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Two methods of magnetoelastic effect utilization to evaluate mechanical strain in the truss structures

***Abstract**. The article presents the possibility of using the magnetoelastic effects to monitor mechanical strain in trusses. Test stand enabling loading of the special truss structure was designed, which allowed for installation of sample members. Study was carried out on two different configurations of the truss. The first configuration consists of three separate sample members. The magnetoelastic characteristics were measured for each member separately. The second configuration consists of three measuring members combined in a single magnetic circuit. Measurements of the hysteresis loops of the sample members was carried out under varying mechanical load, which allowed to obtain magnetoelastic characteristics. The obtained results confirmed the possibility of using the magnetoelastic effects to monitor stresses in the truss structures.*

***Streszczenie.** W artykule przedstawiono możliwości wykorzystania efektu magnetosprężystego do monitorowania naprężeń mechanicznych w kratownicach. Zostało wykorzystane stanowisko badawcze umożliwiające obciążanie specjalnej konstrukcji kratownicowej, pozwalającej na montaż prętów pomiarowych. Badania przeprowadzono na dwóch różnych konfiguracjach kratownicy. W pierwszej konfiguracja są umieszczone trzy oddzielne pręty pomiarowe. Charakterystyki magnetosprężyste zostały zmierzone dla każdego pręta pomiarowego osobno. Druga konfiguracja zawiera trzy pręty pomiarowe połączone w jeden obwód magnetyczny. Pomiary pętli histerezy prętów pomiarowych przeprowadzono dla różnych obciążeń mechanicznym, co pozwoliło na uzyskanie charakterystyk magnetosprężystych. Uzyskane wyniki potwierdzają możliwość wykorzystania efektu magnetosprężystego do monitorowania naprężeń w konstrukcjach kratownicowych.(**Dwie metody wykorzystania efektu magnetosprężystego do oceny stanu naprężeń mechanicznych w konstrukcjach kratownicowych**).*

Keywords: magnetoelastic effect, truss structures, monitor mechanical strain.
Słowa kluczowe: efekt magnetosprężysty, konstrukcje kratownicowe, monitorowanie naprężeń.

Introduction

Truss constructions increasingly require monitoring of the stresses due to the growing security requirements. Contemporary methods for assessment of stresses, such as a strain gauge, the magnetostrictive method [1, 2] or the eddy current tomography [3], have serious limitations. There is therefore a need to develop methodology for allowing the execution of such measurements. The development of magnetic measurements allows the use of them in different scientific fields. A phenomenon that can be used to monitor stresses in the constructions is the magnetoelastic effect [4, 5]. The magnetoelastic effect is a change of the magnetic properties under stress [6-10]. This may be used in the investigation structure of ferromagnetic steels [11, 12], that are commonly used in the industry. One of the most popular construction is made of steel truss, which is use in the construction of bridges, halls, roofs, poles traction.

Experimental

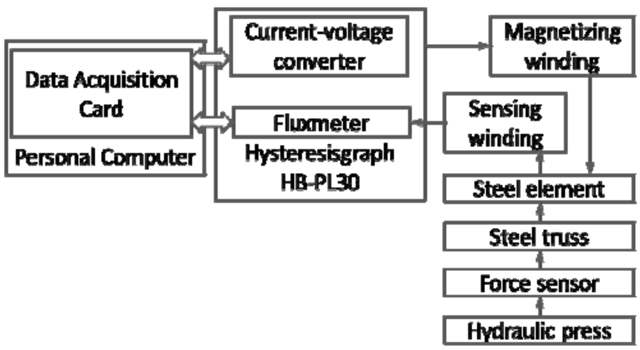

Fig. 1. Schematic block diagram of the test stand

The test stand (Figure 1) enabling loading of the special truss structure was designed. The three central members of truss are sample elements and are interchangeable. They also have reduced cross-sectional area so that the test can be carried out without destroying the whole grid. The study used two configurations of the truss.

The first configuration (Figure 2) has been used for sample members shown in Figure 4a. The measuring elements are designed to be appropriate for individual windings. In the columns of sample members uniform stress distribution was assumed. The magnetoelastic characteristics were measured for each sample member S1, S2, S3 (magnetic cores) separately.

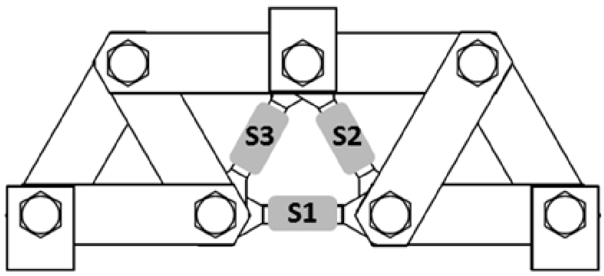

Fig. 2. Schematic diagram of the truss structures for first configuration, S1, S2, S3 - magnetic cores

In the second configuration (Figure 3), the magnetic circuit is closed by means of three sample members. Used samples members are shown in Figure 4b. The magnetoelastic characteristics were measured for magnetic core M1 consisting of three elements.

