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*General paper*

# COMPRESSION MOLDING OF SANDWICH PLATE USING WASTE CORD ASSEMBLAGE OF SYNTHETIC FABRICS
## Melting Behavior of Waste Cord by Infrared Heating

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**Abstract**: The sandwich-type heat insulating board with fiber assemblage as a core layer was molded by applying a compression molding method to the waste cord assemblage whose surface layer was melted partially beforehand by an infrared heating technique. The fairly small thermal conductivity could be achieved for the present molded plastic board. In the complex phenomena during the molding process, this paper focused on the melting behavior of thermoplastic waste cord of synthetic fabrics heated by the infrared heaters. The melting test was performed in the special closed furnace. The temperature response and distributions in the waste cord assemblage were measured by using thermocouples and the melting behavior was observed for various heating power of the infrared heaters. Moreover, the melting rate was measured for the waste cord assemblages with various void ratios. The simple compression molding method described in this paper shows promise as a contribution towards the recycling of wastes of thermoplastic fibrous material, and the experimental results obtained here may be contribute to the establishment of the optimum molding system.

**Key words** : *Waste of synthetic fabrics, Recycling, Heat insulating board, Compression molding, Melting behavior of fabrics, Infrared heating*

## 1. INTRODUCTION

In recent years, increased emphasis has been placed on developing recycling techniques for industrial waste products, with the goals of protecting the environment. For example, the recycling technique for some plastic products such as PET bottles has already been developed [1]. On the other hand, the textile industry has taken a growing interest in developing a system for recycling waste fibers which result from the process of manufacturing products such as textile fabrics, non-woven fabrics, fishing net, lacy cloth etc.. Most of these wastes are, however, now destroyed by fire or buried underground. In consideration of above circumstances, a few recycling techniques for the wastes of fibers have been investigated by present authors [2,3], where the wastes were recycled as a matrix material of fiber reinforced plastics by using a special injection molding method. Our recent interest is the material recyclability of waste cords of synthetic fabrics as a heat insulating board, because the fiber assemblage has a small thermal conductivity in itself. For example, it is expected that the sandwich-type plastic board with fiber assemblage as a core layer may be molded by applying a compression molding method to the waste cord assemblage whose surface layer is melted partially beforehand by an infrared heating technique. The non-contact heating technique using infrared heaters may be advantageous to solidify the melted thermoplastic fabrics by cooling. In the present molding method, it is important to clear the melting behavior of the waste cord assemblage under the infrared heating, because the resultant thickness of the surface plastic plate largely depends on the melting behavior. Therefore, our consideration of this work focuses on the melting behavior of thermoplastic waste cords of synthetic fabrics heated by the infrared heaters.

## 2. WASTE CORD OF SYNTHETIC FABRIC

During the weaving process of synthetic fabrics using the water jet loom as shown in Fig.1, the waste cord is left continuously because of the special mechanism to protect the slackening of selvage. Figures 2(a) and (b) show the recovery bucket of waste cord next to the loom and the gathered waste cords, respectively. For example, we have 200-250 ton/month of waste cord in Fukui prefecture having 50% market share in synthetic textile industry in Japan. About 80% of the waste cord consists of polyester and the rest is nylon6. In this work the representative waste cord of polyester fabric was used for

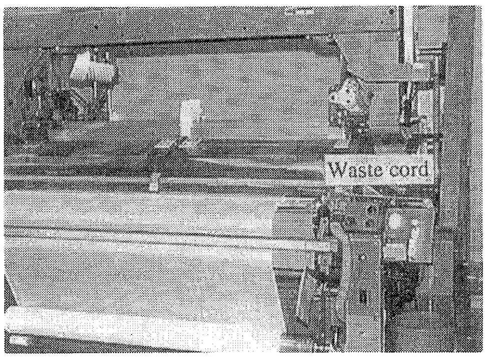


Fig.1. Water jet loom.

