ESTIMATION OF DIMMENSIONS OF MAGNETIC INDUCTIVE DISPLACEMENT RACK TRANSDUCER

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This paper presents a study of a new generation magnetic inductive displacement rack transducer, modeled in F.E.M.M. (a program using finite element method), study which recommends optimal dimmensions for the transducers components, and demonstrates that usually dimensions for the rack are oversized, and propose a new approach of its projection.

1. INTRODUCTION

An ilustrative exemple of displacement transducers is the magnetic inductive displacement rack transducer, 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's 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. 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.

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 millimetter. The bigger displacements than the rack step can be determined with a counter, whitch keeps a record of all full steps, the real measurement adding the suitable value for the current position. This way, we can obtain an accuracy of the microns order.

This paper is concentrated over the modification of mutual inductance between the two loops. In figure 1 is presented a photography of the magnetic rack and of the transmitter-receiver system, the photo beeing made on a real transducer. The main difference between real case and the studied example is that our example has the transmitter and the receiver formed just from a loop each, the real one having instead a system of coils, and those beeing placed concentrically, in our case being planary located, parallel with the rack.

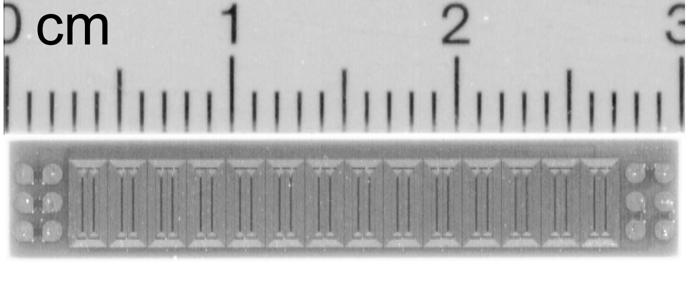

Fig. 1 – A photography of a real transducer

2 THEORETICAL ISSUES

We consider that the transmitter loop is connected on a current source of 100A, the frequency is 10kHz, the dimmension of dents is of microns order. The predefined material in F.E.M.M. as mumetal has a permeability of 25.000 and a null conductivity, in this way avoiding the problem of eddy currents. After describing the geometrical stucture in program – illustrated in fig. 2, on anallize the results. Significants are the values of magnetic potential on the extremities of receiver loop, which determine the modifications of mutual inductance, the most important parameter of transducer. This way, the difference of magnetic potential multiplied with the depht of loop determine the magnetic flux through the receiver:

$$A_2 - A_1 = \Delta A = \varphi / z \ , \qquad (1)$$

where φ is magnetic flux through the receiver and z – the axial coordinate.

$$\varphi = L_{ER} i_E \ , \qquad (2)$$

where L_{ER} is the mutual inductance between transmitter and receiver and i_E transmitter current. Neglecting self inductance of transmitter, we obtain that the calculated flux is the product between transmitter current and mutual inductance between loops.

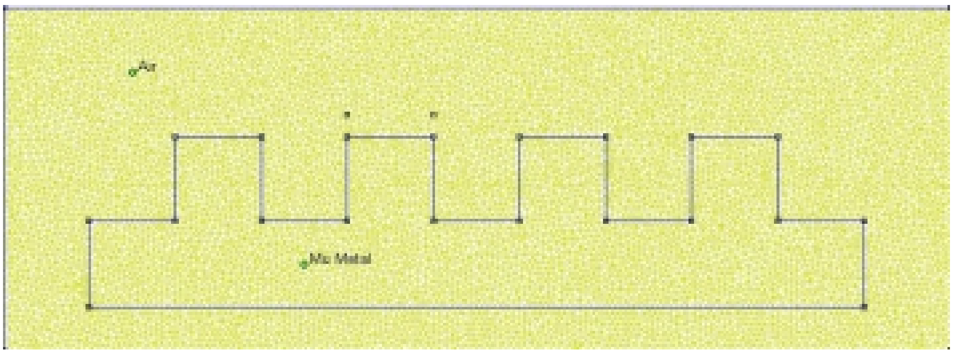

Fig. 2 – F.E.M.M. representation

3. CONSTRUCTIVE CONSIDERATIONS

We start to variate successive main parameters of the rack, meaning the lenght and height of dents, loops dimmensions and their positions. For beginning, we present field lines in transducer – with continous red line is figurated the section of receiver loop – figure 3.

In figure 4 is designed the variation of magnetic potential with distance, assumed from the beginning of transmitter to receiver, represented for o dental step and a half one. We see the decrease at the edge of the first dent, and after that the raise for the interval of the gap and second dent. In consequence, we represent the variation of mutual inductance – figure 5.

