Shift cogging modeling of the continuously cast bars

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Abstract. Physical modeling results while the shift cogging of the continuously cast bars in zone of the secondary cooling the machine of continuous moulding of preparations for the purpose to increase its quality on axial defects and homogeneity of the structure are presented in the article. The shift cogging in the process of the continuously cast bars in zone of the secondary cooling the machine of continuous moulding of preparations was processed by means of lead and aluminium deformable alloys. It is ascertained the positive effect to reduce the columnar crystal zone and lower the central porosity on the last stage of solidification while shift "soft" cogging.

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Introduction

It is well-known, that cogging of the continuously cast bars on the last stage of solidification reduces axial porosity and increases homogeneity of the structure [1-4]. The critical cogging value is up to 3 percent, over it cracks are developed. To raise cogging effectivity is possible by means of shift cogging scheme of the continuously cast bar at the end of solidification period, thus it provides more intensive reduction for axial porosity and higher cogging rate without cracks development. The device to model the shift "soft" cogging of the continuously cast bar with a liquid core is proposed [5]. The developed laboratory device for the shift cogging of the continuously cast bar in the zone of the secondary cooling the machine of continuous moulding of preparations is introduced into the educational process in S. Toraigyrov Pavlodar State University.

To evaluate efficiency of the shift cogging of the continuously cast bar in the zone of the secondary cooling the machine of continuous moulding of preparations in the area of a liquid cup it is important to determine experimentally:

- rate the axial porosity reduction in different cogging schemes
- maximal cogging rate up to cracks development in different cogging schemes in the period of solidification

Methodology

The process of the shift cogging of the continuously cast bar at the end of solidification period was modeled in a sequence of experiments. The rate of the axial porosity reduction in different cogging schemes and the maximal cogging rate up to cracks development at the end of the solidification period were compared in the experiments.

The lead-bismuth alloy was used to model the shift cogging. Lead alloys are widely used to model the steel deformation at the deformation temperatures [6]. Casts with dimension 17x17mm were prepared from the model alloy. The model casts were drilled in the axial part to get perforations 2mm in diameter in order to model axial porosity (Fig.1).

Geometrical sizes of the model cast and the axial contraction cavity are 1 to 10 in scale against the genuine continuous cast steel bar 150x150mm in size and the axial contraction cavity with the maximal diameter 20mm in size, discovered by means of the quality analysis of continuously cast bars in the metallurgical works of the Republic of Kazakhastan [7, 8].

In conditions of laboratory some experiments were conducted to model the shift cogging with aluminium deformable alloys containing: (Si) silicon 0.3 percent, (Cu) copper 0.4 percent, (Mg) magnesium 2.0 percent, zinc (Zn) 0.25 percent, lead (Pb) 0.04 percent, iron (Fe) 0.7 percent, manganese (Mn) 1.5 percent, chromium (Cr) 0.1 percent, titan (Ti) 0.08 percent, tin (Sn) 0.02 percent, aluminium mostly. Model cast bars before the cogging were heated up to 420 Celsius centigrade. The area of the cross-section of the model cast bar before the cogging is equal to 289 square mm, perforation – 3.14 square mm.

Model cast cogging in the cylindrical rollers is gated twice. Model cast cogging in the conic rollers is gated twice. At the first gate the cast bar was cogged by shifting and acquired the cross-section in a shape of a parallelogram, while the second gate the geometry of the detail was restored [9]. The model cast bar was measured with a trammel after the cogging, perforations with a macroscope MPB-2 (magnification 24) with a scale interval equal to 0.05 mm [10].

The artificial defect behavior was described with the perforation closure coefficient, representing the rolling-out coefficient multiplication by the division of cross section areas of perforations before and after deformation.

The perforation closure coefficient describes the ratio between the decrease of cross-section areas of a defect and a workpiece.

Fig. 1 – Lead alloy model cast bars

The rolling-out coefficient was defined with the ratio of the model cast bar areas before and after the total cogging [11].

On the basis of received data the areas, the rolling-out coefficient of a model cast bar and the perforation closure coefficient were defined.

Results and discussion

The results of a shift cogging of model cast bars made of lead alloys in the cylindrical and conic rollers are presented in the table 1. The modeling results of aluminium deformable alloys are presented in the table 2.

Table 1. Results of the model cast bars cogging made of lead alloys

Experiment conditions		Model cast bar measures after cogging, mm	Cross-section area after cogging, mm^2		Rolling-out coefficient of model cast bar	Perforation closure coeffcient
Cogging value, mm	Shift angle, degree		model cast bar	perforation		
1	0	17x16	272,0	2,36	1,06	0,80
2	0	17x15	255,0	1,72	1,13	0,62
3	0	17,5x14	245,0	1,20	1,18	0,45
4	0	18x13	234,0	0,00	1,24	0,00
1	3	17x16	272,0	2,20	1,06	0,74
2	3	17x15	255,0	1,62	1,13	0,58
3	3	17,5x14	245,0	0,94	1,18	0,35
1	7	17x16	272,0	1,82	1,06	0,62
2	7	17x15	255,0	1,48	1,13	0,53
3	7	17,5x14	245,0	0,38	1,18	0,14
1	10	17x16	272,0	1,76	1,06	0,60
2	10	17x15	255,0	1,32	1,13	0,48
3	10	17,5x14	245,0	0,10	1,18	0,04
1	30	17x16	272,0	0,28	1,06	0,09
2	30	17x15	255,0	0,00	1,13	0,00

