

Analysis of the possibilities to use Coselica toolbox for simulate electrical circuits and heat flow

Streszczenie. W artykule opisano analizę możliwości symulowania obwodów elektrycznych i rozplywu ciepła za pomocą toolbox'a coselica dla środowiska obliczeniowego Scilab/Xcos. Zbudowano prosty model nieliniowego obwodu elektrycznego oraz podjęto próbę budowy dyskretyzowanego modelu szybu wentylacyjnego i analizę rozkładu temperatury w tym szybie.

Abstract. Paper describes an analysis of the possibility to simulate electrical circuits and propagation of heat using Coselica toolbox for a computing environment fo Scilab / Xcos. Simple model of non-linear electric circuit was build, and discretized model of the ventilation shaft with an analysis trial of the temperature distribution in the shaft. **The possibility to simulate electrical circuits and propagation of heat using Coselica toolbox**

Słowa kluczowe: obliczenia numeryczne, obwody elektryczne, rozkład temperatury, scilab/xcos, coselica, modelica.

Keywords: numerical calculation, electrical circuits, temperature distribution, scilab/xcos, coselica, modelica

Introduction

Coselica toolbox provides Scilab / Xcos environment new calculation blocks imported from modelika. Library computing of blocks becomes extended by capable of modeling of electrical circuits and heat transfer phenomena. The package expands very significant possibility of building computational models based on mathematical description.

The numerical analysis of temperature distribution, is realized mainly using finite element calculation programs such as FEMM, COMSOL like. It is possible to use visual programming tools that enable the creation of string models of phenomena. These methods are obviously connected with the need to use a number of simplifying assumptions. It is possible to not only map the distribution of the analyzed parameter, but also the course of its evolution over time. Models peripheral field distribution of temperature can be carried in two ways:

1. using an equivalent electric circuit,
2. using a visual programming in computing environments (Scilab / Xcos) using a block corresponding to the analyzed phenomena.

Application of the second approach seems to be more effective and intuitive in the development of the numerical model. In this approach, it is also very easy to build and analyze models combined (eg. electro - thermal).

An attempt was made to build and analyze temperature distribution in a ventilation shaft using a model built using toolbox'a Coselica environment Scilab / Xcos.

Numerical modelling of electrical circuit

The coselica library provides calculation blocks allowing the construction and simulating electrical circuits. Provided tools are divided into thematic groups:

- Sources
- Basic elements
- Semiconductors
- Sensors

Coselica allows to build models of combined electro-thermal phenomena. A simple test of possibilities to simulate electrical circuits were performed for the analysis of transient circuit with choke, as shown in Figure 1. The non-linearity choke was modeled by using approximating function of ATAN, as shown in Figure 2.

An numerical analysis of circuit model for voltage supply of 200V with 50 Hz frequency. Waveforms of current and voltage of the capacitor and inductor and power waveform of inductor and capacitor were obtained. Simulation results are shown in Figures 3.