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(a) Recovery bucket (b) Gathered waste cord

Fig.2. Waste cord of synthetic fabrics.

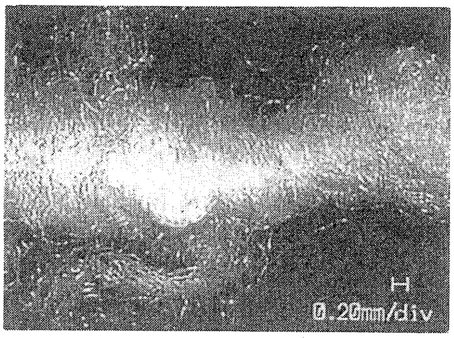



Fig.3. Minute aspect of waste cord.

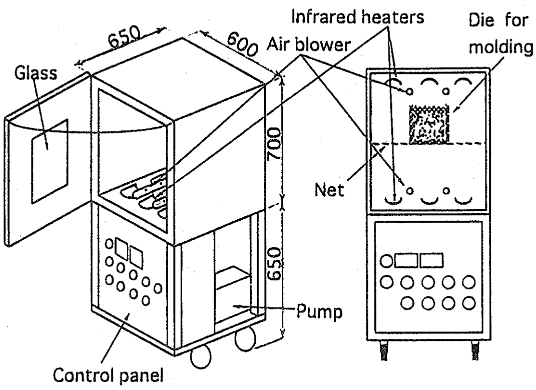



Fig.4. Heating furnace with infrared heaters.

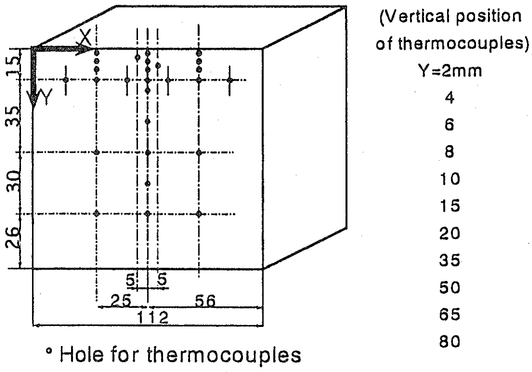



Fig.5. Die for molding.

the molding material. Figure 3 shows the used waste cord minutely, where the cut weft curls around the continuous catcher yarns.

## 3. MOLDING METHOD OF INSULATING BOARD

The molding test was performed in the special closed furnace having separated 18 infrared heaters attached at both upper and lower walls as shown in Fig.4. The die was made of aluminum plates of 3 mm thick and the dimensions are shown in Fig.5. The waste cord assemblage was stuffed into the die with dimensions of 100×100×100mm for molding test. The die was put on the steel net attached to the center of the furnace.

In the present molding method, the upper surface layer of the waste cord assemblage is melted by the infrared heating system in the first place. Aspects of the waste cord assemblage during the process of our molding system were photographed at the outside of the die as shown in Figs.6(**A**)-(**E**). Figures **A** and **B** show the aspects before and after melting process, respectively. After the melting process the compression molding is performed with cooling at the outside of the furnace. As a result, the waste cord assemblage is solidified at the upper surface layer. The aspect of this state becomes **C**. The reverse side of the waste cord assemblage is also melted in the furnace as shown by **D** and the compression molding is performed again. The finished sandwich-type insulating board with non-melted fiber assemblage in the core layer can be obtained as shown by **E**. Thickness of the molded surface plastic layer will depend largely on the melting behavior, and will affect the insulating property.

The insulating property of molded board was examined roughly by measuring the temperatures $T_1$-$T_5$ of experimental system shown in Fig.7 where the acrylic plate was used as a standard specimen having known thermal conductivity. The examples of the temperature response are shown in Fig.8 for molded board and acrylic plate with same thickness, where the temperature $T_1$ and $T_5$ are controlled at 61.7℃ and 17.1℃, respectively. As shown in the figure, the surface temperature $T_2$ is higher for our molded board in comparison with the case of acrylic plate. The experimental results showed that the apparent thermal conductivity of molded board was 40% of that of acrylic plate. This means that the molded board is good for the heat insulating material. The minute consideration of insulating and mechanical properties will be discussed in another paper. This paper focuses on the melting behavior of synthetic waste cord assemblage under the infrared heating system.

