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Conception of Contactless Strip Edge Guiding System on Continuous Galvanizing Line in U.S Steel Košice

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BIOGRAPHICAL NOTES

Dr.h.c. mult. prof. Ing. František Trebuňa, CSc. is a professor of applied mechanics, Head of the Department of Applied Mechanics and Mechatronics and Dean of the Faculty of Mechanical Engineering. He is author of 10 monographs, 12 university textbook, special book publications, 12 university notebooks and more than 300 publications in journals and conference proceedings at Slovakia abroad. He is author of important projects and engineering works. He received several prizes at home and abroad. He received three titles Doctor Honoris Causa (DHC) including two from foreign universities for the development of applied mechanics and mechatronics.

Ing. František Menda successfully accomplished the high school with base on mathematics. Then he began studies at the Faculty of Mechanical Engineering of the Technical University of Košice. He graduated with honours a bachelor- degree study in Mechatronics in 2010 end continued an engineer degree study in same program. He defended his diploma thesis "Design of the conception for contactless control of air knives with drives for zincify production line no.3" in 2012 and accomplished this study with an honours. Nowadays, he is a PhD. student of Mechatronics and is concentrating on measuring of residual stress by Ring-core method.

KEY WORDS

Galvanizing, U. S. Steel, strip, touchless sensor

ABSTRACT

The content of this work is the analysis of contact strip edge guiding system on Continuous galvanizing line CGL3 in the factory U. S. Steel Košice, s.r.o. The effort of increasing of the quality of production along with decreasing of costs involves replacement of contact system by contactless system. The aim is to present contactless strip edge sensor with appropriate electromechanic actuator. The right choice of components and adequate control of sensor movement achieves better strip galvanizing.

1. Introduction

Tough competition in automotive industry forces manufacturers to use construction materials which guarantee high quality, long duration and safety, and all of that by lowest prices. Sheet metals are important automotive parts. Well known producer in this segment in our region is U.S. Steel Company. The factory produces corrosion resistive, galvanized metal strips of high quality. Modern galvanizing line was build and launched to its full production in 2007. Gradually growing customers' demands force enterprises to improve production technology and rise quality of products. This

work deals with increasing of quality of sheet metal galvanized strips by improving used technology in continuous galvanizing line number 3 in the company U.S. Steel Košice.

The aim is to create a conception of contactless strip edge guiding system in coating section of galvanizing line. The concept is based on official line parameters and drawing documentation on which it is made up with the lowest construction changes.

2. Air Knives System

The most important section of galvanizing line is Process section I, where melted zinc is applied on clean and blanching sheet metal. Plate is conducted from furnace to zinc bath, from which it is directed by sink roll vertically up through one correcting and one stabilizing roll to zinc air knives system. Air knives system consists of two wiping jets (air knives) on both sides of plate. Air or nitrogen pressure blowing from these jets, distance between jets and plate, jets and bath and adjustable angles. All of these mentioned allow regulation of different zinc thickness on steel plate [1].

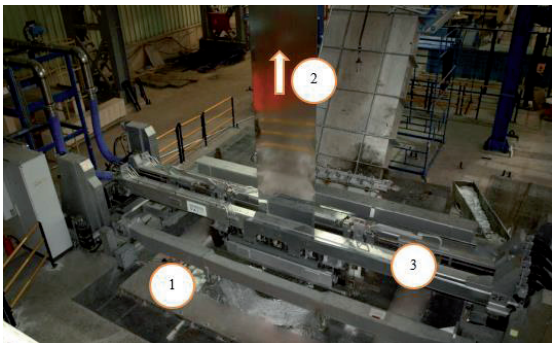


Fig. 1: *Coating section of galvanizing line [2]*

The function of air knives system is to provide uniform zinc coating at whole profile of sheet metal. However, during the jet blowing from both sides of plate, problems occur at the edges. Air flows smash together and as a result laminar flow turns into turbulent. Special auxiliary edge baffles are used to prevent the turbulent flow.

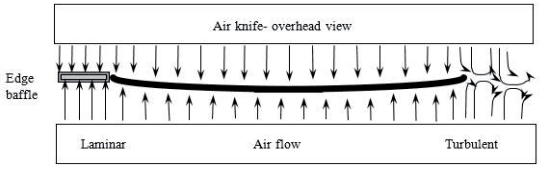


Fig. 2: *The use of edge baffles*

Galvanizing line number 3 in U. S. Steel Košice is a continuous line, which means that particular metal strips are weld together at initializing section of line. Welds are often marked by cut-out.

