Numerical Simulation System for Mould Designer

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Abstract

We report our CAE system on thermal analysis for mould designer who is not expert of numerical simulation. Our mathematical model of thermal analysis is axi-symmetrically. It has an automatic mesh-generator that is based on Delaunay method, by using CAD data. And boundary conditions are also fitted automatically.

1. Introduction

In glass pressing for CRT, metal moulds have non-uniform temperature distributions. It is one of the key techniques to predict the moulds temperature in the manufacture. Since the precision in size or shape of products is dominated by the viscous flow of glass, which depends on temperature.

There are various and complex thermal conditions in the pressing process. It is very difficult to predict the moulds temperature for designers. Therefore the moulds designs are depended on designer's experience. And it takes much time and cost to manufacture new products by trial and error.

A numerical simulation is an effective approach to understand the phenomena. Nowadays there are many commercial soft wares of numerical simulation. They are very useful tool for general-purpose, but only experts can use them efficiently. Further it takes much time for pre-processing; for example mesh generating, setting up input data.

We shall propose CAE system on thermal analysis for mould designers who are not expert in numerical simulation. The mathematical model on thermal analysis is axis-symmetrical. The features of the system are that it has an automatic mesh-generator based on Delaunay method and geometrical data of boundary conditions is also fitted automatically.

2. Numerical simulation system

2.1 Mathematical model

The pressing process for CRT is composed of four main stages as shown in Figure 1. At first stage, molten glass called "gob" falls toward bottom mould. At second stage, gob is pressed by plunger mould and is changed into product shape. At third stage, glass is cooled down by air. At forth stage, glass is token out from bottom mould. Plunger mould presses gob intermittently. Bottom mould repeats form stage 1 to stage 4. Therefore moulds are exposed to cyclic heating and cooling and have non-uniform temperature distributions.

As the mathematical formulation we consider the axis-symmetrical heat transfer [1]. The temperature field in the region Ω is governed by the transient heat transfer equation:

$$\rho c \frac{\partial T}{\partial t} = \frac{1}{r}\left\{ \frac{\partial}{\partial r}\left(\lambda r \frac{\partial T}{\partial r} \right) + \frac{\partial}{\partial z}\left(\lambda r \frac{\partial T}{\partial z} \right) \right\} \qquad (1)$$

subject to the boundary conditions on surface $\partial\Omega$:

$$q = \lambda \frac{\partial T}{\partial n} + h(T_e - T) + e\sigma\left(T_r^4 - T^4\right) \qquad (2)$$

where T is the temperature, t is the time, r and z are the cylindrical co-ordinates, ρ is the mass density, λ is the conductivity, c is the specific heat, $\partial/\partial n$ is the outward normal derivative along $\partial\Omega$, h is the convective heat transfer coefficient, σ is the Stefan-Boltzmann constant and e is the emissivity of radiating and absorbing materials. T_e and T_r are the environmental and the external radiation target temperatures, respectively. Here the treatment of heat transfer between different materials is similar to convective heat transfer.

Equation (1) is discretized in space by using the Galerkin FEM based on quadrilateral elements. The temperature is defined at four vertices of an element and its distribution in by a bilinear polynomial. The time-marching algorithm for transient problem is approximated full-implicit scheme.

2.2 Mesh generation

The system has automatic mesh-generator [2] based on Delaunay method for pre-processing. In the method, at first triangular meshes are generated by using vertices in two-dimensional domain. The feature of the method is that no vertices are involved a circumscribed circle of other triangular mesh in order to obtain precise solution. Next quadrilateral elements are generated with using adjoining triangular meshes.

In this system vertices at mould outline with CAD are given. And vertices in the mould are distributed like structure grid.

3. Illustration for the system

3.1 Procedure of the system

There are various boundary conditions in the process. The system has a function that translates manufacturing operation condition into basic control data on the numerical simulation. The procedure of the numerical simulation is summarized as follows.

