Automatic control system for the declivity angle of the finishing beam

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Abstract - **The paper presents a new system for automatic control of the position of finishing beam of a machine for the deposition of asphaltic mixtures. The system uses an inertial transducer for measuring the inclination angle of the beam. The transducer's functioning is without mechanical contact, the variations of the inclination angle being directly transformed into phase variations. A good agreement has been observed between experimental results and theoretical considerations.**

Index Terms - **control system, declivity angle, finishing beam, inertial sensor**

I. Introduction

The quality of the road surface depends on the asphalt mixture composition and the automatic control system of the finishing beam position, which endow the machine specialized in the deposition and finishing of the asphalt mixture.

The automatic control system for the declivity angle of the finishing beam plays a very important role: it assures an imposed slope of the road surface regardless of the deposed mixture layer thickness.

The paper proposes a new control system for the declivity angle of the finishing beam that uses an inertial sensor for the declivity angle.

II. Theoretical Considerations

The principle scheme of the finishing beam equipped with the automatic control system is given in Fig.1.

The sensor designed for permanent control of the inclination angle of finishing beam, Tr2, is located on the beam GP, and its electromechanical structure is shown in Fig.2.

The sensor comprises the shank (1) which extends with the cylinder (2) and which lodges the aluminum lamellae (k), placed between the inductances L_1 and L_2.

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The entire assembly is sustained by ball bearings in such a way as to maintain its vertical position, by inertia.

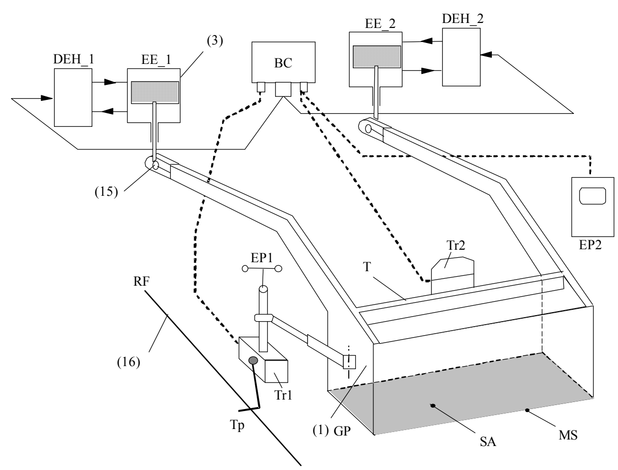

Fig.1. The beam and the position control system

The length of the shank and the mass of the cylinder are designed in such a way as to lead to resonance frequency lower than the frequency of beam vibrations, during the compacting process of asphaltic mixture.

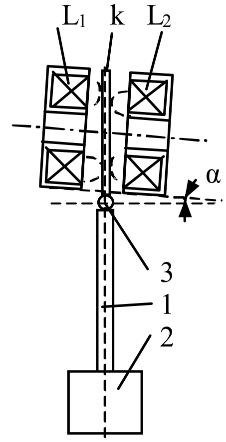

Fig.2. Electromechanical structure of the inertial sensor

In case the finishing beam is perfectly horizontal, namely when the inclination angle is nil, the metallic lamella k occupies a median position between the two inductances, L_1

and L_2. The two inductances, L_1 and L_2 belong to two LC identical circuits, Fig.3.

The two circuits are supplied by an oscillator and are functioning at resonance. When the lamella k occupies a median position between the two inductances, the mutual coupling coefficient M, Fig.4, is the same and thus the signals picked up by the two circuits are in phase.

During machine's displacement, the inclination angle of the beam changes owing to level variations.

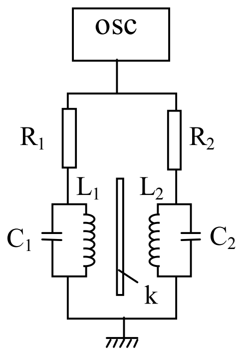

Fig.3. Structure of the electrical circuit

Concomitantly, the relative position of the two inductances and the lamella also changes, since the latter maintains its vertical position by inertia.

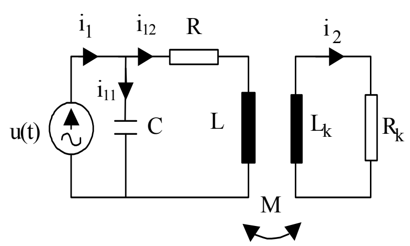

Fig.4. Equivalent scheme for one branch

This alters the mutual coupling coefficients of the two LC circuits, which are differentially coupled. It follows that the inductances L_1 and L_2 are also modified and the phase difference between the signals picked up by the two LC circuits are consequently changed.

