1 Introduction
Magnesium alloy matrix composites are offering several advantages over other MMCs, including lightweight, better specific strength and modulus. [1-5] Despite the practical significance, relatively little research has been conducted on the thermal property of magnesium alloy matrix composites. [6-8] Coefficient of thermal expansion (CTE) and thermal conductivity (TC) of liquid pressed AZ91 magnesium alloy matrix composites could be affected by reinforcement shape.

The squeeze casting process, one of the conventional fabrication methods for the metal matrix composites, has merits such as high productivity and easiness for near-net-shape fabrication, but has shortcomings of poor reliability, the requirement of high-pressure loading of 50 MPa or more in order to enhance the wettability between reinforcements and matrix, and easy collapse of preform patterns. The liquid pressing process is a new-concept process using low pressure near to the theoretically required minimum loading pressure to infiltrate the metallic melt in reinforcement preform.

The objective of this study is to examine the thermal properties of liquid pressed AZ91 magnesium alloy matrix composites. The change in thermal properties with two different shapes of reinforcement is discussed based on thermal property prediction models and micrographic observations.

2 Experimental
The AZ91 magnesium alloy was used as a matrix of composites. Table 1 shows the chemical composition of AZ91 magnesium alloy.
3 Results and Discussion

3.1 Microstructures

Figure 2 shows the SEM micrographs of AZ91 magnesium alloy matrix composites fabricated with different reinforcement shapes of UD C\textsubscript{f} and SiC\textsubscript{p}, respectively. The reinforcements of UD C\textsubscript{f} and SiC\textsubscript{p} are uniformly distributed through the composites and there is no evidence of pores or separated interface. Figure 2(a) showing that the UD C\textsubscript{f}/AZ91 composite has anisotropic microstructures due to continuous carbon fiber. On the other hand, the SiC\textsubscript{p}/AZ91 composite (Figure 2(b)) has isotropic microstructures due to discontinuous SiC\textsubscript{p}.

3.2 Thermal Properties

Figure 3 shows the experimental and predicted CTE of liquid pressed SiC\textsubscript{p}/AZ91 composite as a function of temperature.

Rule of mixture

\[ \alpha_c = (1-V_f)\alpha_m + V_f \alpha_f \]  

Kerner’s model [9]

\[ \alpha_c = (1-V_f)\alpha_m + V_f \alpha_f + \frac{V_f(1-V_f)(\alpha_f - \alpha_m)(K_f - K_m)}{(1-V_f)K_m + V_fK_f + 3K_mK_f/4G_m} \]  

with

\[ K = \frac{E}{3(3-E/G)} \]
where: $\alpha = \text{CTE}$, $V = \text{volume fraction}$, $K = \text{bulk modulus}$, and subscript $c = \text{composite}$, $f = \text{reinforcement}$, $m = \text{matrix}$

As shown in Figure 3, the predicted Kerner’s model completely matches the experimental result of the SiCp/AZ91 composite.

Figure 4 shows the experimental and predicted CTE of the UD Cf/AZ91 composites. The predicted models do not match the experimental result. The discrepancy between the experimental result and the calculated results of UD Cf/AZ91 composite was considered due to increase in constrain effect of the rigid continuous UD Cf as a softening of magnesium alloy matrix. The stiffness of magnesium alloy matrix decreases with increasing temperature, but there is little change in that of continuous UD Cf at the experimental temperature range. Therefore, the effect of continuous UD Cf on the resistance of thermal expansion increases and the CTE of UD Cf/AZ91 composite decreases.

The thermal expansion of UD Cf reinforced AZ91 composite was also calculated using two different models as follows.

Chamberlain’s model [10]

$\alpha_z = \alpha_0 + \frac{2(\alpha'_0 - \alpha_0)\nu_f}{\nu^2(F - V_f) + (F + V_f)\left(\frac{E_f}{E_m}\right)\left(1 - V_f\right)} (F - V_f)$

(4)

Chamis’s model [10]

$\alpha_z = \alpha'_0 \sqrt{V_f} + \left(1 - \sqrt{V_f}\right)\left(1 + V_f\nu'_0 E'_0 / E_m\right) \alpha''$  

(5)

where: $\alpha = \text{CTE}$, $V = \text{volume fraction}$, $F = \text{packing factor}$, $E = \text{young’s modulus}$, and subscript 1 = 1-direction, 2 = 2-direction, $f = \text{reinforcement}$, $m = \text{matrix}$

Figure 5 and Figure 6 show the TC of SiCp/AZ91 and UD Cf/AZ91 composites with the raw materials of SiCp, UD Cf, and AZ91. The TC of SiCp/AZ91 composite decreased from 84.80 W/mK at room temperature to 77.05 W/mK at 200°C. On the contrary, the TC of UD Cf/AZ91 composite
increased from 6.58 to 8.05 W/mK with increasing temperature. The TC of AZ91 magnesium alloy [11] and carbon fiber [12] increase with increasing temperature and that of SiC decreases with increasing temperature. [13] So the trends of experimental TC of both composites were in good agreement with estimated results from the data of the raw materials. The relatively low TC of both composites comparing with calculated results are considered due to the interfacial defects and reaction layers between matrix and reinforcements. Generally, the interfacial defects and reaction layers disturb the heat flow, which results in the decrease of TC of composite.

4 Conclusions
In this study, the CTE and TC of liquid pressed AZ91 magnesium alloy matrix composites were examined with different reinforcement shape, and the following conclusions are drawn.
1. The prediction of CTE shows that the predicted model of SiCp/AZ91 composite is in good agreement with experimental result. UD C/AZ91 composite, on the other hand, the predicted results exhibited different trends compared to the experimental results. The present study suggests that the discrepancy between the experimental result and the calculated results of UD C/AZ91 composite was considered due to increase in constrain effect of the rigid continuous UD C as a softening of magnesium alloy matrix.
2. The TC of UD C/AZ91 increased with increasing temperature. SiCp/AZ91 composite, on the contrary, shows different trend in TC. It means that the trends of experimental TC of both composites were in good agreement with estimated results from the data of the raw materials. The relatively low TC of both composites comparing with calculated results are considered due to the interfacial defects and reaction layers between matrix and reinforcements.

References