Permanent magnets using for reed switches control

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Abstract **– At first, the main properties of reed switches and permanent magnets are discussed. Then, there are compared the results of magnetic flux density measurement and calculations in the axis of free permanent magnet via approximate formula and per FEM - without presence of reed switch. In the end of paper there are shown results of magnetic flux density FEM computations with presence of a reed switch.**

1. INTRODUCTION

In some cases, we need to control, movement of band delivering some materials, soil etc. If it is difficult to get it with an optical sensor (in a very dusty area) we need to use a contactless transducer based on magnetic principle. In this case, we can use the Hall effect and the acquired signal electronically evaluate. The signal is generated from the magnetic field next to the circuit with the Hall probe supplemented by other circuits.

A more simple solution (listed here), is a usage of a reed switch and an optional permanent magnet [1], [2]. The reed switch will clamp together at a defined value and unclamp again, when magnetic flux density goes down and reaches certain level (lower than starting value). Bracing and contact-breaking of the reed switch connected to circuit create electric impulse, which is possible to evaluate.

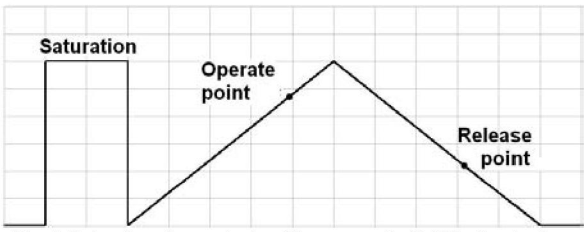

Fig. 1 Saturation the contacts with a magnetic field before testing for Pull-in and Drop-out

Reed switch can be used, for example, for opening or closing of a door controller. In this case, PM usually gets vertically closer to the switching points. This configuration is very sensitive for base position and contacts, especially when we need a longer distance of switch and PM. This paper deals with an example, when supply line of reed switch is parallel with the PM axis. Considering this example, the position of reed switch along axis is not important and we do not need to adjust it. In this case, it does not matter, when an unwanted change of position happens. This model example deals with the case, when the reed position and permanent magnet end distance must be from 2 cm to 4 cm (due to operating matters). If we want reliable switching, the 4 cm distance is obviously critical.

2. USED COMPONENTS

a) reed switch

The simplest reed switch consists of two springy metal reeds (strips) sealed in a glass tube. This glass tube is filled with an inert gas which prevents corrosion, see Fig. 2. The switch is activated by an external magnetic field.

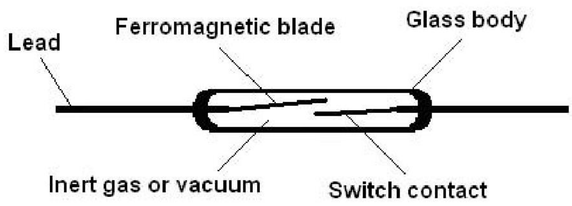

Fig. 2 The basic hermetically sealed form reed switch (normally open) and its components

This magnetic field can be provided by approach a permanent magnet close to the switch, or by passing current through a coil which is wrapped around the switch. In this case it can also be used as a high speed relay.

b) Usable permanent magnets and short remark to temperature influence on permanent magnets working point

There are four families of permanent magnets. They are Alnico, ferrite, SmCo and NdFeB, see tab. 1. Permanent magnets $Nd_2Fe_{17}B$ and SmCo ($SmCo_5$ and Sm_2Co_{17}) are characterized by high coercivity, remanence and energy product $(BH)_{max}$, but they are more expensive, especially SmCo. Cheaper are ferrite and Alnico magnets. Resistivity to self - demagnetising field is very small by Alnico magnets.

For this purpose, the most suitable are permanent magnets made of high coercivity materials to be able to resist to demagnetising fields. The optimal materials are NdFeB alloys. They are relatively cheap and have excellent magnetic properties, see e.g. [3]. While using NdFeB permanent magnets, it must be ensured that working temperature does not

	Ferrite	Alnico	SmCo		NdFeB	
Property	Ceramic 8	Alnico 5	1-5	2-17	Bonded	Sintered
B_r (T)	0,4	1,25	0,9	1,04	0,69	1,34
α (%/°C)	-0,18	-0,02	-0,045	-0,035	-0,105	-0,12
$(BH)_{max}$(kJ/m^3)	30,5	44	160	208	80	254
H_{ci} (kA/m)	264	52	2400	2000	720	1200
β (%/°C)	+0,4	-0,015	-0,3	-0,3	-0,4	-0,6
H_s (kA/m)	800	240	1600	2400	2800	2800
T_c (°C)	460	890	727	825	360	310

Tab.1.The Four Families of Permanent Magnets

Notes:

The quantity α is the reversible temperature coefficient of B_r (20°C to 100°C minimum)

The quantity β is the reversible temperature coefficient of H_{ci} (20°C to 100°C minimum)

The field required to saturate the magnet is H_s

T_c is Curie temperature

exceed 150°C because Curie temperature is only 310°C.

