MODELLING THE INFLUENCE OF TEMPERATURE ON THE CHARACTERISTICS OF THE FERROMAGNETIC CORE

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PRESENTATION OUTLINE

Introduction

Description of the model

Results

Conclusions

INTRODUCTION



Why electrothermal modeling?

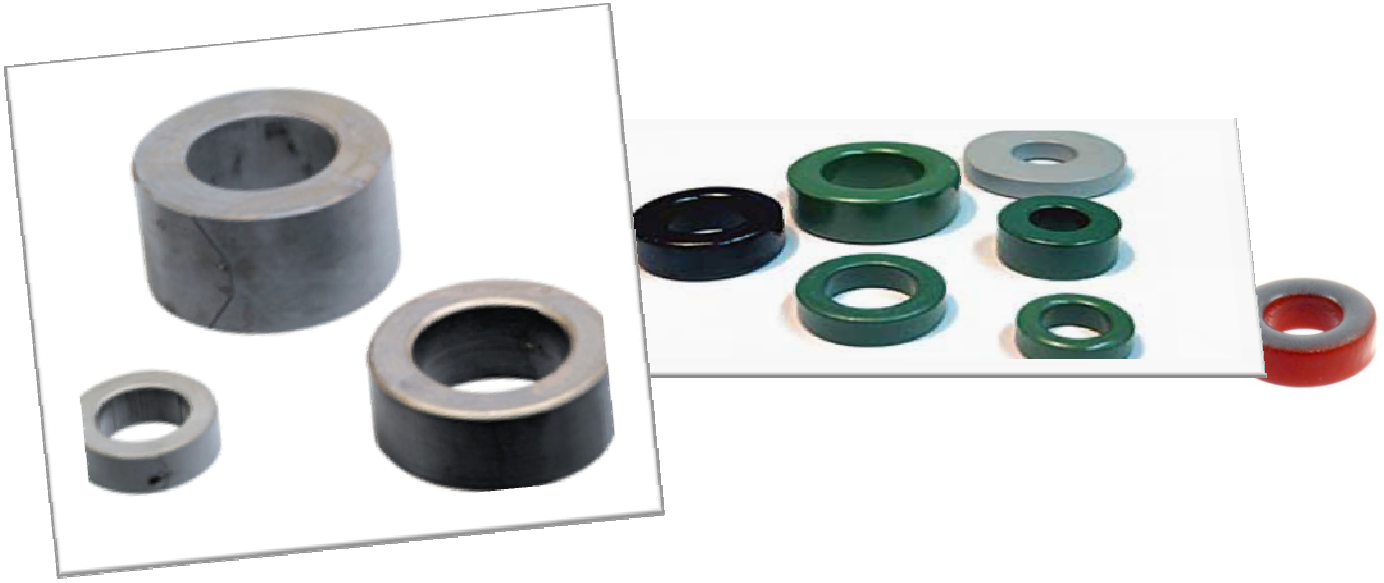
The temperature affects the properties of ferromagnetics significantly.

For example, the values of the core saturation flux density and the permeability of the core significantly changes with temperature changes.

The models of electronic components play a significant role in the process of design and analysis of electronic circuits.

Currently, SPICE is the standard program for the analysis of electronic circuits.

Classical Jiles-Atherton model implemented in this program does not include the influence of the temperature on the characteristics of the core .



Aim of the presentation

This presentation proposes a new model of ferromagnetic core dedicated for SPICE taking into account the influence of temperature on core characteristics.

The base to formulation of this model is the classic Jiles-Atherton model.