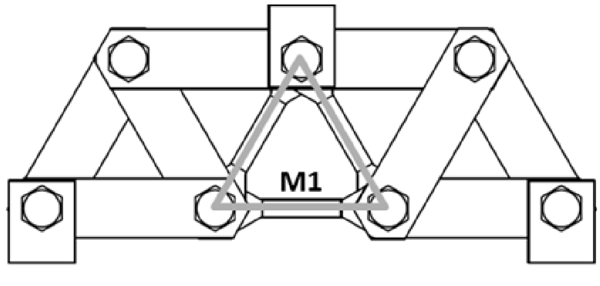

Fig. 3. Schematic diagram of the truss structures for second configuration, M1 - magnetic core

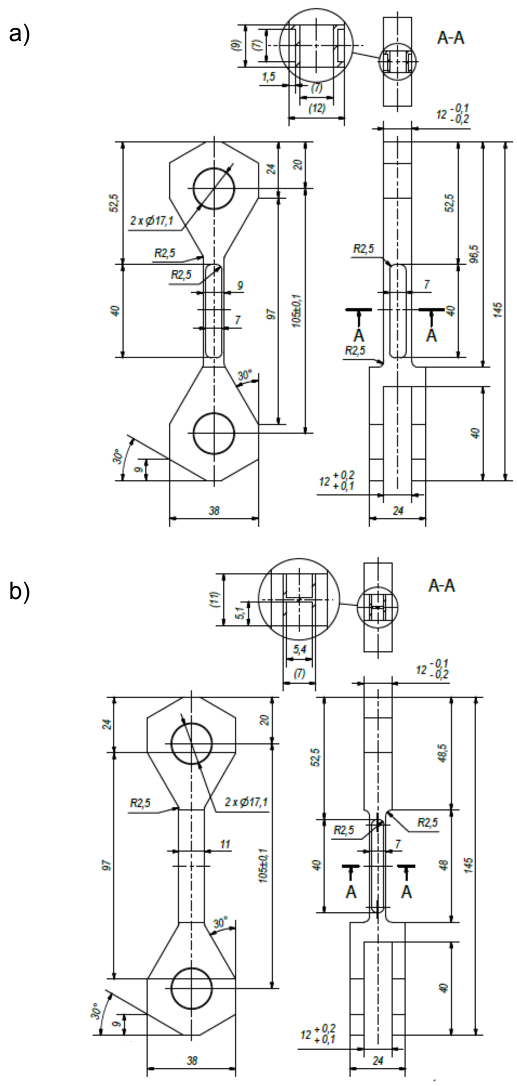

Fig. 4. Schematic diagram of the sample members

The hysteresis loops measurements are done on the hysteresisgraph. The system is composed of voltage-current converter and fluxmeter. The hysteresisgraph is controlled by PC with Data Acquisition Card. Current waveform, generated by the voltage-current converter, generates magnetizing field in sample members through the magnetizing windings. The voltage induced in the sensing winding is coupled to the input fluxmeter. The device converts the measured voltage on flux density.

The mechanical load was exerted vertically by the oil hydraulic press on the upper central node of the truss. The truss was supported on the bottom edge nodes. Value of the force was measured with force sensor. The values of tensile stress and compressive stress for sample members is shown in Table 1.

Table 1. The value of stresses in the sample members

No.	σ (MPa)	
	tensile stress	compressive stress
0	0	0
1	20	13
2	40	27
3	60	40
4	80	53
5	100	67
6	120	80
7	140	93
8	160	107
9	180	120
10	200	133
11	250	167
12	300	200
13	350	233
14	400	267
15	450	300
16	500	333

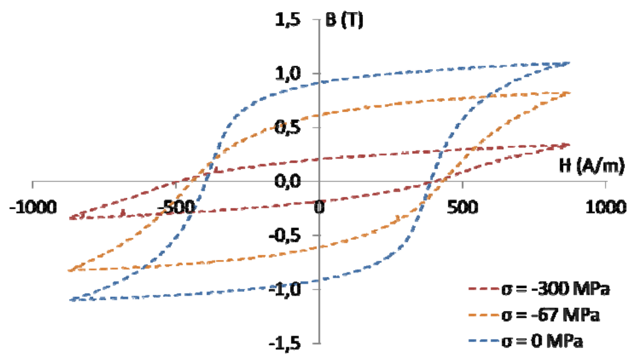

Figure 5. Magnetic hysteresis loops of the compressed sample under various mechanical loads for first configuration. H - magnetizing field, B - flux density, σ – compressive stress