1. Control data on simulation is set with linking operation condition.
2. Geometrical data for FEM is generated with CAD.
3. By solving Equation (1), the temperature field is obtained.

When mould design should be modified, the procedure is repeated from step 2.

Figure 2 shows the whole procedure leading to glass pressing. The upper figure shows the conventional procedure and the lower figure shows present one. The present system can reduce a feedback process for mould designs without glass pressing.

3.2 Simulation sample

To illustrate the way of using the system, 7-inch panel glass pressing is shown. This example is a laboratory test. The process is a batch production and not an actual manufacturing process. Each mould in this case is isothermal at first.

The computational conditions are summarized in Table 1. The computational region for every material is subdivided into elements as shown in Figure 3.

In this case, it takes 5.0 second to move the pressing position after loading and gob is pressed for 6.3 second.

Figure 4 shows the temperature contour and Figure 5 shows time histories of temperature at the center of glass inside surface. In the fact, it is the most important key point to identify various parameters such the convective heat transfer coefficient on the simulation. The convective heat transfers between glass and moulds are from 965 to 1500 W/m^2K.

4. References

[1] PITTMAN J. F. T., ZIENKIEWICZ O. C. et al, Numerical Analysis of Forming Processes, Wiley, New York, 1984.

[2] TANIGUCHI T., "Mesh Generation for Finite Element Analysis in Structural Engineering Problems", Proc. Korea-Japan Joint Seminar on Emerging Technology in Structural Engineering and Mechanics, 1988, p. 78-89.