In the new model:

the temperature dependence of the parameters of this model are taken into account

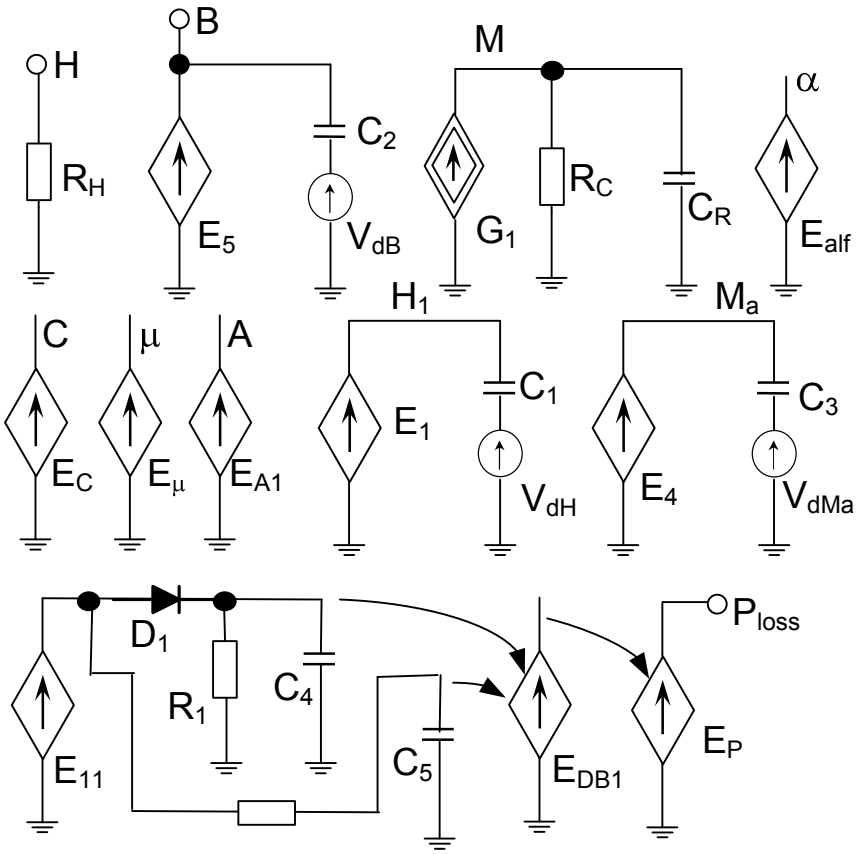
the description of the power losses in the core is used.



DESCRIPTION OF THE MODEL



The network representation of the model



Model description

In model the input signal is put between the terminal H and the ground. This signal represents the magnetic force H.

The flux density corresponds to the voltage on the terminal B.

The power losses in the core are equal to the voltage at the terminal P_{loss}.

Initial magnetization curve

$$M_a = \left[\frac{B_{S0} \cdot (1 + \alpha_{BS} \cdot (T_R - T_0))}{\mu_0} - H_S \right] \cdot F\left(\frac{H + \alpha \cdot M_a}{A} \right)$$

$$F(x) = \frac{x}{\sqrt{x^2 + 1}} \left[1 - 0.9 \cdot \exp\left(-\frac{|x|}{2.5} \right) - 0.1 \cdot \exp\left(-\frac{|x|}{25} \right) \right]$$

Equation of the histeresis loop

$$M = \frac{R_3}{C_2} \cdot \frac{(M_a - M \cdot C_2) \cdot \operatorname{sgn}\left(\frac{dH}{dt} \right)}{C_1 \cdot H_{C0} \cdot [1 + \alpha_{HC} \cdot (T_R - T_0)]} \cdot \frac{dH}{dt} + \frac{R_3}{C_2} \cdot \frac{C}{C_1 \cdot (1 + C)} \cdot \frac{dM_a}{dt}$$

Temperature dependences

$$\alpha = 3 \cdot \frac{A}{M_{n0} \cdot [1 + \alpha_{BS} \cdot (T_R - T_0)]} - \frac{C}{(\mu - 1) \cdot (1 + C)}$$

$$C = \frac{\mu - 1}{\frac{B_{R0} \cdot (1 + \alpha_{BR} \cdot (T_R - T_0))}{\mu_0 \cdot H_{C0} \cdot [1 + \alpha_{HC} \cdot (T_R - T_0)]} - \mu}$$

$$\mu = \mu_{ip} \cdot [1 + \alpha_\mu \cdot (T_R - T_0)] \cdot x + 1.01$$

$$x = \begin{cases} 1 & for\ T_R < T_C \\ 1 - (T_R - T_C) \cdot 0.06 & for\ T_C < T_R < T_C + 17 \\ 0 & for\ T_R > T_C + 17 \end{cases}$$