Table 2. Results of model cast bars cogging made of aluminium alloys

Experiment conditions		Model cast bar measures after cogging, mm	Cross-section are after cogging, mm^2		Rolling-out coefficient of model cast bar	Perforation closure coeffcient
Cogging value, mm	Shift angle at each side of a cast bar, degree		model cast bar	perforation		
2	0	17x15	255,0	3,00	1,13	1,08
2	0	17x15	255,0	3,10	1,13	1,12
2	0	17x15	255,0	3,20	1,13	1,15
2	0	17x15	255,0	3,12	1,13	1,13
2	0	17x15	255,0	3,08	1,13	1,11
4	0	17x13	221,0	1,82	1,31	0,76
4	0	17x13	221,0	1,80	1,31	0,75
4	0	17x13	221,0	1,76	1.31	0,73
4	0	17x13	221,0	1,86	1,31	0,77
4	0	17x13	221,0	1,82	1,31	0,76
2	2	17x15	255,0	1,82	1,13	0,66
2	2	17x15	255,0	1,86	1,13	0,67
2	2	17x15	255,0	1,78	1,13	0,64
4	2	17x13	221,0	1,08	1,31	0,45
4	2	17x13	221,0	1,20	1,31	0,50

By means of the table data, the visible full closure of a perforation with a diameter 2mm, that models shrinkage porosity, is reached by the rolling-out coefficient equal to 1.24 without shift cogging. While the shift cogging the full closure of a perforation is reached by the less coefficient equal to 1.13.

The regressive analysis in the software application batch to process the modeling results of statistic data in Microsoft Office Excel 2013 was exploited.

As a result the regression equation in terms of the linear dependence like:

$$Y = k_1 x_1 + k_2 x_2 + b$$

where *b*- absolute term of equation,
k_1 и k_2 – variable coefficient of x_1 и x_2;
x_1 и x_2 – variable values of equation

Whereas the shift angle is x_1 and the rolling-out coefficient is x_2 the regression equation to calculate the perforation closure coefficient concerning the shift angle and the rolling-out coefficient of the model cast bar is resulted to:

$$Y = 5{,}26 - 0{,}02 x_1 - 4{,}15 x_2$$

The correlation coefficient with value R^2=0.89 that shows the good result convergency. The model validity, the Fisher ‘s test were compared to the table data. The Fisher ‘s test F_p = 0,53 shows the less value than in the table F_t [12]. Thus, it is possible to conclude the validity of the offered model.

For different rolling-out coefficients the diagrams concerning the perforation closure coefficient in dependence of the shift angle value of the model cast bar were drawn, the regression equations, correlation coefficients were calculated (Fig. 2,3).

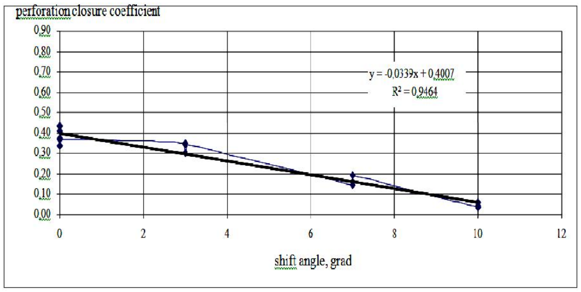

Fig. 2 – Perforation closure coefficient in dependence of the shift angle value of the model cast bar from lead alloys (Fisher's test =0.91)

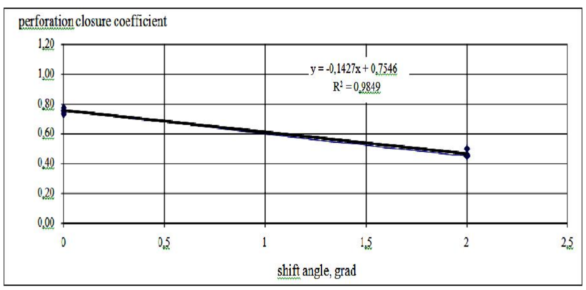

Fig. 3 – Perforation closure coefficient in dependence of the shift angle value of the model cast bar from aluminium alloys (Fisher's test =0.98)

On the next stage of experiments the task to define the maximal degree of cogging at the end of solidification period by means of the shift cogging without cracks development.

Macrostructure investigation of the model cast bars resulted:

1. In the axial area of the cast bar cogged with the shift deformation scheme the axial porosity was not detected.
2. The shrinkage cavity in the cast bar, cogged with the shift deformation scheme, expands less deeper than in the cast bar without cogging.
3. Inner cracks in the axial area of the cast bar are not detected at the deformation rate up to 5 percent and little shift angles (not more than 15-18 degrees). At the deformation rate over 5 percent and shift angles about 18 degrees the periodical cracks on the surface of the cast bar are detected and explained by the alloy plasticity loss.

Conclusions

1. Results of experiments exploiting different schemes to model cogging of the continuously cast bars revealed the higher reduction rate for axial shrinkage defects than with linear cogging.
2. Dependencies to define the perforation closure coefficient in dependence of the shift angle value and the rolling-out coefficient. The results of dimensions and calculations of regression equations on the Fisher's test prove the validity of the offered model.
3. On the basis of the physical modeling of the lead and aluminium deformable alloys it is defined that exploiting the shift cogging of the continuously cast bars with a liquid axis for the purpose to lower the axial shrinkage porosity is possible by the little cogging rates (up to 5 percent) and the little shift angles (up to 18 degrees). The increase of the cogging rate and the shift angles enlarges the risk of cracks development.

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