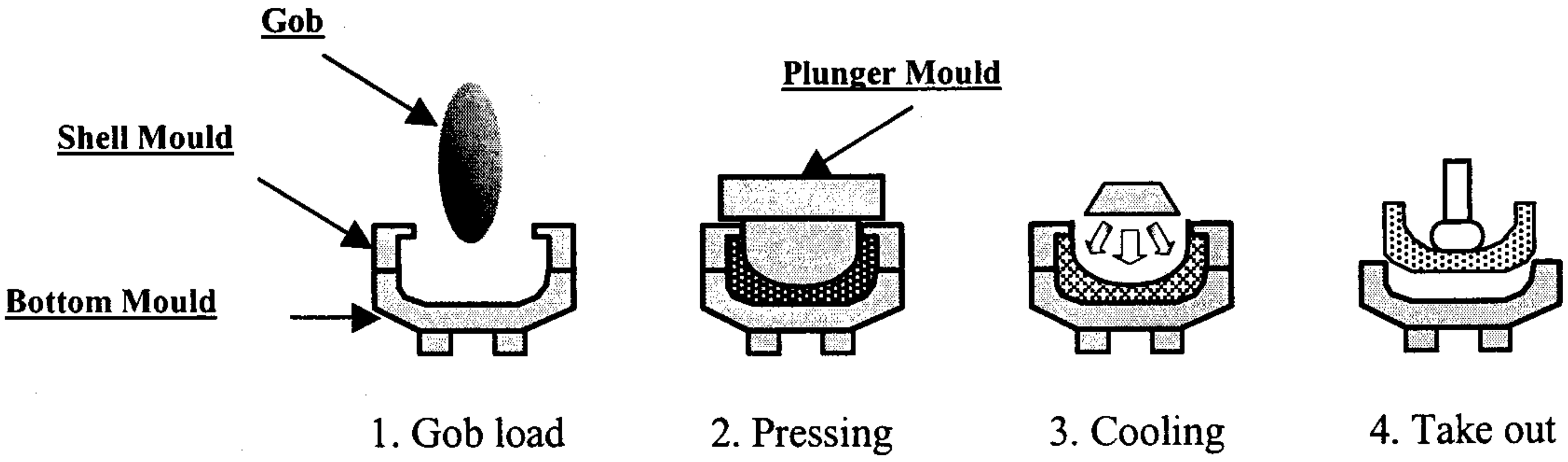

Fig.1: Pressing process for CRT glass

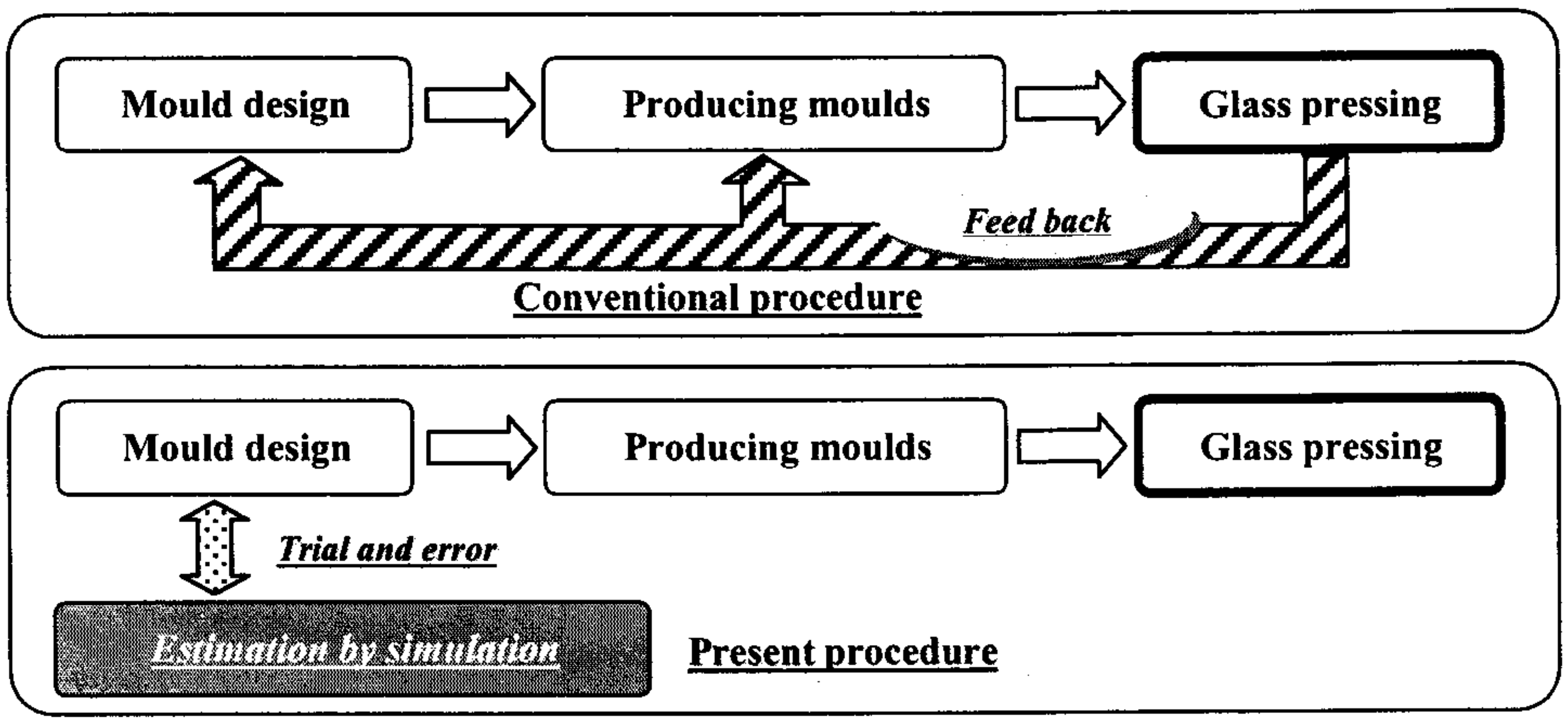

Figure 2. The whole procedure for glass pressing

Table 1. Computational condition

Property	Unit	Glass	Bottom	Shell	Plunger
Density	kg/m^3	2.8×10^3	7.7×10^3	7.7×10^3	7.7×10^3
Conductivity	W/mK	1.74	28.7	33.1	29.8
Specific heat	J/kgK	1.047×10^3	0.46×10^3	0.46×10^3	0.46×10^3
Emissivity	-	0.9	0.7	0.7	0.7
Initial temperature	K	1373	738	773	768
Number of elements	-	1974	1034	278	1376
Number of nodes	-	2129	1157	325	1485

