

DETECTION OF RUPTURES ON PRESTRESSING WIRES BEHIND MAGNETIC SHIELDS USING LEAKAGE FLUX MEASUREMENT

DETEKTION VON BRUCHSTELLEN MAGNETISCH ABGESCHIRMTER SPANNSTÄHLE MITTELS STREUFLUSSMESSUNG

DETECTION DE RUPTURES DE FERS DE PRECONTRAINTE SOUS ECRAN MAGNETIQUE PAR LA MESURE DE FLUX MAGNETIQUE

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Summary

It is very difficult to detect by magnetic measure of the leakage field ruptures on single prestressing wires within prestressing tendons as the intact surrounding prestressing wires act as a magnetic shield. By applying a homogenous magnetic field along the prestressing wire, the detection of ruptures under a magnetic screen may be essentially improved in comparison to usual magnetizing by yoke magnets.

Zusammenfassung

Brüche einzelner Spannstähle in Spannbündeln sind mit der magnetischen Streufeldmessung nur schwer nachweisbar, da die umgebenden intakten Spannstähle magnetisch abschirmend wirken. Durch Anwendung eines homogenen, längs zum Spannstahl orientierten Magnetfeldes kann die Nachweismöglichkeit magnetisch abgeschirmter Bruchstellen im Vergleich zur üblichen Magnetisierung mittels beweglicher Jochmagnete erheblich verbessert werden.

Résumé

Il est difficile de détecter par la mesure magnétique du champ de dispersion les ruptures de fers de précontrainte isolés dans les armatures de précontrainte étant donné que les fers intacts entourants agissent comme écran magnétique. Par application d'un champ magnétique orienté le long des fers de précontraintes il est possible d'améliorer considérablement la détection de ruptures sous écran magnétique par rapport à l'aimantation habituelle à l'aide d'aimants culasse.

Keywords: Nondestructive testing, prestressing wires and tendons, magnetic flux leakage measurement

1. INTRODUCTION

For the detection of ruptures of prestressed steels in practice the necessary magnetization is obtained by means of a movable magnetization device, which often contains also the magnetic field measurement sensors. Ruptures of the prestressed steels will be detected by a typical pattern of the magnetic leakage field. This method works very successful for the evaluation of pretensioned bars, embedded immediately in concrete [1,2]. However in case of bundles of prestressed bars in a covering tube difficulties occur due to the magnetic shielding effect of the intact bar, surrounding a broken wire. To overcome this problem the resolution of the magnetic field sensors and also the procedure of the magnetization have to be improved. This paper represents the results of investigations on a simple model (dummy) in order to show the influence of an improved magnetization.

2. THEORETICAL CONSIDERATIONS

Assuming a real magnetic behaviour the leakage field \underline{H}_L results with consideration of the excitatory field \underline{H}_0 from the following equations [2]:

$$\mu = \mu(\underline{H}, \underline{H}') \quad (1)$$

$$\underline{H} = \underline{H}_s + \underline{H}_0 \quad (2)$$

$$\underline{H}_s = -\text{grad } \Phi \quad (3)$$

$$\text{div}(\mu \text{ grad } \Phi) = \mu \text{ div } \underline{H}_0 + (\text{grad } \mu)^T \cdot \underline{H}_0 \quad (4)$$

μ is the magnetic permeability. Equat. (1) describes the ferromagnetical behaviour of the steel. Φ is the magnetic potential.

By application of a homogenous field the pattern of the leakage field is controlled only by the distribution of the permeability. In this case an optimal monitoring of ruptures can be expected. In case of a rupture surface which is perpendicular to the axes of steel the term $\text{grad} \mu \cdot \underline{H}_0$ becomes a maximum. Therefore it is

obvious to choose the direction of the excitatory field in direction of the prestressing bars.

3. EXPERIMENTAL INVESTIGATIONS

3.3. Experimental set up

In order to simplify the problem a dummy which is shown in fig. 1 was considered.

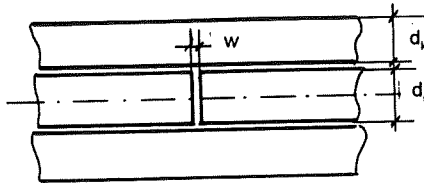


Fig. 1 Schematic representation of a magnetic shielding

Corresponding to fig.1, the dummy had the following dimensions:

total diameter	$d_g = 30$ mm
thickness of shielding	$d_k = 5$ mm
diameter of steel	$d_s = 10$ mm
crack with	$w = 1$ mm

The excitatory field was generated in the inner area of a large coil with the following dimension (s.fig. 2)

diameter of the coil	$D = 300$ mm
length of the coil	$l = 600$ mm
number of turns	$N = 600$
diameter of wire	$d = 2$ mm

The current was chosen about 2 A.