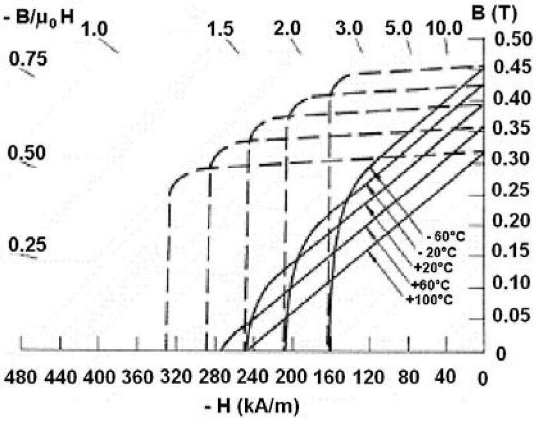

Fig. 3 The dependence of demagnetization curves on temperature for ferrite magnets (typically)

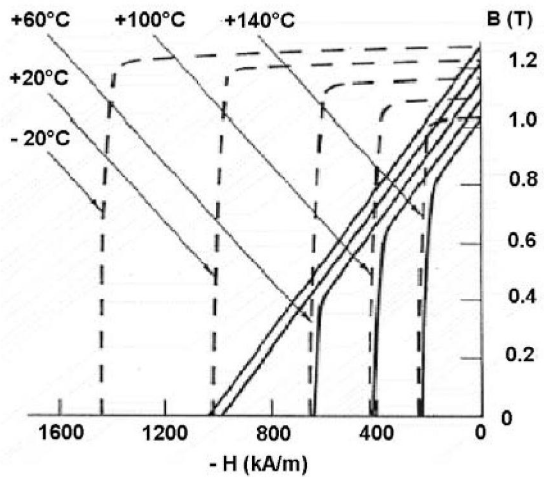

Fig. 4 The dependence of demagnetization curves on temperature for NdFeB magnets (typically)

At the design of PM working point, we must be very careful to possibility of the irreversible losses origin. We must not get to demagnetising curve knee area at the temperature change. To the demonstration, there are ferrite and NdFeB demagnetisation curves given in Fig. 3 and Fig. 4 for several temperatures [3].

3. THE SETTING OF SUITABLE PM DIMENSIONS FOR WORKING POINT

If we wish to obtain a working point of PM, the simplest way is to use graphs in Fig. 4 for Alnico (upper) and lower for other types of PM. Then we obtain working point as an intersection of demagnetisation curve and load line which position is given by ratio B/μ_0H [5]. Some more detail information about self demagnetisation problem can be found in [6], e.g.

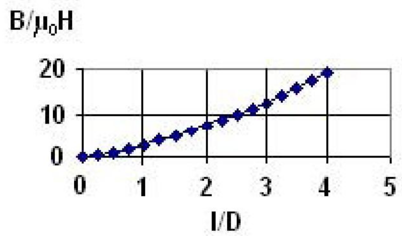

Fig.5 The relation between B/μ_0H and l/D for Alnico magnets

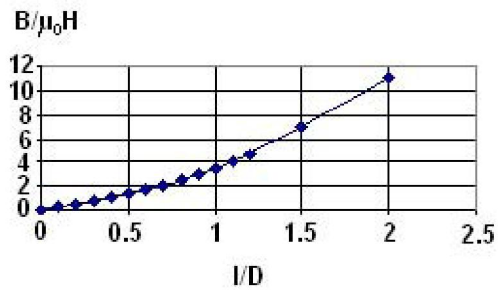

Fig.6 The relation between B/μ_0H and l/D for ferrites , ReCo and NdFeB magnets

In Figs. 5 and 6, there is l the length of permanent magnet and D is the diameter.