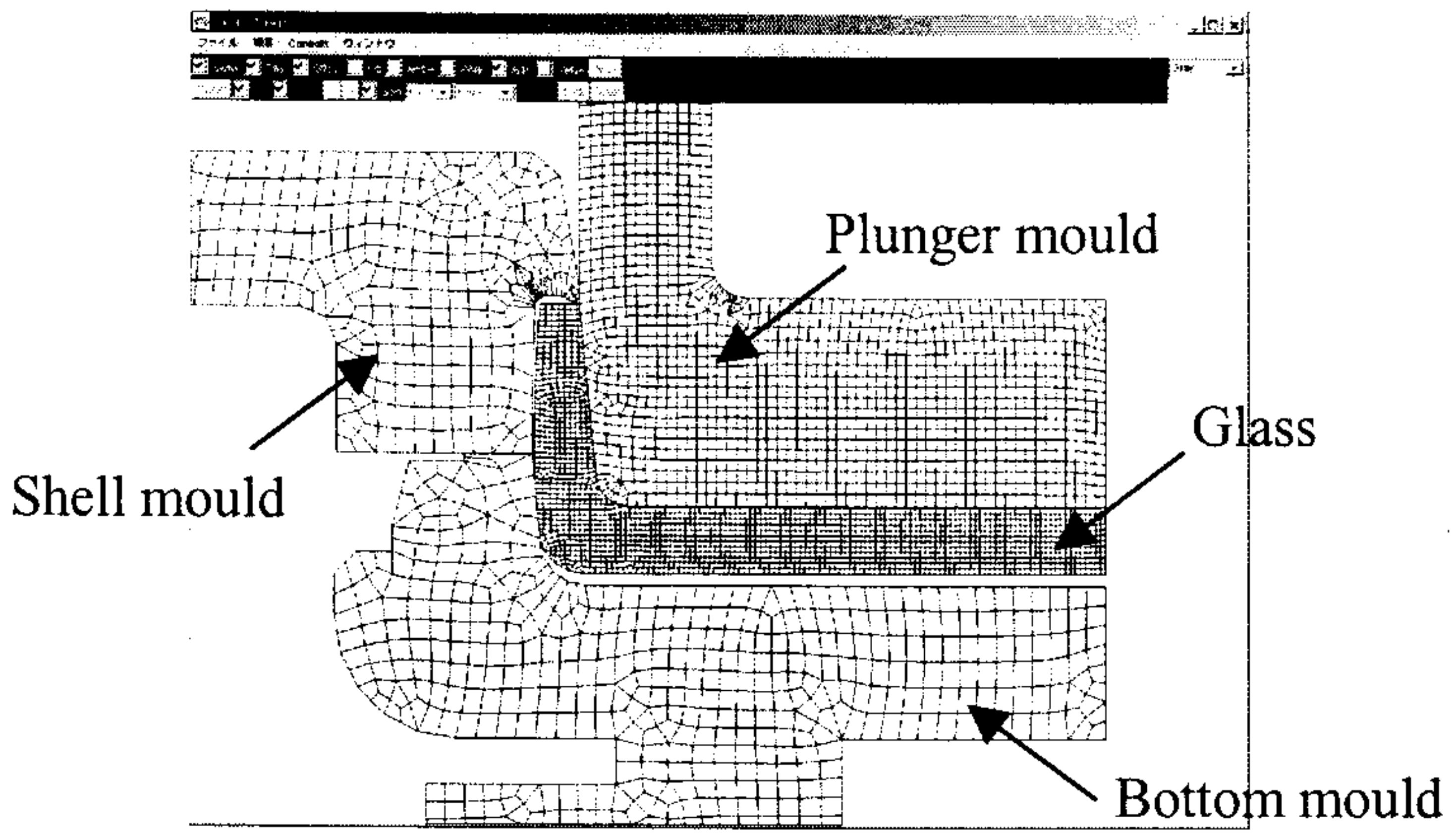

Figure 3. Finite element subdivision of computational domain

