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Features Of Stress-Deformed State Of Rolled Sheet By Asymmetric Technology

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ABSTRACT

At present, the optimization of energy-saving technologies in mechanical engineering for production of rolled sheets with different configurations by modern simulation methods is becoming an important direction of informatization of engineering production. At the same time, in the active zone, the process of asymmetric cold rolling of metal sheets is accompanied by an inhomogeneous stress-deformed state. In non-canonical regions of deformations, an approach for determining the optimal technological parameters and studying the stress-deformed state of the cold rolling process by an asymmetric technology in the active zone of elastic-plastic deformations on the basis of simulation modeling with the applied software package LS-DYNA by LS-PrePost (R) of V4.6.1 version has been proposed in this paper.

KEYWORDS

Optimization, cold rolling, elastic-plastic deformations, metal sheets, asymmetric technology

INTRODUCTION

In the process of cold rolling of metal sheets, the use of asymmetric technologies opens up the new opportunities for producing different profiles. Complicated stress-deformed states arise in the

zones of active elastic-plastic deformations. Therefore, the development of optimal resource-saving technologies for cold rolling of metal sheets is an urgent and topical problem of modern

mechanical engineering [1-6]. In this case, in the active zone of elastic-plastic deformation of metal sheets the cross-section geometry is a curvilinear

trapezoid, hence the area to be calculated becomes non-canonical [7].

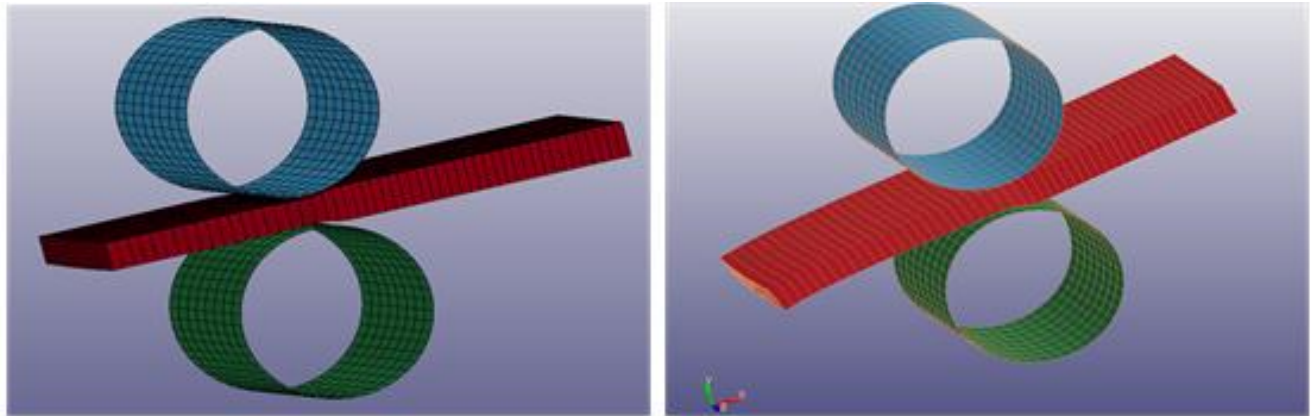


Fig. 1. Symmetric (a) and asymmetric (b) rolling of aluminum alloy

MATERIALS AND METHODS

Asymmetric and symmetric rolling of aluminum alloy sheets was realized with a setup made under laboratory conditions. The setup has two cylinders (forming rollers) of the same size with a diameter of 20 mm, they are rotated by two independent DC motors. The speeds of cylinder rotation are controlled by a computer with special software. During the conventional rolling experiment, the rotation speed of both cylinders was 20 s⁻¹. For asymmetric rolling, the rotation speed of the upper and lower cylinders was 18 s⁻¹ and 22 s⁻¹, respectively. Hence, the upper plane in the active zone moves with the speed $v_a = 22$ mm/sec and the lower one with the speed $v_n = 18$ mm/sec. The third variant of rolling was also considered, in which the rotation speed of the upper and lower cylinders varied asymmetrically at regular intervals.

