Multifunctional Complex of Thermomechanical Calibration by Screw Compression

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Abstract. In the present paper, a soft-hardware system is considered intended for controlling the complex for high-temperature thermomechanical calibration by screw compression. The functional capabilities and block diagram of the complex are presented. The operation algorithm is briefly described and the criteria for selecting parameters of processing are given. The machining program structure, data on the operator panel, manual mode and measured parameters of the calibration process are shown.

1 Introduction

High-temperature thermomechanical processing by screw compression is a method for obtaining axisymmetric metal products from structural steels with improved mechanical and performance characteristics [1, 2]. For the realization of the search for optimal parameters and the integrated study of the influence of each selected parameter on the final quality level of hardened metal products, a multifunctional research complex for thermomechanical calibration (Fig.1) has been designed and constructed [3, 4].

Fig. 1. Block diagram of the complex.

The complex allows the following:

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1. To control the variations of force and kinematic parameters in the coordinates of the carriage movement during the entire cycle of processing. Such parameters are the rotational torque of the gripper rotary drive with an angular velocity of rotation; the axial force of the drive of the gripper linear advance with a speed; the retained force of a mandrel for a hollow workpiece; the radial force acting on rollers; the gripper rotational velocity; the rotational speed of the rollers; axial velocity.
2. To provide the specified force characteristics of the process, the control of the velocities of rotation and linear advancement, the control of post-deformation hold.
3. To create the required modes of cooling: it is done by controlling the cooling medium temperature and the medium consumption in a sprayer
4. To save all the data incoming from a flash memory card with the registration of time or movement for further analysis.

2 Algorithm of operation and criteria for selecting processing parameters

In the structure of the control program for the complex the regulated parameters are in the form of sets created for each particular production or research task. Figure 2 shows the list of the parameters of processing entered by an operator on the display of the complex.

"Name of the parameter set"			a1	Initial carriage position, mm	0,00
s1	Carriage speed, mm/sec	0,0000	a7	Compression start point, mm	0,00
s1	Workpiece rotation speed, rpm	0	a8	Compression end point, mm	0,00
a3	Start point of rotation, mm	0,00	a9	Irrigation start point, mm	0,00
a4	End point of rotation, mm	0,00	a10	Irrigation end point, mm	0,00
a5	Initial heating point, mm	0,00	a11	Steady-rest entry point, mm	0,00
a6	Heating end point, mm	0,00	a12	Steady-rest output point, mm	0,00
Sprayer 1 water 2 water + air			a2	Carriage end point, mm	0,00

Current carriage position 0,00

EXIT

Fig. 2. Photo of the display of the complex

It is possible to activate the manual mode by pressing the corresponding buttons on the panel (Fig. 3). The initial position of the carriage is selected by moving it manually to the required coordinate at visual control.

Fig. 3. The "manual operation mode" tab

In the general case, the algorithm of making a set of the parameters of processing includes the following operations:

1. The capacity of the heating unit is determined.
2. Based on the input data, the calculation is made of the rotation velocity of a component, the angle of the turn of rollers and the percent increase of the angle of advancement relative to the angle of the roller turn.
3. Using the values of the rotation velocities and speeds of advancement and taking into account real geometry parameters of the processing rollers (the diameter, the width of the conical part and the width of the cylindrical part) and the workpiece, the amount of unit strain on the both parts of the rollers is calculated.
4. The coordinate of the beginning of the operation cycle is entered. Taking into account the lay-out diagram, the above coordinate is selected so that the nonmachining part of the workpiece would be minimized and the gripper would not be heated by the inductor.
5. The operation parameters of the deformation unit are specified.
6. The sprayer parameters are entered.
7. The coordinate of the advancement of the supporting steady-rests is specified.
8. The coordinate of switching the inductor off is specified.
9. Taking into consideration the elongation of the workpiece, the coordinate of the stop of the gripper axial advancement is calculated.
10. The parameters are input in the form of sets on the control panel. The installation is ready for the initiation of the processing cycle.

In the process of adjusting each set, the controller saves the readings of the sensors of the complex onto removable media for providing synchronization with the current coordinate of the carriage in accordance with the periodicity specified by the service engineer of the complex; the time reference to the current moment is fixed.

3 Results

In Fig. 4, one can see the graphical representation of the values of the force parameters: the axial force F on a workpiece, the forces of the roller pressing F_1 , F_2 and F_3 and the axial force on the carriage F_c depending on the position of the workpiece in the complex. A workpiece made from structural steel was processed [5, 6]. On the workpiece section with the length from 0 mm to 200 mm the variations of the axial force are due to the transient processes associated with the beginning of the workpiece processing. The length of this section is normally equal to ten diameters of the workpiece. On the section from 200 mm to 280 mm the processes take place associated with the beginning of the deforming rollers operation [7]. On the mentioned section, the axial force of the carriage movement sharply decreases as the intensity of plastic deformation decreases. The growth of the axial force on the section from 600 mm to 680 mm is associated with the workpiece cooling through the end surface and with the heating of the deforming rollers due to the contact with the workpiece. On the section of 680 mm – 1040 mm the axial force decrease takes place due to the end of the deformation. The workpiece is moved to the zone of cooling by the sprayer (the processes in the zone are described in [8-10]) and the workpiece processing comes to an end.

Fig. 4. Power processing parameters of the workpiece

4 Conclusion

A multifunctional complex for thermomechanical processing is developed allowing the control of the main force and kinematic parameters of the calibration process by screw compression. The technical regimes form the required structure and mechanical and operating characteristics of components. The complex allows studying the influence of the main process variables on the stress-strain state of workpieces and selecting technical regimes of processing which guarantee obtaining improved physical and mechanical characteristics of material and high quality of metal products.

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