## 4. TEMPERATURE MEASUREMENT AND MELTING TEST

The melting test was performed in the same furnace discussed above. The temperatures in the waste cord assemblage were also measured in the experiments. The small holes for thermocouples were shown in Fig.5, and the thermocouples of type K with 0.2 mm diameter were

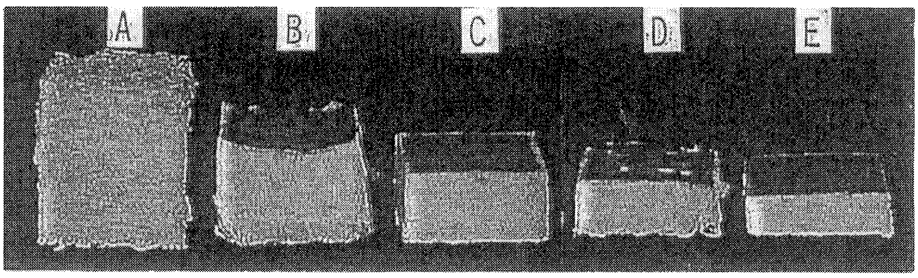



Fig.6. Aspects of waste cord assemblage during molding.

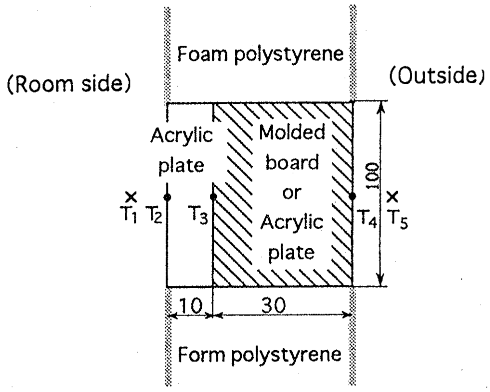



Fig.7. Measuring system for insulating property.

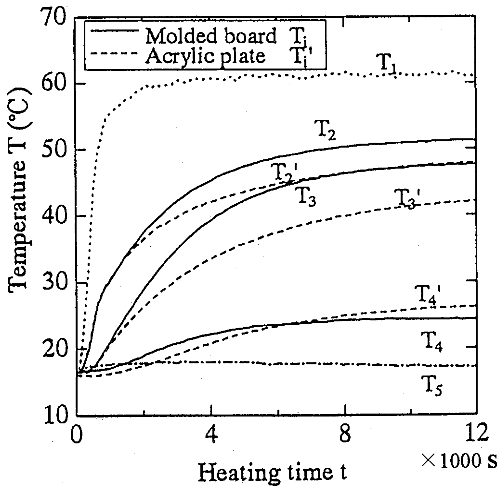


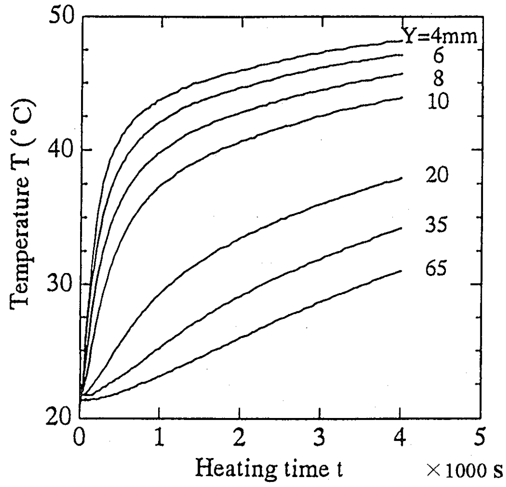

Fig.8. Measuring of insulating property.

inserted horizontally into the middle portion of die. The initial void ratio $V_f$ within the waste cord assemblage was varied 0.8-0.95 in the experiments, where the value of $V_f$ was evaluated from the known values such as volume of die, mass of waste cord assemblage and density of polyester. The initial vertical distance between upper infrared heaters and the upper surface of waste cord assemblage was fixed at 170mm throughout the experiments. The melting test was performed for various temperatures $T_h$ of upper infrared heaters.

