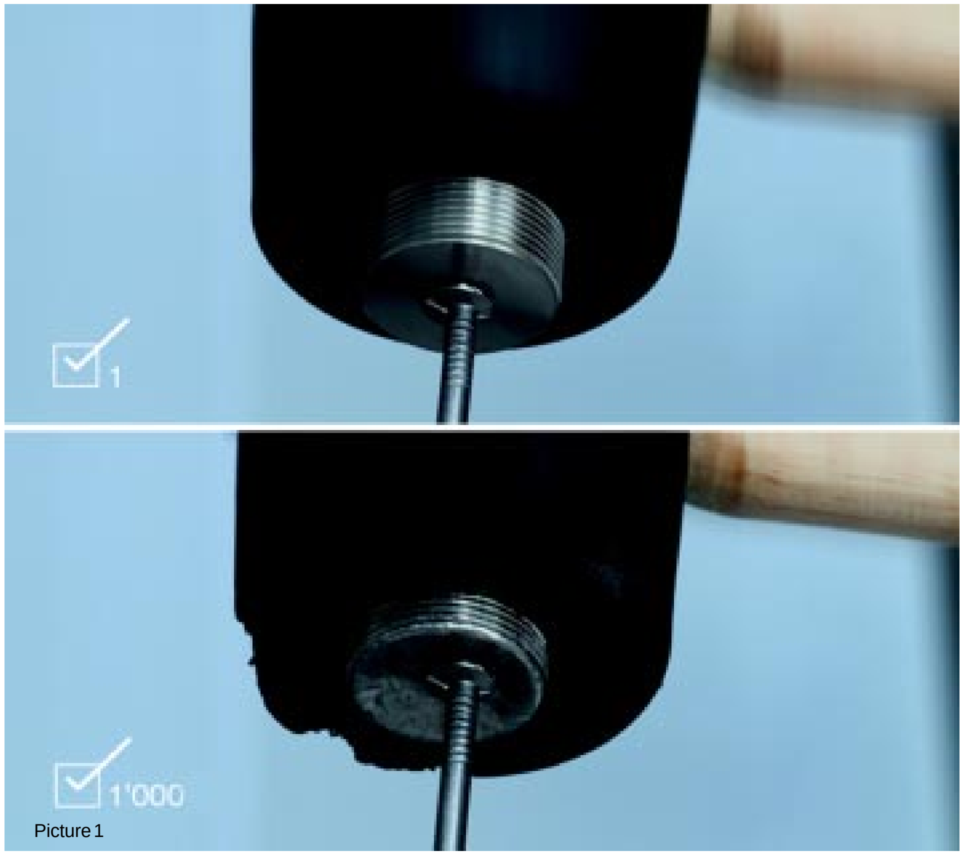
Mechanical damage to inductive proximity switches: the hammer demonstration

Sensor systems used in production units are, by their very nature, exposed to all kinds of situations where they can easily be damaged. This can result in sensor failures, which in turn lead to machine downtimes and maintenance overheads, the costs of which are continually escalating, due to the increasing complexity of installations and the consequent rise in the number of sensors used. For this reason, increasing sensor operating reliability is a matter of high priority. The reliability of the devices themselves has, in fact, reached a level today that leaves little to be desired – provided that their specification limits are not exceeded. In practice however, even when taking the utmost care, this cannot always be permanently guaranteed. For this reason, there is a growing interest for sensors having as wide a "misuse tolerance" as possible. This is particularly valid for inductive devices, which from the quantity point of view, generally dominate the European and USA markets.



Picture 1

The problem

As a general rule, 80% of inductive proximity switch failures are caused by mechanical damage. This damage occurs almost exclusively at the inherent weak point of the devices, namely at the sensing face. In cylindrical metal executions - the most widely used sensor type - the face is protected by a thin-walled plastic cap. Thicker walls would lead to shorter usable operating distances. Clearly, this plastic cap is not very robust, and, moreover, in service is located at probably the most exposed position, i.e. close to moving parts. To further aggravate the situation, the field-generating element, the ferrite core and coil, is located directly behind this plastic cap. Mechanically, this ferrite core behaves similarly to a relatively delicate, easily breakable ceramic. And, on top of all this, breakage of the core results in either total failure, or at least a drastic reduction of the device's performance. For this reason, realization of an improvement in "misuse tolerance" has to start here.