4. CALCULATIONS OF MAGNETIC FLUX DENSITY IN THE PM AXIS

a) via approximate formula [4]

$$B_x(x) = \frac{B_r}{2}\left[\frac{l+x}{\sqrt{r^2+(l+x)^2}} - \frac{x}{\sqrt{r^2+x^2}}\right] \qquad (1)$$

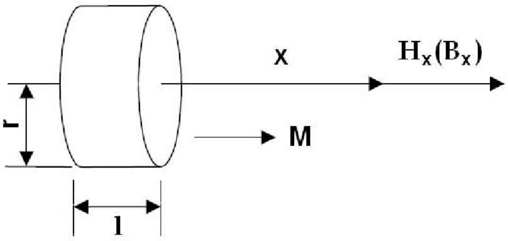

Fig.6 The explanation for equation (1)

b) via Finite Element Method [8]

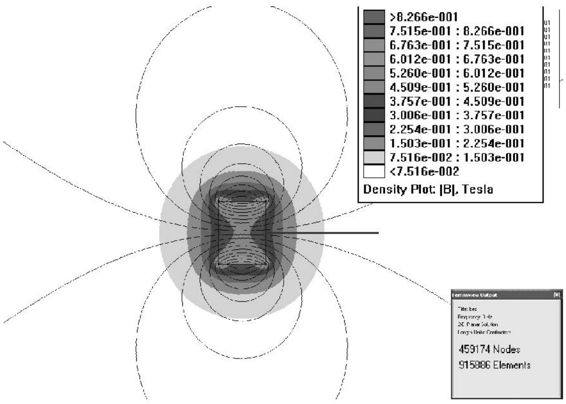

Fig. 7 Magnetic flux density map in the PM surroundings with the abscissa

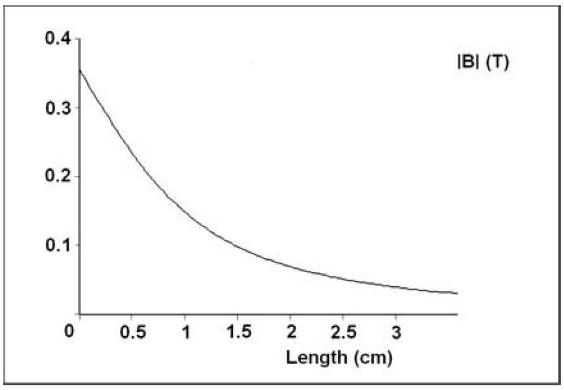

Fig. 8 Magnetic flux density absolute value dependence along the abscissa in Fig.7

c) The confrontation of results

The confrontation of results is realised for cylindrical NdFeB PM of diameter 20 mm and length 15 mm. The curve above (No. 1) is the result of measurements, the thereunder (No. 2) curve is result of calculations per (1) and the curve No. 3 is the result of computation by FEM, see Fig. 8. Used PM has $(BH)_{max}$ = 256 kJ/m^3.

It is visible on the graph in Fig. 9, that relatively good correspondence between measured and by two methods calculated results is in the distance 15 mm (and more) from PM end. But it is the area at which we are interested in this case.

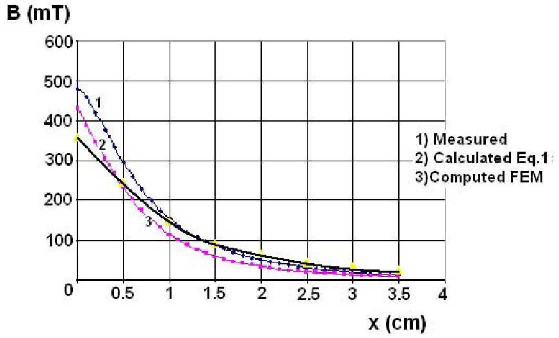

Fig. 9 Magnetic flux density (mT) as a function of distance from PM end (cm). The comparison of obtained results

5. A REED SWITCH IN THE PROXIMITY OF PM COMPUTED BY FEM

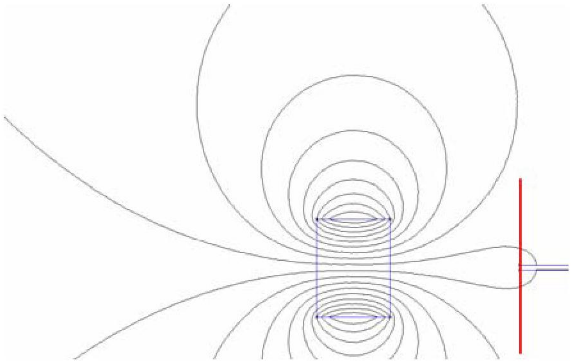

Fig. 10 Configuration PM – reed switch with magnetic flux density lines

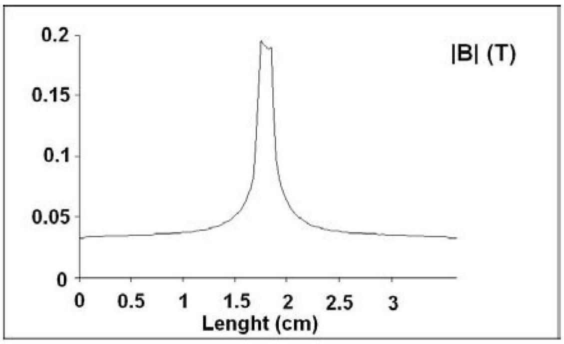

Fig. 11 Magnetic flux density distribution (absolute value) along thick line in Fig.10

The distance between the PM end and the end of reed switch lead is 26,5mm. The other cases can be discussed during the conference. As one of the problems, the case of iron plate under permanent magnet can be discussed, e.g., see Fig. 12 to Fig.15.

