

# A Study on Heat transfer due to Cylinder Block Shape through Analysis

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## Abstract

A computer program has been developed to predict the heat transfer characteristics and the temperature distribution in the cylinder block. The finite element method is employed to handle the complex geometries associated with the practical cylinder block. In this study, the thermal behavior characteristics of the cylinder blocks that formed with integral, V-shaped, W-shaped were analyzed, using the 3-dimensional finite element method. Before numerical analysis were conducted. In this study, the changes of the thermal temperatures are analyzed according to the structures and the times due to the forms of the three cylinder blocks of automobiles.

**Keywords:** Cylinder Block, Finite Element Analysis, Heat Transfer, V-Shaped, W-Shaped

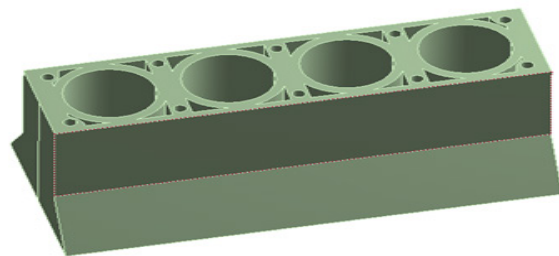
## 1. Introduction

With the recent demand for the improvement of efficiency, the saving of energy, the reduction of pollution, etc. of cars, researches on the high output and the miniaturization of engines have been performed vigorously. According to such trends, the outputs of engines have been increasing and the engine structures have been placed in the thermal loading conditions that are much more excessive than in the past. When the high-output engine gets into the thermal loading condition, the temperature of the wall surface of the combustion chamber gets high and the oil viscosity of the engine gets lowered. Due to the oxidization of the engine oil and others of the like, there is the danger of the ignition plugs and the valves melting down or exploding. Such thermal loading has bad influences on the engine. And it causes knocking, early ignition, the transformation of the cylinder bore, the scuffing of the ring, the transformation of the left side of the valve, etc. Also, the metallic frictions are caused between the cylinder wall and the piston because of the lowering of the viscosity of the engine oil. And, again, because of this, the damages to and the loss of output of

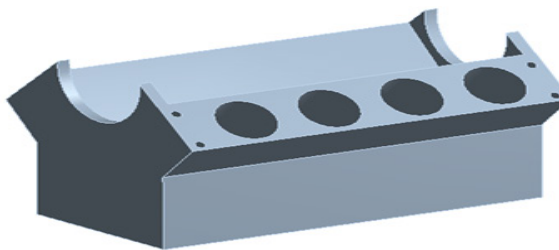
the component parts are caused. In the opposite way, if, in order to unconditionally reduce the thermal loading of the engine, the engine is designed to be cooled so that the temperature of each part of the engine is below the reasonable temperature, it has influences on the evaporation of the fuel. Due to the increase of the amount of consumption of fuel, the incomplete consumption, etc., harmful emissions increase, and the average temperature and pressure are lowered. Therefore, the force exerted on the piston is reduced. Thereby, the reduction of the output of the organ and the lowering of the heat efficiency take place<sup>1-7</sup>. As a result, the engine must operate within a reasonable temperature range. And, for this analysis, the clear and definite evaluations of such thermal loading must take place. It can be said that optimally designing by accurately predicting the thermal behaviors regarding the component parts of the combustion chambers in the initial designing phase based on such evaluations is the core point of engine designing<sup>8-10</sup>. Concurrently with this, in order to heighten the reliability of predictions, it would be important to directly make engines and to investigate the temperature changes through experiments. Generally, the researches on thermal behaviors of the engines' struc-

