

## POWER INTENSIFICATION OF SWELLING PROCESS

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**Abstract:** The paper deals with the outcomes of investigations carried out to determine the impact of power intensification of a deformation process by means of applying additional axial pressure over the fronts of round billets. By increasing axial pressure, the value of  $\Pi\sigma$  index and the "rigidity" of the stressed state pattern drops down that promote redistribution of metal within the area of deformation. This resulted in 15% decrease of the index of swelling and 76 to 78% increase of the permissible level of swelling during deformation of low carbon steel specimen.

**Key words:** Hydrostatic swelling, intensification

**Özet:** Makale, boru şekilli bir parçanın şişirilmesinde ilave aksel basınç uygulayarak güç yoğunlaştırmanın etkilerini araştırmak üzere yürütülen çalışmaların sonuçlarını özetlemektedir. Aksel basıncın artırılması,  $\Pi\sigma$  gerilme indeksini ve gerilme halinin rijitliğini azaltarak şekil değiştirme bölgesindeki malzemenin düzgün akışını sağlamaktadır. Bu yöntemle düşük karbonlu çelik parçalar için, şişirme indeksinde % 15 civarında bir düşüş ve şekillendirilebilirlikte % 76 ile % 78 arasında bir artış elde edilmektedir.

**Anahtar Kelimeler:** Hidrostatik şişirme, yoğunlaştırma

### Introduction

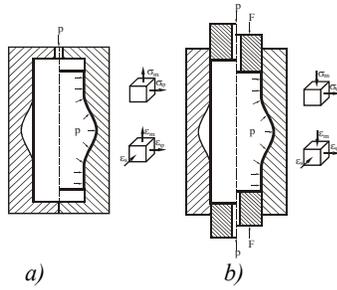
Round billets swelling is a process which causes their cross-sectional measurements to increase by means of pressure impact acting outwards on their internal surface [1,2]. In industrial application swelling is performed in special dies equipped with punches or, alternatively, in elastic (rubber or polyurethane) medium. Much more effective are the deformation processes of swelling by means of hydrostatic pressure in liquid medium. Here the fluid functions as a standard shaping punch by means of which a uniform loading over the billet under deformation is achieved. In order to intensify the rate of swelling without any presence of flaws and to ensure the proper rate of variable thickness, it is necessary to provide optimized power loading as well as the most favorable pattern of stressed and strained state[3,4,5,6].

The aim of this investigation is to intensify the process of deformation in swelling and to enlarge the range of feasible engineering applications.

### Formulation of the Problem

In swelling round billets by means of hydrostatic pressure exerted through oil work fluid, the stressed and strained state pattern remains unambiguous until the point of contact of their walls with the die surface (Fig.1- a). Both tangential and meridian stresses  $\sigma_\phi$  and  $\sigma_m$  are tensile whereas the stresses along the wall thickness acting over the normal toward the generatrix of the element under swelling are of negligible value.

In this section meridian and tangential deformations  $\epsilon_m$  and  $\epsilon_\phi$  are indicative of elongation whilst radial deformations  $\epsilon_r$  indicate wall shrinkage. Following the contact of the wall of the section under swelling with the die surface there arise compressive radial stresses  $\sigma_r$  which are equal to the pressure of the work fluid ( $\sigma_r = p$ ) at the inner surface of the billet whereas at its outer surface ( $\sigma_r = \sigma_k$ ). This unfavourable scheme of stressed and strained state accompanied by considerable compressive stresses and thinning of walls is the reason for limiting the permissible rate of swelling.



