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Mechanics

Method of Calculation of the Breaking Force of the Continuous Cast Billets on a Rotor-Type Casting Machine

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ABSTRACT. The process of breakage of continuous cast billets is the main factor in assessing energy-power parameters of a rotor-type casting machine.

In the paper on the example of SiMn20, FeSi45 and FeSi75 the impact of various characteristics on forces occurring during breaking the billets is shown. These characteristics are chemical content of cast metal, physico-mechanical parameters, cross-section of continuous cast billet, geometry of knives for breaking of breaking mechanism, the distance between the pressure roll and breaking knife.

We offer such working principle (vibratory motion of breaking knives) that significantly decreases breaking forces for ultrastrong ferroalloys with the ultimate strength higher than 200 kg/mm^2. *© 2011 Bull. Georg. Natl. Acad. Sci.*

Key words: *breakage of continuous cast billet, vibratory motion of breaking knife.*

In the process of continuous casting of ferroalloys the cutting of the hardened billets into measured length pieces is fulfilled. At present for cutting the continuous cast billets the following devices are used [1,2]: flying shears, cast billet saws, gas-cutters, plasma cutting and breaking devices. Special difficulties appear when the billets made of brittle materials, such as ferroalloys, must be cut.

The above mentioned methods of cutting the continuous cast billets are not applicable to ferroalloys. The application of these devices for cutting ferroalloys besides technical difficulties may cause the occurrence of considerable stresses, cracks, breaking of the pieces and great losses of metal. Therefore for curved machines of continuous casting of ferroalloys, it is advisable to use breaking devices. In our case a rotor-type casting machine is used.

The process of breakage of continuous billets is the main factor in the assessment of the energy-power parameters of rotor machine. Let us consider this process in detail on the example of double-strand pilot device of rotor-type while casting FeSi45, FeSi75 SiMn20.

The scheme of breakage of continuous billet is shown in Fig.1 (the calculations are fulfilled for one strand). Billet 1 moves together with moving crystallizer (drum) 2 and

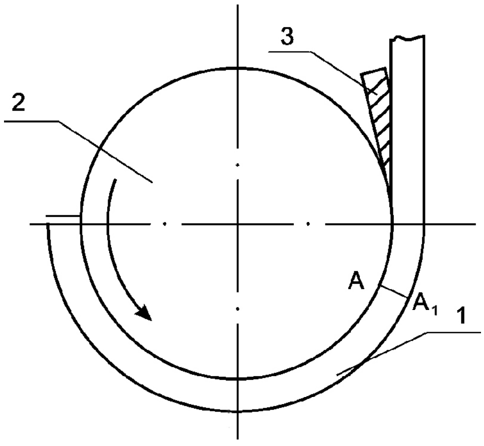

Fig. 1. The scheme of breakage of continuous cast billet.

comes up to stationary knife 3, which lifts the billet from the bottom of the furrow up to its breakage in the cross-section AA_1, where the stress reaches the ultimate strength. Let us have the schemes of deformation by means of the configuration of knife 3.

In the case, shown in Fig.2 at the distance ℓ from some support cross-section the bending force $P'=P\cos\alpha$ and compression force $T'=E\cos\alpha=\mu P$ (μ is friction coefficient) act. Because the angle α is small $\cos\alpha\approx 1$ and $P'=P$, thickness of the knife $h(x_1)$, where x_1 is a coordinate, counted off from point A, in which the billet is connected to the knife at the point A, $h=h_0$. Thus from the beginning of bending $x_1=v\tau$, where v is casting rate, and τ – time, deflection of the billet $Y=h(v\tau)-h_0$, $\ell=\ell_0+v\tau$, where ℓ_0 is the distance from the support up to the point A, in which bending began.‘

Bending moments $M=P(\ell_0-x)$,

deflection $$Y(x)=\iint\frac{M}{EI}, \tag{1}$$

where E is modulus of elasticity of the billet material, $I=\dfrac{bh^3}{12}$ – inertia moment, b, h – dimensions of billet cross-section.

Taking into account that at $x=0$, $Y=0$, $Y'=0$, $Y'=\dfrac{dY}{dx}$, we get

$$Y'=\frac{P}{EI}\left(\ell x-\frac{x^2}{2}\right), \tag{2}$$

$$Y=\frac{P}{EI}\left(\frac{\ell x^2}{2}-\frac{x^3}{6}\right); \tag{3}$$

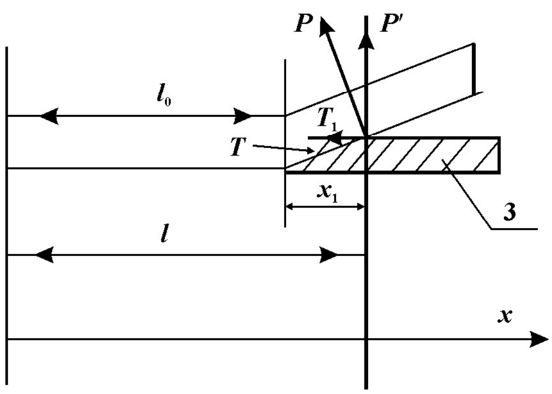

Fig. 2. Scheme of action of forces while breaking the billet.

