Electromagnetic strip stabilization in galvanizing lines

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Abstract

The paper will give some basic information of electromagnetic stabilisation of strips in industrial production lines. Simple DC current coils were used to control the position and the flatness of the strips between 600 mm and 1850 mm width. The optimized geometry for the inductors was developed with a 3D BEM program. The newest technologies of PWM converters, PID controllers and eddy current position measuring system allow a strip position control within a tolerance of ± 1 mm.

Introduction

However a defined touch less position control of strips has many advantages in an industrial production line, the electromagnetic position control was introduced in process lines for ferromagnetic strips even within the last two years. Especially the better control of the thickness of zinc coating in galvanizing lines and the potential saving costs for zinc metal has forced the development in electromagnetic position control systems. Two systems are on the market. The "EMASS" (**E**lectro **Ma**gnetic **S**trip **S**tabilisation) system of EMG Automation GmbH and the "DEMCO" (**D**ynamic **E**lectro-**M**agnetic **C**oating **O**ptimizer) system of FOEN GmbH are using the same basic physical principals. Why has it taken so long time to install an electromagnetic stabilisation system in a process line for strips? The latest developments of DC converters, strip position measurement and fast PLC controls have leveraged this technology in strip processing lines.

1. Physical basics

The physical model for the strip stabilisation unit is very simple. The electromagnet of the strip stabilizer works analogue to a lifting magnet. The force on the strip can be calculated using the magnetic field energy. (1)
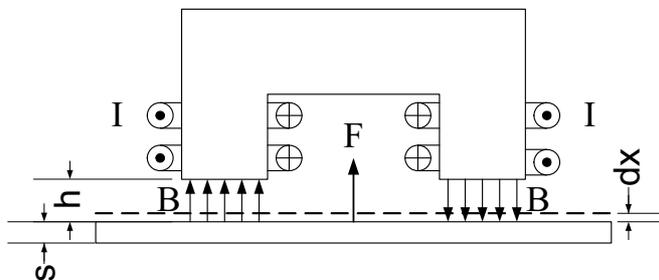

Fig. 1. Principle drawing of a strip stabilisation unit

$$F_{(x)} = -\frac{dW_{mag}}{dx} \qquad (1)$$

$$W_{mag} = \frac{1}{2\mu_0}B^2 A_L \cdot 2h \qquad (2)$$

Equation (2) gives the correct magnetic energy, if the distance between the strip and the magnetic core is small against the core width

and the thickness of the strip is big enough to avoid magnetic saturation.

In reality the magnetic core has to be as small as possible. The magnetic energy, which is stored in the air gaps between the core and the strip, is a function of x. Therefore the force at the surface of the strip is a nonlinear function of x. The magnetic induction B depends on the current I and the total reluctance of the magnetic circuit.

Therefore the design of the magnetic core for the inductor has become a sophisticated job and engineers use 3D CAD programs to optimize the core of the strip stabilizer.

2. Technical components of a strip stabilisation system

To explain the motion control of the strip, the advantages of strip stabilisation control in the air knife region of a galvanizing line will be discussed.

The air knifes have a short distance to the strip. The thickness of the zinc layer is controlled by these tools. Changes in the distance will result in different air pressure at the strip surface and therefore in a different thickness of the zinc layer. It is obvious, that 6 coils are the minimal number of magnets, to control the strip deformations along the width. At greater strip width 10 magnets are used in production lines. Two magnets, one in front and one behind the strip, are working together to force a particular region of the strip at its correct position. The strip moves and twist with frequencies between 1 and 10 Hertz. Higher moving frequencies are very seldom. Figure 3 shows the principle design of a stabilizer with 10 magnet coils.
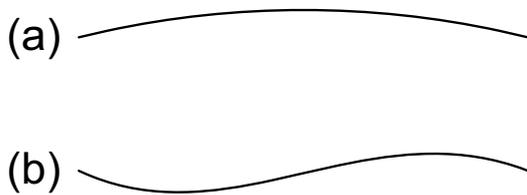

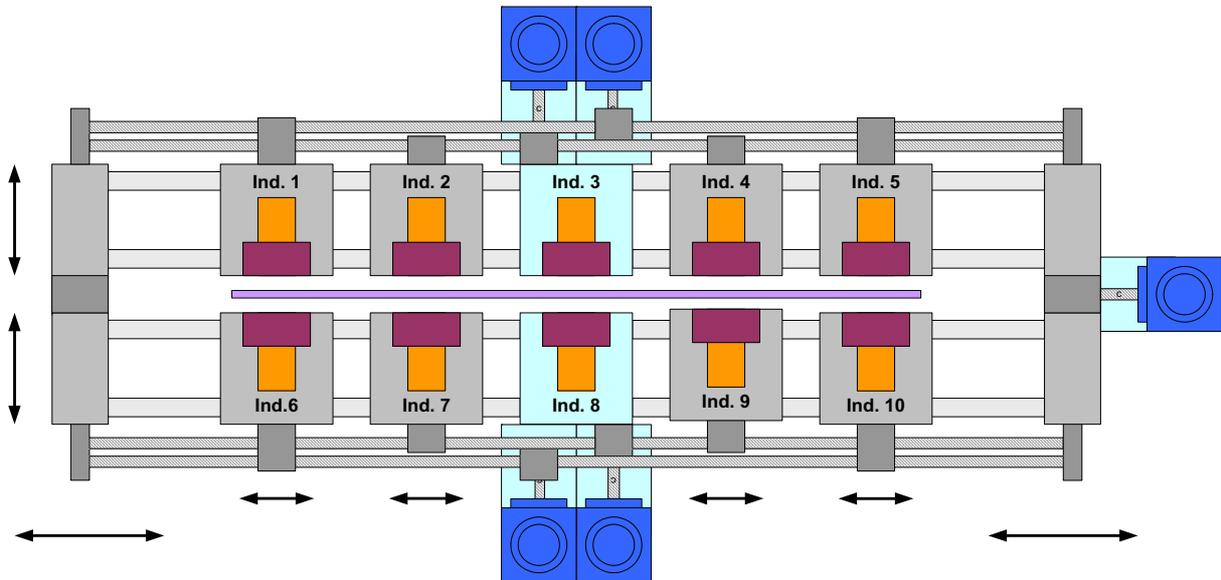Fig. 2. The most strip deformations in production lines a) cross bow b) double cross bow