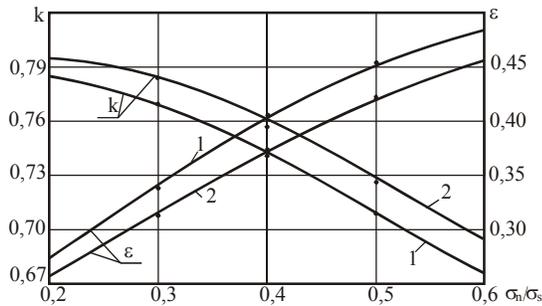
**Fig.1** Hydrostatic swelling of round billets  
*a) conventional process; b) intensified process*

Additional axial load is applied to the front surfaces of the round billet in order to intensify the deformation process and enlarge the range of its technical capacities (Fig.1- b). Thus the billet is simultaneously acted upon through the inward hydrostatic pressure  $p$  and the additional axial loading  $\sigma_n$ . This allows for a change in the stressed and strained state pattern and swelling is performed through ambiguous stresses, i.e. compressive meridian  $\sigma_m$  and tensile tangential  $\sigma_t$ , which bring about to radial and meridian deformations of shrinkage ( $\epsilon_s < 0$  and  $\epsilon_m < 0$ ) on one hand and tangential deformations of elongation ( $\epsilon_\varphi > 0$ ) on the other. This pattern of stressed and strained state is most favourable for deformation and facilitates the process of plastic shaping.

**Investigations Outcomes**

The possibilities for power intensification of the process of swelling have been investigated by means of a purpose-built laboratory test stand [6] equipped with replaceable set of tools. Machine oil type AN32 (Bulgarian State Standard 5291-86) having dynamic viscosity  $\eta = 0,30 \text{ Pa}\cdot\text{s}$  has been used as work fluid. Sample round billets are made of low carbon steels 10 ( $R_m = 320 \text{ MPa}$ ,  $R_e = 230 \text{ MPa}$ ,  $A_5 = 22\%$ ) and 20 ( $R_m = 400 \text{ MPa}$ ,  $R_e = 270 \text{ MPa}$ ,  $A_5 = 20\%$ ) having inner diameter of  $d_i = 32 \text{ mm}$  and thickness of wall  $s_0 = 1,0 \text{ mm}$ . By utilizing the specially developed program module [4] and computer aided control stressed state parameters have been investigated for different values of additional axial pressure upon billets  $\sigma_n = (0,10 \div 0,60)\sigma_s$ . Boundary coefficients and rates of swelling have been determined on condition of absence of flaws and loss of stability.

An overall analysis of outcomes shows how increased additional axial pressure brings about to expansion of boundary rate of swelling from  $\epsilon = 0,273$  (with  $\sigma_n/\sigma_s = 0,20$ ) to  $\epsilon = 0,485$  (with  $\sigma_n/\sigma_s = 0,60$ ) for steel type 10 and from  $\epsilon = 0,258$  (with  $\sigma_n/\sigma_s = 0,20$ ) to  $\epsilon = 0,454$  (with  $\sigma_n/\sigma_s = 0,60$ ) for steel type 20 (see fig.2).



**Fig. 2** Change in the indices of swelling in relation to the axial pressure. 1 - steel type 10; 2- steel type 20

The permissible value of axial pressure in all investigated billets of low carbon steel is  $\sigma_n/\sigma_s = 0,60$ . Further rise in axial pressure causes loss of stability of the thin wall billet.

The axial pressure acting upon the billet should reach a value greater than the value of meridian stress  $\sigma_m$  and also a transition to a pattern of two dimensional compression (Fig.1- b). This is related to a change in the stressed state factor  $\Pi_\sigma$ , which indicates the ratio of resistances against changes in volume and shape. With the rise in axial pressure from  $\sigma_n = 0,20\sigma_s$  to  $\sigma_n = 0,60\sigma_s$  the  $\Pi_\sigma$  factor drops from  $\Pi_\sigma = 1,24$  to  $\Pi_\sigma = 0,893$  from steel type 10 and  $\Pi_\sigma = 1,18$  to  $\Pi_\sigma = 0,867$  fro steel type 20 hence the reduced rigidity of the stressed state pattern (fig.3). As a result the redistribution of metal in the deformation area is facilitated to a considerable extent, the coefficient  $k$  is reduced whereas the permissible rate of swelling is raised.

