THEORETICAL AND PRACTICAL IMPROUVEMENTS CONCERNING THE INDUCTIVE DISPLACEMENT TRANSDUCER WITH MAGNETIC RACK

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În lucrare este prezentat unul dintre cele mai moderne traductoare de deplasare, cel cu cremalieră magnetică, urmărindu-se optimizarea sa constructivă. Abordarea este originală, nefiind axată pe proprietățile de material ci pe alte modalități de creştere a senzitivității.

In this paper, one of the most modern inductive displacement transducers, the one with magnetic rack, is studied, the conclusions following his constructive optimizations. The approach is original, not being focused on magnetic material properties, but finding other ways to increase the transducer sensitivity.

Keywords: inductive magnetic rack transducer, finite element method, mutual inductance.

1. Introduction

An ilustrative exemple of displacement transducers is the magnetic inductive displacement rack transducer [1],[2], studied in this paper. In this category of transducers, relevant is the relative movement of the mobile element over the static magnetic rack, which movement determine the variation of the mutual inductance. It is constituted from a ferromagnetic part, the rack, made from a very high permeability material with a low conductivity (mumetal), and, in a paralel plane of the rack, the stable element, which contains the transmitter and the receiver.

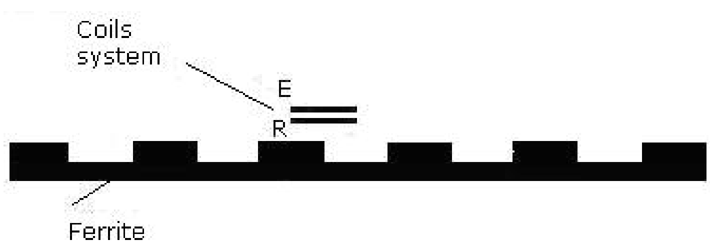

Fig. 1. The draft blueprint of a classical magnetic rack transducer

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The first one, in fact a loop plugged to a high frequency current, have the mission to produce a magnetic field which induce in the receiver (another loop) an alternative voltage, function of the sequence of dents and gaps of the rack.

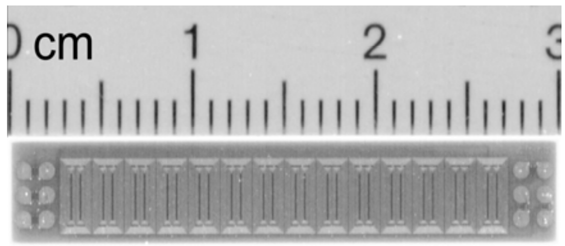

Fig. 2 The real image of a classical magnetic rack transducer

The transducer is made for exactly measuring of averages displacements, of the order of centimeters or even meters, although the displacements directly measured with the inducted voltages don't exceed the value of the rack step, about one millimetre. The displacements bigger than a rack step can be determined with a counter, which keeps a record of all full steps, the real measurement adding the suitable value for the current position.

2. Theoretical innovations

An original contribution is to multiply the sensitivity using systems of coils spatially shifted, on the length of a dental step, a system like a caliper (Fig. 3). This way, if we have *n* coils, we can not to analyze the variation of signal to establish exactly the position of coils over a rack dent, being interested only in a threshold value, which, when is exceeded, the meaning is a new coil pass over a dent. Counting the number of coils which pass over a dent, we can easy obtain an accuracy of *n* times smaller than the dental step, and the sophisticated part of electronic preparation of signal is not necessary. This innovation is extremely useful in the case with the dental dimension very small (tenth or hundredth of millimeters, going to a technological minimum). In this case, the variation of inductivity over a dental step is not significant, choosing on this curve a point which, when is threshold, we can consider the loops has past over the dent. The signal is almost impossible to be processed electronically, and, instead of dividing the signal is preferable to increase the number of sensors with binary response, limiting the errors this way. For the miniaturist constructions, cause the difficulties of realization of those, is very complicated to find the same values over all the rack dents. The solution with the signal analyze is not working yet, the only way is to find a common threshold, witch when is passed, the runner distance must be increased.

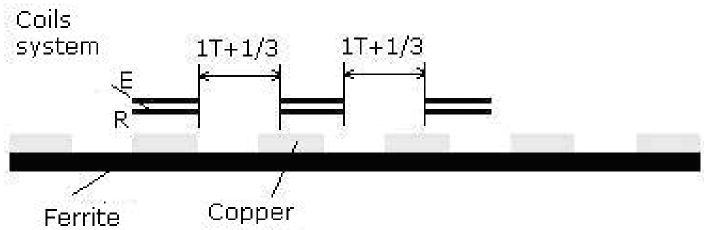

Fig. 3 The theoretical blueprint of a magnetic rack transducer

Another innovation is the replacement of rack dents with copper depositions, this way increasing the differences between the position of coils over a dent or over a gap, with the apparition of eddy currents. We realized a study regarding the influence of mutual inductivity of coils over a ferrite wall, and after over a copper wall (Fig. 4).

