COMPOSITE CORES IN CURRENT TRANSFORMERS

Jozef Kwiczala *, Boguslaw Kasperczyk *
***The Silesian University of Technology, Gliwice (Poland)**

Keywords: *composite core; current transformer; measurements; error;*

Abstract

The parameters of a composite core and metrological properties of a current transformer using this core are described in the paper. The paper presents the results of investigations of the current transformer consisting of two toroidal cores of the same geometrical dimensions: the first one made of silicon-iron steel, the standard magnetic material used for construction of current transformers and the other one made of amorphous or nanocrystalline alloys, e.g. Metglas tape (B_{max} *= 1,4 T;* H_c *= 5 A/m;*μ_{max} *= 150 000) or Finemet tape (*B_{max} *= 1,2 T;* H_c *= 1,2 A/m;* μ_{max} *= 450 000). The errors of the current transformer using the composite core are smaller than those of the transformer using the standard magnetic materials.*

1 Introduction

The current transformer (CT) accuracy depends above all on the properties of a magnetic material used for constructing magnetic cores [1]. The parameters of the magnetic materials applied in current transformers up to now do not comply with the designer's requirements any longer because of too high core losses, especially at increased frequencies of transformed signals. The demand for current transformers of increased accuracy, higher frequency and large rated power is becoming more and more frequent nowadays. Moreover, the lower costs of production are also essential as far as current transformers are concerned.

The main purpose of this work was to construct a current transformer whose metrological properties would be better than those of a current transformer with a core made of standard magnetic materials and a little worse than those of one with a core made of expensive materials of very good magnetic properties.

It is possible, of course, to construct the core of cheap materials and to increase the accuracy class by appropriate realization of windings (fractional windings) or application of electronic systems. These methods, however, do not allow compensating the transformer phase errors, which results in non-meeting the requirements of the accuracy class. Moreover, additional electronic systems considerably increase the price of a current transformer.

The authors of this work are of opinion that investigations of the influence of the present-day magnetic material properties on the current transformer accuracy as well as working out the structure of composite cores that may be used in current transformers from the viewpoint of their optimal metrological parameters are essential.

2 Magnetic materials of current transformers cores

Silicon-iron alloy is a magnetic material commonly used for construction of current transformer cores. However, because of its large active power losses it is replaced with other magnetic materials in current transformers of high accuracy, e.g. amorphous metals and nanocrystalline alloys whose permeability is very high (hundreds of thousands) and core losses are very low (several mW/kg). These materials, however, are much more expensive than silicon-iron steel.

Amorphous metals are mainly used for construction of modern power transformers due to their properties (low core losses). Their application to constructing current transformers has not been common so far because of less saturation magnetic induction and higher price.

The possibilities of the use of composite cores – magnetic circuits composed of cores made with materials of different magnetic properties – for constructing measuring current transformers were investigated in the work.

The following composite cores were realised:

a) the core made of silicon-iron steel (089-27-N5) of the low magnetic permeability, high core losses and high saturation magnetic induction (B_{max} = 1,8 T; H_c = 28 A/m; μ_{max} = 30 000; P_c = 0,40 W/kg),

b) the composite core composed of silicon-iron steel and an amorphous metal (Metglas : B_{max} = 1,4 T; H_c = 5 A/m; μ_{max} = 150 000; P_c = 0,09 W/kg),

c) the composite core composed of silicon-iron steel and a nanocrystalline alloy (Finemet: B_{max} = 1,2 T; H_c = 1,2 A/m; μ_{max} = 450 000, P_c = 0,02 W/kg),

d) the composite core composed of an amorphous metal (Metglas) [2] and a nanocrystalline alloy (Finemet) [2, 3].

The case (a) is the standard construction of a current transformer core. The cases (b) and (c) are the examples of composite cores in which a part of the standard material (silicon-iron steel) is replaced by materials of better magnetic properties. The case (d) is a composite core made of modern materials only.