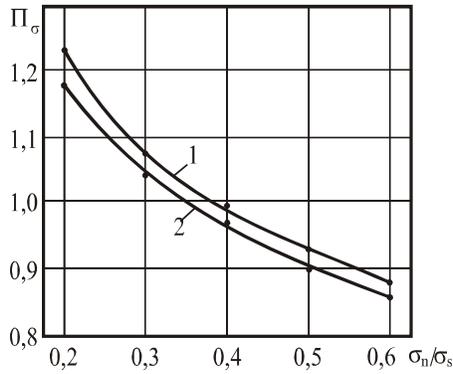


Fig. 3 Change in the stressed state index in relation to the axial pressure 1- steel type 10; 2- steel type 20

The ductility resource, which is evaluated by the  $\lambda_p$  index and determined in compliance with the technique in [7], grows up with the transition to ambiguous tensile- compressive pattern of stressed state. When there is a change in the axial pressure from  $\sigma_n/\sigma_s = 0,20$  to  $\sigma_n/\sigma_s = 0,60$  the resource of ductility grows with 24÷27% (see fig.4). This allows for intensification of the deformation process and the increase of the boundary rate of swelling by 78% for steel type 10 and by 76% for steel type 20 (fig. 2) and remaining good amount of ductility margin which is a resultant difference between the complete resource  $\lambda_p$  and used resource  $\lambda$  (fig. 4).

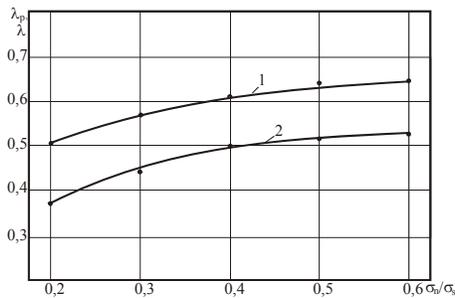


Fig.4 Change in the ductility resources in relation 1-  $\lambda_p$  and 2-  $\lambda$  to the axial pressure (steel type 10)

The change of ductility indices in relation to axial pressure is presented on a general space diagram (fig. 5). Apart from the curves of change in the ductility resources  $\lambda_p$  and  $\lambda$  and the stressed state index  $\Pi_\sigma$ , depending on axial pressure  $\sigma_n/\sigma_s$ , the dual dependences  $\lambda_p - \sigma_n/\sigma_s$ ,  $\lambda_p - \Pi_\sigma$  and  $\Pi_\sigma - \sigma_n/\sigma_s$  are also presented in the three coordinate planes thus giving some idea of the rate and further possibilities for intensification of the deformation process.

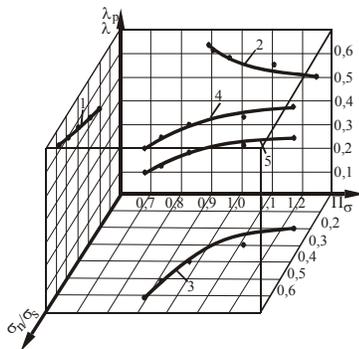


Fig. 5 Indices relationships in intensified process of swelling (steel type 10): 1:  $\lambda_p - \sigma_n/\sigma_s$ ; 2:  $\lambda_p - \Pi_\sigma$ ; 3:  $\Pi_\sigma - \sigma_n/\sigma_s$ ; 4:  $\lambda_p - \Pi_\sigma - \sigma_n/\sigma_s$ ; 5:  $\lambda - \Pi_\sigma - \sigma_n/\sigma_s$

**Conclusion**

Applying additional axial pressure upon the fronts of the round billets will cause a change in the stressed- strained state pattern henceforth the swelling is affected in the condition of compressive meridian and tensile tangential stresses. Increase in the axial pressure leads to reduction of  $\Pi_{\sigma}$  index and also of the “rigidity” of the stressed state pattern. Ductility resource grows by 24 to 27 % and redistribution of metal in the deformation area is facilitated. This allows for intensification of the deformation process so that for axial pressure  $\sigma_n = 0,60\sigma_s$  there is a reduction of 15 % in the coefficient of swelling of low carbon steel billets and an increase by 76 to 78 % of the permissible rate of swelling and retaining of good amount of ductility margin.

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