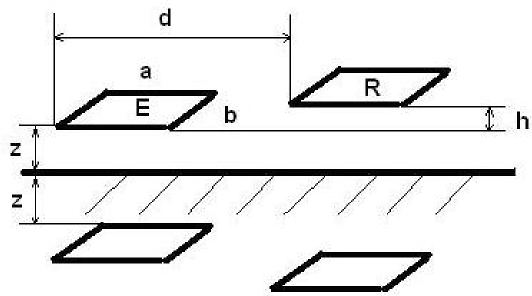

Fig. 4 The study of mutual inductance using the images method

The Neumann mutual inductivity formula for 2 loops is:

$$M = \frac{\mu N_1 N_2}{4\pi} \oint_{\Gamma_1} \oint_{\Gamma_2} \frac{ds_1 ds_2}{R_{12}} \tag{1}$$

For our situations, of coils decomposed in rectangular segments, it became (Fig. 5):

$$M = \frac{\mu}{4\pi} \int_0^l \int_0^l \frac{ds_1 ds_2}{\sqrt{(s_1 - s_2)^2 + d^2}} \tag{2}$$

According [3], we obtain the mutual inductance for two parallel segments:

$$M =\sim \frac{\mu l}{2\pi} (\ln \frac{2l}{d} - 1) \tag{3}$$

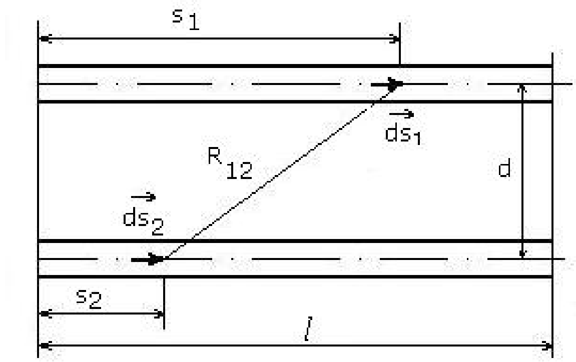

Fig. 5 Diagram for two parallel rectangular coil segments

The mutual inductivity between coils is calculated with the Neumann formula (1), and then, using images method, the coils decomposition in segments being simplified by their rectangular structure. This way, the perpendicular segments don't have a contribution to the total inductivity. The difference between the two situations is the way we consider the loops image, for the ferrite wall we take the images covered by currents with the same direction, and for the copper wall covered by opposite direction currents.

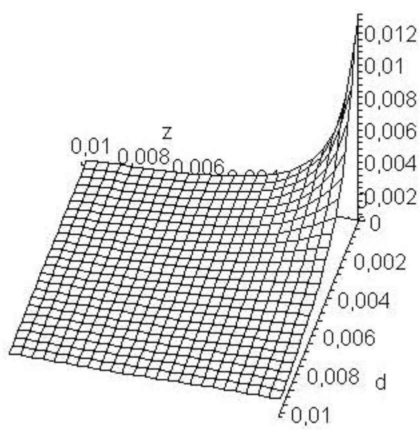

Fig. 6 The variation of *T* term with the distance between coils and their distance to the wall

Having a subtraction, the difference in those two situations will be given by the double of the term which represents the mutual inductivity between the emitting coil and the image of the receiver, which term I noted with *T* (Fig. 6).

3. Constructive optimization

From the previous studies [4],[5],[6], we distinguish that, dimensional, the transducer has to his base an "constructive unit", this meaning that the length of dents, of the gaps and loops must be equal. It remains to study the influence of thickness of the copper. The study is made using the FEMM program, based on finite element discrimination, being researched the differences of magnetic flux between the positions "entirely over the dent" and "entirely over the gap", function of more thicknesses of the copper dents (Fig. 7).

$$\delta = \sqrt{\frac{2\rho}{2\pi f \mu_0 \mu_r}} \, , \qquad (4)$$

For the copper case

$$\delta_{(\mu m)} = \frac{66 * 10^3}{\sqrt{f_{(Hz)}}} \qquad (5)$$

For the frequency of 50kHz, the distance is 0,295 mm.