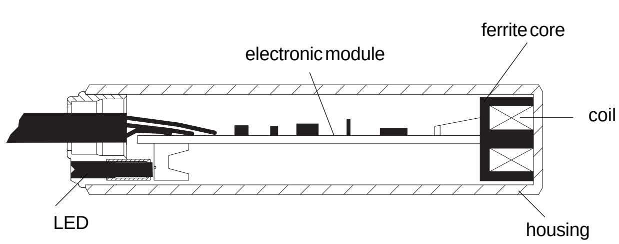


Fig. 1

Possibilities for improvement

The situation described above can basically be improved in several ways:

1. Improved mechanical protection of the sensing face.
2. Less break-sensitive core material.
3. Lower sensitivity of the device to core breakage.
4. The use of coreless coils.

The possibilities and limits for improvement are analyzed below.

1. Improved mechanical protection of the sensing face

One idea is to replace the plastic cap by a high-quality metal cap with as thick a wall as possible. Ideally, the whole housing should even be in one piece – preferably of stainless steel. Unfortunately, this would be in direct conflict with the laws of physics as applicable to proximity switches, as the sensing face must be permeable to the alternating magnetic field generated in the sensor head. For this permeability, the well-known formula for the penetration depth of an alternating magnetic field into an electrically conducting body applies:

$$\alpha = 0{,}503 * \sqrt{\frac{\rho}{\mu_r * f}} \qquad \left[\mathrm{mm} \,/\, \frac{\Omega \mathrm{mm}^2}{\mathrm{m}} \,/\, \mathrm{Mhz}\right]$$

α penetration depth to 1/e

ρ specific electrical resistance

μ rel. magnetic permeability

f frequency

From this formula, it is evident which metal properties are advantageous: low magnetic permeability coupled with a high specific electrical resistance. In this respect, stainless steel is very suitable. Additionally, for high penetration, the magnetic field frequency needs to be as low as possible. The usual operating frequencies of inductive devices (a few hundred kHz) are however much too high, and would only permit totally inadequate wall thicknesses (i.e. at 500 kHz and with stainless steel: 0.02 mm for 10% pre-damping).

2. Less break-sensitive core material

No efforts have been spared in trying to substitute the ceramic bonding agents used for the ferrite. The focus has been on plastics, which have, in principle, proven to be a possibility. However, the magnetic properties of such materials are so poor that they are unusable for proximity switches, in particular those with increased operating distances.

3. Lower sensitivity of the device to core breakage

Core breakage reduces inductivity and increases losses in the coil generating the alternating magnetic field. Since traditional inductive proximity switches exploit losses in the oscillator resonant circuit, of which the field-generating coil is a part, they are extremely sensitive to core breakages. In particular, devices with increased operating distances are susceptible to irreversible functional breakdowns already as a result of single core breakage.

In the case of executions working on the transformer principle, the situation is considerably more favorable. Here, the important factor is coupling, which is less influenced by core breakage. The technology normally used, which corresponds to a kind of differential transformer, gives acceptable operating distances, albeit only with fairly high operating frequencies. This, however, conflicts with the requirement of high field-penetration depth. For this reason, a metallic cover over the sensing face cannot be considered.

4. The use of coreless coils

With respect to core breakage, this variant is clearly the most radical. However, in this case, other problems emerge. In effect, coreless coils basically also require relatively high operating frequencies, so that a metal cover at the sensing face cannot be considered either. However, here too, this is a serious disadvantage, since coreless coils are also rather sensitive from the mechanical point of view.

