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The Control System of Balancing of the CCM Mold Oscillation Mechanism

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The functionality of the control system of the operation mode of the oscillation mechanism of the CCM mold, designed to minimize the dynamic imbalance and stabilizing mechanism of oscillation modes are viewed.

Keywords: MECHANISM OF OSCILLATION, CCM, BALANCING, CONTROL SYSTEM

Introduction

Mold oscillation mechanism (MOM) is an integral part of modern continuous casting machines (CCM). Purpose of oscillation mechanism is to provide the vibrational motion of the mold of CCM according to the given settings.

In the process of continuous casting of steel in the CCM due to changes in casting speed, the terms of engagement of the crystallizing bar with working surface of the mold tube, and changes in the technical condition of oscillation mechanism is a distortion of the given parameters of the vibrational motion of the mold. This results in surface defects on billets, increases the likelihood of a breakthrough of the liquid metal at the outlet of the mold and accelerates wear of MOM because of the increase of dynamic and static loads.

Results and Discussion

Monitoring and diagnostics of lever MOM is performed using various automated systems, of both foreign and domestic production [1-3]. Diagnostics of technical state of MOM is either idling or directly in the casting. As a rule, parameters of vibration (vibrodisplacement, vibrovelocity and vibroacceleration) should be registratered and monitored. It uses as a primary device accelerometers installed on the perimeter of the oscillation table (output link of oscillation mechanism on which the mold is fixed with optional equipment) or on intermediates and mechanisms of MOM drive . To assess the conditions of interaction of the billet with working surface of the mold tube it is necessary to use sensors of vertical displacement and tensometers. Monitoring of recorded parameters is used to determine the deviation of actual mode settings from set point. Obtained with monitoring and diagnostic information allows the assessment of the technical condition of MOM drive components and mechanisms and relative measure of the terms of engagement of the crystallizing bar with working faces of mold tube. This does not pay enough attention to quality forecasting billets and recognition of the early stages of failure in oscillation. In addition, the existing monitoring and diagnostics do not provide unambiguous information necessary to adjust the balanced state of the MOM, ie not literally monitoring systems. Regulation of the mechanical balance of the knuckle-lever MOM becomes necessary due to periodic changes in the production load and condition of MOM in the continuous casting of steel in the CCM [4].

The aim of this work is to develop a monitoring system that will implement the methodology of balancing knuckle-lever MOM considering design and the kinematic parameters of the mechanism, as well as the dependence of the equipoise on technological loads.

In general, the designs of knuckle-lever MOM represent various modifications of four-bar motion or its combination. Kinematic schemes of such mechanisms can be reduced to a generalized (equivalent) scheme shown in **Figure 1**.

As seen from the kinematic scheme, balancing lever system of MOM is carried out by means of air springs or coil springs with adjustable rigidity to form a countervailing force proportional to the force pulling the billet from the mold, which can vary depending on the mode of casting and unbalanced degree of oscillation mechanism.

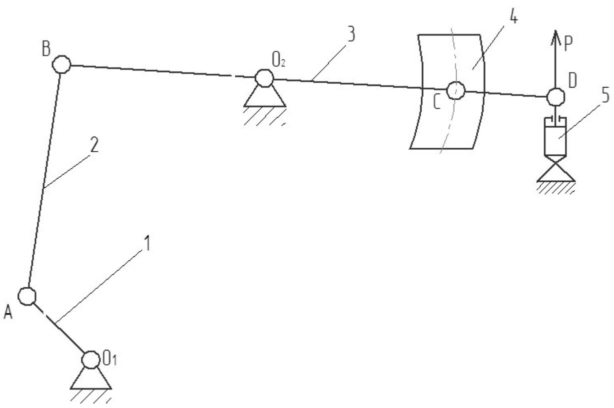

Figure 1. Generalized scheme of the mold oscillation mechanism: 1 - cam gear, 2 - rod, 3 - oscillation table, 4 - mold, 5 - pneumatic shock absorber

Monitoring system of MOM developed by the authors suggests operational changes in the equipoise P, created by supporting air springs in order to correct the position of general center of mass of oscillation mechanism.