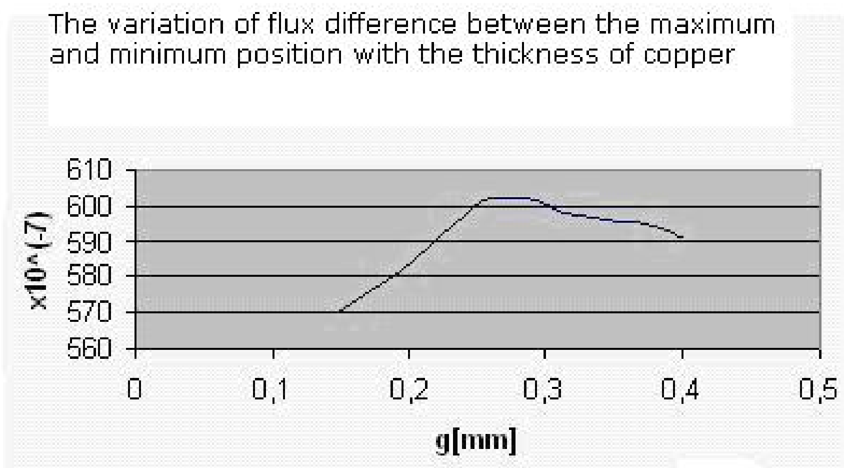

Fig. 7 The emphasis of the optimal thickness

4. The signal acquisition and processing

The acquisition chain is figured below, in Fig. 8:

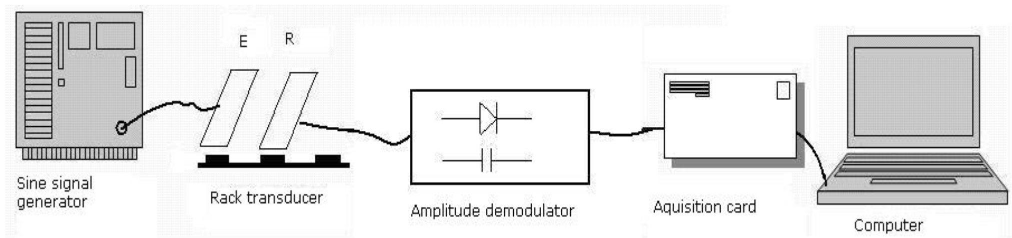

Fig. 8 The acquisition chain for transducer signal

Because the ferrite used for the rack construction endure just a little over 50.000 Hz, the generated signal will have this frequency, and his RMS value will be 3,16 V – the biggest value the generator can develop. The signal is a sine, feeding the 3 emitting coils of the transducer. The inducted voltage have the values from the Table 1, the dimensions of coils being 3 x 5 cm and 70 loops from copper wire of 0,1 mm^2 .

Table 1

Values of inducted voltage

Frequency [kHz]	10	50
max. voltage (over ferrite gap) [V]	0, 086	0, 62
min. voltage (over copper) [V]	0,041	0, 38

The induced voltages are amplitude demodulated by the next devices (Fig. 9), designed for a carrier frequency between 0,5 and 2 Hz, and a RMS value between 30mV and 2V. The modulation degree was considered about 54%.

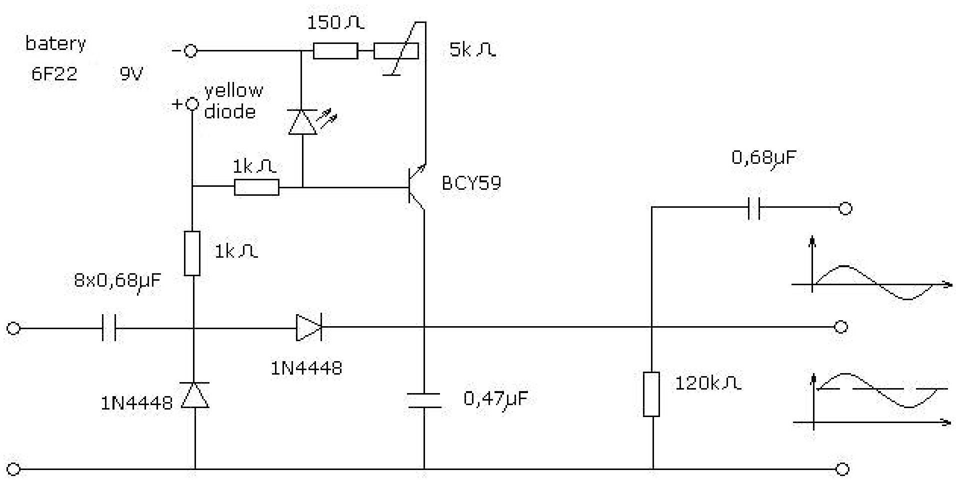

Fig. 9. The amplitude demodulation blueprints

The signal waveforms are presented in Fig. 10.