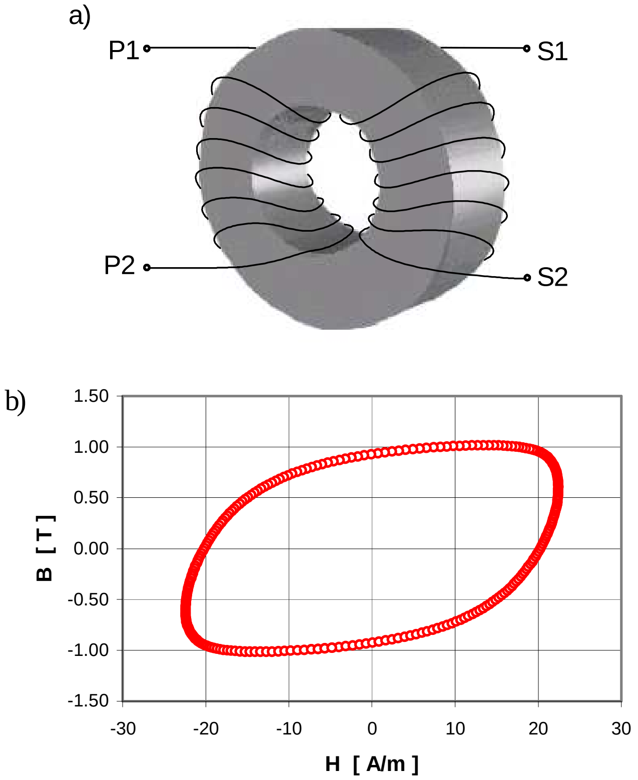

Fig. 1. Magnetic core (a) and hysteresis loop (b) of silicon-iron steel

The geometrical dimensions of the cores and the metrological parameters of the current transformers are as follows:

- the transformer current ratio: I_2/I_1 = 5/5 A/A
- the rated value of the ampere–turns: Θ_N = 300 A
- the diameter of the winding wire: D = 1 mm
- the geometrical dimensions of the cores: 120 x 95 x 10 mm
- the rated burden: S_N = 10 VA

The current transformer core made of the standard magnetic material (silicon-iron steel 089-27-N5) is shown in Fig. 1a, whereas Fig. 1b presents the hysteresis loop of this core material. The maximum value of the magnetic induction in the core depends on the voltage drop along the shunt branch impedance at the rated burden (10 VA) and is equal to about 1 T for this type of transformer construction.

The system for determining the current and phase errors of CT was realised. The system is based on a magnetic current comparator enabling very accurate comparison of two currents [4, 5]. It is possible to determine the current transformer errors from 0,001% to 10%.

The characteristics of the current and phase errors of this transformer as a function of the secondary current at 25% and 100% of the rated burden (2,5 VA and 10 VA) are shown in Figs. 2a and 2b, respectively.

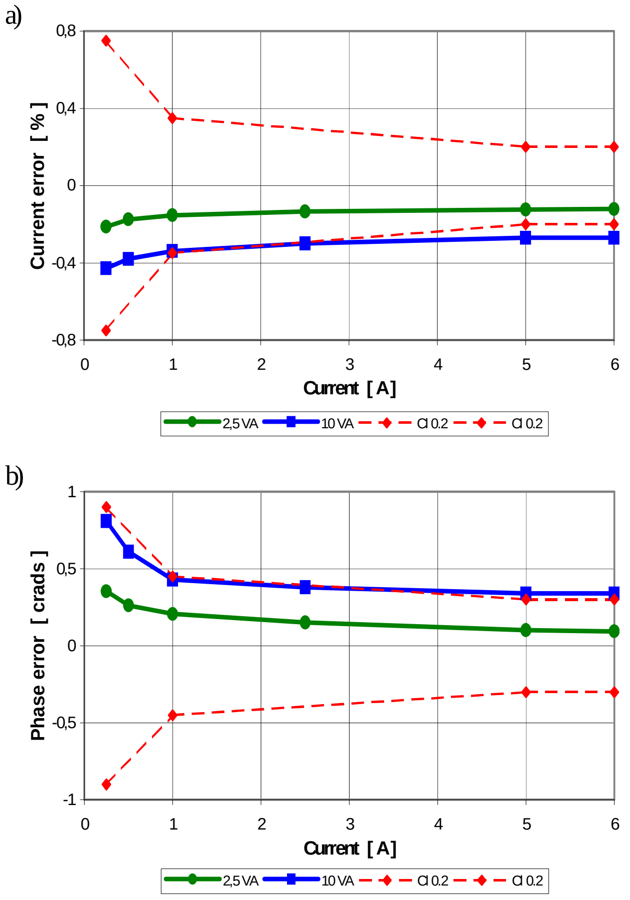

Fig. 2. Current (a) and phase (b) error of CT with silicon-iron steel core

The current and phase errors of this transformer for the rated burden (10 VA) are greater than the limit errors specified in the standard for that particular Class 0.2 accuracy [6, 7].