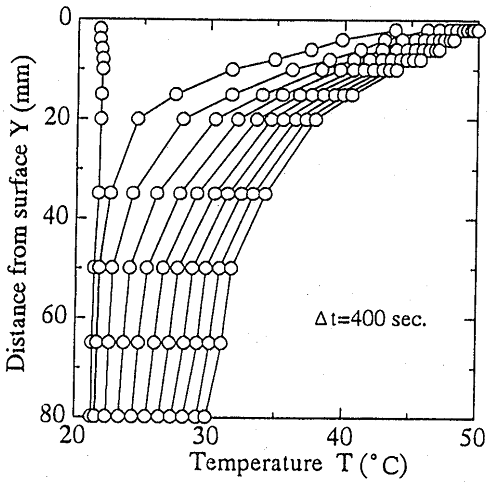
## 5. EXPERIMENTAL RESULTS AND DISCUSSION

### 5.1. Temperature Response and Distribution

Attention is first focused upon the temperature response and distribution of the waste cord assemblage heated by the upper infrared heaters, and the typical results of $V_f$=0.95 and $T_h$=80℃ are shown in Figs.9(a) and (b). As shown in the figures, the temperature rises




(a) Temperature response




(b) Temperature distribution

Fig.9. Temperature fields. ($V_f$=0.95, $T_h$=80℃)

suddenly at the surface region, especially upper 20 mm region in this case of the waste cord assemblage. It is easy to expect that the temperature fields largely depend on the void ratio $V_f$. Figure 10 shows the effect of $V_f$ on the vertical temperature distribution in the waste cord assemblage. As expected, the temperature rises rapidly

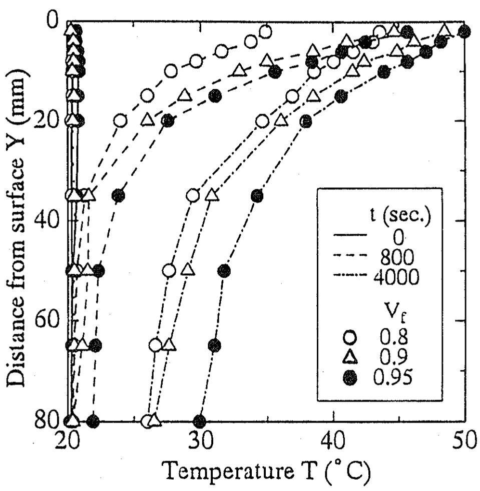



Fig.10. Effect of $V_f$ on temperature fields. ($T_h$=80℃)

And also widely for the case of large $V_f$, because the thermal difusivity of air is fairly larger than that of polyester resin of waste cord.

**5.2. Melting Behavior**

Figure 11 shows the aspects of melting behavior of waste cord assemblage of $V_f$=0.9 during the melting process, where the temperature of upper heaters was fixed at 400℃. The waste cord assemblage was photographed after the solidification of melted surface by taking out it from the die. Therefore, each photograph indicates the different specimens. It is noted from the figure that the surface of the waste cord assemblage subsides downward with melting and keeps almost horizontal at $t$=2400s in spite of the subsidence of almost 40mm. Figure 12 shows the effect of heating temperature on the melting behavior. The non-uniform melting can be seen in the figure of low temperature (350℃), where the melting region spread locally. This may be caused by the following reason. Namely, the surface temperatures of the waste cord assemblage are not uniform always and exceed the melting point locally in the case of low temperature of heater. Once the melting of wastes occurs locally, the melted resin soaks into the non-melted waste cord assemblage, and the thermal conductivity and the effective area of heat conduction increase there. As a

