

# Thermal simulation of rotating machine equipped with Active Magnetic Bearings

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**Abstract:** Lately higher speed and higher power drive technology is more demanding in many industrial application such as several kinds of turbo machinery ex. compressor, expander and generator relating to various kind of gas processing. Active magnetic bearing should be a one of potential device to support such high power density rotor. On the other hands, high power density will induce several technical problems.

One of these technical problems is thermal problem. Hence the rotor supported by active magnetic bearing can only dissipate generated heat by means of convection and radiation (no conduction), elongation of the rotor may cause serious change in mechanical air gap, especially axial air gap between rotor and touch down bearings shall be carefully considered.

For handling this problem, thermal analysis of entire machine is needed.[1] The mathematical model of entire machine shall be consisting of rotor and all of non-rotating components such as active magnetic bearing's actuator, motor stator, housing and cooling jacket. Further more it is better to simulate transient thermal behavior of each machine components, author has developed Matlab/simlink based simulation tool for this purpose.

## 1. THERMAL SIMULATION

To design active magnetic bearings actuator, it is very much important to check the operation temperature of such actuator under given environment temperature, environment gas, and cooling condition. Normally such operational temperature is limited by insulation temperature of coil windings.

### 1. 1 THERMAL SIMULATION by simulink

Authors constructed block diagram of thermal system which can be expressed by fundamental components of thermal capacitance, thermal transfer block consisting of conductance, convection and radiation. With this system, the system has in-coming heat as system input and temperature as system output. It is interesting to compare above mentioned thermal system model to mechanical system as well as electrical system.

Fig.1 shows system parameter comparison between above mentioned thermal system, mechanical system and electrical system.

It is also remarkable that proposed thermal system does not have a component corresponding to spring in mechanical system or capacitance in electrical system.

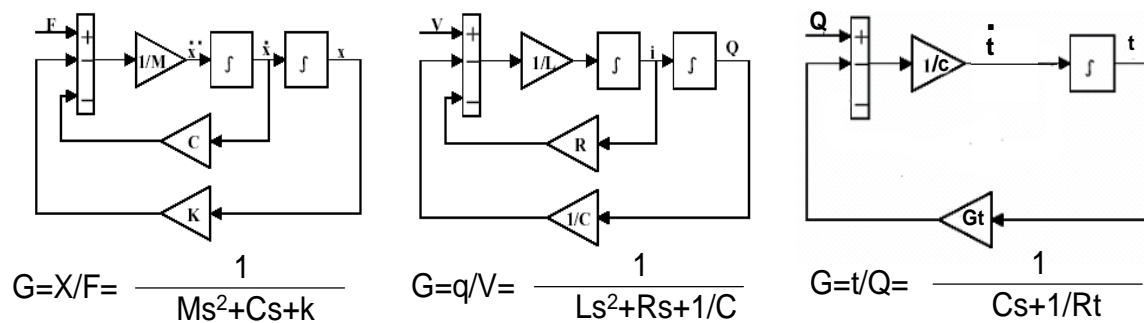


Fig.1 system parameter comparison  
 mechanical system, electrical system. and thermal

## 1.2 Basic behavior of simulink thermal system

Based on the proposed thermal system, temperature behavior of the given thermal capacitance and given thermal conductance with step response heat energy input was simulated. The simulink model of such fundamental system is shown in Fig.2 and temperature behavior is shown in Fig.3.