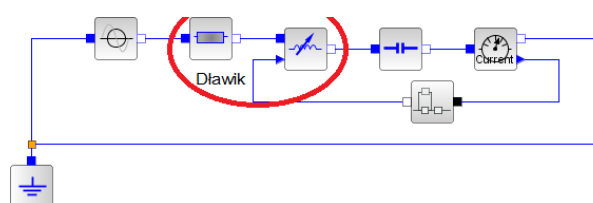


Fig. 1. Diagram of the tested circuit



Fig. 2. Diagram of the nonlinearity of the inductor

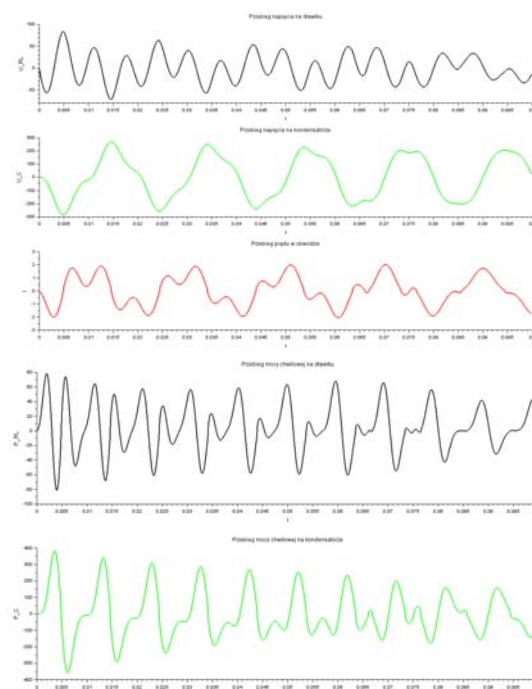


Fig. 3. Waveforms obtained from the simulation

Heat transport in Coselica

Coselica is toolbox that implements a computational blocks of modelika to computing environment of Scilab / Xcos. This module extends the capabilities of Xcos blocks of electrical, heat transfer and mechanics. The created




model will be used calculation blocks performing the task of transporting heat.

Heat transfer can be implemented in three ways:

- conduction - transfer of energy from one particle to another,
- convection - convection motion of liquids or gases caused by temperature gradients or external forcing,
- radiation - transfer of heat energy in the form of infrared radiation.

Coselica provides a calculation blocks performing the above method of heat transfer, as shown in Table 1.

Table 1. Blocks of heat transport

Block	Type of heat transport	Comments
	Thermal Conductor	The block is defined by one parameter - the constant of thermal conductivity G [W/K]
	Convection	The block is controlled by an external parameter - convection coefficient Gc
	Body Radiation	The conductivity of the radiation between the two surfaces Gr [m ²]



Toolbox also includes a block thermal capacity, which enables to simulate the accumulation of heat by spatial objects. This block is defined by three parameters: heat capacity C [J/K], the initial temperature T [K] and the parameter that defines the steady state. Toolbox also includes blocks of extortion heat (temperature), unit conversion and temperature sensors.

The model built using the toolbox coselica, analyzed variable in the transport of heat is the heat flow Q.

It should be noted that the capacity and thermal conductivity are not constants and it is desirable to take account of their dependence on external factors such as temperature. It is also desirable that as in the case of natural convection used to control capacity and thermal conductivity through their parameterization.

Coselica toolbox is distributed under the GPL license with source code. It is possible to modify and add your own calculation blocks. To account for the capacity and thermal conductivity of the temperature blocks are modified and the heat capacity of conductive heating by adding additional numerical input, which are fed values will be appropriate capacity and thermal conductivity designated in the operation of the simulation, as shown in Table 2.

Table 2. Modified blocks

Blok	Name	Comments
	Controlled heat capacity	Heat Capacity C [J/K] given as the value
	Controlled Thermal Conductor	Thermal conductivity G [W/K] specified as a value

The assumptions and principal blocks of the model

The proposed measurement experiment was to determine the map of the temperature distribution in a ventilation shaft between areas of different temperatures. The test area is divided into computing areas of 9x15, as shown in Figure 4.

In addition, the upper and lower walls of the shaft divided into 5 parts. In the experiment, we assumed constant atmospheric pressure.

The diagram also indicated the anticipated and possible heat flows in the analyzed model. Assumed that between the border area (input and output shaft and the walls) and air and between cells air heat exchange by natural

convection. The flow of heat in the walls of the shaft takes place on the basis of conductivity. As presuppositions assumed that the pressure and volume of individual air cells are constants.

It assumed that natural convection can take place in four directions, as shown in Figure 4.

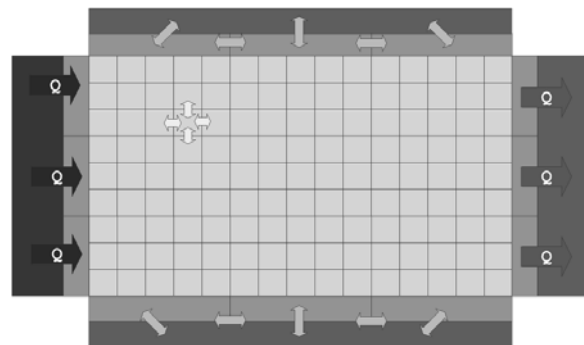


Fig. 4. Diagram of the ventilation shaft model

Convection block has three inputs, the two are connected with heat, while a third is associated with the external control of convection coefficients. Convection coefficient (1) it is dependent on several parameters, which in turn are tabulated function of temperature.

$$(1) \quad G_c = A \cdot Nu \cdot \frac{\lambda}{x}$$

where: A - area of convection, Nu - Nusselt number, λ - thermal conductivity, x - the way of the convection.