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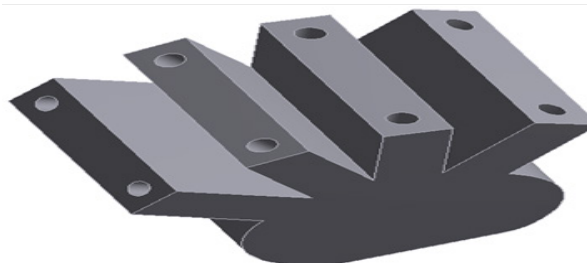
tures can be distinguished into the researches on the thermal deliveries of the structures and the researches on the thermal stresses. And, recently, relating to the thermal stress problems of the high-output engines, the researches on the temperature distributions of the structures have been becoming an important research field<sup>11-14</sup>. However, regarding the analyses of engines' temperatures and the experiments carried until now, most of them have mainly been those relating to the diesel engines based on the researches by Paul E. Allaire. As a result, in this research, the research on the special characteristics of the temperature distributions of the engine structures for cars has been performed regarding the 3 forms of the SOHC engine with 4 cylinders and 4 strokes by using the ANSYS. The research this time has had diverse



**a) Model 1**



**b) Model 2**



**c) Model 3**

**Figure 1.** Analysis models of model 1, model 2 and model 3.

shapes, from the integral cylinder blocks, to the V-form, and to the W-form and has had different numbers of the cylinders. Therefore, differently from the previous experiments, the predictions and the judgments can be made in diverse angles.

## 2. The Study Models and the Analysis Conditions

### 2.1 The Study Models

As seen in Figure 1, this research took a look at the special characteristics of the heat deliveries regarding the 3 forms of the general-type cylinder blocks, the V-type cylinder blocks, and the W-type cylinder blocks of automobiles. Regarding the shapes of the models, the 3D modeling was performed by using the CATIA by referring to the actual cylinder blocks. Afterwards, the heat analysis was carried out by using the ANSYS. The model is a structure steel. The material properties are shown in Table 1. And the joints of the models by each shape and the number of the elements are as shown in Table 2.

**Table 1.** Material Properties

|                                 |               |
|---------------------------------|---------------|
| Young's Modulus (GPa)           | 200           |
| Poisson's Ratio                 | 0.3           |
| Density(kg/m <sup>3</sup> )     | 7850          |
| Thermal Expansion               | 1.2e-005 1/°C |
| Tensile Yield Strength(MPa)     | 250           |
| Compressive Yield Strength(MPa) | 2.50          |
| Tensile Ultimate Strength(MPa)  | 460           |
| Thermal Conductivity(W/m.°C)    | 60.5          |
| Specific Heat(J/kg.°C)          | 434           |

**Table 2.** Number of nodes and elements

| Model   | Nodes | Elements |
|---------|-------|----------|
| Model 1 | 21121 | 11016    |
| Model 2 | 11789 | 11799    |
| Model 3 | 14739 | 7991     |