In terms of mathematical simulation, the body under consideration is represented as a metal sheet with thickness h , width b and length l in the Cartesian coordinate system $Oxyz$ (here Oxz is located in the middle of the metal sheet). In the process of symmetric and asymmetric rolling with the constant speed v_B, v_H the active zone undergoes elastic-plastic deformation (Fig. 1,2). In this case, the thickness decreases from h_n to h_k . Here, the sample length l is 51 mm, the thickness h is 4 mm, the width b is 20 mm, the roller radius is $R=10$ mm, the rotation speed of the roller is $\omega = 20$ s⁻¹, the friction coefficient between the roller and the sample is $r_1 = 0.2$ and $r_2 = 0.2$. The speed of the metal sheet motion is $c = 20$ mm/s. The above formulation of the problem was implemented with a package of applied programs LS-DYNA by LS-PrePost (R), version V4.6.1. [8-15]

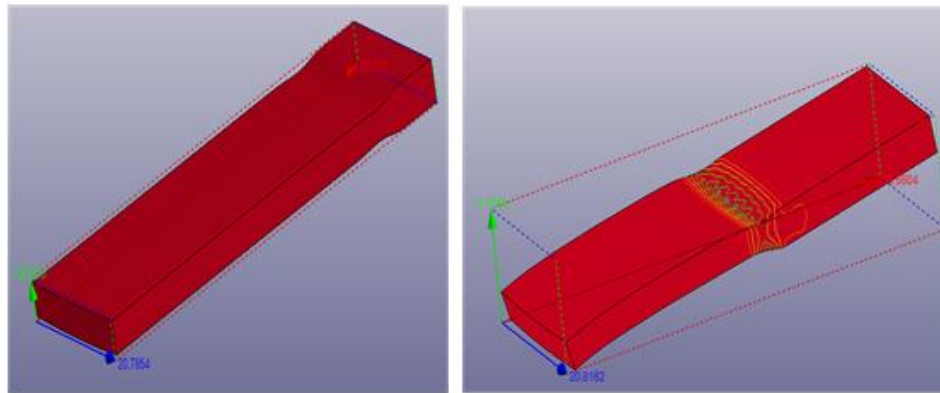


Fig. 2. The location character of the metal sheet after symmetric deformation (a) and asymmetric deformation (b)

RESULTS AND DISCUSSION

After elastic-plastic deformation between symmetrical rollers, the lengthening of the metal sheet was 18.3%, the widening was 3.83%, and the decrease in thickness was 18.66%. The similar results were obtained for asymmetric technology: 18.93%; 5.8%, 20.66% and for the case of changeable asymmetry 22%, 4.3%, 21%, respectively. As seen from the results obtained, the rolling effect for the asymmetric technology is higher as compared to the symmetrical one.

For changeable asymmetry, the greatest effect is achieved for lengthening of the sample and decreasing of its thickness. At the same time, after the asymmetric technology, the deviation from the horizontal position was 11.76 mm. (Fig. 2). It should be noted here that after asymmetric rolling with the properly selected parameters, as a result, the rolled sheets become panels with the required radii of curvature, the bending rigidity of which will be much higher than for panels obtained by traditional methods.