3 Structure of composite cores

The cores of the same geometrical dimensions were investigated. The first part of the core was made of silicon-iron steel, whereas the other one – of Metglas or Finemet. The structure of composite cores is presented in Fig. 3a. The resultant hysteresis loops of these cores are shown in Fig. 3b. Such a resultant “magnetic material” has the high initial permeability, the small ratio of the maximum permeability to the initial one and the low hysteresis loss.

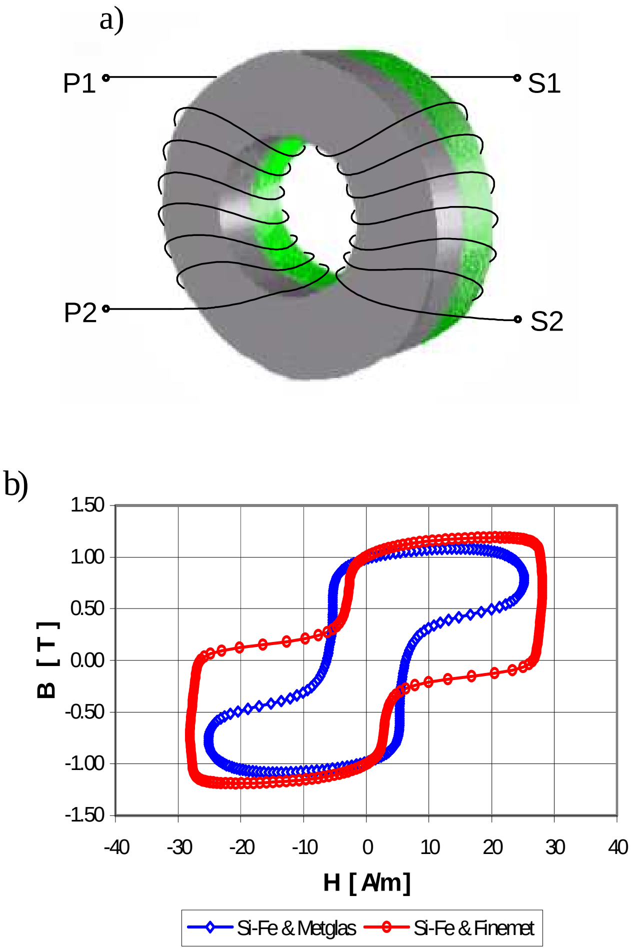

Fig. 3. The structure of composite magnetic cores (a) and their hysteresis loops (b)

The characteristics of the current and phase errors of the CT with the composite core made of silicon-iron steel and Metglas as a function of the secondary current at 25% and 100% of the rated burden (2,5 VA and 10 VA) are shown in Figs. 4a and 4b, respectively.

The current and phase errors of this transformer for the rated burden (10VA) are smaller than the limit errors specified in the standard for that particular Class 0.1 accuracy [6, 7].

