

SURFACE STRAINING OF STRIPS BY DRAWING BETWEEN SPINNING ROLLERS

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POVRCHOVÉ DEFORMOVANIE PÁSOV ŤAHANÍM MEDZI OTÁČAJÚCIMI VALCAMI

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Abstrakt

Zo strany technického vývoja neustále rastú požiadavky na kvalitu vyrábaných materiálov s charakteristickým komplexom fyzikálnych, mechanických a chemických vlastností vrátane vysokú oteruvzdornosť, zvýšenú pevnosť, žiarupevnosť atd. Vzhľadom na tieto požiadavky boli vyvinuté technologické procesy zaručujúce tvorbu v povrchových vrstvách kovových pásov jemnej mikrokryštalickej štruktúry, napríklad pri povrchovej deformácii dôsledkom súčasného valcovania a ťahania medzi sa rýchlootáčajúcimi valčekmi so zadanou rýchlosťou pomerného posunu povrchu pásov a valčekov. V danom prípade na opracovanom povrchu sa vytvárajú vrstvy s jemnokryštalickej štruktúrou, ako výsledok impulzného ohrevu súbežne s plastickou deformáciou a nasledujúceho rýchleho ochladzovania dôsledkom odvodu tepla z relatívne tenkých povrchových vrstiev do hĺbky kovu. Mikroštruktúra povrchových vrstiev v prípade ocelí pozostáva s ultrajemného martenzitu s rovnomerne rozloženými jemnými sekundárnymi karbidmi. Stupeň jemnosti štruktúry je oveľa väčší v porovnaní s bežným kalením. Okrem toho sa zlepšujú aj užitočné vlastnosti, akými sú odolnosť voči korózie, zvýšená húzevnatosť, elektrochemické charakteristiky a atď.

Zistene, že štruktúra a vlastnosti povrchových vrstiev je veľmi citlivá na podmienky uskutočnenia technologického procesu a preto je možné, meniac parametre tvárnenia, dosiahnuť požadovanú kvalitu povrchových vrstiev. Však pri vol'be režimov opracovania pásov je nutne vychádzat z energosilových charakteristik procesu. Vzhľadom na to, že tieto charakteristiky závisia od veľkého množstva premenných parametrov, v článku je riešená úloha stanovenia parametrov procesu spracovania povrchových vrstiev pásov ťahaním medzi sa otáčajúcimi valčekmi. Analýza procesu tvárnenia povrchu pásov pri ťahani medzi sa rýchlootáčajúcimi valčekmi so zadanou rýchlosťou pomerného posunu povrchu pásov a valčekov preukázala, že sa vytvorí v tvárnenej vrstve jemná kryštalickej štruktúra, zaručujúca vysoké exploatačné vlastnosti. Získali sa vzťahy pre výpočet namáhania pri ťahani, čo dovoľuje voliť režimy spracovania pásov s ohľadom na požadovanú kvalitu povrchových vrstiev. Zo získaných vzťahov vyplýva, že veľkosť sily ťahania sa zväčšuje v závislosti od výšky stupňa deformácia a klesá zo zväčšujúcou sa hrúbkou pásu. Zväčšovanie rozmerov valčekov spôsobuje zvyšovanie sily ťahania.

Abstract

The problem of definition of power parameters for the process that takes place in superficial layers of band during drawing it through revolving rollers is considered. The analysis of superficial deformation process of tapes that are drawn between fast revolving rollers with the given speed of relative moving of surfaces of tapes and rollers has shown that in this case on a treated surface small crystal layers with high service properties are formed. The expressions for engineering account of drawing are introduced. That allows finding the rationally regime of tapes processing to achieve required quality of superficial layers. The analysis of the received equations showed that the effort of drawing increases with the increase of a degree of deformation and decreases with the increase of an initial thickness of a tape. The increase of rollers' size leads to the growth of the effort of drawing.