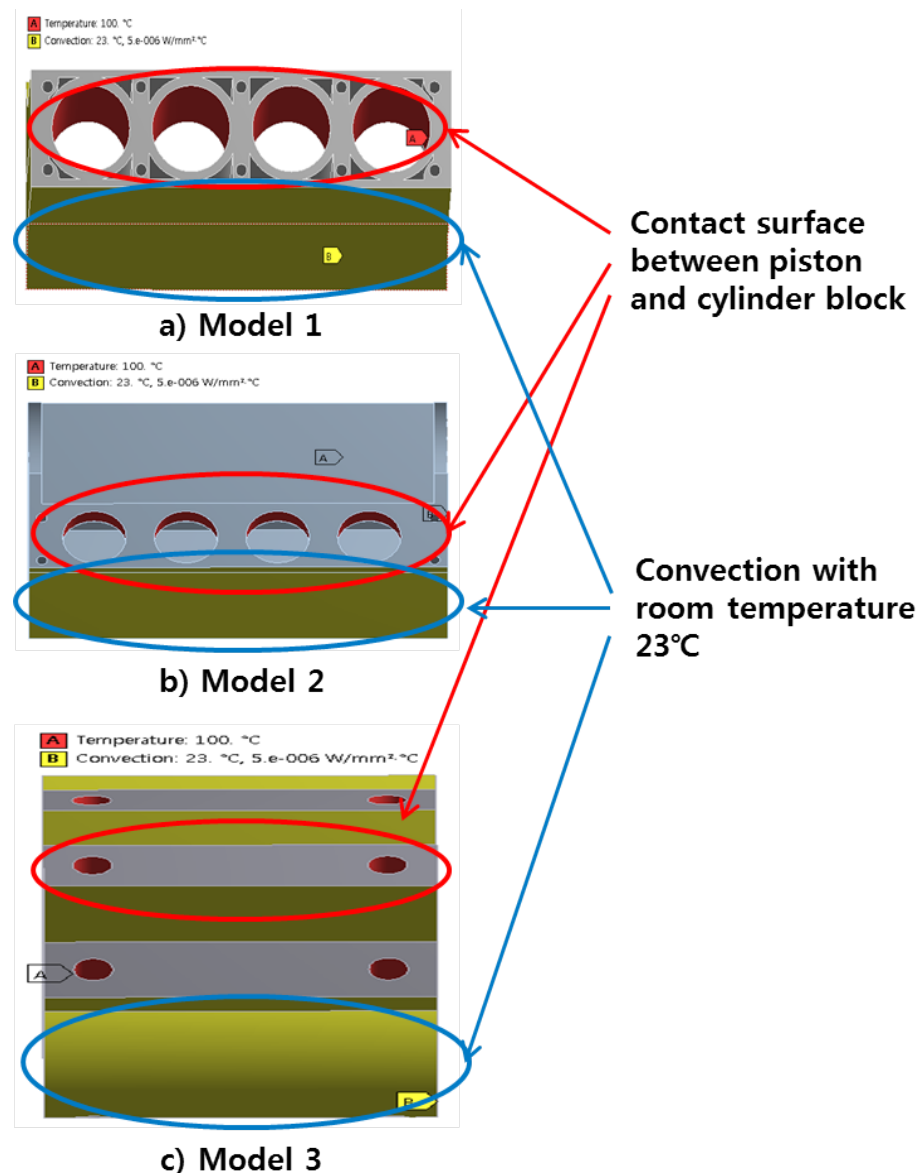
## 2.2 The Setting up of the Analysis Conditions

As for the boundary conditions of the 3 models, it was assumed that the heat of  $100^{\circ}$  was exerted in the same way on the side parts that are in contact with each piston as shown in Figure 2 and that the block wall surface was exposed to the air of  $23^{\circ}$ . The convection setup was made on all the sides that are in contact with air.