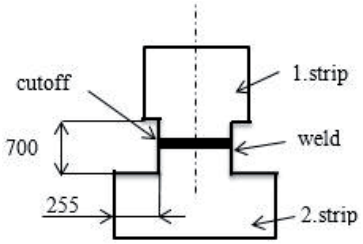


Fig. 3: *Scheme of strip connection [3]*

The part of plate in weld area doesn´t fulfill desired features, therefore the waste in front and behind is cutaway at the end of line. The weld position is precisely detected at each section of the line by this cutoff made in the weld section. Operator by air knives has to take care of baffles. They should always move aside while weld part of plate comes through the section and then come back close to the edge of plate. These baffle movement is important in case of possible collision of baffles with changing width of the plate after the weld part.
In figure 4 there is a schematic kinematical layout of currently used contact system for turbulences prevention during removing excess liquid coating metal as a continuous steel strip exits a coating bath.

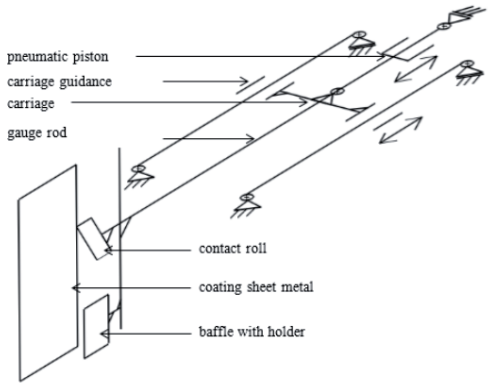


Fig. 4: *Kinematical layout [1]*

Description of all parts with their parameters required for next calculations [1]:

1. compressor - compressed air of 0,6 MPa pressure, possible to use nitrogen instead

2. pneumatic piston

■ *two way, controlled by regulator*
■ *length: 1210 mm*
■ *cylinder diameter: 25 mm*
■ *in the end position effect of constant downforce 49N invoked by constant pressure 0,1 MPa on piston surface in cylinder*
■ *movement: 300 mm.s^{-1}*
■ *signal for moving aside: 2s before detected weld*
■ *signal for moving forward: 2s after weld passed*

3. linear guidance for bearing carriage

■ *guidance length, respectively the length from the first end position (aside baffles) to another one (closed baffles): 1000 mm*

4. carriage

■ *bearing movement with guidance*
■ *magnitude of force needed to overcome rolling friction and actuate carriage carrying the baffle is F=4,3 N*

5. gauge rod

■ *serve for determining the baffle end positions*

6. baffle with holder

■ *replaceable set in case of running coating process*
■ *total weight in range 35 to 40 kg*
■ *distance between baffle and plate in closed position: 3-5 mm*

7. contact roll

■ *contact with the strip edge, not supplied with end switch. constant downforce in closed position which causes undesired strip edge deformation*

8. coating sheet metal

9. control unit

■ *PLC SIEMENS 416-2XK04-0AB0*
■ *CPU 416-2, 2,8 MB*
■ *control of piston movement automatically, based on information about weld position acquired from main PLC, operator inputs available*
■ *unit is placed in box well isolated from negative outside conditions, near air knives system*
■ *process only digital signals*

3. Contactless strip edge guiding system

Solution includes:

■ *the choice and a placement of appropriate contactless strip edge sensor*
■ *replacement of used pneumatic actuator by electromechanic one*
■ *conception of control algorithms*
■ *construction drawings of projected system*

3.1 Sensor

Required technical specifications of contactless sensor:

■ *operative temperature: up to 100°C*
■ *plate thickness (scan edge): 0,3-2,0 mm*
■ *modulating output signal, fast response*

Inductive sensor BMI 4 produced by EMG [4], based on Faraday induction law is chosen as a best choice for required conditions.

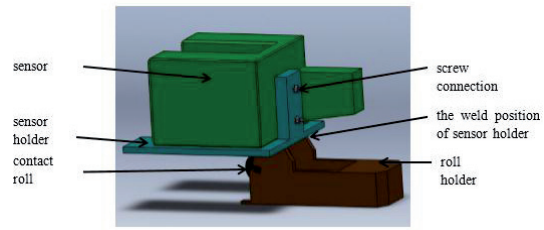


Fig. 5: *Sensor assembly [1].*

Sensor is fork shaped, so it is important to attach it by holder, which will protect sensor from possible transverse plate oscillation.

3.2 Positioning

Contactless strip edge guiding solution include replacement of used pneumatic piston by electromechanic actuator. Main requirements for this purpose:

■ *downforce: more than 20 N*
■ *movement: more than 300 mm.s^{-1}*
■ *length of guidance: more than 700 mm*

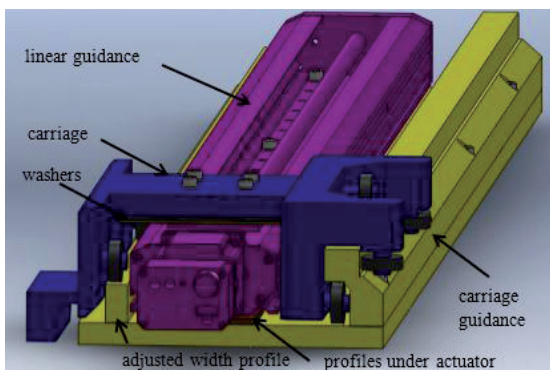


Fig. 6: *Linear stage assembly [1].*

Motorized linear stage T-LST1000D produced by Zaber [5] is chosen as a best solution for movement purposes. This actuator allows very precise positioning, control unit and sensor of actual position are integrated into stage. Sensor of actual position allows operator to set and track actual baffles posi-

tions instead of current status when he knows only end positions. High movement speed and short response allow baffle positioning without undesired time delays. Dimensions of stage well fit appropriate space in current air knives system.

