ROBOTS USED IN AUXILIARY OPERATIONS OF ELECTRIC ARC STEEL FURNACES

Constantin Brezeanu*, Mariana Trofimescu**, Gabriela Firouzi***

* Eng. Silcotub S. A. (Tenaris Group) Călărași
e-mail: br79c@yahoo.com
** Eng. "Dinu Lipatti" High School, Bucharest
e-mail: trofimescumariana@yahoo.com
*** Prof. eng. "Gh. Asachi" High School, Bucharest
e-mail: gabriela_firouzi@yahoo.com

Abstract: The paper presents some building schemas of manipulator - robots used in auxiliary operations of electric arc furnaces that are found in steel works. The technology of making steel in electric arc furnaces requires that the liquid steel outlet is filled following the primary elaboration. An "EBT SAND" type manipulator is used to fill the steel outlet, the kinematic scheme of which corresponds to SCARA robots. To unlock the steel outlet, an "EBT STAP" type manipulator is used, which is equipped with an oxygen lance to open the tap-hole. To clean the furnace outlet following the discharge, an "EBT STROP" type manipulator is used to allow the correct reconditioning of the tap-hole. It consists of an electrically driven swing arm and a hydraulic lift that cleans the EBT tap-hole.

Keywords: manipulator, steel, steel furnace, exhaust outlet, robot arm

1. SCARA SERIAL ROBOT

SCARA is the acronym for Selective Compliance Assembly Robot Arm or Selective Compliance Articulated Robot Arm, of 1981, a new concept of assembly robots. It is an articulated structure with two articulations, similar to human arms.

The robot characteristics allow its arm to reach limited areas, and then to come back to its initial position or to "go out of the way". It is useful for transferring parts from one cell to another or for loading/unloading process stations [4, 9].

SCARA robots are generally faster and easier to program than similar Cartesian robot systems. The fact that they are only mounted on a platform requires little space, which is very practical. SCARA serial robots can be more expensive than similar Cartesian systems, and the control software requires the reverse kinematic method for linear interpolated motions. This software is provided together with the SCARA robot and it is transparent for the industrial user.

Fig. 1.1. Building schema of the SCARA serial robot

Fig. 1.2. Working area of the SCARA robot (vertical and horizontal plan)

Fig. 1.3. Building schema of the robot in the extended position of its working area [4, 9]


2. "EBT SAND" TYPE MANIPULATOR USED FOR REFILLING THE LIQUID STEEL OUTLET
The manipulator called “EBT SAND”, Eccentric Batter Throw (fig. 2.1), is a SCARA robotic arm which has been modified for reconditioning/filling the EBT outlet after discharging the steel so as to maintain the heat inside the furnace. It is used for discharging a quantity of material, for example olivine sand, from a pot that has been previously prepared and placed nearby.

The manipulator consists of (fig. 2.2): 1 – main electric panel; 2 – main arm gear motor group; 3 – secondary arm gear motor group; 4 – electric panel for the material management device; 5 – pneumatic box; 6 – slag remove device [1]

The manipulator can perform the following movements:

a. Lifting the main arm, by means of an electric motor, commanded by an inverter and controlled by an encoder;

b. Lifting the secondary arm, by means of an electric motor, commanded by an inverter and controlled by an encoder;

c. “Slag removal” system driven by a pneumatic cylinder controlled by the double solenoid electric valve;

d. The material discharge outlet at the edge of the manipulator, controlled by an electric valve.

The manipulator is also equipped with the following: intermittent light signal and a siren; devices for signalling the status of the equipment in motion; a system for weighing the material ladle used for managing the recharge of the ladle tap-hole and for unloading the material; video camera used for correctly positioning the SAND manipulator and for checking the status of the EBT manipulator and for checking the status of the EBT tap-hole and the material discharge process.

2.1. Conveyor system used for taking the material to the SAND manipulator.

The material used by the equipment, olivine sand, is placed inside a ladle next to the manipulator, which is periodically loaded by a running crane. The ladle is provided with a minimum level sensor, signalling to the operator that it is necessary to recharge the material. The ladle outlet is equipped with a worm gear transport system driven by an electric motor, which is necessary for taking the material from the fixed ladle to the one provided next to the “EBT SAND” manipulator.

The control system will automatically load the ladle next to the equipment when it is in the rest position, the recharge position (fig. 2.3).
Fig. 2.3. Positioning the manipulator device for operation [1]

Fig. 2.4. Industrial joystick with touch screen

2.2. Using the equipment during maintenance.

If all the activation conditions are met, it is possible to:
1. Switch on/off the running crane that takes the material from the fixed ladle to the one next to the equipment using the light button. When the crane is moving, the light button is on.
2. Open/close the material discharge outlet on the equipment ladle using the light button;
3. Rotate the main arm using the selector;
4. Rotate the secondary arm using the selector;
5. Lift/lower the “slag breaking” system using the selector.

During the maintenance mode: all the activated motions are directly controlled by the operator; Safety signals are always active even when all the automated cycles have been deactivated.