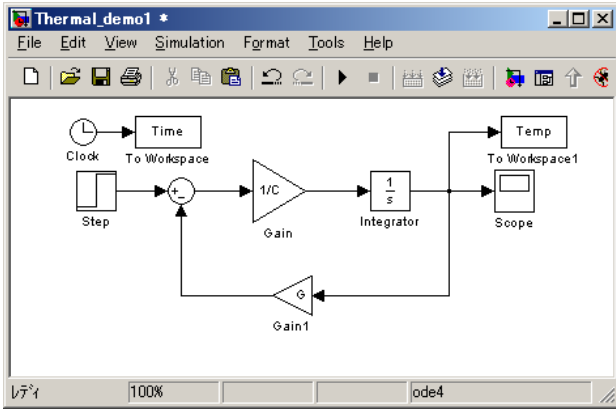


Fig.2 simulink thermal system model

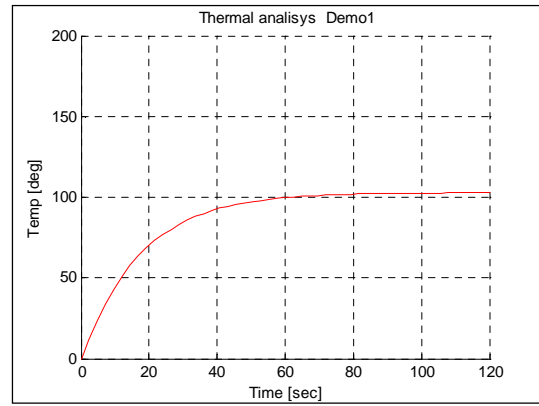


Fig.3 Temperature behavior Fig.2

Hence this fundamental system has heat energy input and temperature as its out put, system can be connected to describe a larger and complicated system.

Fig.4 shows simulink model of 2 blocks and Fig.5 shows its temperature behavior in case of heat energy input in one block.

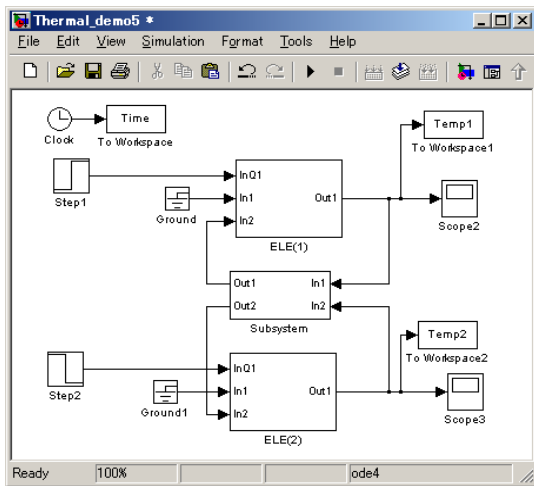


Fig.4 simulink 2 thermal block model

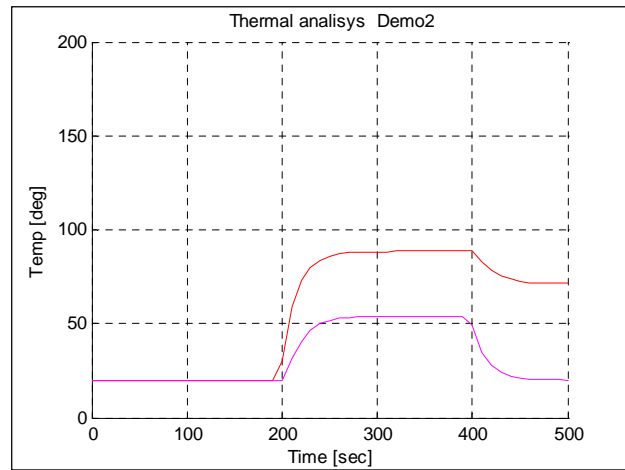


Fig.5 Temperature behavior of Fig.4

In this system description, cooling can be taken into account by setting negative heat energy input to the system block. It is also possible to set radiation as well as convection into this system model.

To verify proposed simulink thermal model, very simple naked coil was simulated. The measured temperature behavior of bear coil with coil current of 1[A] and corresponding simulation result are shown in Fig.6 and Fig.7