Value of the Nusselt number (2) is directly dependent on two parameters, Grashof numbers (3) and Prandl. Prandl number is a function of temperature. The model uses a polynomial approximation of this number.

$$(2) \quad Nu = C \cdot (Gr \cdot Pr)^n$$

$$(3) \quad Gr = \frac{g \cdot \beta \cdot \Delta t \cdot l_0^3}{\nu^2}$$

where C and n - constant values dependent on product of Gr and Pr, as shown in Table 3, g - acceleration due to gravity, β - coefficient of volume expansion, Δt - temperature difference, l_0 - linear dimension, ν - viscosity index of fluid.

Table 3. Constants C and n as a function of Prandtl and Grashof numbers

Pr·Gr	C	n	The nature of the flow
$<10^{-3}$	0,45	0	No flow
$10^{-3} - 5 \cdot 10^2$	1,18	0,125	Laminar flow
$5 \cdot 10^2 - 2 \cdot 10^7$	0,54	0,25	Transition flow
$>2 \cdot 10^7$	0,135	0,333	Turbulent flow

The parameters appearing in equations (1, 2 and 3), which are functions of temperature, such as viscosity and thermal conductivity in the model are approximated by polynomials, as shown in Figure 5 and Table 4. They are designated based on the characteristics available in the literature.

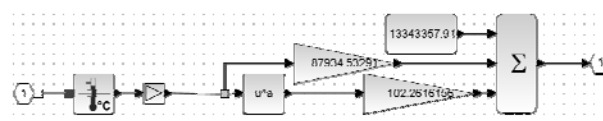







Fig. 5. Numerical model of viscosity approximation

Table 4. superblock approximating tabulated variables

Blok	Opis
	Viscosity - ν - second degree polynomial
	Prandtl number - Pr - eighth degree polynomial
	Fluid density - ρ - fifth degree polynomial
	Specific heat - c_p - fifth degree polynomial
	Thermal conductivity - λ - second degree polynomial

Based on equations and relationships describing the model of Nusselt number, the numerical model of the convection was created, as shown in Figure 6.

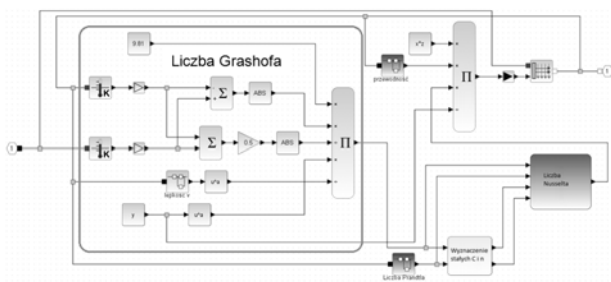


Fig. 6 Diagram shows model of natural convection

The model used two blocks of programmable scripting language Scilab to determine the Nusselt number. Approximation equation of the model parameters are stored in superblocks.

Another element of the model being built is a circuit diagram of air cell, as shown in Figure 7.

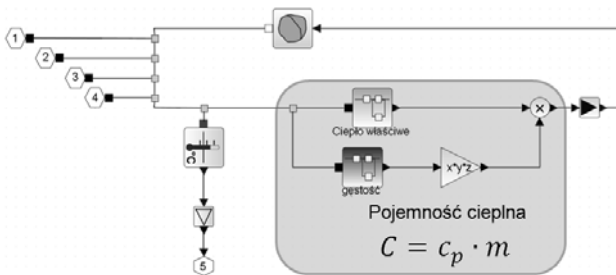


Fig. 7. Block diagram of the air cell model

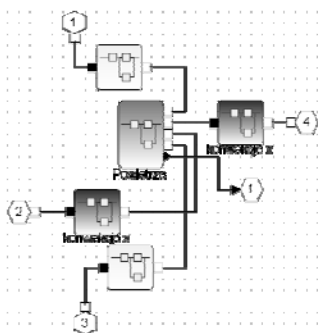


Fig. 8. The calculated system of the temperature of the digitized area with heat transfer blocks

In the proposed model are defined five ports, where four of them are responsible for the transport of heat from the

convection blocks in four directions, and the fifth is an output temperature sensor cells.