## 3. The Analysis Results

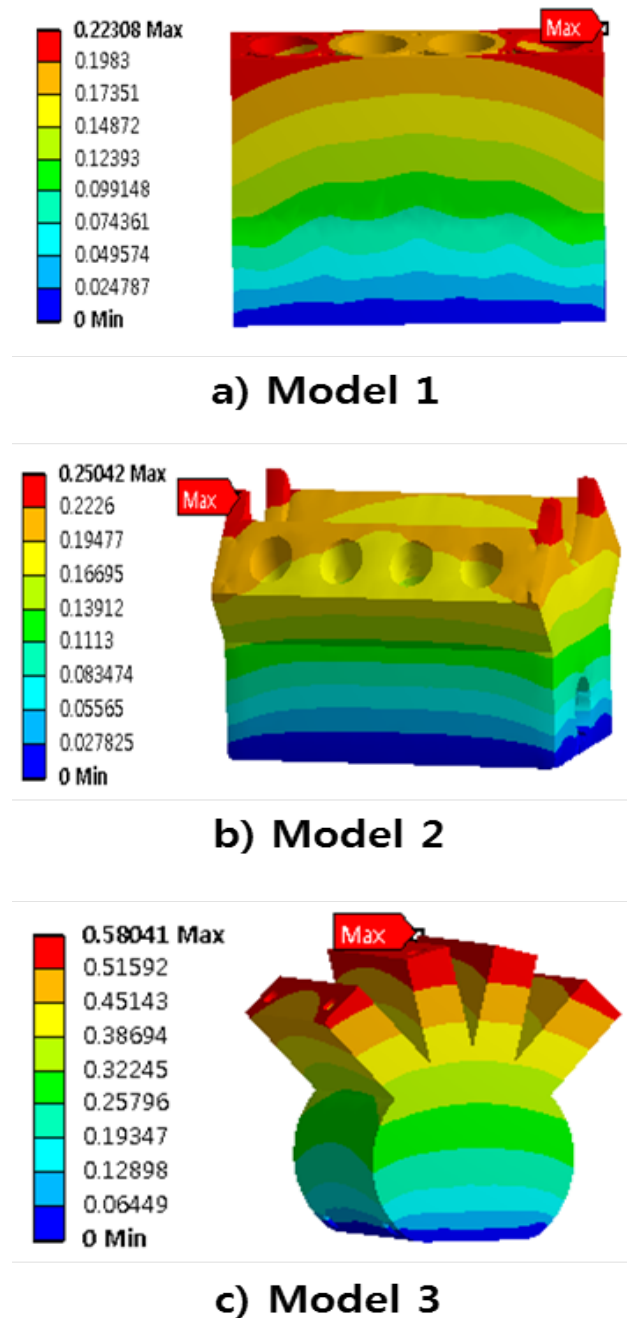
### 3.1 The Results of the Structure Analysis According to the Conditions

Figure 3 shows the results of the analysis regarding the amount of transformation related to the cylinder blocks. The maximum amount of thermal deformation of the model 1 integral cylinder blocks is 0.22308mm. The maximum amount of thermal deformation of the Model



**Figure 2.** Find Cut Dimension – Pseudo Code.

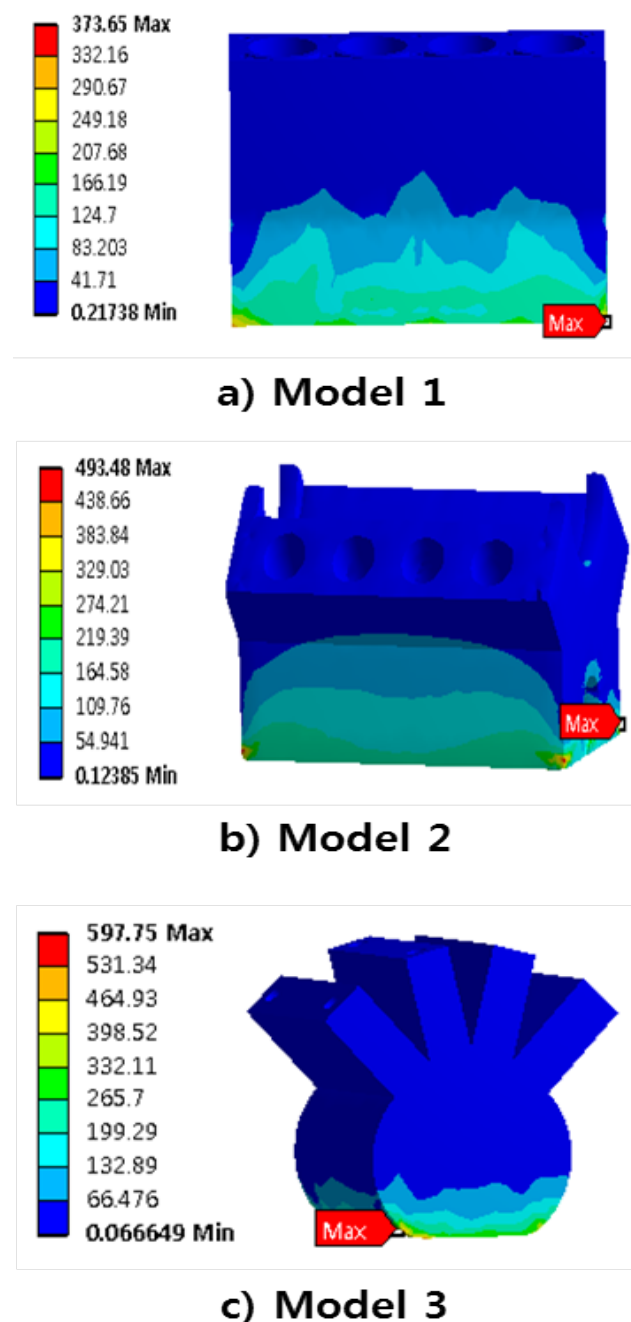
2 V-type cylinder blocks is 0.25042mm. The maximum amount of thermal deformation of the model 3 W-type cylinder blocks is 0.58041mm. As for the V-type cylinder blocks, the external changes of the cylinder can be checked differently from the integral cylinder blocks and the W-type cylinder blocks.