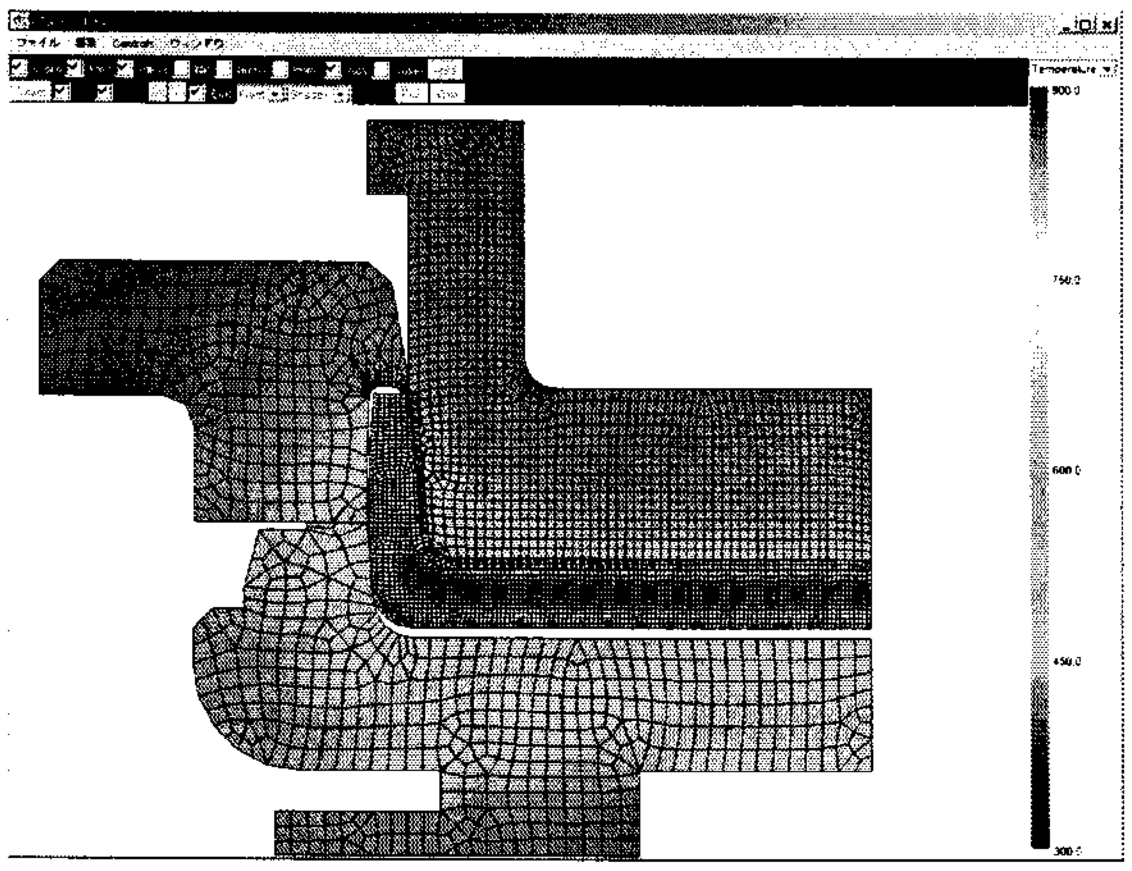

Figure 4. Temperature contour