3.3 Controlling

The choice for right control unit must follow this requirements:

- *ability to receive and process modulating signal from sensor*
- *modulating output for actuator controlling*
- *active communication with superior PLC*

Calibration needs and programming of new system for continuous operation require new, independent control unit. SPC16 produced by EMG [6] is chosen as a right control unit.

4. Complete Design

Final conception of contactless strip edge guiding system at galvanizing line n.3 is based on current contact system from FOEN supplier. The solution is designed with an effort for minimum construction changes in existing system. Current pneumatic cylinder and gauge rod need to be replaced in case of using contactless sensors. Logical structure in UML language was created for this conception.

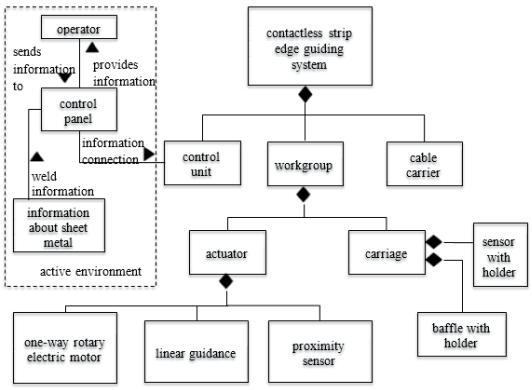


Fig. 7: *Logical structure in UML language [1]*

The overall model of contactless strip edge guiding system is created by mounting all chosen components together.

The placement of designed cable carrier requires changes in system covering. New drawing of cross-section was made. Modified assembly drawing consists of: empty cross-section, new cross-section (with applied new parts) and appropriate bill of material. Complete 3D model and animation of contactless strip edge guiding system was created in SolidWorks program [1].

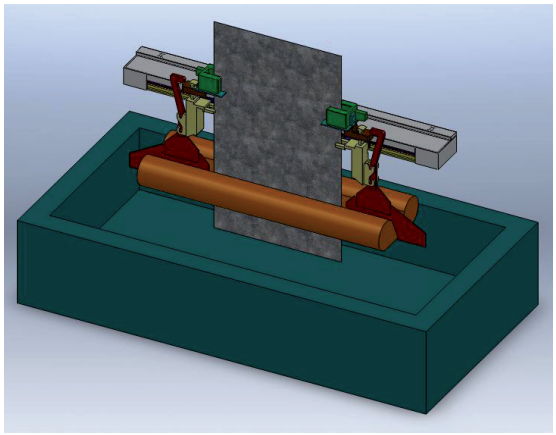
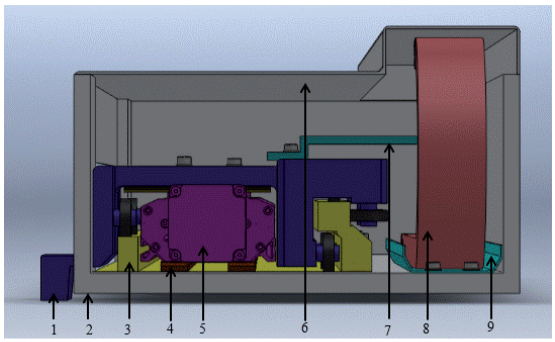


Fig. 8: *3D design of contactless strip edge guiding system [1]*



1-carriage, 2-housing, 3-carriage guidance, 4-profiles under actuator, 5-actuator, 6- opening top, 7- connection part, 8- cable carrier, 9- guide channel for carrier

Fig. 9: *Cross-section of cladding part of system [1]*

5. Conclusion

The appropriate conception of contactless strip edge guiding system for galvanizing line in company U.S. Steel Kosice was chosen in this work. The final design was reconsidered by responsible company employees and in recent time it is in initializing state of process.

The most important elements of whole design are inductive sensors. High requirements such as function, safety and minimal errors are important in that case. Sensor failure could cause system destruction and subsequently shutdown of the line what means high economic loss. That is the reason for buying BMI4 from EMG.

For positioning carriage with sensor and baffle are not so strong requirements. Of course, on positioning velocity depends total waste of plate and final galvanizing quality. Suggested linear guiding stage

is a lot cheaper than one from EMG company.

Installation and system check out could do company employees instead of external supplier, what will significantly decrease the total expenses. Suggested construction changes of currently used system are not as big as those offered by FOEN.

6. Acknowledge

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