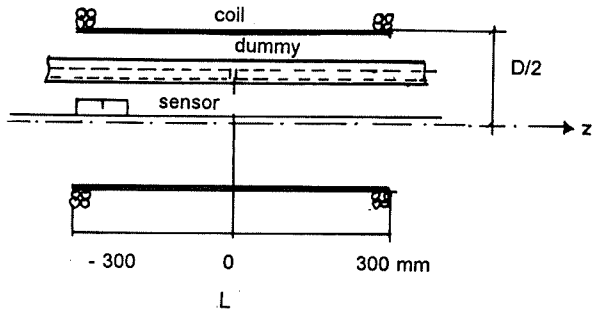


Fig. 2 Experimental setup

The measurement was performed by means of the magnetic flux measurement device which is available in the FMPA. In fig. 3 the pattern of the excitatory field H_z (axial component) in the inner area of the coil is shown.

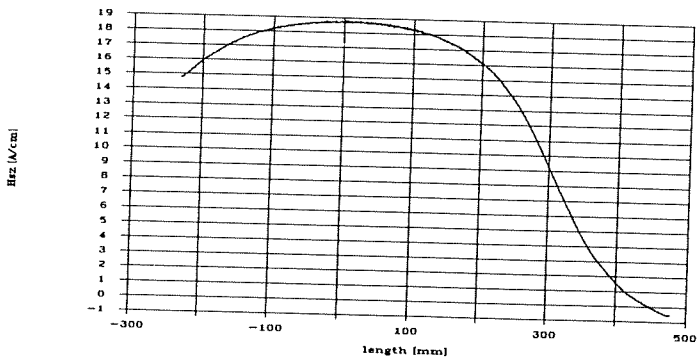


Fig. 3 Axial component H_{oz} of the magnetic field H_0 in the coil

It can be seen that in the area of interest (-300 to 300 mm) the field is satisfactory homogenous. The magnitude of the field is sufficient to get in the steel a magnetization close to the magnetic saturation.

At all tests the dummy was demagnetized by means of an eddy current coil in order to get a virgin state before the starting of a new-magnetization. The distance between the probe and the dummy was about 20 mm.

3.2. Results

Fig. 4 plots the axial component of the leakage field of the pure magnetic shielding (dummy without ruptures).

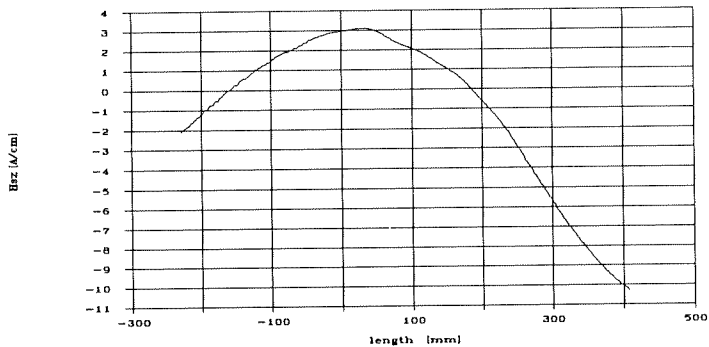


Fig. 4 Axial component H_{zz} of the leakage field of the pure shielding (without rupture)

Fig. 5 plots the leakage field of the dummy with a rupture at $z=0$ mm.

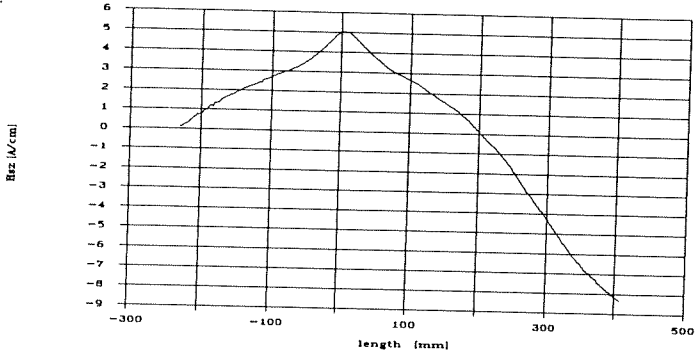


Fig.5 Axial component H_{zz} of the leakage field of the dummy (with a rupture at $z = 0$ mm)

Fig. 6 represents the difference between the leakage flux measurements of the pure shielding and the dummy with a rupture. The result of a numerical calculation is also shown in fig. 6.

