http://fbe.trakya.edu.tr/tujs
Trakya Univ J Sci, 8(2): 95-98, 2007
ISSN 1305–6468
DIC: 243KEGB820712070108

Araştırma Makalesi / Research Article

POWER INTENSIFICATION OF SWELLING PROCESS

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Alınış: 25 Eylül 2007
Kabul Ediliş: 20 Kasım 2007

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 Пσ 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 eksenel basınç uygulayarak güç yoğunlaştırmanın etkilerini araştırmak üzere yürütülen çalışmaların sonuçlarını özetlemektedir. Eksenel basıncın arttırılması, Пσ 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 puncheons 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 puncheon 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 σ_φ and σ_m are tensile whereas the stresses along the wall thickness acting over the normal toward the generetrix of the element under swelling are of negligible value.

In this section meridian and tangential deformations ε_m and ε_φ are indicative of elongation whilst radial deformations ε_s indicate wall shrinkage. Following the contact of the wall of the section under swelling with the die surface there arise compressive radial stresses σ_r which are equal to the pressure of the work fluid (σ_r= p) at the inner surface of the billet whereas at its outer surface (σ_r= σ_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.

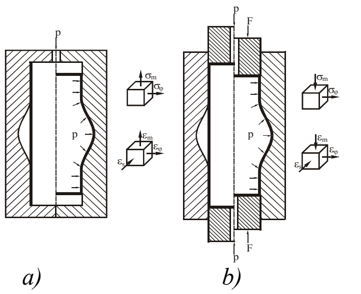

Fig.1 *Hydrostatic swelling of round billets*
a) conventioanl process; b) intensified process

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 σ_n. This allows for a change in the stressed and stressed state pattern and swelling is performed through ambiguous stresses, i.e. compressive meridian σ_m and tensile tangential σ_t, which bring about to radial and meridian deformations of shrinkage ($\varepsilon_s < 0$ and $\varepsilon_m < 0$) on one hand and tangential deformations of elongation ($\varepsilon_\varphi > 0$) 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 η= 0,30Pa.s has been used as work fluid. Sample round billets are made of low carbon steels 10(R_m= 320MPa, R_e=230MPa, A_δ= 22%) and 20(R_m= 400MPa, R_e=270 MPa, $A_{\delta=}$ 20%) having inner diameter of d_o= 32mm and thickness of wall s_o= 1,0mm. 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 σ_n= (0,10÷ 0,60)σ_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 ε= 0,273 (with $\sigma_n/\ \sigma_s$ = 0,20) to ε=0,485(with $\sigma_n/\ \sigma_s$ = 0,60) for steel type 10 and from ε= 0,258(with $\sigma_n/\ \sigma_s$ = 0,20) to ε=0,454 (with $\sigma_n/\ \sigma_s$ = 0,60) for steel type 20 (see fig.2).

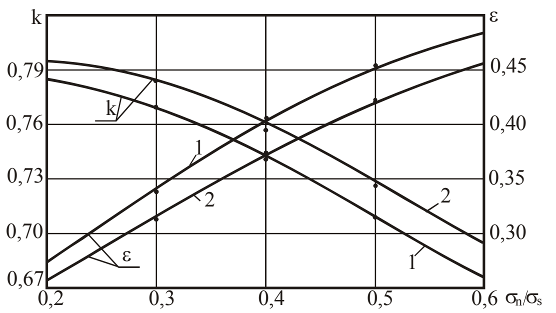

Fig. 2 *Change in the indices of swelling in relation to the axial pressure. 1 - steel type 10; 2– steel type 20*

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 σ_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 Π_σ, which indicates the ratio of resistances against changes in volume and shape. With the rise in axial pressure from σ_n= 0,20σ_s to σ_n= 0,60σ_s the Π_σ factor drops from Π_σ= 1,24 to Π_σ= 0,893 from steel type 10 and Π_σ=1,18 to Π_σ= 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 permissble rate of swelling is raised.

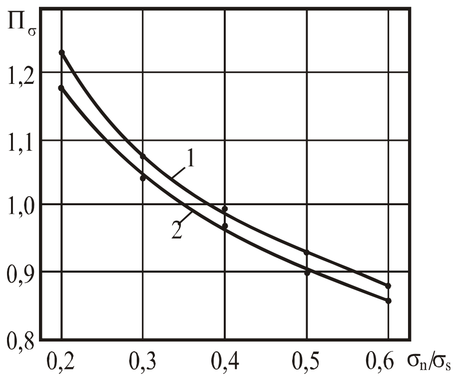

Fig. 3 *Change in the stressed state index in relation to the axial pressure 1- steel type 10; 2– steel type 20*

The ductility resource, which is evaluated by the λ_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 σ_n/σ_s= 0,20 to σ_n/σ_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 λ_p and used resource λ (fig. 4).

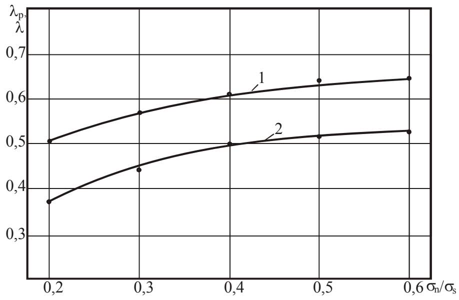

Fig.4 Change in the ductility resources in relation 1- λ_p and 2- λ to the axial pressure (steel type 10)

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 λ_p and λ and the stressed state index Π_σ, depending on axial pressure σ_n/σ_s, the dual dependences λ_p- σ_n/σ_s, λ_p- Π_σ and Π_σ- σ_n/σ_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.

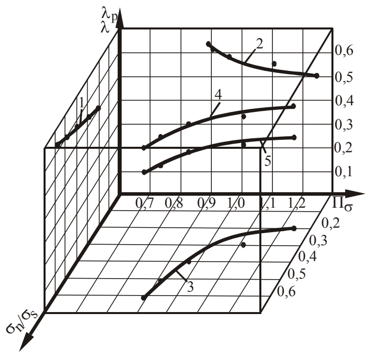

Fig. 5 *Indices relationships in intensified process of swelling (steel type 10): 1: λ_p - σ_n/σ_s; 2: λ_p - Π_σ; 3: Π_σ - σ_n/σ_s; 4: λ_p - Π_σ - σ_n/σ_s; 5: λ - Π_σ - σ_n/σ_s*

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 Π_σ 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.

Acknowledgement

Authors specially thank to Prof. Erol Akata, Trakya University – Turkey, for his helps in final editing of this article

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