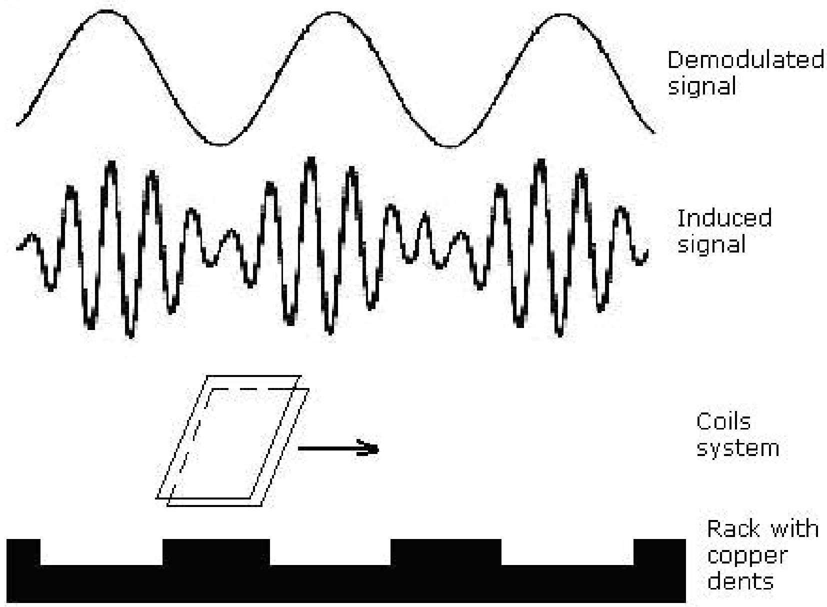

Fig. 10 Signal waveforms

5. The software

A dedicated software for aquaring signals is LabView, developed by National Instruments. The main advantage is the easy conversion between a value aquired by the card and a programing variable, witch can be used in a familiar programing media (like C++ or Matlab).

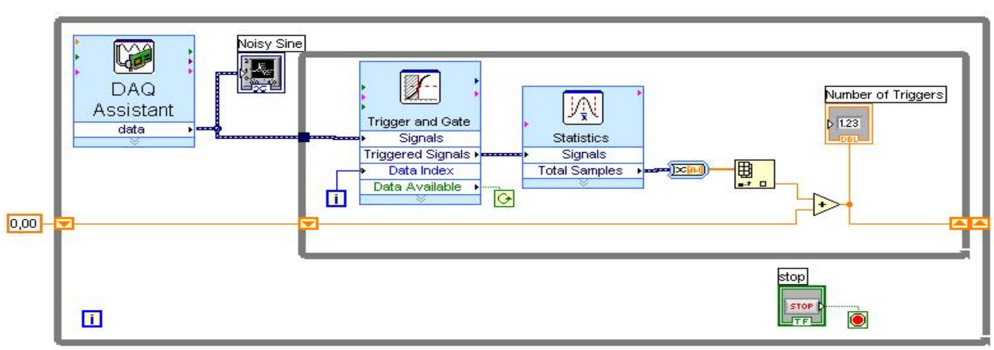

Fig 11. The LabView diagram for trigger counter

The structure of a programe is repetitive, based on a DO WHILE cycle, te allow a fast rescaning of entry ports.Here I present an example of diagram for trigger counter (fig 11). The main problem in this case is noise elimination, to prevent fake trigger. This can be easy done with a LabView implemented function, the rest of diagram being focused on the counting of peeks witch exceed a treshold value. For the case with 3 coils, the sens of movement must be determined. This can be done with an aditional C program, implemented in LabView structure, witch program must find the succesion of peeks given by different coils. Very important in this analyze is the trigger block, where is made the comparation with the treshold and the noise is eliminated.

6. Conclusions

The original idea of this study is to use copper dents instead of ferrite, to increase the flux difference between the maximum and minimum positions, and to multiply the coils, shifting them, a system inspired from a caliper. This way, we have just to find when the signal exceed a threshold value, using a basic electronic part, not being necessary to analyze the signal to find where the coils are situated over a dent. The main application is about the possibility to miniature the transducer, the trend in modern industry. Also, is important the physical realization of the device, and the use a computer card to analyze the signal.

R E F E R E N C E S

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