Handling controls of the L₁ arm segment and of the L₂ arm segment as well as of the slag breaking system during the maintenance mode are controls with "maintained drive", the driven motion stops if the control device is released. The equipment can move out of the parking and operation positions, used during the automatic mode. This is useful during certain furnace maintenance operations (e.g.: replacing the ladle), when it is necessary to move the equipment to special positions.

The emergency shutdown control has been provided on the control panel in order to immediately shut down the equipment in case of danger or malfunction of any control devices.

Using the equipment during the automatic mode: the automatic mode (the normal use of the equipment by operators) is possible only by means of the controls on the touch screen.

Activating the automatic cycle: it is possible to start an automatic cycle only if all the following are met:
- all the safety signals are OK and the controls on the touch screen have been selected;
- the EAF furnace has been activated for the automatic cycle of the robotic arm;

Controls are provided on the control panel, as well as on the touch panel for emergency situations.

The control system has two control stations, including:
local controls for maintenance; an emergency shutdown button and a related reset button; the emergency shutdown button is always active, even when the commands on the EAF panel are not active; a manual handling joystick; a set of controls on the touch screen.

The joystick will control the motions of the equipment selected on the touch screen and it can be used in turn, as it is jointly used by “STROP”, “STAP” and “EBT SAND”; the available configurations are included in the control guidelines that has been specifically designed and built.
- No warning signal from the automatic system, the EBT SAND arm is in the rest position.

The automatic cycle: if all the activation requirements have been met, the operator can use the equipment.

The buttons “EBT SAND HOLE CLEANER DOWN” and “EBT SAND HOLE CLEANER UP” can drive the “slag breaking” system, in order to break any slag crusts that have formed.

When the tap-hole below the EBT door is clean, the material can be discharged using the “EBT SAND MATERIAL DISCHARGE START” button.

The material discharge outlet is opened and the material goes inside the EBT tap-hole.

After the set quantity of material has been discharged or if the operator has pressed the “EBT SAND MATERIAL DISCHARGE STOP” button, the discharge outlet is closed.

The operator can open and close the discharge outlet several times in order to load an additional quantity of material.

If the EBT reconditioning operation has been successfully completed, the “EBT SAND REPOSITIONING” button is pressed on the touch screen.

The equipment is automatically put in the parking position. When the arm reaches the parking position, the ladle next to the equipment is automatically filled by actuating the running crane.

2.3. Automatic repositioning cycle

If the equipment is not in the parking position, the system automatically repositions the equipment in the parking position and the arm is ready for a new cycle.

Setting the equipment operation positions can be edited directly.

Signals: The equipment statuses, alarms, and operation settings have been presented and can be consulted.

Emergency shutdown controls: The operator must activate the emergency shutdown controls when it is necessary to stop the manipulator in a very short time in order to avoid dangers.

When activating the emergency shutdown controls, the equipment is immediately shut down. The emergency shutdown circuit can be restarted when all the emergency shutdown controls have been manually reset to the “not pressed” position.

Note: the joystick, S23, is jointly used by the “STROP”, “STAP” and “EBT SAND” machines, and it can be used only by one piece of equipment at a time.

3. THE “EBT STAP” TYPE MANIPULATOR FOR UNLOCKING THE LIQUID STEEL DISCHARGE Outlet

The STAP type system is a swing and lift device, driven by an electric motor, which opens the EBT tap-hole in the emergency regime, thus avoiding the use of the oxygen lance by a human operator.

The “STAP” manipulator is a piece of equipment meant to open the EBT tap-hole from below in order to transfer the steel from the furnace into the pot (fig. 3.1).

An automatically driven telescopic oxygen lance is placed by the manipulator inside the closed EBT hole. After the correct position is reached, the operator can activate the oxygen injection for opening the tap-hole on the touch screen. As soon as the steel begins to pour into the pot, the operator must activate the repositioning control in order to get the equipment back to the parking position.

Fig. 3.1a. Plant view, manual work – the necessity of using robots

Fig. 3.1b. Building schema of the STAP type manipulator, used for unlocking the discharge outlet

Fig. 3.1c. STAP manipulator.

It consists of the following elements (fig. 3.1): 1) pedestal; 2) bolts for mounting the motherboard; 3) main electric panel; 4) pneumatic joints box; 5) vertical
motion column; 6) electric drives box; 7) main arm; 8) oxygen lance for opening the tap-hole [1].

Signals and safety functions: the safety controls that the automation system is equipped with are:
1. General emergency shutdown button of the furnace
2. Additional control for general emergency shutdown
3. STAP emergency shutdown control from the system that manages access to dangerous areas, gates, barriers, etc.
4. Emergency shutdown button on the local controls box.
Signals 1, 2 and 3 are generated by the operator and are connected to the automation system.

3.1. Motions of the manipulator - robot

The manipulator can perform motions, T+3R (fig. 3.2), each of them being performed with the help of an electric gear-motor commanded by an inverter and controlled by an encoder.