**Figure 3.** Thermal deformations of model 1, model 2 and model 3.

### 3.2 The Results of the Analysis of the Equivalent Stresses

As we take a look at the equivalent stresses of the 3 forms of the cylinder blocks, it is as shown in Figure 4. In the case of the integral-type, the maximum equivalent stress



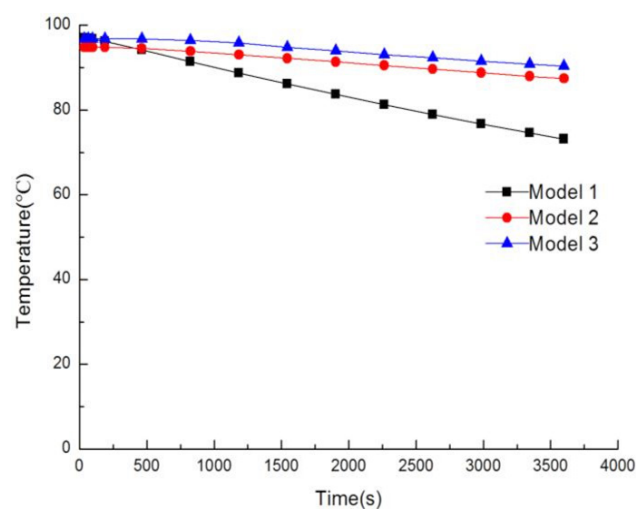
**Figure 4.** Equivalent stresses of model 1, model 2 and model 3.

resulting from the amount of heat transformation is 373.65MPa. The maximum equivalent stress of the V-type cylinder blocks is approximately 494MPa. And the maximum equivalent stress of the W-type is 598MPa. Or, in other words, in the a little bit more structural aspect than the simple integral cylinder blocks, the amounts of the heat transformations of the complicated V-type cylinder blocks and of the W-type cylinder blocks which are a little bit more complicated than the V-type cylinder blocks have big equivalent stresses regarding the amounts of heat transformation.