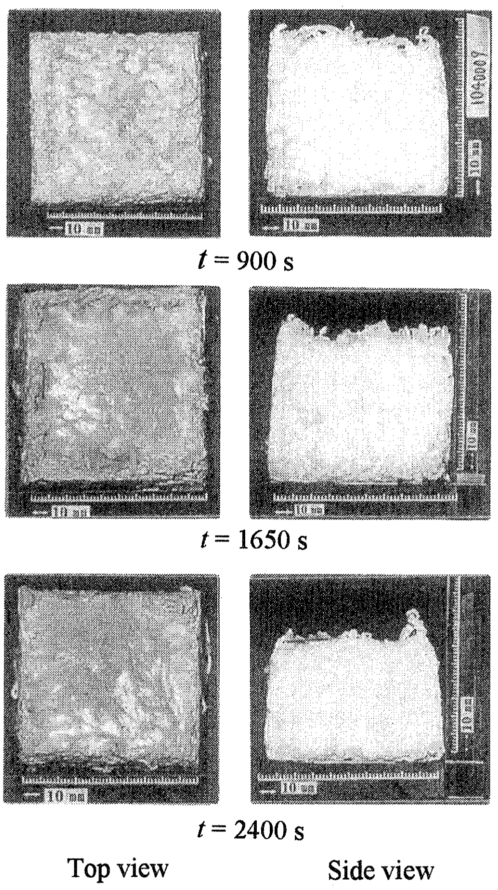



Fig.11. Aspect of melted waste cord. ($V_f$=0.9, $T_h$=400℃)

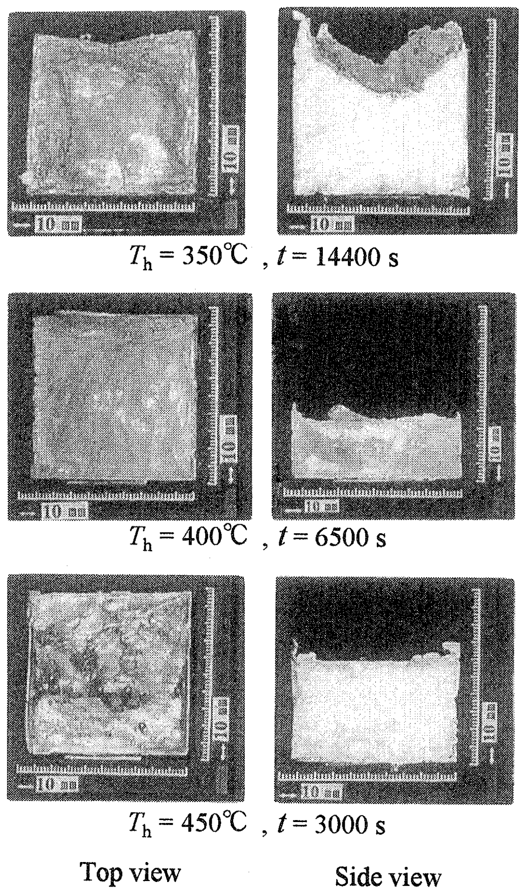
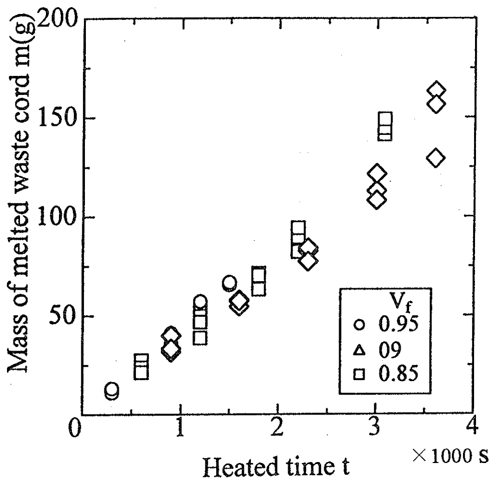
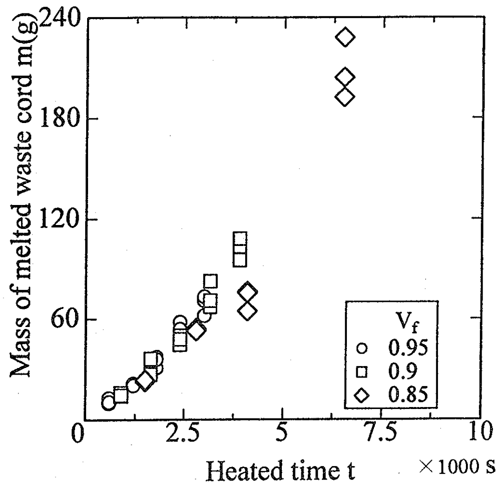