A single calculation cell describing the Air, along with calculation blocks realizing heat exchange between adjacent regions in the four possible directions shown in Figure 8.

Numerical model

Construction of the assumed model using blocks programmed and convection air cell has proved impossible to accomplish in Scilab 5.5 environment. The program during the formation of model underwent suspension. It became necessary to make significant simplification of the model by bringing only air cell division along the x-axis.

It seems that the problems with the construction of the assumed model due to the number of blocks in the model (the number reached 1,000 blocks) and the number of links existing between them.

Based on the developed models of calculation, a simulation model was built in an environment Scilab using a Coselica toolbox, as shown in Figure 8.

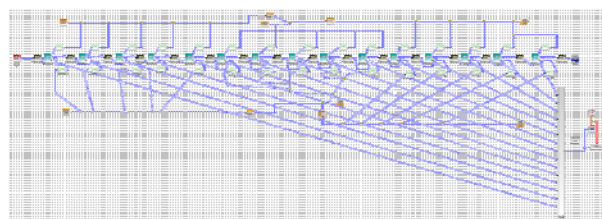


Fig. 8. Numerical model for the simplified ventilation shaft model

Simulation results

Simulations were carried out for two materials of the ventilation shaft, an insulator and a conductor of heat. Simulation parameters are summarized in Table 5.

Table 5. Simulation parameters

Parameter	Value
Time	t_c – Simulation time – 1 s, 200 s k – step of calculation – 0.01 s, 2 s
Temperature	$T_c=100\text{ }^\circ\text{C}$ – temperature of the warm end $T_z=0\text{ }^\circ\text{C}$ – temperature of the cold end $T_s=T_p=10\text{ }^\circ\text{C}$ – initial temperature
Air cell	(x,y,z) – $4 \times 4 \times 20$ cm $p=1013,25$ hPa
Ventilation shaft	Copper: $c_p=380$ J/(kg K), $\lambda=400$ W/(m K), $\rho=8920$ kg/m ³ Glass: $c_p=780$ J/(kg K), $\lambda=1$ W/(m K), $\rho=2500$ kg/m ³

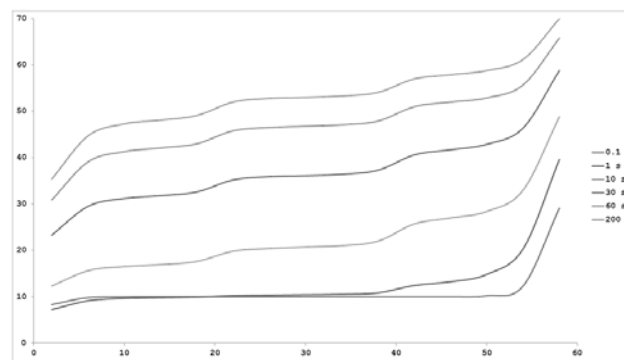


Fig. 9. Temperature distributions along the axis of the shaft at selected time points for the copper shaft

The simulation results presented in the form of temperature distribution along the axis of the ventilation

shaft, as shown in Figures 9 and 10, the selected time steps and the temperature profile over time, as shown in Figures 11 and 12 at selected points in the shaft.