but at $x=\ell$, deflection is equal to $h(v\tau)-h_0=Y'$ and from the equation

$$Y_1=\frac{P\ell^3}{3EI}. \tag{4}$$

The most bending stresses are $\sigma_u=\dfrac{P\ell}{W_c}$, and taking into account compression with force T

$$\sigma=\frac{\mu P}{bh}+\frac{P\ell}{W_c}, \tag{5}$$

where $W_c=\dfrac{bh^2}{6}$ is a moment of resistance.

At breaking the billet the largest stress in the support cross-section is equal to the ultimate strength (we think that brittle material is resistant up to the moment of breaking).

Then it follows from (5)

$$\sigma_b=\frac{\mu P}{bh}+\frac{P\ell}{W_c}, \text{ hence } p=\frac{\sigma_b bh^2}{\mu h+6\ell}. \tag{6}$$

Inserting the value of P into (4) we get

$$Y_1=\frac{4\sigma_b\ell^3}{Eh(\mu h+6\ell)}. \tag{7}$$

In Figs 3, 4, 5 the dependence of deflection and breaking force on the billet length is shown. However, for ultrastrong ferroalloys, such as ferrochrome and others, where breaking point at compression reaches more than 200 kg/mm^2, application of vibratory “oscillating” motion of knife is prospective.

$Y_1=Y_0+a\sin\omega\tau$, where Y_0 is a constant, a, ω – amplitude and frequency of knife vibrations.

In this case breakage in resonance regime at coinciding of the frequency of vibration of the knife with frequency of billet vibration, working as the bar for deflection is possible.

It is known that for the bar subjected to transverse bending, frequency of the natural transverse oscillations (3)

$$\omega_k=\frac{\lambda^2}{\ell^2}\sqrt{\frac{Eb\ell^3 g}{12j}},$$

where E is modulus of elasticity, kg/cm^2; g – acceleration of gravity (g = 980.0 cm/sec^2); ℓ – bar length, cm; l –

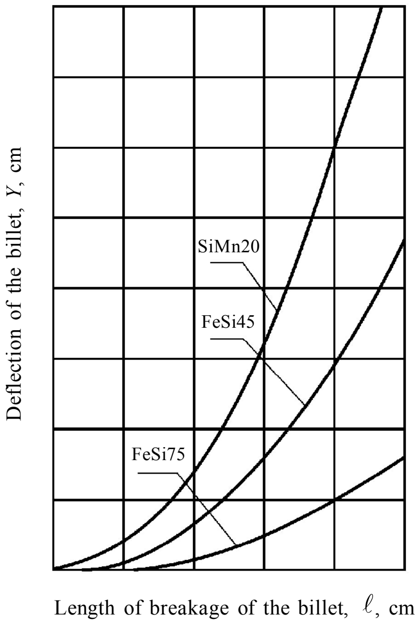

Fig.3. Dependence of the deflection of the length of the billet.

constant, dependent on the securing condition; j – specific weight of the billet, kg/cm^3.

$\lambda_1 = 1.875$; $\lambda_2 = 4.694$; $\lambda_3 = 7.855$ correspond to the first three frequencies for outrigger and $\lambda_1 = \pi$; $\lambda_2 = 2\pi$; $\lambda_3 = 3\lambda$ - for double-support girder.

In our case console most of all corresponds to the conditions of securing.

then at λ_1=1.875 it follows that $\ell = 5.6\sqrt{\dfrac{Ebh^3}{j\omega_k}}$.

If the knife vibrates with frequency ω_k, then the bars

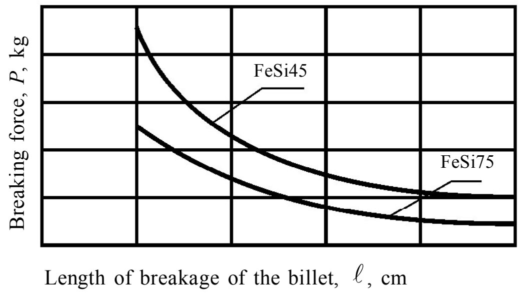

Fig.4. Dependence of the breaking force on the billet length.