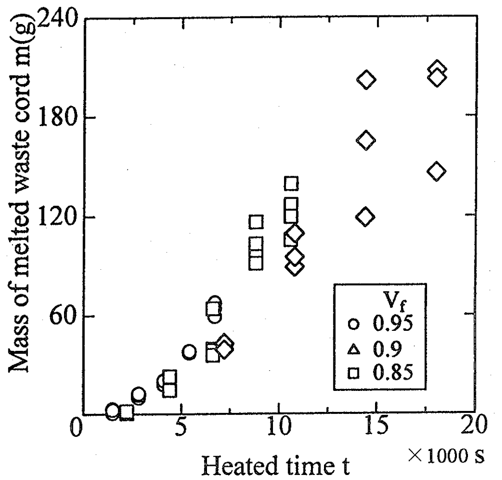

Fig.12. Aspects of melted waste cord. ($V_f$=0.85)




(a) $T_h$ = 450℃




(b) $T_h$ = 400℃




(c) $T_h$ = 350℃

Fig.13. Effect of $V_f$ on mass of melted waste cord.

result, the melting should concentrate on the local region. In the case of high temperature of heater, the surface temperature of waste cord assemblage exceed the melting point everywhere and then the waste cord melts almost uniformly as shown in the figures of $T_h$=400 and 450℃. Notice, however, that in the case of higher set temperature, the resin has thermal damage such as burn.

Attention will now be turned to the melting rate. The mass of the melted waste cord assemblage was measured at the various heating times by using a precision balance after removing the non-melted waste cord. The measured mass is plotted as a function of heating time in Figs.13 (a), (b) and (c) for $T_h$=450, 400 and 350℃, respectively. As shown in these figures, the mass increases with increasing heating time with almost linear variation. The large variation in data can be seen in the case of low temperature of heater, especially for small $V_f$. This may be caused by the non-uniform melting of waste cord assemblage discussed above. It should be noted here that there is only a small effect of $V_f$ on the mass. Namely, the melted mass of the waste cord becomes almost constant independently of the void ratio under the fixed heating time. This fact may be caused by the following temperature fields in the waste cord assemblage. Figure 14 shows the temperature response in the waste cord assemblage again for the case of $T_h$=450℃. The melting point of the waste cord is also shown in the figure. It is noted from the figure, that the temperature near the surface rises suddenly and reaches at the melting point quickly for the case of large $V_f$. The area of the temperature fields of over melting point becomes wider for the case of larger $V_f$ under the fixed heating time. It is noted, however, that the mass of waste cord existing there is smaller for the case of larger $V_f$. As a result, the mass of the melted waste cord may be almost constant independently of the void ratio under the fixed heating time.