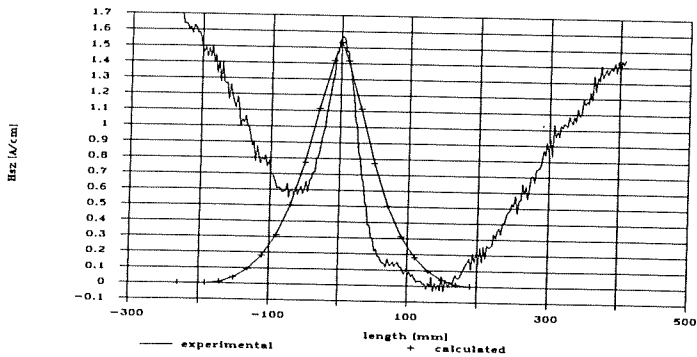


Fig. 6 Difference of leakage field measurements between fig.5 and fig. 4.

The comparison between calculated and the measured signal shows a satisfactory accordance. It can be seen, that despite the magnetic shielding, the rupture produces a significant signal in the leakage field. The rupture can also be detected by measuring the remanent field after switch off the current in the coil. However the signal becomes very smaller than in case of measuring the leakage field.

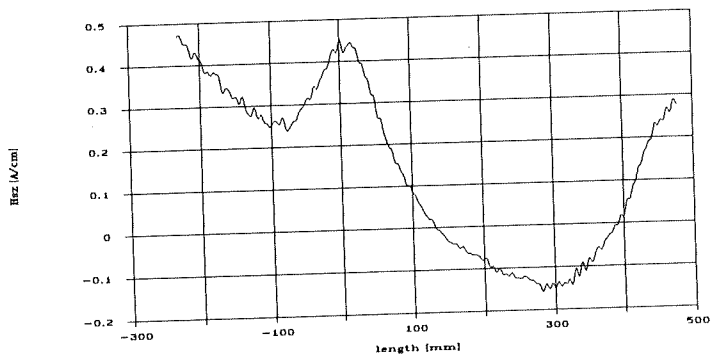


Fig. 7 Axial component of the remanent field

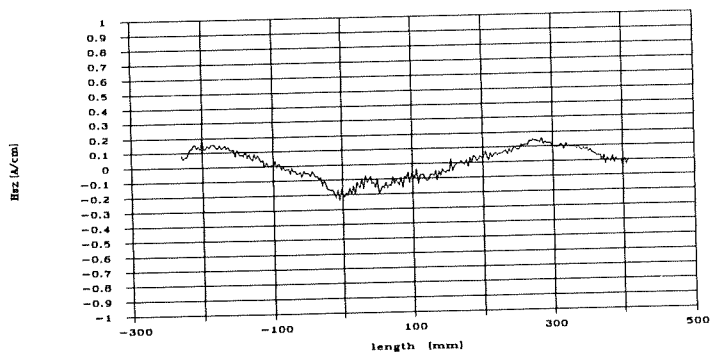


Fig. 8 Leakage field obtained by an conventional magnetization

In contrast to this results which are obtained by application of a homogenous field, using the conventional device (yoke magnet) the detection of the rupture seems not possible. Fig. 8 shows the leakage field obtained by means of the conventional magnetization device.

4. CONCLUSIONS

The following conclusions can be drawn:

- Due to the application of a homogenous excitatory field to the whole specimen the rupture can be detected from measurements of the leakage field.
- In case of conventional magnetization no effect of a rupture was found.

In practice the magnetic inspection of prestressed beams can not be performed in this above described manner.

Therefore the results obtained in this investigation have to be considered as an optimum. At present some work for the improving of the magnetization device with regard to the above results is still in progress.

5. REFERENCES

[1] Hillemeier, B.; Flohrer, C.; Schaab, A.: Die zerstörungsfreie Ortung von Spannstahlbrüchen in Spannbeton-Deckenträgern. Beton- u. Stahlbetonbau 84 (1989) pp. 268-270

[2] Sawade, G.: Quantitative aspects of the detection of ruptures of prestressed steels, Otto-Graf-Journal (2) 1991 pp.287-310