Considering the equivalent circuit for one branch, fig.4, it follows that:

$$I_{11} = sCU(s) \tag{1}$$

$$I_{12}(s) = \frac{U(s) - sMI_2(s)}{R_1 + sL_1} \tag{2}$$

$$I_2(s) = -\frac{sMI_1(s)}{R_2 + sL_2} \tag{3}$$

and

$$I_1(s) = I_{11}(s) + I_{12}(s) \tag{4}$$

The transfer function of the circuit is:

$$\frac{U}{I_1}(s) = \frac{z_1(s)z_2(s) - s^2M^2}{z_2(s)z_3(s)} \tag{5}$$

where:

$$z_1(s) = R_1 + sL_1 \tag{6}$$

$$z_2(s) = R_2 + sL_2 \tag{7}$$

$$z_3(s) = 1 + sC(R_1 + sL_1) \tag{8}$$

By calculating the frequency response one gets:

$$\varphi(\omega) = arg\left(\frac{U}{I_1}(j\omega)\right) = \\ = arg\left(\frac{R_1R_2 - \omega^2 L_1L_2 + \omega^2 M^2 + j\omega(R_1L_2 + R_2L_1)}{R_2 - \omega^2 R_1CL_2 - \omega^2 R_2CL_1 + j\omega(R_1R_2C + L_2 - \omega^2 L_1L_2C)}\right) \tag{9}$$

The parameters M, L_k and R_k depend on the inclination angle of the beam, α, therefore on the position of the lamella k, as compared to the two inductances. Since the lamella k is made from aluminum, and the two circuits are in resonance, the change in the inclination angle determines important changes of the phase difference between the signals picked by the two circuits.

As noticeable from Fig.1, the position of the finishing beam is determined by the action of the actuators $EE_{1,2}$ upon the ends of the beam's arms. These actuators are hydraulic servomotors with double effect. Their command is achieved by means of some electro hydraulic distributors $DEH_{1,2}$. In some cases distributors with proportional action were used, the static characteristic of which is shown in Fig.5.

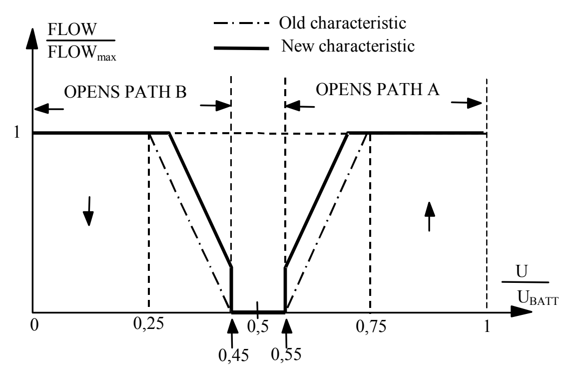

Fig.5. The static characteristic of a proportional distributor

Since in most of the cases low levels of the error signals are used, the distributor's coming out from zero zone is performed by small opening of the flow section, disregarding the selected path. Therefore the flow of conveyed fluid will be low causing an extremely slow motion of the hydraulic servomotor. Consequently, if an increased error occurred in a certain direction, due to the rather low correction rate, the control would be effectively lost on the corresponding channel.

For the above reasons it is necessary that the distributor's characteristic to be modified in such a way as its coming out from the insensibility zone to be no longer performed by a slow starting from zero but by means of a jump. Due to the modified static characteristic, the hydraulic servomotor will present a rapid enough reaction caused by the jump opening of the distributor's flow section that allows a fast correction of the error signal till the admissible zone.

III. Experimental Results

The electronic scheme of the sensor is given in Fig.6. The inductances L_1 and L_2 were made from two ferrite cores with a 9 mm-diameter.

For an accurate functioning of the sensor, the two branches, Fig.3, must be identical. Due to this fact, the two circuits were made in such a way that their resonance curves have the same behavior.

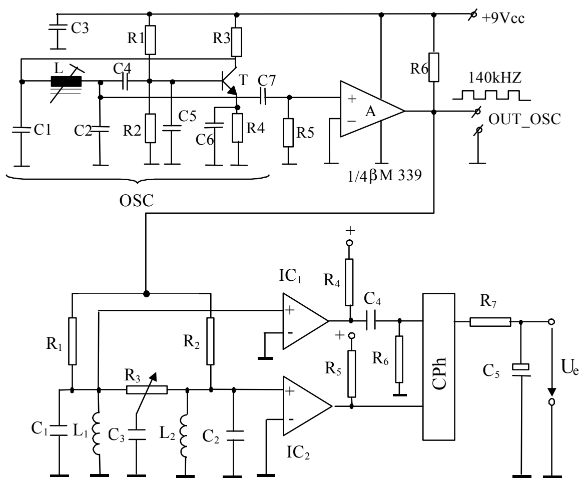

Fig.6. Electronic scheme of the sensor

The group R_3C_3 is meant to compensate the eventual differences that can occur in the functioning of the two circuits owing both to their positioning and to the non uniformities in the metallic lamella, k, in such a way as, for a median position of the lamella, the signals picked up by the two circuits to be in phase.

The two circuits are excited by a sinusoidal oscillator with enhanced thermal stability. The signals picked up by the two circuits are applied to the forming units represented by the circuits IC_1 and IC_2, at the output of which rectangular signals are obtained. The signals supplied by the forming unit IC_1 are derived by the circuit R_6C_4 and applied to the phase comparator, CPh, together with the signals picked at the output of the forming unit IC_2.