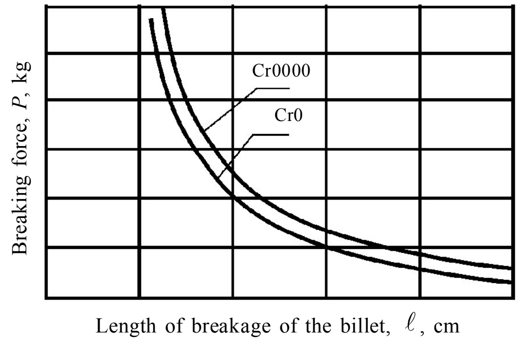

Fig.5. Dependence of the breaking force on the billet length (Cr0 and Cr0000)

with the length of $\ell_{(\omega_k)}$ will be broken. Thus regulating the vibration of the knife, we can control the length of the parts into which we cut the billet (Figs.6,7).

Vibratory motion of the knife considerably decreases the breaking force the continuous cast billet.

Knowing the breaking forces of the billets will make it possible to calculate the energy-power parameters of the main unit of the cast machine and determine the driving gear power.

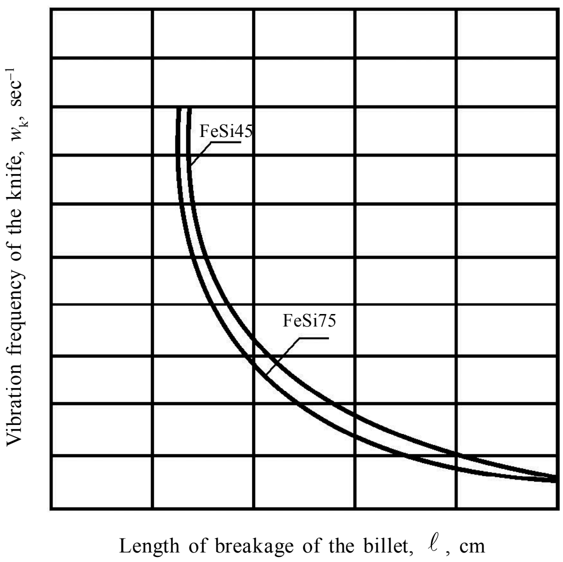

Fig.6. Dependence of the breaking force of the billet on the vibration frequency of the knife.

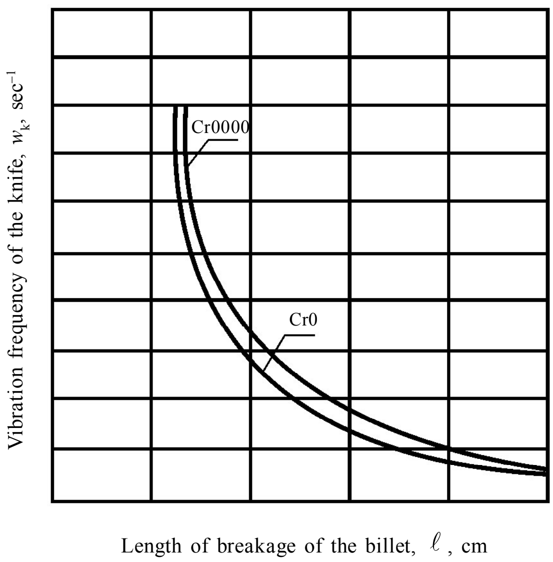

Fig.7. Dependence of the length of the breakage on the vibration frequency of the knife

მექანიკა

როტორული ტიპის ჩამომსხმელ მანქანაზე უწყვეტი სხმულის დანაწევრების ძალის განსაზღვრის მეთოდი

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როტორული სახის საჩამოსხმო მანქანის ენერგოძალოვანი პარამეტრების განსაზღვრისას ძირითად ფაქტორს უწყვეტი სხმულის დანაწევრების პროცესი წარმოადგენს.

ნაშრომში SiMn20, FeSi45 და FeSi75 მაგალითზე წარმოდგენილია ჩამოსასხმელი ლითონის ქიმიური შედგენილობის, ფიზიკო-მექანიკური მაჩვენებლების, სხმულის კვეთის, ტეხვის მექანიზმის სატეხი დანების (სოლების) გეომეტრიისა და მიმჭერი გორგოლაჭების მიმართ მათი განლაგების გავლენა ტეხვის პროცესში წარმოქმნილ ძალებზე. ზემტკიცე ფერადი შენადნობებისათვის, რომელთა სიმტკიცის ზღვარი კუმშვაზე 200კგ/მმ^2-ს აღემატება, შემოთავაზებულია ტეხვის მექანიზმის მუშაობის განსხვავებული პრინციპი (სატეხი დანების ვიბრაციული რხევითი მოძრაობა), რაც მნიშვნელოვნად ამცირებს ტეხვის ძალებს.

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