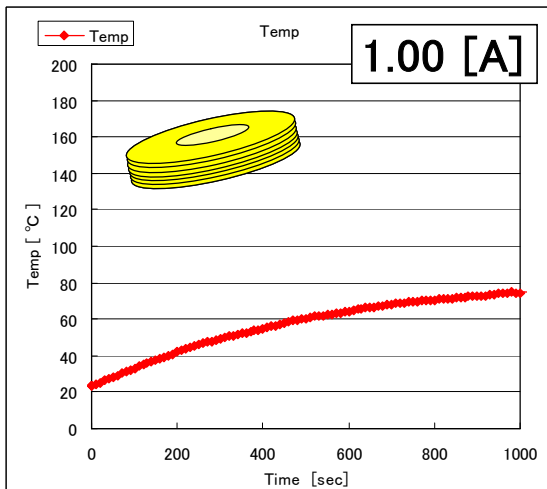


Fig.6 Measured coil temperature

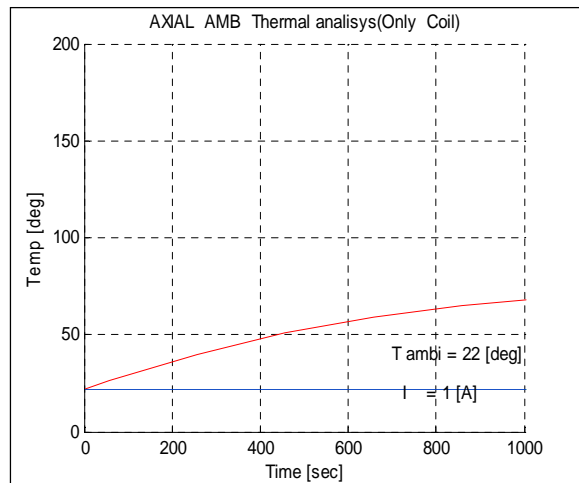


Fig.7 Simulated coil temperature

Judging from the comparison of measured and simulated data, since temperature rise behavior depending on time is quite accurate, thermal capacitance; convection and radiation for the coil are well estimated in this simulink model.

## 1. 2 THERMAL SIMULATION of AMB actuator

In case of simulation of electro-magnets temperature behavior, it is at least needed to establish coil and stator core mathematical thermal model.

### 1. 2. 1 THERMAL SIMULATION of axial AMB

Thermal model of Axial AMB actuator can be obtained by adding iron core block onto above mentioned coil model, even it is possible to enhance the model by adding casing structure around axial AMB or adding epoxy molded effect in the model.

Fig.8 and 9 shows basic thermal model structure of axial AMB and Fig.10 shows measuring set up.

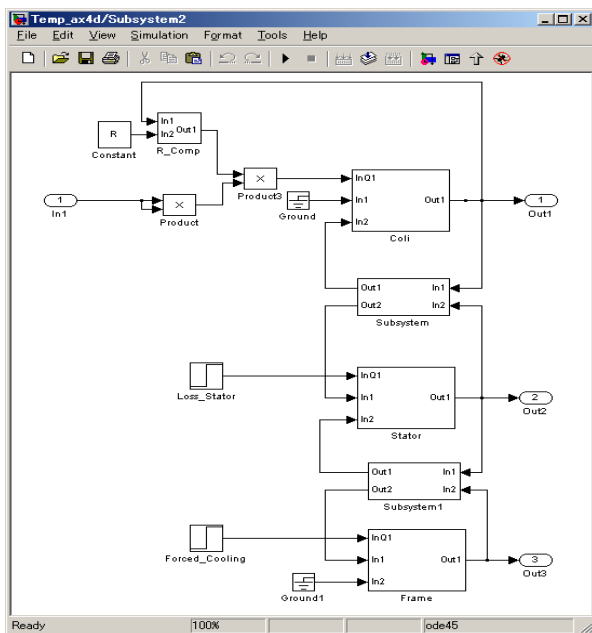


Fig.8 simulink model of AxAMB

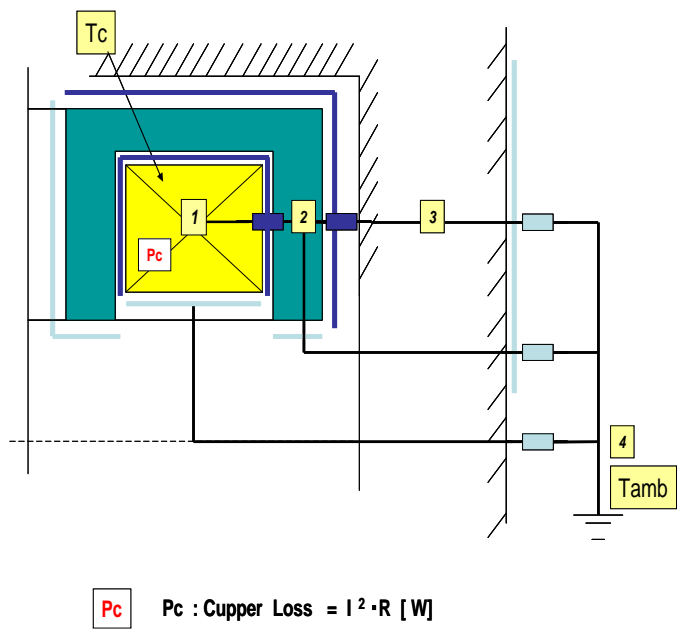


Fig.9 Thermal model of Axial AMB

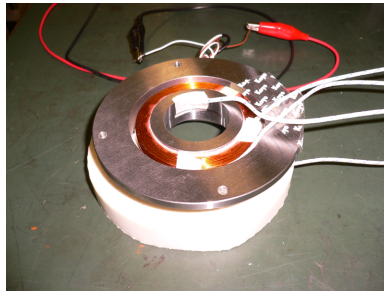


Fig.10 Temperature measurement of AxAMB

Fig 11 shows measured data of AxAMB without epoxy molding of the coil and Fig.12 shows simulated data.