MOM like any knuckle-lever mechanism can be balanced statically or dynamically[5]. Static balancing implies equal to zero total principal vector of inertia forces for the cycle of its work, which is possible in a fixed position of the common center of mass of the mechanism.

The center of mass position of cam gear 1 and rod 2 during the MOM work remains the same, so to balance statically it is necessary to ensure control and appropriate adjustment of the center of mass of oscillation table 3, including mold installed on it with additional equipment, subject to the impact of technological load P. Positioning center of mass of oscillation table in the control system should be carried out indirectly by fixing bending stress at point E by means of strain gauges (**Figure 2**).

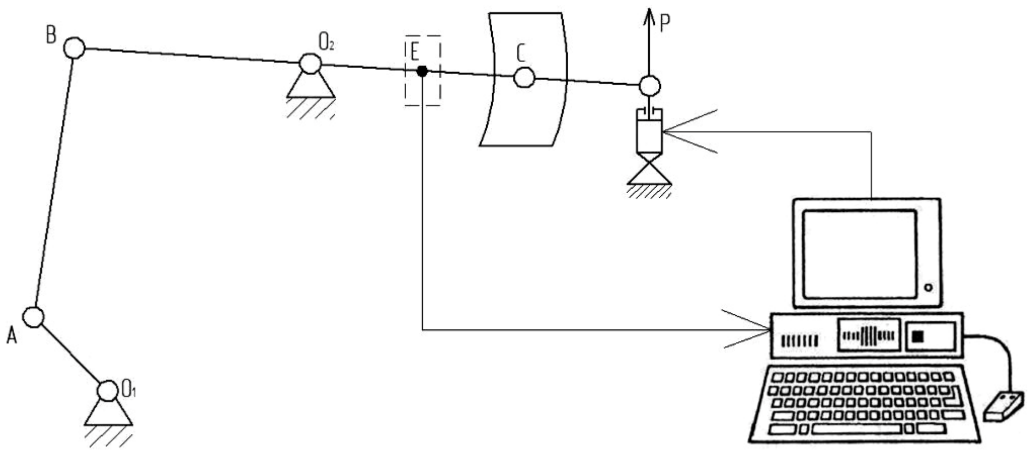

Figure 2. Control scheme of the common center of mass of MOM

The Having the dependence of the radius vector of the center of mass of the MOM oscillation table on bending stress at point E $r_к = f(\sigma_{FE})$, and knowing the value of $r_{к(ур)}$ at static-balanced state of MOM for the cycle its work, you can get an option to edit position of the common center of mass of mechanism rs in real time. The dependence of the equipoise P on the position of the common center of mass of the mechanism $P = f(r_s)$, further adjustment of a balanced state of MOM by changing the pressure in the air springs that support table oscillation is performed.

Dynamic balancing of the lever mechanism assumes equal to zero for the cycle of its work of both a general principal vector of inertial forces and the overall strength of the resultant moment of inertia [5] $M_{F\Sigma} = 0$, $F_\Sigma = 0$.

Given the fact that the dynamic equilibrium at the moment may only be performed in an indirect way, except the control and adjustment of the position of the common center of mass of MOM it is required to monitor the kinematic and dynamic characteristics of its input and output units.

Control of the law of the vibrational motion of the mold *s*(*t*), in the developed control system, should be carried out using the accelerometer to change the temporary forms of acceleration, velocity and displacement. Accelerometers are set on the perimeter of the oscillation table. Changing the torque on the motor shaft $M_{дв}$ - control by setting on the motor shaft strain gauges with current collecting device or magnetoelastic sensors of cross type (torductors) [6].

Knowing the optimal design values of the time on the engine $M^{p}_{дв}$ displacement of the mold $s(t)^{p}_{кр}$ and the radius vector of the common center of mass of the MOM r^{p}_{s}, adjustment of the equipoise as close as possible to the real values of the monitored parameters (r_s, $M_{дв}$ and $s(t)_{кр}$) to their optimal values is performed.