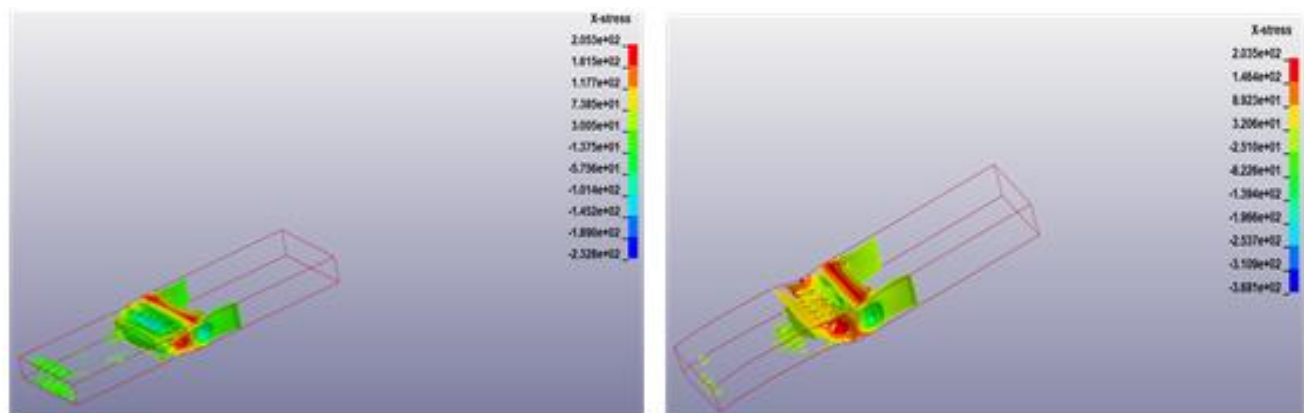


Fig.3. The character of the distribution of longitudinal stress σ_{xx} according to symmetric technology (a) and asymmetric one (b)

The maximal intensity for the stress tensor components is in the active zone of elastic-plastic

deformations between the rollers (Fig. 3). As seen from Fig. 3, the main area before and after rolling is outside the influence of longitudinal stress σ_{xx} . In the active zone, a very complex character of the distribution of the stress field is observed; the tension stress is dominant, its maximal value is 205 MPA. At

the same time, at the point where the rollers contact with the metal sheet plane there is a maximal compressive vertical stress σ_{yy} equal to 488 MPA for the symmetric case and to 497 MPA for the

asymmetric one. The increase in the compressive effect of the rollers by asymmetric technology is explained by the difference in the rotation speed of the cylindrical rollers.

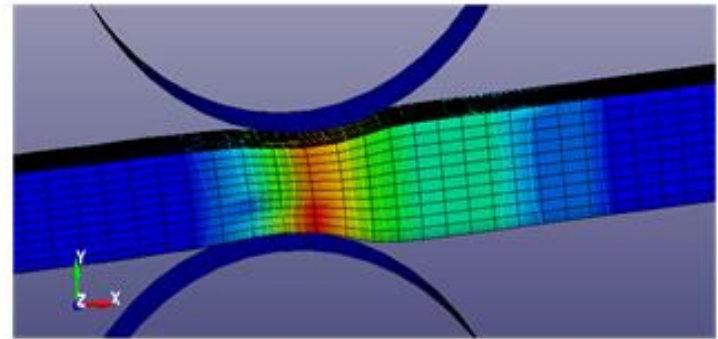
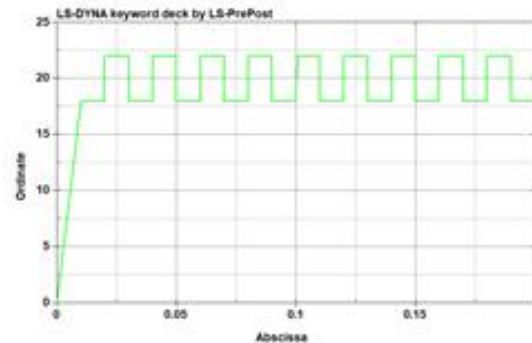


Fig.4. The distribution of the normal stress σ_{yy} on the metal sheet after rolling by changeably asymmetrical technology.

The interval where the roller speed changes is presented in Fig.4 (left figure), as well as a character of the vertical stress σ_{yy} with the maximal value equal to 522 MPA. In this case, in contrast to the asymmetric technology, the rolled sheet remains flat. For this case, according to the Mises theory for elastic-plastic deformations, the intensity of the stress deviator is 478 MPA. The strength limit for different aluminum alloys is up to 565MPa.

In the remaining parts, there are passive stress-deformed states for which the arising residual plastic deformations are determining. As the results obtained show, between the symmetric and asymmetric rollers the normal components of the arising stress-deformed state prevail while the tangent components of the stress and deformation tensor are small except σ_{xy} in the active rolling region.