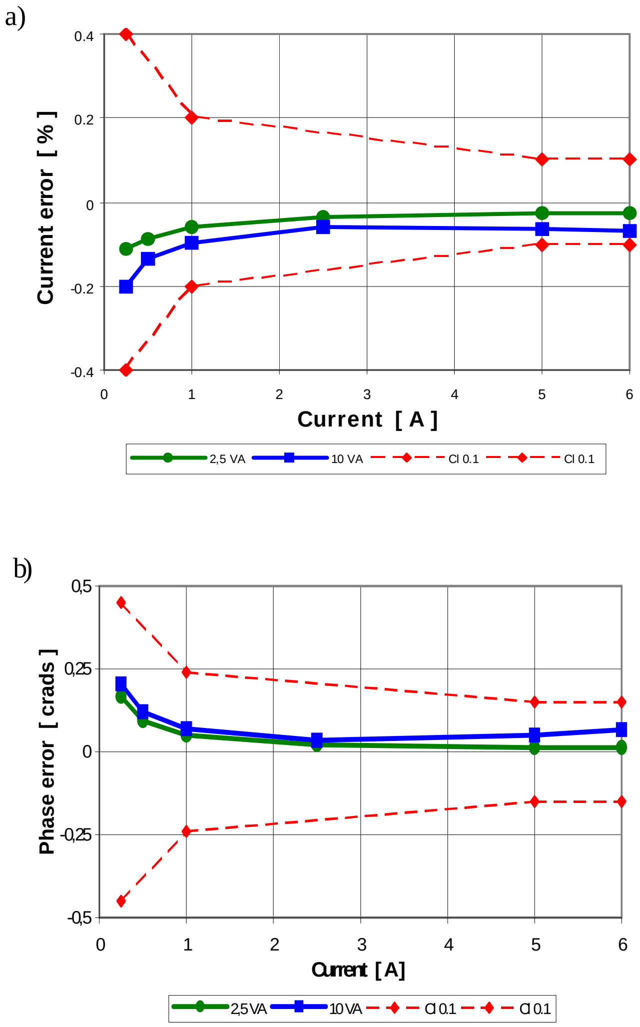

Fig. 4. Current (a) and phase error (b) of CT with silicon-iron steel and Metglas composite core

The errors of the CT with the composite core using Finemet presented in Fig. 5 are smaller than those of the CT with the composite core using Metglas for the current smaller than 40% I_N and the low burden (2,5 VA). The greater values of the current, the greater these errors. For the rated burden they exceed the limit errors for Class 0.1 accuracy [6, 7] for the current greater then 5 A.

The explanation of this fact is that Finemet, in spite of better magnetic properties (higher permeability and lower losses), reaches saturation sooner than Metglas because of the lower saturation magnetic induction.

The way to decrease the errors of such a CT at the higher burdens and currents is increase in the rated ampere-turns of the CT by increase in the number of turns.

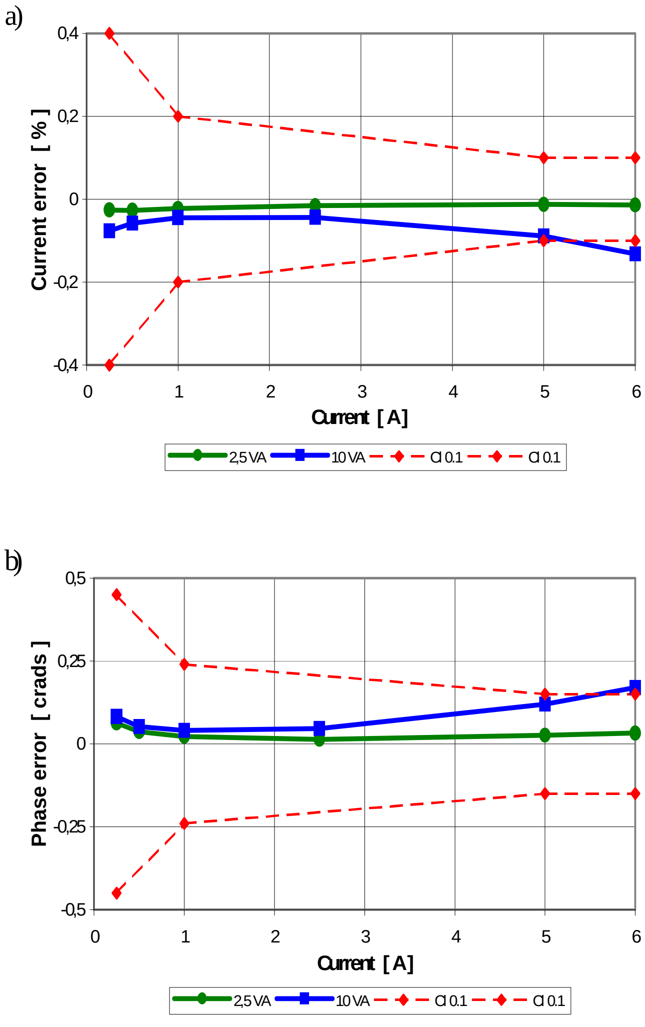

Fig. 5. Current (a) and phase (b) error of CT with silicon-iron steel and Finemet composite core

This way of error minimization was verified experimentally by constructing the composite core using Metglas and Finemet.

The rated burden was lowered to 5 VA and the rated ampere-turns were increased to 500 A. The hysteresis loop of the core of such construction is shown in Fig. 6.