After processing received by sensors data (control) on industrial computer of the control system of MOM, equipoise of the pneumatic shock absorber is defined as dependence

$$P = f(r_s \rightarrow r^{p}_{s}, M_{дв} \rightarrow M^{p}_{дв}, s(t)_{кр} \rightarrow s(t)^{p}_{кр}).$$

Scheme of work of the control system of the balanced state of MOM is as follows (Figure 3): data of the sensors installed on the links of oscillation mechanism are fed to industrial computer, where they are compared with static information (i.e. the target), processed and readouted as numerical and graphical dependencies for staff of CCM. By results of calculations the necessary equipoise is determined and the corresponding pressure adjustment in the impact attenuation bag is performed.

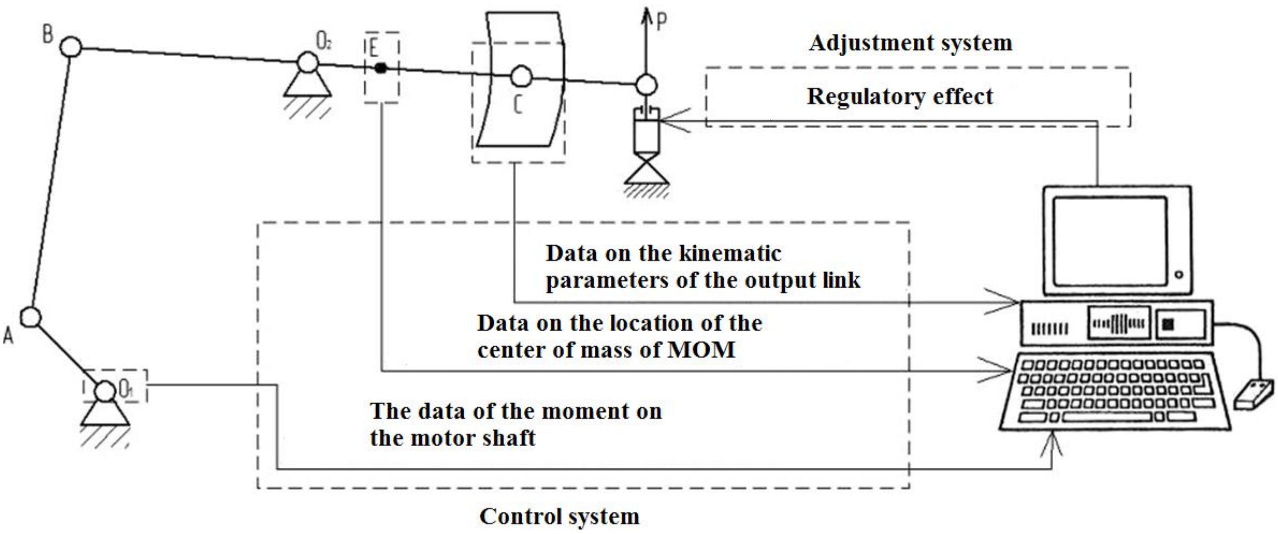

Figure 3. Structural diagram of the control system of MOM

It should be noted that the modern spring designs of MOM (usually equipped with hydraulic drive) are also equipped with control systems [7], the work of which is based on recording parameters of the vibrational motion of the mold, billet pulling rate and uniformity of the load in the horizontal directions. Thus the design of spring MOM also requires the control and regulation of the balanced state of a mechanical system in response to dynamic loads that can be partially compensated for the elastic properties of the springs. Therefore developed algorithms and methods of control of the operating mode of knuckle-lever MOM can also be used for spring oscillation mechanisms.

Conclusions

The developed control system of knuckle-lever MOM maintains a balanced state of oscillation mechanism in the process of continuous casting of steel in CCM, provide a relative constancy of the parameters of the vibrational motion of the mold and the torque on the motor shaft of the drive mechanism of oscillation. This will stabilize stresses arising from the nodes of the mechanical system of MOM and reduce wear of its individual parts. However, pneumatic dampers, as well as other means of balancing lever mechanisms, can not fully compensate the dynamic imbalance, and are only able to decrease it.

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