Key words: deformation, superficial layer, rolling, dragging, power characteristic, calculations

1. Introduction

The development of engineering has led to the necessity to create materials, which have special complex of physical, mechanical and chemical properties on their surface namely high wear resistance, increased strength, high-temperature strength etc. With this purpose the number of technological processes for formation surface microcrystal layer on metal tapes [1], for example, with the help of superficial deformation by means of rolling and drawing between fast revolving rollers with the given speed of relative moving surfaces of tapes and rollers, are developed in the past decades [2]. In this case fine microstructure layers are formed on a treated surface. Such structure results from pulse heating in combination with plastic deformation and following high-intensity cooling due to fast removal of heat from surface superficial layers into the depth of the metal [3, 4].

The chemical composition of these layers essentially differs from that one of the as received material. In spite of the fact that this process is very shot many chemical elements seem to be redistributed during treatment and it concerns first of all carbon. The increase of the carbon content in surface layer may be attributed to the carbon atoms migration from inside volumes of metal and, in the case of lubrication liquids employment, (machine, industrial etc. oil that is diluted by kerosene) directly from them.

Microstructure of received superficial layers consists of a fine needle martensite and retained austenites with precipitates of ultrafine carbides. Average size of martensite needles is considerably less than that one in martensite formed after usual hardening. The rate of the refinement is less in the hypoeutectoid carbon steels, and more distinct in both the eutectoid and hypereutectoid steels as well as in the alloy steels containing elements that promote refinement of martensite [5]. The decrease in size of both the austenite grains and carbide particles is also observed in superficial layers. As consequence the superficial layers to be received by the given method, have higher microhardness and corrosion resistance, favourable electrochemical characteristics and residual stress of compression, enhanced toughness and resistance to formation and growth of corrosion cracks.

We have found out that the structure and properties of the superficial layers greatly depend on conditions in which the process is carried out and as a result they can be affected [6], differing from those of untreated metal. So by means of changing process parameters, we can receive required quality of superficial layers including surface strength, hardness, viscosity etc.

On the other hand, while choosing the regimes of processing it is necessary to take into consideration power-energetic characteristics of this process. This characteristics depend on a great number of variable parameters, so their definition is necessary, but difficult problem.

2. Calculation of analytical dependences

Let's consider a problem of definition of power parameters of the process that takes place in superficial layers of band during rolling and drugging. Let's suppose that the deformation zone is a ring sector, which is restricted by two radii r_1 and r_2 (fig.1). This supposition is considered to be true. Though it will be more exactly to suppose that deformation zone is a wedge, which is restricted by two surfaces of ruptured speed [6].

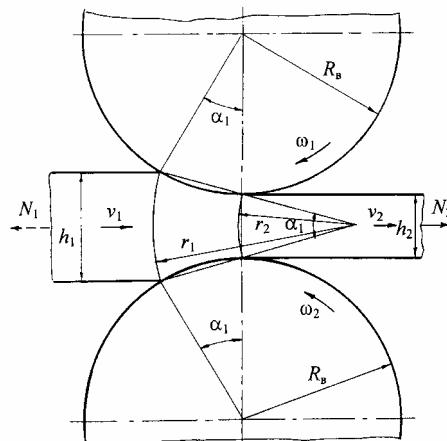


Fig.1 The scheme of the deformation zone

From geometry of the deformation zone follows:

$$r_1 = \frac{h_1}{2 \sin \alpha_1 / 2}, \quad r_2 = \frac{h_2}{2 \sin \alpha_1 / 2}, \quad (1)$$

where h_1 and h_2 are the thickness of the tape before and after deformation.

As the inclination angle of wedge of deformation zone α_1 is too small ($\alpha_1 < 10^\circ$), we can consider that $r_1 = h_1/\alpha_1$ and $r_2 = h_2/\alpha_1$.

Let's write down expressions of resultant forces in cylindrical sections of radii r_1 and r_2 :

$$\begin{aligned} N_1 &= 2b \int_0^{\alpha_1/2} \sigma_r r_1 d\theta, \\ N_2 &= 2b \int_0^{\alpha_1/2} -\sigma_r r_2 d\theta, \end{aligned} \quad (2)$$

where N_1 - effort of backward pull; N_2 - effort of drugging through revolving rollers; σ_r - radial stress; b - width of a tape.