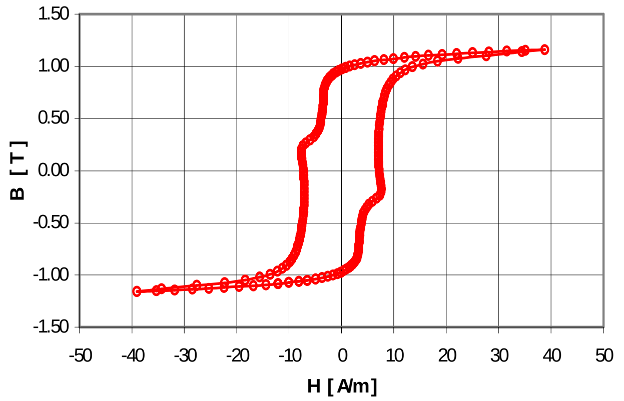

Fig. 6. Hysteresis loop of Metglas and Finemet composite core

The errors of the CT with the composite core made of Metglas and Finemet are presented in Fig. 7. They do not exceed the limit errors for Class 0.05 accuracy.

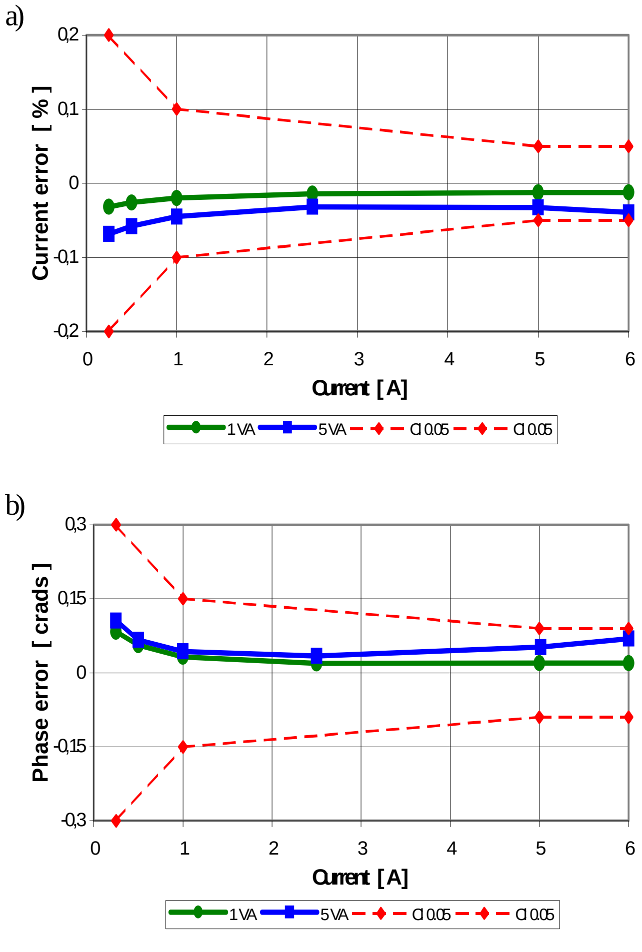

Fig. 7. Current (a) and phase (b) error of a CT with Metglas and Finemet composite core

4 Conclusions

The presented results of measurements support the idea of constructing magnetic composite cores and prove its usefulness.

Such cores composed of a cheap material of medium magnetic properties and an expensive one of very good parameters ensure the high accuracy of current transformers and relatively low realisation costs, which is important in the present market economy.

This problem is a live issue since there is very large demand for measuring transformers of high accuracy class. It is connected with their application to measuring systems of essential economic importance, for instance in the process of calculating costs of electric energy.

In these systems measuring transformers are used for supply of very accurate and expensive digital electricity meters.

Manufacturers of measuring transformers are interested in the results of the authors' investigations.

Acknowledgements

The authors wish to thank The State Committee for Scientific Research (KBN) for sponsoring this project – Grant Nr PBZ-KBN-115/T08/02.

References

[1] Wright A., *Current Transformers*, London, Chapman and Hall Ltd., 1968.

[2] Wojcik N., Kolano R., Kolano A., J. Magn.Magn. Mater., pp 215-216, 2000.

[3] Kolano A., Mateja-Kaczmarska K., J. Magn.Magn. Mater., pp 432-433, 2003.

[4] Kwiczala J., Milek M., IEEE Trans. on Instr. and Meas., vol. IM-38, pp 979-983, 1989.

[5] Kusters N. L., IEEE Trans. on Instr. and Meas., vol. IM-13, pp. 197-209, 1964.

[6] IEC 60044-1:1996, *Instrument transformers. Part 1 - Current transformers.*

[7] ANSI Standard C57.13-1978. *Requirements for Instrument Transformers*.