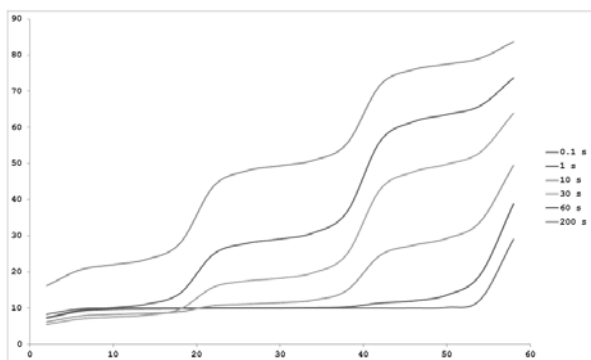


Fig. 10. Temperature distributions along the axis of the shaft at selected time points for the glass shaft

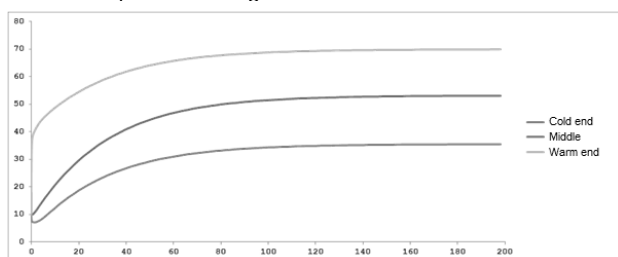


Fig. 11. Courses of change in temperature of the air cell in the copper shaft

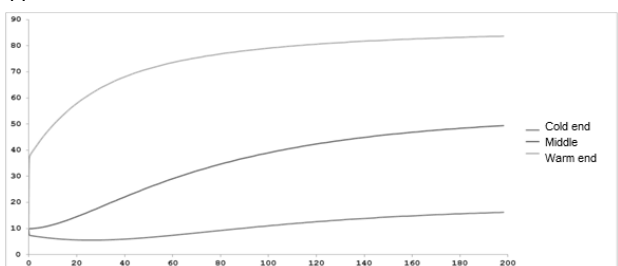


Fig. 12. Courses of change in temperature of the air cell in the glass shaft

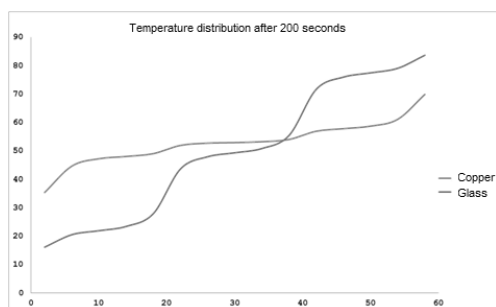


Fig. 13. Comparison of temperature distribution in copper and glass shafts

Additionally presented at Figure 13 compare of temperature distributions in the glass and the copper shafts after 200 seconds of the simulation. It may be noted that in the middle of the shaft similar temperature were obtained.

Noticeable jagged waveforms in Figures 8 and 9 due to a difference at air's discretization and the walls of the shaft were shown. Air was divided into 15 regions but the wall of the shaft only for 3.

The duration of the simulation is dependent on the computer processing power that ranges from about 1.5 hours to 14 hours. The simulations were run on two computational units, one was equipped with i7 processor and 8 GB of RAM, and the second processor Core2Quad and 2 GB of RAM. Although Scilab is in 64-bit version, unfortunately, for proper work toolbox Coselica required 32-bit system Scilab, which results from the application of 32-bit C compiler.

Conclusions

It seems that the modeling method presented in the article passed the exam. It provides a simple and intuitive build even complex models. When using an efficient system of hardware simulation results are obtained fairly quickly.

Open source of Coselica module makes it possible to modify or add your own calculation blocks. This feature makes it possible to reduce the number of blocks occurring in analyzed in the article model by introducing of calculation made by them to the block as opposed to creating the superblock.

The superblock in Xcos'ie is intended only "cosmetic", ordering the visual form of a constructed model. It does not entail a separation model into smaller parts. Created by the Scilab system of equations takes into account all the existing in a model links. Created for the investigated model equations reaches a very large level and despite the simplicity of the model has a very time consuming calculations. This should allow a reduction in the number of blocks of model calculation to about 10% of their current number and in effect build and simulate much more complex models in a much shorter period of time.

It also seems that application of model exchange by convection with a discretized area of calculation was not exactly the right solution. It will be necessary to develop a model based on fluid mechanics to solve described problem properly.

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