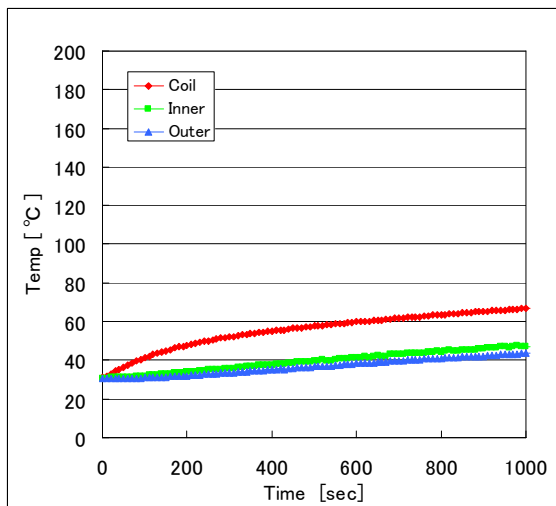


Fig 11 measured data of AxAMB without epoxy molding of the coil

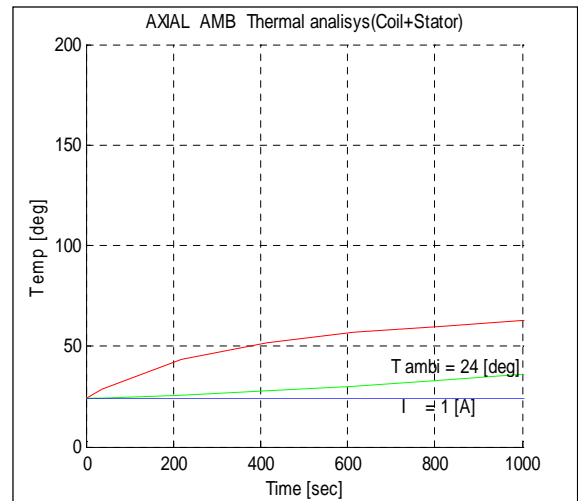


Fig 12 simulated data of AxAMB without epoxy molding of the coil

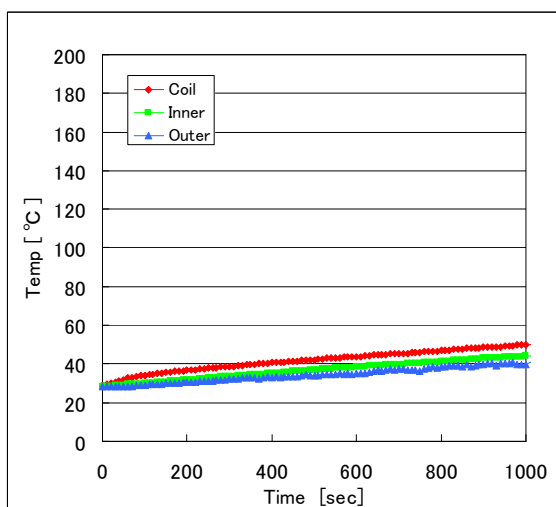


Fig 13 measured data of AxAMB with epoxy molding of the coil

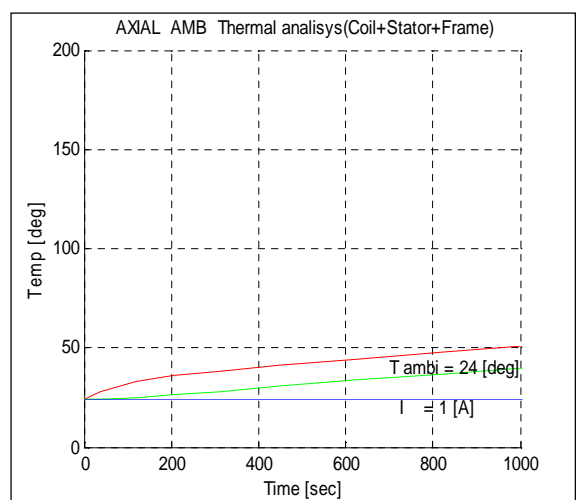


Fig 14 simulated data of AxAMB with epoxy molding of the coil













