

DEFINING THE TECHNOLOGICAL BOUNDARIES OF ROTARY FRICTION SPINNING FOR SMALL-DIAMETER NECK FORMATION

The operational reliability of belt conveyors equipped with solid rollers without inserts largely depends on the reliability, durability, and ease of maintenance of these rollers. Taking into account the significant quantity of rollers installed in a conveyor system and the necessity for their periodic inspection, maintenance, and replacement, it becomes absolutely crucial to establish a stable, reproducible, and highly efficient manufacturing technology for their production. In this context, an effective and proven method involves manufacturing rollers from tubular billets with relatively small-diameter necks, which are precisely formed through the process of rotary friction spinning — a specialized technique that enhances production efficiency.

The rotary friction spinning process for forming small-diameter necks on tubular billets is carried out as follows: initially, the tubular billet is securely clamped in the spindle of a spinning machine and rotated at a controlled speed. During rotation, the billet is heated uniformly to a forging temperature, suitable for plastic deformation, and subjected to shaping by a set of specially designed friction tools. The technological process can be divided into two interconnected and continuous stages (Fig. 1, a): the initial formation of a conical bottom section, followed by the subsequent transformation of this bottom into a precise neck structure. These stages are performed sequentially without any interruptions, thanks to the synchronized action of consecutively positioned friction tools mounted on a moving support (Fig. 1, b). The tools, moving tangentially relative to the billet's surface, first form a hermetically sealed bottom (with the shape of a truncated cone characterized by a generatrix inclination angle φ_0 and a vertex diameter close to the desired neck diameter), and then, through further localized deformation, shape the conical section into a stable neck using the second tool. The entire spinning operation, covering both stages, is completed within a single controlled heating cycle and a single coordinated working stroke of the tool assembly.

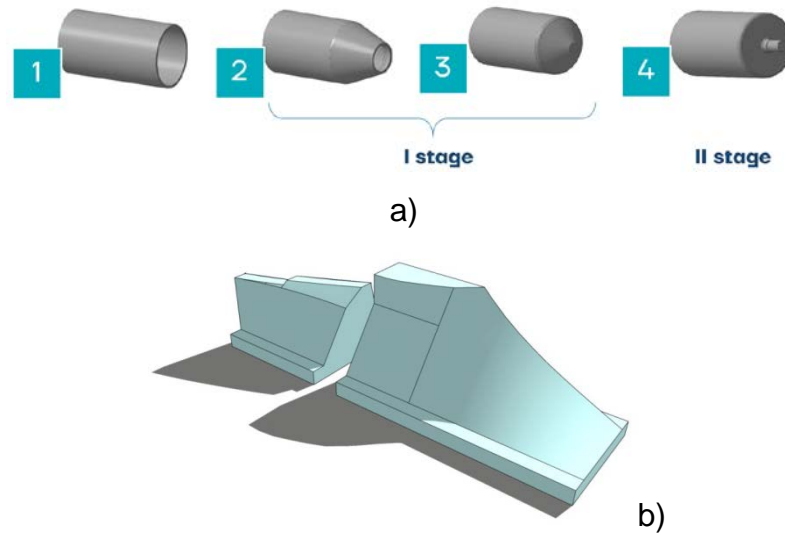


Fig. 1 - Stages of neck formation (a) and arrangement of two consecutive friction tools (b)

Experimental trials have revealed that stable and defect-free formation of small-diameter necks on tubular billets is reliably achieved only when the inner diameter of the formed neck remains no less than ten percent greater than the wall thickness at the neck section ($0.1S_n$). Therefore, the following necessary condition must be strictly satisfied:

$$d \geq 2.1 \cdot S_n. \quad (1)$$

If this critical condition is not met, various types of defects, particularly neck twisting, are likely to occur, severely compromising the quality and performance of the roller. It should also be noted that the wall thickness, which ultimately determines the minimum feasible neck diameter, is dynamically formed during the spinning process and depends not only on the initial material dimensions and degree of reduction but also on a range of additional factors, including the geometry of the friction tools, the thermal conditions, and the specific technological parameters of the spinning process. Therefore, the accurate determination of the minimum neck diameter achievable through rotary friction spinning becomes a key factor in process optimization and ensuring product quality. The general deformation zone scheme of a thin-walled billet during spinning is shown in Fig. 2.