The rising rate of the temperature decreases suddenly when the temperature exceeds the melting point in the figure. This means that the surface of the melted waste cord assemblage reaches the fixed position of the thermocouple, and the thermocouple goes outside of the waste cord assemblage. The temperature at the inflection point is higher for larger Y because the melted resin heated longer time reaches there.

Figure 15 shows the effect of temperature of heater on the temperature response in the case of $V_f$=0.85. As expected, the temperature rises more quickly and the inflection of temperature response can be seen in early heating time for higher temperature of heater. Moreover, the temperature of upper surface of the waste cord assemblage takes a fairly higher value. Therefore, the surface of the melted waste cord assemblage is in danger of having thermal damage, if the temperature of heater has a higher value.

## 6. CONCLUSION

The melting behavior of thermoplastic waste cord of synthetic fabrics heated by the infrared heaters has been investigated. The following results are obtained;

(1) The fairly small thermal conductivity could be

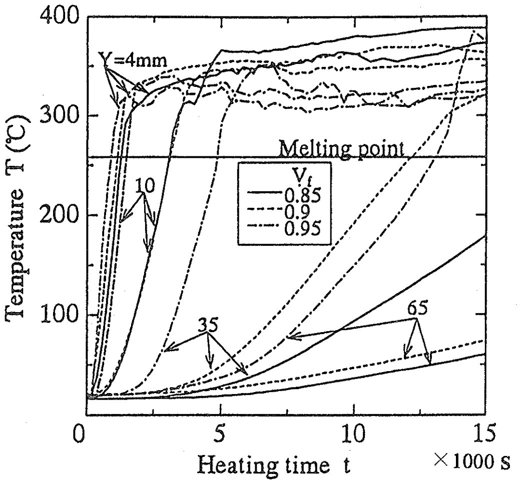



Fig.14. Effect of $V_f$ on temperature response. ($T_h$=450℃)

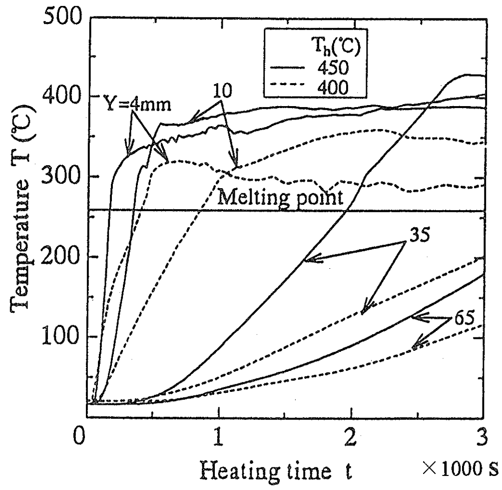



Fig.15. Effect of $T_h$ on temperature response. ($V_f$=0.85)

achieved for the present molded plastic board.

(2) Under the infrared heating, the temperature of the waste cord assemblage rises rapidly and also widely for the case of large void ratio.

(3) The surface temperature of the waste cord assemblage is not always uniform and exceeds the melting point locally in the case of low temperature of heater.

(4) The melted mass of the waste cord becomes almost constant independently of the void ratio under the fixed heating time.

This is a first step of our consideration about the recycling system of waste cord of synthetic fabrics, and the results were obtained from the special case of experiments. The results obtained in this paper, however, may contribute to the establishment of the compression molding system of the heat insulating board using a waste cord assemblage.

## REFERENCES

1. G.E.Wissler, Proc. of ANTEC Conf., (1990)1434.
2. T.Kimura, M.Takeuchi and K.Nakanishi, Proc. of ICCM-10, Vol.VI (ed. by A.Poursartip and K.Street), The 10th Int. Conf. on Composite Material Society, Canada (1995)373.
3. T.Kimura, M.Takeuchi and K.Nakanishi, Proc. of 4th Japan Int. SAMPE Symposium, Vol.2 (ed. by Z.Maekawa, E.Nakata and Y.Sakatani), Soc. Adv. Mater. Process Eng., Japan (1995)777.