Fig. 3.2. Motions of the elements of the manipulator – robot [1]

The motions are (fig. 3.2): lifting / lowering the arm; rotating the base platform; rotating the arm; lifting the lance.

The manipulator is equipped with an intermittent light indicator and a siren. These devices are activated to signal the equipment motion status.

The maintenance mode is only possible by means of the local touch screen. Activation requirements: all the safety signals are OK; the key selector must be in the 0 position = ON, activation local controls.

If all the activation conditions are met, the following are possible: lifting and lowering the arm using the selector; rotating the base platform using the selector; rotating the arm using the selector; lifting the lance using the selector.

All automatic cycles are de-activated; the oxygen injection cannot be activated; activation signals from the furnace are not taken into consideration if the equipment is operated directly by the operator. Safety warning signals are always active.

During the maintenance mode, there are “maintained actuation” controls. The motion stops if the control device is released; the equipment can be moved beyond the parking and operation positions used during the automatic mode. This is useful during certain maintenance operations performed on the furnace.

The emergency shutdown control is provided for manual control /disconnecting in order to immediately stop the manipulator; in case of danger or malfunction of certain control devices, the oxygen line cannot be opened.

3.2. The automatic mode

The normal use of the equipment by operators is only possible by means of the control panel.

Fig. 3.3. Positioning trajectory of the manipulator-robot in the working area [1]

The emergency shutdown circuit can be restarted by pressing the button (=CLIENT+Y01-S2) on the touch screen, only when all the emergency shutdown controls have been manually restarted in the “not pressed” position.

4. “EBT STROP” TYPE MANIPULATOR USED FOR CLEANING THE FURNACE TAP-HOLE

After discharge, the tap-hole must be cleaned for a correct reconditioning of the furnace. This manipulator consists of an electrically driven swing arm and a hydraulic lifting device, which cleans the EBT tap-hole, for a quick and reliable operation below the electric furnace without any manual intervention.

The manipulator is an assembly that can be installed either on the mobile platform (at the bottom) or next to the EBT tap-hole.

A metal pin is introduced in the EBT tap-hole from below (fig. 4.1) in order to clean it.

Fig. 4.1a. Building schema of the “EBT STROP” robot
Safety signals and functions

The automation system is equipped with the following safety inputs:
1. General shutdown button in case of an emergency on the furnace control panel;
2. Additional general shutdown control in case of an emergency;
3. STROP emergency shutdown control from the system that manages access to dangerous areas, gates, barriers, etc.
4. Emergency shutdown button on the local controls box. Signals 1, 2 and 3 are generated by the operator and are connected to the More automation system.

4.1. Motions performed by the manipulator

The following motions have been identified (fig. 4.1):
1. Rotating the arm by means of the electric motor commanded by an inverter and controlled by the encoder to bring the manipulator arm from the parking position into the operation position and vice versa.
2. The vertical motion (UP / DOWN) of the hydraulically driven metal pin and controlling the position (PARKING / OPERATION) by means of the encoder, in order to clean the EBT tap-hole. The devices, pressure switch valves, are placed on the hydraulic valves bench (+HPU). These are necessary for handling the cylinder.

The manipulator is provided with an intermittent light indicator and a siren, activated to signal the state of the equipment during operation.

4.2. Operation mode

The control system is equipped with two control stations:
a) Local maintenance controls, jointly used with the STAP manipulator, and provided with a key selector “Activation local controls ON/OFF”.

It is used by the operator only for maintenance operations.
b) The control panel controls are active when the local control box is inactive and consist of: an emergency shutdown button and a corresponding reset button.

The emergency shutdown control is always active, even when the controls on the EAF panel are not active.

4.3. Using the equipment during maintenance

The local controls are used. The activation conditions are as follows:

All the safety signals are OK; the key selector is in the 0 position = ON, activation local controls.

If all the activation conditions are met, it is possible to: rotate the arm from the parking position into the operation position by means of the selector; lift and lower the pin by means of a selector.

During the maintenance mode, all the automatic cycles are inactive; activation signals from the furnace are not taken into consideration as the arm is directly controlled by the operator. Safety signals are active at any time.

All controls during the maintenance mode are “maintained actuation” controls. The actuated motion stops if the control device is released. The equipment can be moved beyond the parking and operation positions used during the automatic mode. This is useful during certain furnace maintenance operations, when it is necessary to move the equipment to special positions.

The emergency shutdown control is provided on the touch screen in order to immediately shutdown the equipment in case of danger or malfunction of any control devices.

Bibliography

2. *** AIST Associacion Iron & Steel Technology. Steel's first technology event, Aistechn (r) 2015
5. https://issuu.com/stahleisen/docs/int_2017-2 ;
8. Antonescu, O., Brezeanu, C., Antonescu, P., Kinematic aspects regarding the composition of concurrent rotational motions, Proceedings of the 26th Meeting of Work on Standardization of Terminology, Bucharest, Romania, Sep. 4-9, pp. 43-48, 2016;