At the output of the phase comparator, a series of pulses are obtained with variable factor, depending on the inclination angle of the beam. This series of pulses is integrated by the circuit R_7C_5 in such a way as to obtain, at the sensor's output, a continuous voltage U_e, proportional inclination angle, α, of the finishing beam.

In Fig.7 the phase-frequency characteristic of the LC circuit is illustrated for three distinctive values of the inductance L, determined by the lamella's displacement, *i.e.* by the angle α.

It is noticeable that phase variation, as a function of the inductance L, is linear in the proximity of the resonance frequency.

The dependency of phase variation as a function of inductance variation has been illustrated in Fig.8.

An important variation of the phase difference is noticeable for relatively small inductance variations determined by the change of the inclination angle.

The functional scheme of the system of automatic control of the declivity angle of the beam is given in Fig. 9.

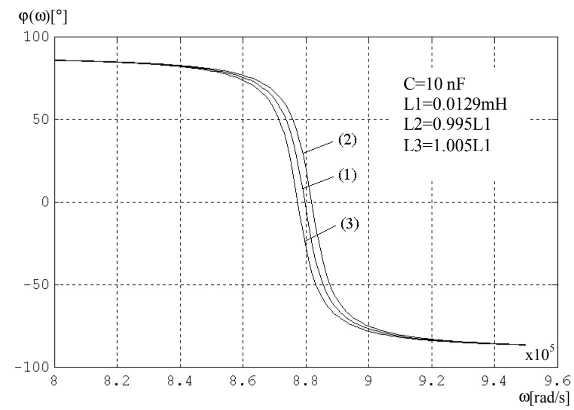

Fig.7. Phase-frequency characteristic of the LC circuit

The measured value of the transversal section slope of the deposited layer is converted into an continuous electric signal, by means of the action of modules (1)-(4). The prescribed value of the slope is provided by the modules (9)-(11). It is necessary that, at the input of the window comparator, module (5), as a function of the required sense of the slope, either the sum or the difference between the transducer and the prescribed signals to be applied.

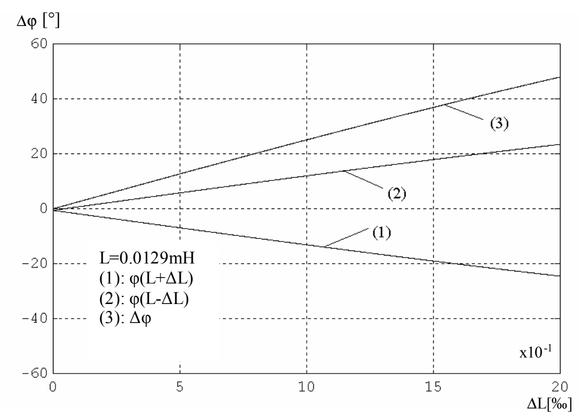

Fig.8. Dependency of the phase difference with the inductance

The change of the static characteristic of the proportional distributor, in such a way that the coming out from the zero zone to be achieved by a jump performed by module (7). The control signal, coming from module (5) is sent to the distributor by means of module (6). The control signal, to the distributor, is signaled by means of module (8). Through the control signals sent to the distributor, the system has to maintain the error signal within the allowed zone of this control channel.

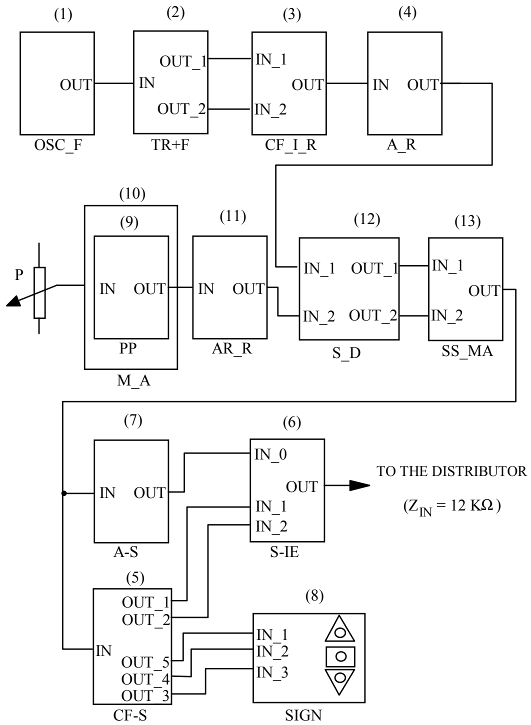

Fig.9. Structure of the cross section's slope control system

IV. CONCLUSIONS

A new automatic control system for the position of finishing beam of a machine for distribution of asphaltic mixtures, concrete and aggregates has been reported.

For the control of inclination angle a new type of sensor has been introduced. Its functioning is based on two differentially coupled LC circuits, functioning in resonance.

The control of the inclination angle is performed by means of the phase difference between the signals picked up on the two LC circuits.

Experimental results have thoroughly confirmed theoretical considerations.

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