can see that the longitudinal strains in as-formed skelps edges within the area of stands BD1-BD3 when the upward gradient is within $H = 0÷30$ mm exceed the allowable values. The values of as-formed skelps longitudinal strains within the area of stands BD1-BD3 when the upward gradient is within the range of $H = 35÷50$ mm do not exceed the allowable values.

The three proposed versions of the forming zones with the down trajectory do not provide for the high-quality and stable forming of skelps since longitudinal strains in as-formed skelps edges within stand BD4 exceed the allowable values. For the down trajectory forming within stands BD1-CL4, strains in as-formed skelps are within the range of 0.179÷0.193 %. For the down trajectory forming within stands BD1-FP1, strains in as-formed skelps edges are within the range of 0.178÷0.192 %.

For the down trajectory forming within stands BD1-FP2, strains in as-formed skelps edges are within the range of 0.177÷0.188 %. While it should be mentioned that for the three versions under consideration, the longitudinal strains within the area of stands FP1-FP3 when the forming zone upward gradient is within $H = 0÷50$ mm, do not exceed the allowable value.

Increase in the length of the forming down trajectory does not result in longitudinal strains reduction while making them equal within the area of stands BD1-CL4.

4 Updated forming parameters and longitudinal strains of as-formed skelps

The survey shows that for the given configuration of the forming mill, the down trajectory forming of skelps contributes to the decrease in longitudinal strains values, however, it does not provide conditions for high-quality forming along the entire forming zone.

To ensure allowable values of longitudinal strains of as-formed skelps throughout the entire forming mill, as-formed skelps profile parameters shall be adjusted. Curvature of as-formed skelps resulting in unacceptable longitudinal strains shall be distributed along the entire forming zone.

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The most suitable forming scheme is the scheme of the down trajectory which is located within the area of stands BD1-CL4, since the amount of the longitudinal strains with the said area is lower by 20.3 %.

The initial curvature ($1/R$) of as-formed skelps is to be changed to the curvature values ($1/R_{corr}$) in such a way that the amount of the longitudinal strains does not exceed the allowable values. As a result of adjustments made, the as-formed skelps curvature within the area of stands BD1-CL2 increased within 4.1÷15.85 %, while it decreased within 0.93÷6.93 % at the area of stands BD3-FP3.

Results of updated values of curvature for the down trajectory forming scheme within the area of stands BD1-CL4 are specified in Table 1.

Based on as-formed skelps curvature adjusted values, the field of longitudinal strains is determined for the down trajectory forming within the area of stands BD1-CL4 when the initial as-formed skelp upward gradient is within the range of $H = 0÷50$ mm.

Table 1. Values of as-formed skelps curvature for the down trajectory forming scheme within the area of stands BD1-CL4.

Stand	BD1	CL1	BD2	CL2	BD3	CL3	BD4	CL4	FP1	FP2	FP3
$1/R$	0.0021	0.0060	0.0103	0.0148	0.0193	0.0235	0.0265	0.0295	0.0320	0.0352	0.0376
$1/R_{corr}$	0.0025	0.0065	0.0107	0.0154	0.0183	0.0219	0.0250	0.0283	0.0313	0.0349	0.0372
Δ, %	15.85	8.32	3.41	4.1	-5.56	-6.93	-5.59	-4.11	-2.4	-0.96	-0.93

Results of longitudinal strains re-calculations for the down trajectory forming within the area of stands BD1-CL4 are given in Fig. 3.

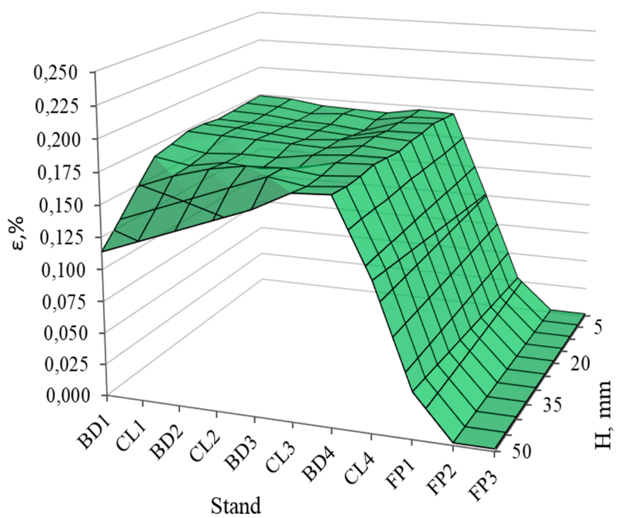

Fig. 3. As-formed skelps longitudinal strains for the down trajectory forming within the area of stands BD1-CL4.

As the chart shows, the updated parameters of forming affect the as-formed skelps longitudinal strains which are within the allowable values range. For forming zones with the initial as-formed skelps upward gradient within the range of $H = 0÷30$ mm at the area of stands BD1-CL4, strains are found at the same level within ($e = 0.171÷0.174$ %). For forming zones with the initial as-formed skelps upward gradient within the range of $H = 35÷50$ mm at the area of stands BD1-CL4, strains have uniform pattern of changes and can be found within ($e = 0.121÷0.173$ %).

5 Conclusion

Analysis of forming zones with various length of forming down trajectories shows that increase in the length of the forming down trajectory does not result in longitudinal strains reduction while making them equal within the area of stands BD1-CL4. The most suitable forming scheme to ensure forming parameters adjustment is the down trajectory forming scheme which is located within the area of stands BD1-CL4, since the value of longitudinal strains within the said area is lower by 20.3 %. As-formed skelps longitudinal strains decrease as a result of decrease in as-formed skelps curvature within the range of 4.1÷15.85 % at the area of stands BD1-CL2 and as a result of decrease in curvature within the range of 0.93÷6.93 % at the area of stands BD3-FP3 that contributes to the sustainable and stable forming process.

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