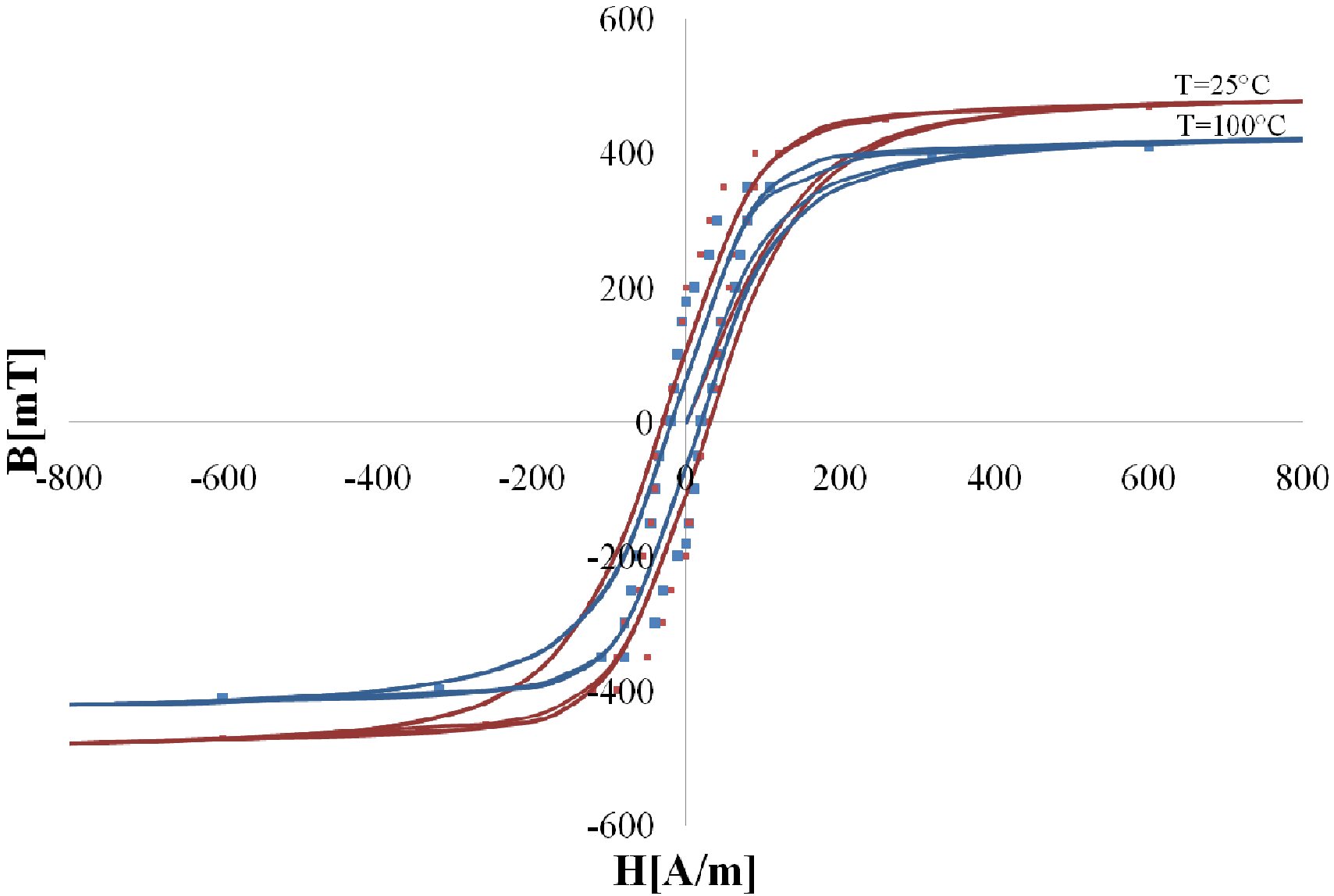
Power loss

$$P_{loss} = \left(\frac{B_{pp}}{2} \right)^{\beta - \alpha} \cdot \left(1 + \alpha_P \cdot (T_R - T_m)^2 \right) \cdot \frac{P_{V0}}{T} \int_0^T \left| \frac{dB}{dt} \right|^\alpha dt$$