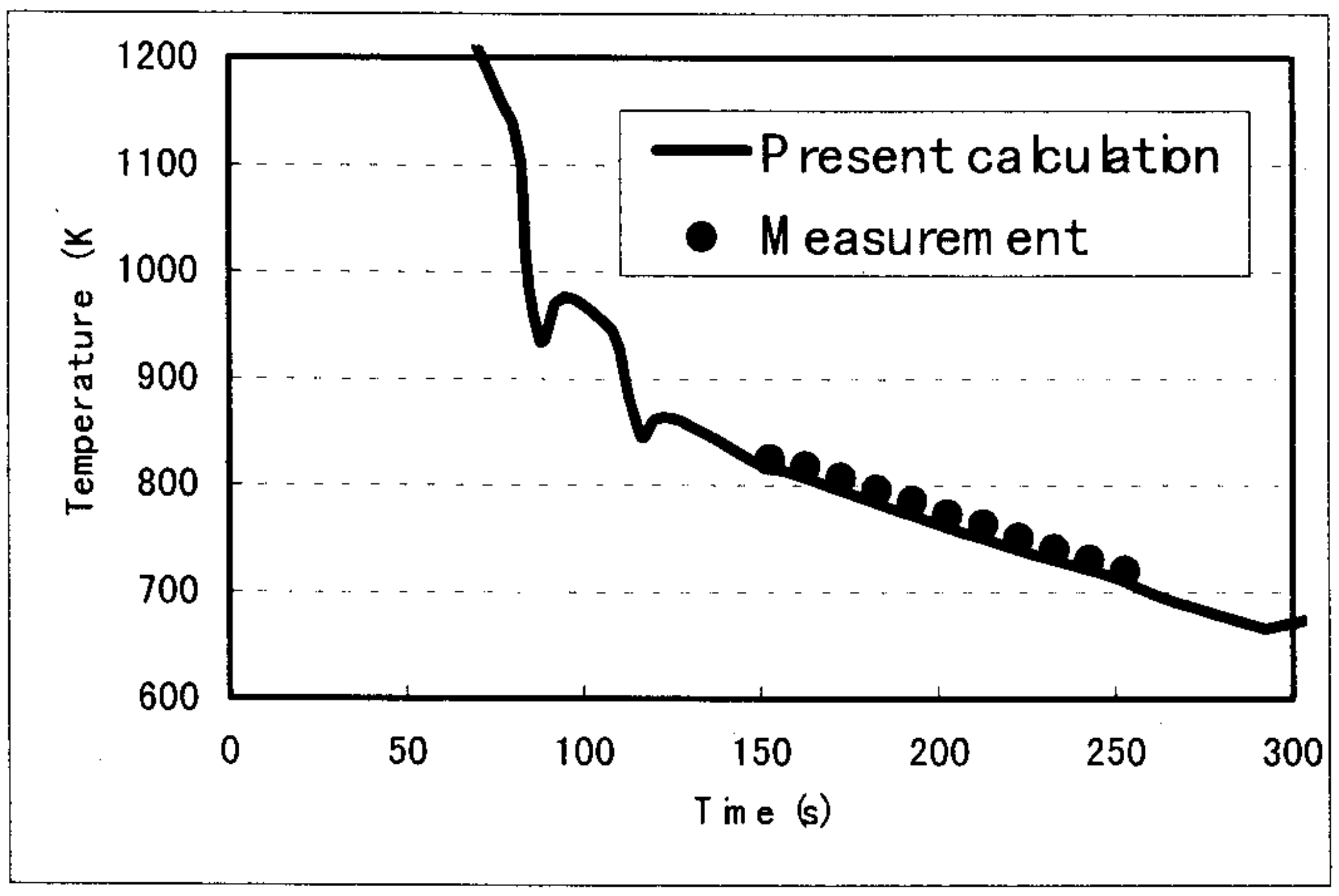

Figure 5. Time history of temperature at the center of glass inside surface