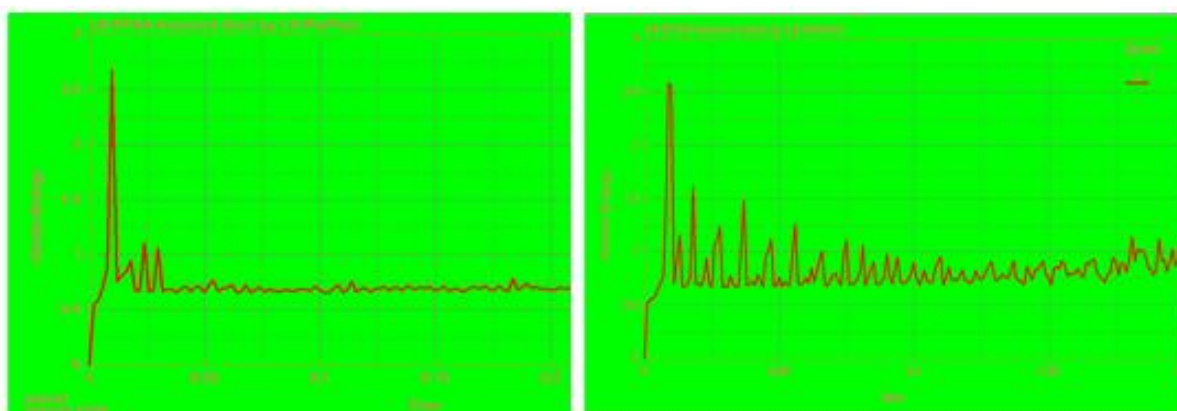


Fig. 5. The changes in kinetic energy for asymmetric (a) and changeably asymmetric technology (b) during the rolling process

Competitiveness of finished products also depends on energy-saving technologies [16-18]. For optimization of energy-saving technologies for cold rolled products using symmetric-asymmetric technology, it is necessary to study kinetic and potential energies.

A qualitative picture for potential energy for asymmetric technologies coincides with that for

symmetric technology that serves as a parameter for reducing energy costs. As it should be expected, for changeable asymmetric technology the amount of consumed energy is about 54% as compared to asymmetric technology. At the same time, the efficiency of changeable asymmetric technology is higher than that of the other technologies considered (Fig. 5-6).

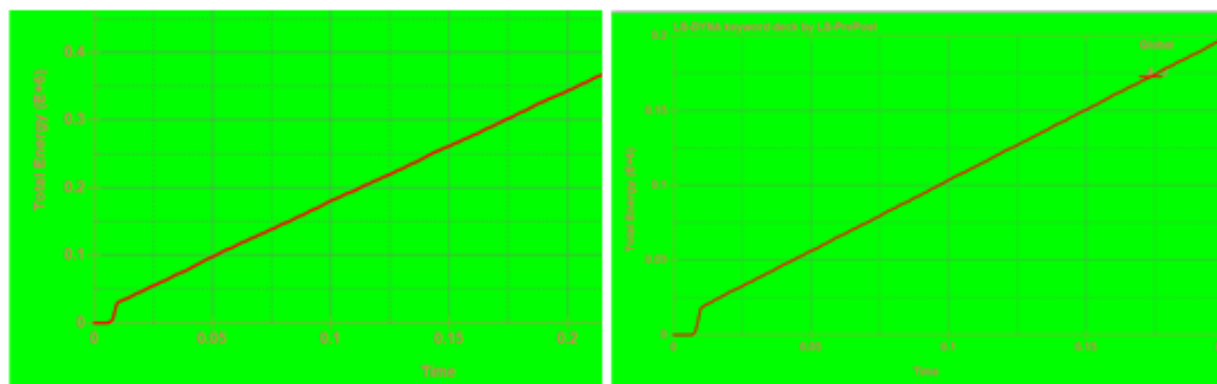


Fig. 6. The changes in Total energy for asymmetric (a) and changeable asymmetric technology (b) in the process of rolling

CONCLUSIONS

The character of the qualitative changes in kinetic energy with time is the same for all the technologies. It should be expected that for symmetric technology there are almost no fluctuations. For asymmetric technology, with an increase in the rolled part of the metal sheet, the level of fluctuations increases. At the same time, for changeable asymmetric technology fluctuations retain their initial level.

Thus, for the case of changeable asymmetric technology of metal sheet rolling, the productivity is higher and energy consumption is significantly lower.

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