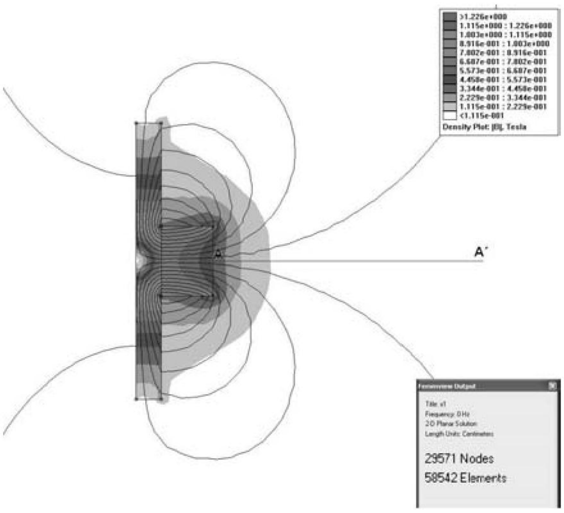

Fig. 12 Magnetic flux density absolute value map in the PM surroundings with the abscissa A A´ in the axis

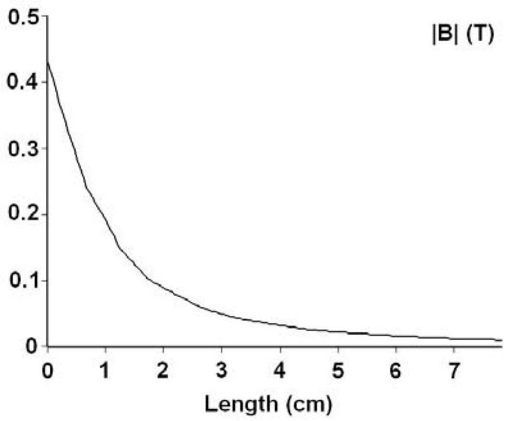

Fig. 13 Magnetic flux density absolute value dependence along the abscissa in Fig.12

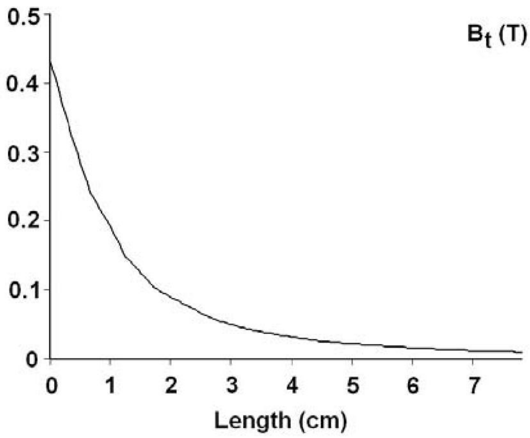

Fig. 14 Magnetic flux density dominant (tangential) part dependence along the abscissa in Fig.12

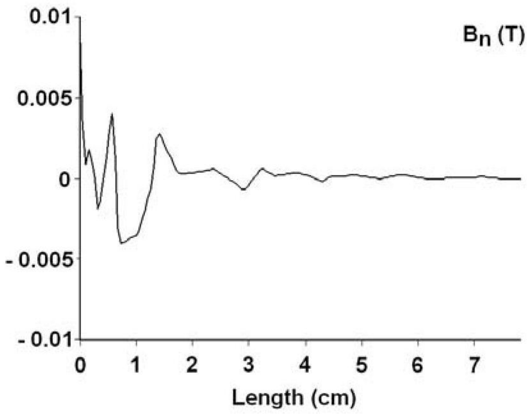

Fig. 15 Magnetic flux density normal part dependence along the abscissa in Fig.12

6. CONCLUSIONS

The main purpose of this paper was to outline a good design method of suitable PM for reliable reed switching. It was experimentally found that the used reed switch is very reliable in 50 mT flux density in front line point. The designed approach allows you to outline a possibility of using the right PM.

This paper was very shortly engaged in the problem of temperature influence on working PM point, but it was not focused on possible reed switch bias. This outlined approach can be also used for the Hall probes or switches with the Hall probe base.

References

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