Pneumatic Manipulators for Interrupting Converter-Slag Flow

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DOI: 10.3103/S1068798X07100073

Various methods of stopping slag flow are used to ensure the required metal quality when casting converter steel. One of the most effective is to use manipulators mounted next to the converter that cut off the slag flow by means of a ball plug [1]. In the oxygen-converter shop at Magnitogorsk Metallurgical Works, the manipulator used for this purpose takes the form of a parallelogram-type mechanism, with a hydraulically driven arm. The mechanism for releasing the ball plug is mounted at the front of the arm. The plug is released above the steel-discharge vent, about 30–60 s before the end of steel discharge from the converter to the ladle. The arm is in the converter for 7 s; the working cycle lasts 25 s. This manipulator occupies a considerable area and requires manual operations when loading the ball plug in its clamp. The manipulator may only operate in manual mode, since its positional accuracy depends on the operator’s skill.

A promising means of cutting off the converter slag is to use a pneumatic manipulator in the form of a slag stopper mounted directly ahead of the discharge vent. This manipulator employs flexible drive elements with no sealed moving parts (pistons, plungers). The basic drive element is a flexible steel strip, whose changing curvature ensures motion of the slag stopper. Compressed air is supplied to an enclosed corrugated cushion between the strip and the base. The manipulator may operate either manually or automatically. The stopper is moved manually from the control board. Special information systems permit automatic operation.

A manipulator for closing the converter’s discharge vent is shown in Fig. 1 [2]. It includes gas-supply mechanism 1, mounted on shaft 2 with aperture 3, and lever 6, mounted on bearing 4 close to output vent 5 of the converter. Lever 6, which culminates in nozzle 7, takes the form of a gas-supply pipe 8. Lever 6 is equipped with drive 9 and a system for supplying the drive’s working gas. Aperture 10 in the bearing aligns with the aperture in shaft 2 when nozzle 7 enters the discharge vent 5 of the converter. Additional pins 11–14 on lever 6 and bearing 4 permit the attachment of elements 15 and 16 of drive 9. These drive elements consist of flexible links 17 and 18 (hinged at additional pins 11, 12 and 13, 14, respectively) and elastic shells 19 and 20, which take the form of bellows, for example, and are connected to the system supplying the drive’s working gas.

The manipulator operates as follows. During oxygen injection into the steel in the converter, lever 6 with nozzle 7 moves to its initial position A. Converter output vent 5 is open. The converter’s output vent is closed as follows. After injection ends, the working gas is supplied to elastic shell 19 at some pressure. Shell 19 acts on flexible link 17, which becomes bowed. As a result, the longitudinal linear dimension between the additional pins 11 and 12 is reduced, and so lever 6 with nozzle 7 moves through a certain angle, to working position B. When nozzle 7 approaches the converter’s output vent 5, aperture 3 in shaft 2 and aperture 10 in bearing 4 begin to overlap, and the shutoff gas (nitrogen) passes through pipe 8 and hence through nozzle 7 to vent 5. Nozzle 7 forms a nitrogen jet. The converter begins to turn to the discharge position, and the shutoff gas cuts off the primary slag supplied to the discharge vent on tipping. Lever 6 with nozzle 7 returns to its initial position A.

As steel discharge continues and slag appears in discharge vent 5, the lever returns to working position B, and a jet of nitrogen is sent to vent 5. After the slag supply is cut off, the converter returns to its original vertical position, and lever 6 returns to its original position A. The lack of moving parts (coupling rods, pistons, seals) ensures stable operation of the device. The system is characterized by stable supply of nitrogen at the instant when the slag supply is cut off, reduced slag delivery to the casting ladle, and improved quality of the cast steel.

Possible pneumatic drives of the manipulator are shown in Fig. 2. In the drive in Fig. 2a, compressed gas is supplied at some working pressure to one of the drive elements during manipulator operation. At the same time, the gas leaves the other drive element through distributor 1. Controllable chokes 2 are employed. The drive in Fig. 2b employs pressure valves 1, which are normally closed, and three-line distributors 2. The drive in Fig. 2c employs geared pneumatic valves 1 and two-line distributors. In the drives in Figs. 2b and 2c, some specified pressure is maintained in one drive element while compressed gas is supplied to the other.

One of the most important problems in manipulator operation is gas-jet injection in the melt.

During injection by a gas that cannot be assimilated (nitrogen or inert gas), the gas–melt interaction changes

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Fig. 1. Manipulator for interrupting slag supply.

Fig. 2. Pneumatic drive for manipulator.