Fig. 3. Principle layout of the stabilizer unit

Each pair of inductors can be positioned to an individual place along the strip width. The air gap between the inductors is at working position in a range of 50 to 100 mm.

2.1. Special DC current coils

The design of the magnet core has a substantial influence of the magnetic field in front of the inductor. Figure 4 show two different core designs.
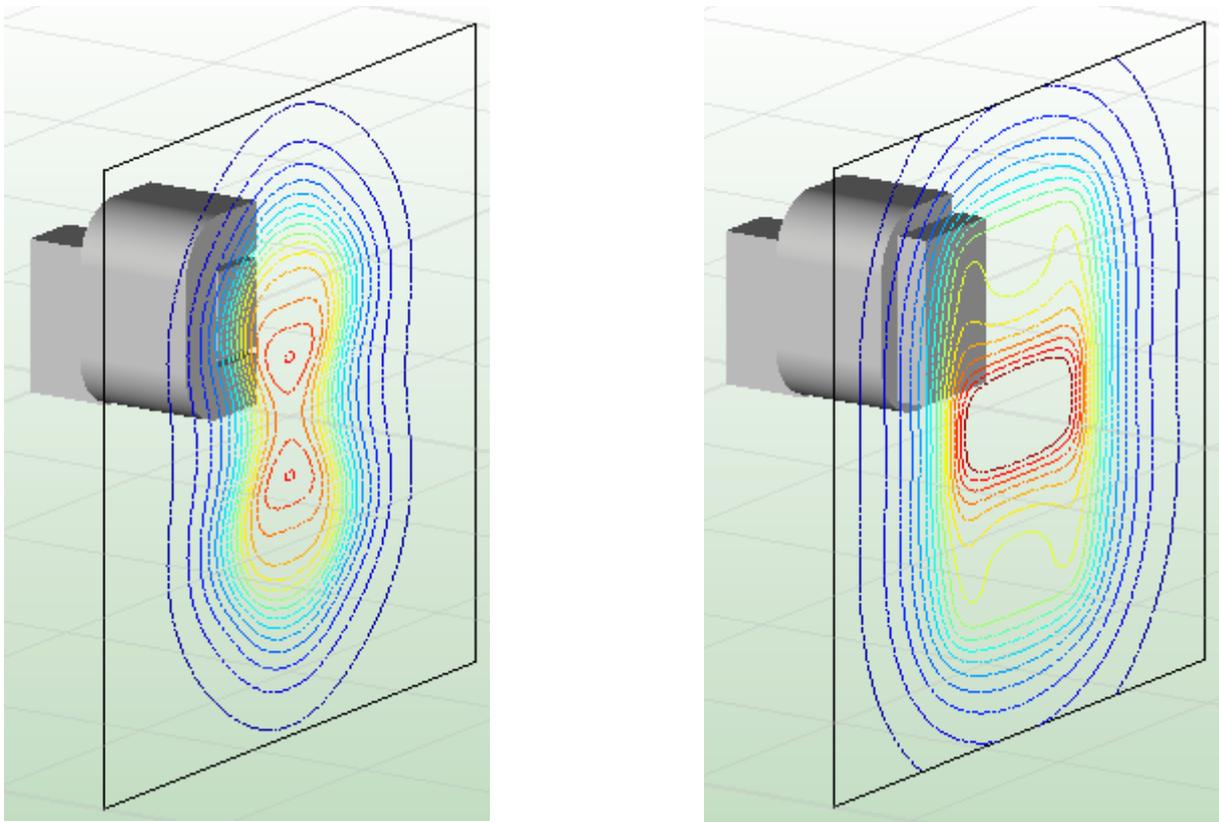

Fig. 4. Magnetic field lines 30 mm in front of the inductor, shown is ¼ of the inductor design, the model uses symmetric conditions

The effect is substantial on the magnetic field in front of the inductors. The smaller field design was used for the first installations. Less influence was expected on the neighboured inductors.

2.2. PWM converter and fast PLC with PID control

The movements of the strip can be influenced by electromagnetic forces. The magnetic force can be controlled by the coil current. It is necessary to know the position of the strip, the speed and the direction of the strip moving. A modern eddy current distance control system measures the distance between the inductor and the strip in a tolerance between ±1mm. A PWM-converter generates the current for the magnetic coil. But how fast has to be the loop from measuring a displacement of the strip, determine the needed current in the PLC and adjusting the coil current by the PWM-converter?

Measurements have shown that the moving frequencies of the strip are between 1 and 10 Hz. Therefore the reaction by the system has to be 10 times faster than 100 ms. The time constant of the current system (PWM-converter and magnetic coil) in the DECO system is less than 1 ms. The PID controllers in the PLC have a reaction time of 0,4 ms. The time constant of the total loop is less than 4 ms.

Conclusions

Modern electronics is the basic for new applications of strip control in strip production lines. The discussed equipment is installed in a production line since one year. The request from the market for such systems is increasing. The optimisation of the inductor geometry is the target for the near future.

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