### 3.3 The Analyses of the Temperatures According to the Times

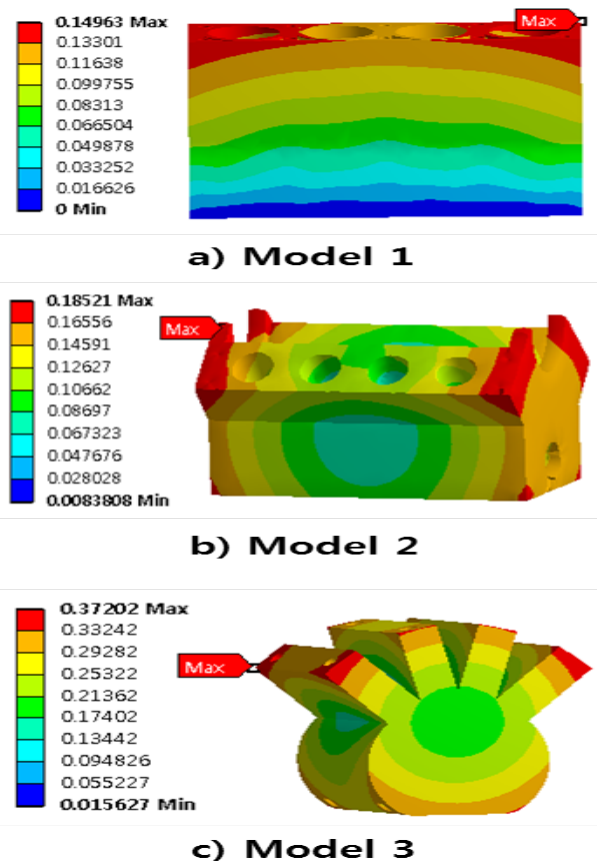
As a result of having performed the temperature analyses of the cooling of the cylinder blocks according to the times when the heat was exerted on each cylinder block, it is as shown in Figure 5. If we take a look at the temperature changes according to the times of the integral cylinder blocks, the temperature begins at approximately 100°, maintains the temperature of 87° by dropping by over 10° when 1544 seconds have passed. And, lastly, it can be confirmed that the temperature is 74.522° when it has become around 3,600 seconds, which is a cooling by a total of 26° from the initial temperature. If we take a look at the amounts of the changes of the temperature according to the times of the V-type cylinder blocks, the temperature maintained 95° ~ 96°, with there being only a little bit of temperature change during the 1544 seconds, with the temperature beginning at approximately 100°. After this, even after 3,600 seconds had passed, the final temperature was 90.78°. Therefore, we were able to see that only approximately 10° of cooling took place. If we take a look at the table of the amounts of the temperatures according to the times of the W-type cylinder blocks, it did not show any big differences of the changes of the temperatures, changing from 100° to 93.774° during the 3,600 seconds.

As we take a look at the whole amounts of the thermal deformations regarding the 3 models after 3600 seconds, we can see that the integral cylinder blocks of model 1 had changed by approximately 0.14963. We can see that the V-type cylinder blocks of Model 2 had changed by 0.18521mm and that the W-type cylinder blocks of model 3 had changed by 0.37202mm. During the 3,600 seconds, approximately 0.07 mm of change took place to model 1.



**Figure 5.** Time-temperature graphs at model 1, model 2 and model 3.

Model 2 had changed by approximately 0.06 mm. And model 3 had changed by approximately 0.2 mm.



**Figure 6.** Thermal deformation after 3600s at model 1, model 2 and model 3.

## 4. Conclusions

In this study, the changes of the thermal temperatures according to the structures and the times due to the forms of the three cylinder blocks of automobiles are analyzed as follows;

As a result of the structural analysis, we can find out that the maximum amounts of the thermal transformations of each of the 3 forms of the cylinder blocks showed big differences in the order of the sizes of the W-type -> the V-type -> the integral when the comparative analysis was performed under the same conditions. Or, in other words, we can find out that the amounts of the thermal transformations of the integral cylinder blocks were the smallest.

As a result of taking a look at the maximum equivalent stresses of the 3 forms of the cylinder blocks, the integral had the smallest equivalent stress. Or, in other words, it can be said that the cylinder blocks of the integral structure is the best.

As a result of interpreting the temperatures according to the times, when looking at the temperature changes according to the times of the three forms of the cylinder blocks, we were able to find out that the integral cylinder blocks had greatly changed by a temperature difference of 25.255°. And we were able to find out that the temperature differences of the remaining V-type cylinder blocks and the remaining W-type cylinder blocks did not show big differences.

As a result of having taken a look at the temperature changes according to the maximum amounts of transformation, the equivalent stresses, and the times, we can say that the integral cylinder blocks are the best form blocks.

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