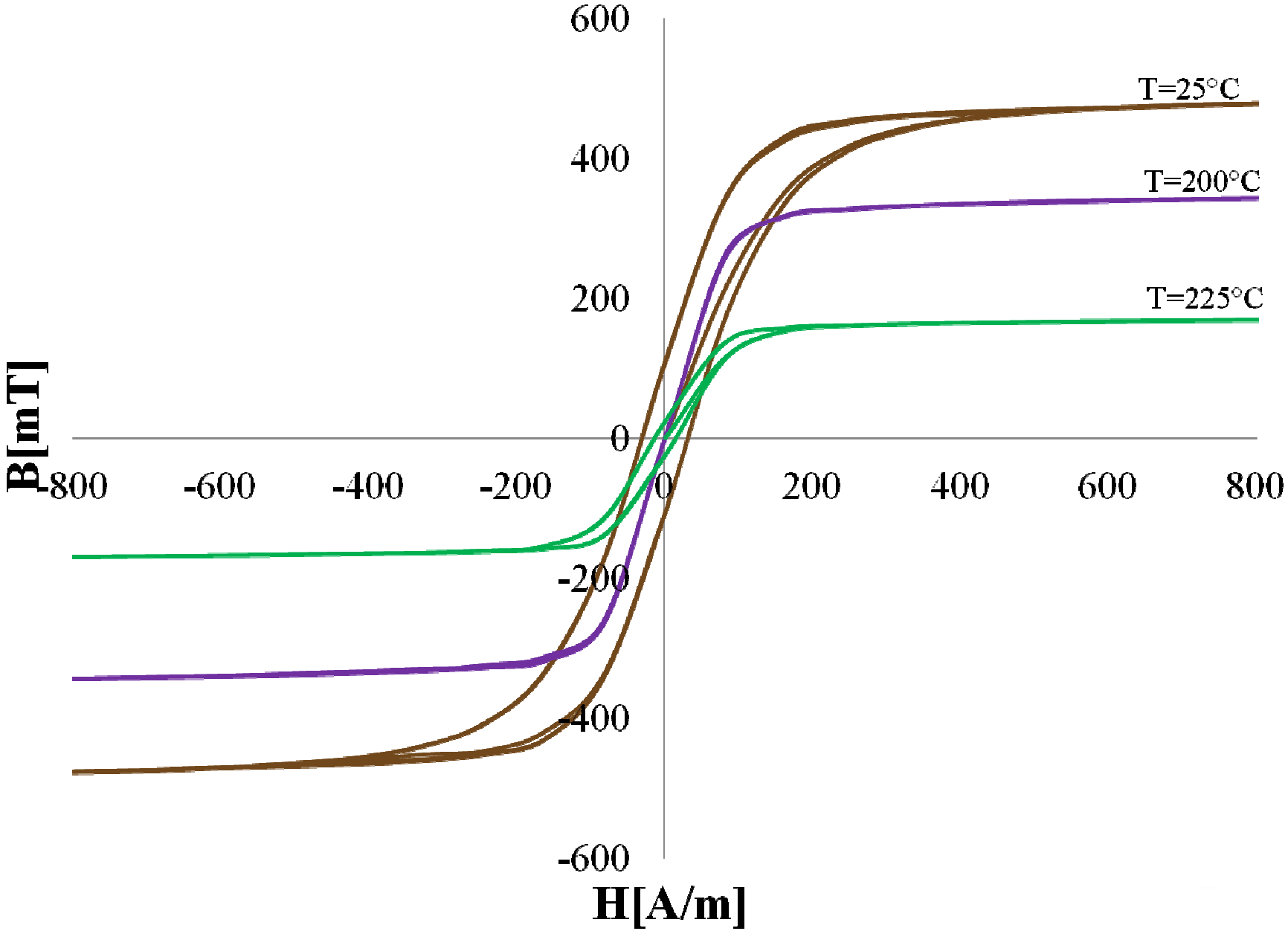
RESULTS



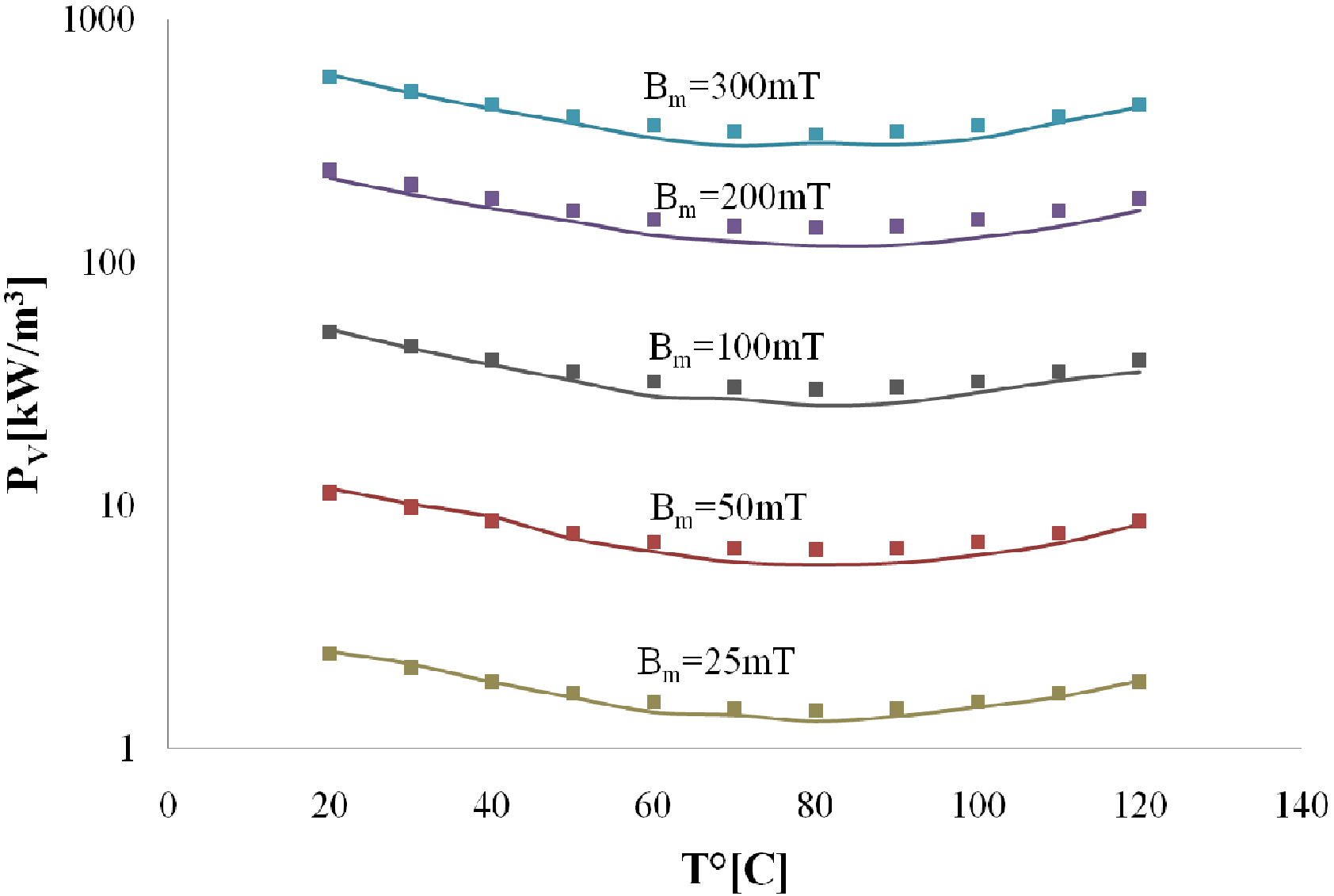
Material N27



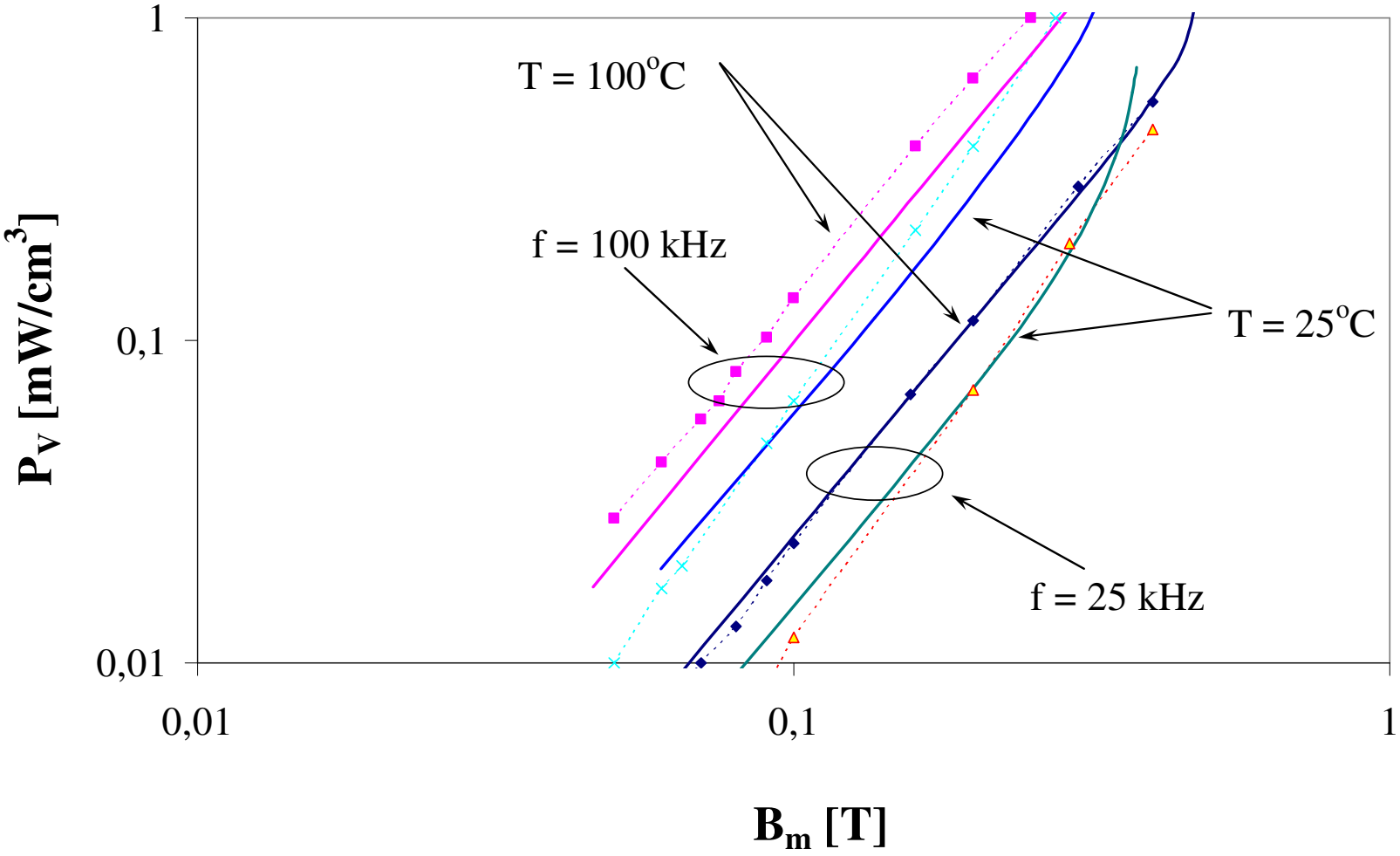
Material N27



Material N27



Core RTF F-867



CONCLUSIONS



The new model of the ferromagnetic core based on the basic equation described by Jiles-Atherton was formulated

Model possesses a different analytical description of the initial magnetization curve where used submission of exponential function instead of the classic Langevin function

Influence of temperature on the magnetizing characteristic of the core is taken into account

Model contains the description of the core losses resulting from the core remagnetization

The presented model uses only 16 parameters, but most of them can be calculated from the catalogue data

Satisfied agreement between results of calculations with new model and results of measurements in wide range of temperature changes