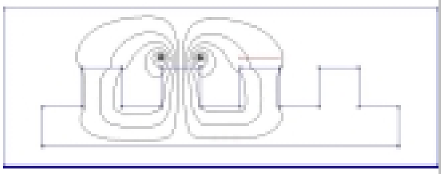

Fig. 3 – Field lines in transducer

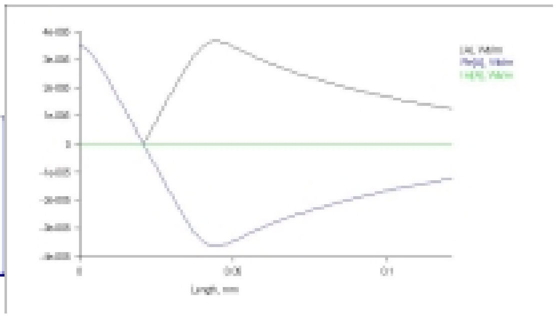

Fig. 4 – Variation of magnetic potential with distance

We can easily see in figure 5 that optimal distance between loops is obtained when are superposed, then follow a low value section, where the mutual inductance became zero, then a module grow when the distance between loops is for a rack dent. This situation, with a one dental step distance, is ilustrated in figure 3.

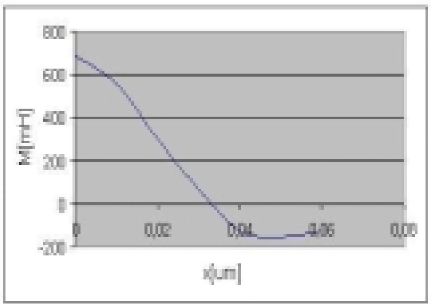

Fig. 5 – Variation of mutual inductance

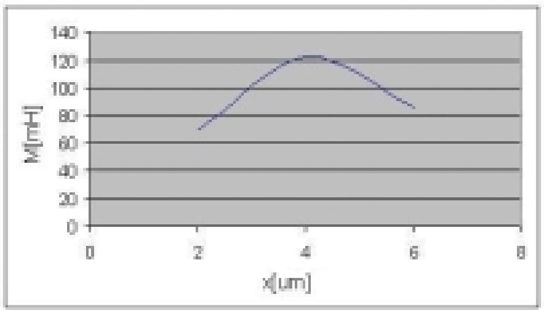

Fig. 6 – Variation of inductance with loops dimmensions

In figure 6 is shown the variation of mutual inductance with the lenght of loops, the optimal appering for the lenght equal with the rack dent.

In figure 7, one of the most important constructive aspect of the rack, the dimmensioning of dents. Usually, in practice, the dents are square shaped about one millimeter, but necessary for obtaining the highest value of mutual inductance is just a 3-4 micrometers dimmension. It's though preferable a bigger value to avoid constructive problems and to lower production costs. In figure 7 is ilustrated this fact, after 3,5 µm the value of mutual inductance remains constant.

In final, in figure 8 is presented the case when the rack is to the edge, the transmitter is over the last dent. There are studied the errors, which, surprisingly, appers just for the last dent, when the transmitter loop is over the last but one dent the mutual inductance have the usually value.

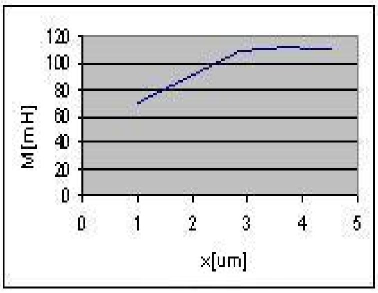

Fig. 7 – Variation of mutual inductance with the dimmensions of rack dents

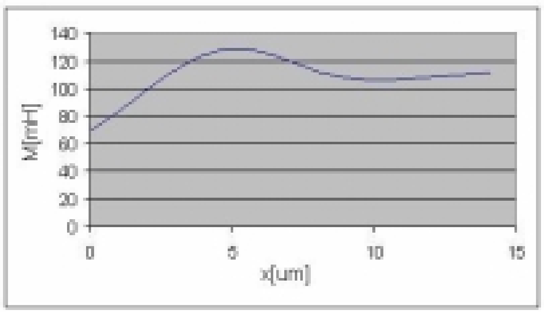

Fig. 8 – Variation of mutual inductance to the edge of the rack

4. CONCLUSIONS

In this paper we etablish and optimise the main parameters of the magnetic inductive displacement rack transducer. Resuming the results, the most important conclusion is that concerning dents dimmensions, which results from this study to be much lower then in practice. Dimmensioning of loops to the lenght of the dent is also important. And the study of “edge effect” is usefull, finding that the approch of the loops to the edge of the rack is not generating induction modifications as expected.

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