Radial stress during drugging and rolling, in case, when intensity of friction forces is equal by quantity to the yield point when shear takes places, can be presented by equation [7]:

$$\sigma_r = \tau_s \left(\left(\frac{\pi}{2\alpha_1} + 1 \right) \cos \frac{\pi\theta}{\alpha_1} - \beta - \frac{2C}{r^2} \right), \quad (3)$$

where τ_s is resistance to clear shift; β - Lode's coefficient; C – constant.

By substituting equality (3) in dependence on definition of resultant forces in cylindrical sections we receive:

$$N_1 = 2b \int_0^{\alpha_1/2} \tau_s \left(\left(\frac{\pi}{2\alpha_1} + 1 \right) \cos \frac{\pi\theta}{\alpha_1} - \beta - \frac{2C}{r_1^2} \right) r_1 d\theta, \quad (4)$$

$$N_2 = 2b \int_0^{\alpha_1/2} \tau_s \left(\left(\frac{\pi}{2\alpha_1} + 1 \right) \cos \frac{\pi\theta}{\alpha_1} - \beta - \frac{2C}{r_2^2} \right) r_2 d\theta.$$

After integrating we receive:

$$N_1 = 2\tau_s b r_1 \alpha_1 \left(\frac{1}{2\alpha_1} + \frac{1}{\pi} - \frac{\beta}{2} - \frac{C}{r_1^2} \right), \quad (5)$$

$$N_2 = 2\tau_s b r_2 \alpha_1 \left(\frac{\beta}{2} + \frac{C}{r_2^2} - \frac{1}{2\alpha_1} - \frac{1}{\pi} \right).$$

To definite constant C we consider, that is no backward pull. So we receive:

$$C = r_1^2 \left(\frac{1}{2\alpha_1} + \frac{1}{\pi} - \frac{\beta}{2} \right). \quad (6)$$

Taking into consideration constant C we have:

$$N_2 = 2\tau_s b h_2 \left(\frac{1}{2\alpha_1} + \frac{1}{\pi} - \frac{\beta}{2} \right) \left(\frac{h_1^2}{h_2^2} - 1 \right). \quad (7)$$

3. Conclusion

The analysis of dependence (7) shows, that the effort that is necessary for dragging of a tape through vast revolving rollers increases with the growth of a degree of deformation and decreases with growth of initial thickness of a tape (fig. 2). The increase of rollers size leads to the decrease of inclination angle of wedge of deformation zone α_1 and to the increase of effort.

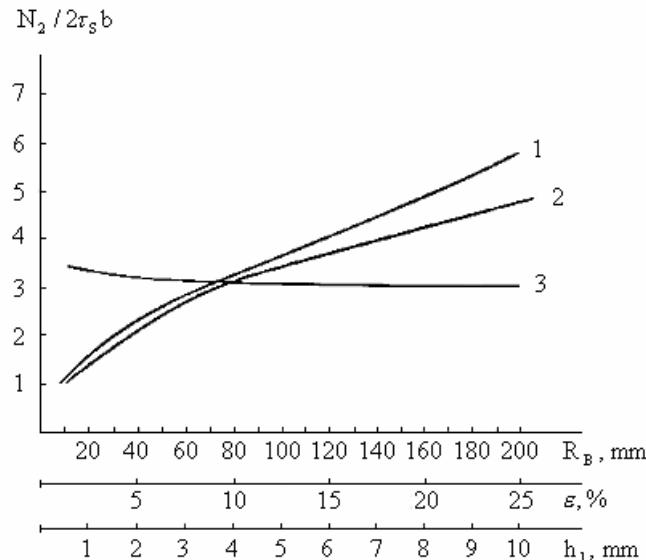


Fig.2 Diagram of functional dependence of relative size of dragging effort N_2/σ_{sb} from: 1-degree of deformation ε for $h_l = 1$ mm, $R_B = 100$ mm; 2 – radius rollers R_B for $h_l = 1$ mm, $\Delta h = 0,1$ mm, $\varepsilon = 10\%$; 3 – initial thickness of a tape h_l for $R_B = 100$ mm, $\Delta h = 0,1$ mm, $\alpha_1 = 0,316$

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