The solution

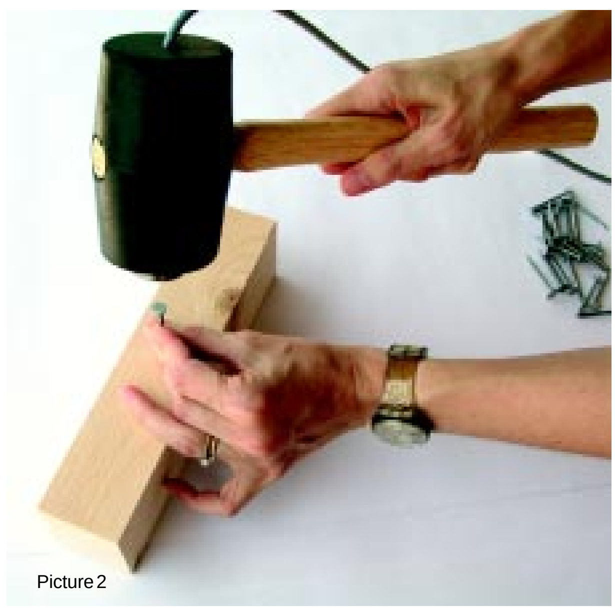
At the present time, only one technology fulfils all the requirements mentioned as well as avoiding the disadvantages: the Condet® technology used by Contrinex. This technology is based on the principle of direct transformer coupling, does not require high operating frequencies (approx. 10 kHz) and, as a result, permits a substantial metal wall thickness at the sensing face. The Contrinex series 700 devices, which all function using Condet® technology, are built into one-piece, thick-walled stainless steel housings. The wall thickness at the sensing face is for instance 0.4 mm for size M12, and as much as 1.0 mm for size M30. As a result of the transformer principle, core breakages, which even here, despite the outstanding mechanical protection, can never be completely excluded, do not appreciably influence the device's properties. Important here are the ratio of the number of turns and the coupling factor, both of which are not at all, or at least only minimally, changed as a result of core breakage. This also applies to repeated and multiple core breakages. These advantages of Condet® technology in no way detract from the other properties, in fact, quite the opposite. The achievable operating distances remain largely unmatched by competitors' devices. On non-ferrous metals especially, they are even several times greater than those of the best devices otherwise available. With such long operating distances, devices can be mounted further away from moving parts, which already leads to considerably increased operating reliability. In addition, there are no reductions with respect to switching frequency, temperature range, EMC etc.

Proof: the hammer demonstration

As a dramatic illustration of the above-mentioned advantages, one of Contrinex's clever sales engineers thought up a striking, in more than one sense of the word, way of providing proof: the hammer demonstration.

For this, a series 700 proximity switch (standard production sample) is built into the head of a conventional rubber hammer. For practical reasons, a size M30 device, connected to a likewise standard proximity switch test box, is used. With this so-modified hammer, nails (not too small) are now hammered with force into a piece of wood, using the device's sensing face as the striking surface. The buzzer of the proximity switch test box confirms trouble-free functioning of the proximity switch before, during and after hammering.

The use of this hammer demonstration at exhibitions did



Picture 2

Picture 3

not merely attract a lot of attention. It also demonstrated that such a hammer survives knocking in several thousand nails, even when they are sometimes hammered in crookedly by some less-than-skilful visitors. Then, it is often not even the sensor that has to be changed! Surprisingly, it even outlasts the rubber hammer without problem, as the latter eventually disintegrates after being so badly maltreated by some not particularly accurate visitors.

Neither does the proximity switch escape without traces of damage after such use. First of all, the sensing face becomes notched, then more and more dented (1 … 2 mm deep!). As the devices so mistreated show after subsequent dismantling, the ferrite cores are broken in many places, and in some cases, only a granular structure remains, held together to some extent exclusively by the device's potting compound. It is little short of a miracle that not only have the proximity switches survived, but also that their properties are scarcely altered.

Picture 4

Conclusions

With the series 700 devices, Contrinex has succeeded in making a quantum jump with respect to misuse tolerance. Of course, even these devices are not completely indestructible. According to available, extensive application experience however, a drastic reduction in the number of replacements in all known difficult cases with high failure rates can be expected. This is achieved by:

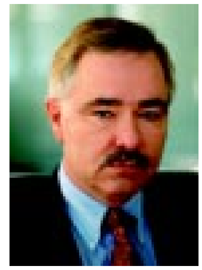
– Sensing faces of thick-walled stainless steel.

– One-piece housings.

– Insensitivity to core breakages.

– Long operating distances, even on non-ferrous metals.

Of course, everything has its price, and the series 700 devices are no exception. They are more expensive than standard devices, but their prices remain within very reasonable limits. If the overall cost situation instead of the individual device price is taken into account, the economy in many cases is significant and any thoughts concerning the additional price for the devices are quickly forgotten.



Dipl.-Ing. Peter Heimlicher studied electronics at the ETH in Zurich. In 1972, immediately after his studies, he founded CONTRINEX AG, of which he has been Managing Director ever since. His company is specialized in the manufacture of high-performance inductive and photoelectric proximity switches.

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