According to the research works conducted by Kaporovich V.G., it has been established that the wall thickness of the deformed section during spinning relates to the current radius via the following theoretical expression:

$$s_i = s_0 \left(\frac{r_0}{r_i} \right)^\omega, \quad (2)$$

where $\omega = f(l, l_0, \alpha, \sigma_s, \mu)$ - is a power-law coefficient that accounts for the influence of the stress-strain state components of the wall.

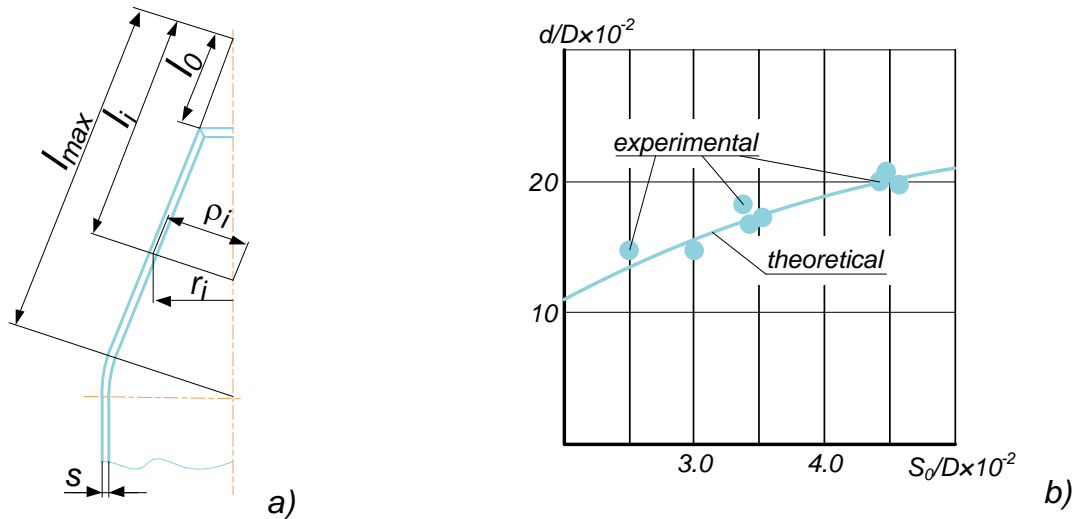


Fig. 2 - Deformation zone of the thin-walled billet during rotary friction spinning.

Further experimental studies carried out by Kogan B.Ya., Shekhet Ya.M., and Kulik O.M. demonstrated a strong and reliable correlation between the experimental values of wall thickness obtained during cone spinning of tubes (with an s/d ratio of approximately 0.15, produced from Steel 10) and the theoretical values derived from a simplified yet accurate expression:

$$s_i = s_0 \sqrt{R_0/R_i}. \quad (3)$$

Given that the probability of defects and process instability significantly increases as operating parameters approach the boundary of stable processing conditions, it is practical and safer for industrial-scale production to operate with a reasonable margin from this critical boundary. Thus, for technological reliability, it is reasonable to introduce a correction factor into equation (3) when determining the actual feasible limits for safe operation.

After applying the appropriate corrections and transformations, the following important expression is obtained:

$$d_n \geq 1.63 \sqrt[3]{s_0^2 D}, \quad (4)$$

where d_n represents the minimum reliably achievable neck diameter, and D is the outer diameter of the tubular billet prior to deformation.

Analysis of Results The comparative assessment of theoretical and experimental datasets (Fig. 2, b) confirms a high degree of concordance, validating the applicability of Equation (4) for defining safe process parameters. Consequently, this enables enhanced process control, defect mitigation, and optimized production reliability, substantially extending the operational lifespan of belt conveyor systems in industrial environments.