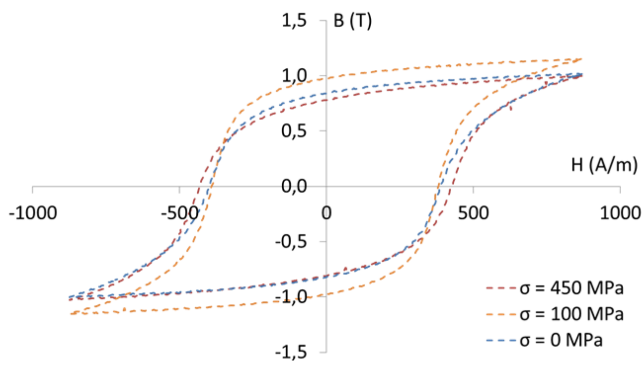

Figure 6. Magnetic hysteresis loops of the stretched sample under various mechanical loads for first configuration. H - magnetizing field, B - flux density, σ - tensile stress

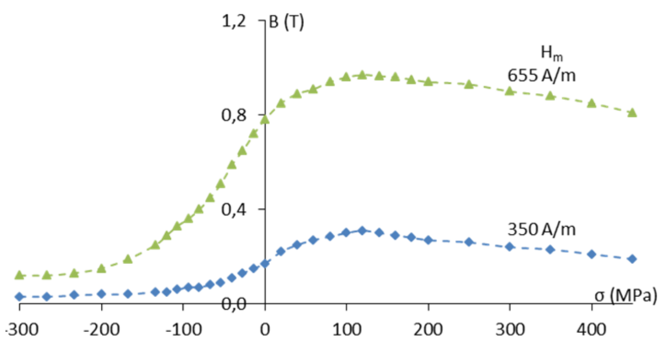

Figure 7. Magnetoelastic B(F)H characteristics for compressive and tensile stress for first configuration,
σ – stress, B - flux density, Hm - magnetizing field

Results and discussion

Measurements of magnetoelastic characteristics were made for two different configurations of the truss.
Figure 5, 6, 7 shows the measurement results for first configuration. The shape of the hysteresis loop changes

under compressive stress (Figure 5) and tensile stress (Figure 6). The magnetoelastic characteristics B(F)H consists of two parts: the negative force value shows the results for compressed component and the positive values of force for the tensed member (Figure 7). The value of flux density at first increases, and after crossing Villari point, decreases.

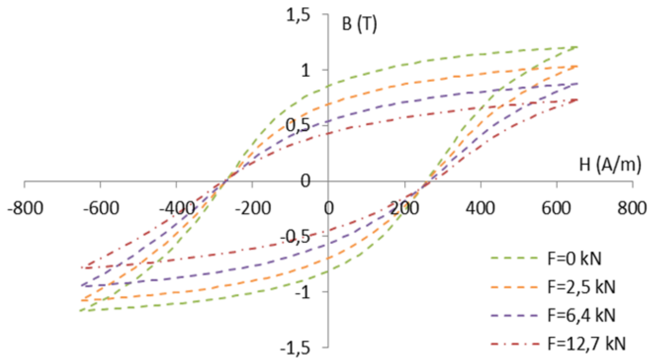

Figure 8. Magnetic hysteresis loops of the sample magnetic circuit, under various mechanical loads for second configuration. H - magnetizing field; B - flux density, F – force

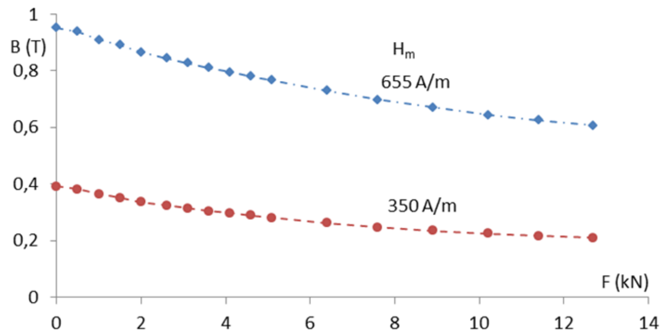

Figure 9. Magnetoelastic B(F)H characteristics for compressive and tensile stress for second configuration. F – force, B - flux density, Hm - magnetizing field

Figure 8, 9 shows the measurement results for second configuration. The magnetoelastic characteristics were determined for the three sample members combined in a single magnetic circuit. The shape of the hysteresis loop changes under stress (Figure 8). The value of flux density, shown in the magnetoelastic characteristics B(F)H (Figure 9), decreases under external force. The magnetoelastic characteristic B(F)H for second configuration is monotonous and unequivocal

Conclusions

Test stand enabling loading of the special truss structure, which allowed for installation of sample members was developed. The measurements were carried out for two different configurations of the truss. In the first configuration the magnetoelastic characteristics were measured for each sample member separately. It allows to measure separately: tensile stress in the tensed sample member and compressive stress in a compressed sample members at the same time. The disadvantage of this method is the need to perform special openings for the winding of the sample. In the second configuration sample magnetic circuit was simply composed of the three sample members. The magnetoelastic characteristics are obtained for the entire magnetic circuit, which cannot distinguish the effect of tensile and compressive stresses. The advantages of the second configuration over the first are simpler sample construction and monotonous, unequivocal characteristic.

The results confirmed the possibility of using magnetoelastic effects to monitor stresses in the truss structures. On the base of the B(F)H characteristic and measurement of flux density, stresses in the given truss, and therefore force acting upon it, can be assessed.

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