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Study on the Effects of Various Factors on Side Seal Strength

Tsuyoshi NISHIZAKA*, Takeshi DOI ** and Hiroyuki SHIRAIWA**

The purpose of this study is to improve the strength of side seal bag. For that purpose, the form of heat cutter, material of heat cutter and operating conditions were examined. Side seal method is one of the bag-making methods. Flat films put on two sheets, such as CPP (Cast Polypropylene film) and OPP (Oriented Polypropylene film), are cut thermally and welded by the specified width. The relation between the intensity of a side seal bag and each operating condition was investigated. A breaking load of CPP film increases with increasing thickness of film. When a thickness of CPP film becomes over 30 micrometers and over the breaking load become almost steady value. A breaking load increases with decreasing the number of times per minute of decision. A breaking load increases with increasing preset temperature of a heater. Additionally, as a result of executing a two-dimensional heat conduction FE (Finite Element) program which changed the material (thermal conductivity) of the heat cutter, it was ascertained that thermal conductivity of cutter affects greatly temperature near the tip of cutter. Furthermore, the shape of the heat cutter which may be able to improve temperature near the tip of cutter was examined.
Keywords：cutter, side seal, thermal conductivity, finite element program

1. Introduction

Bags have become an indispensable part of our daily life. The most common type of bag is currently plastic. There are even many different types of plastic bags depending on the manufacturing method and the materials. These bags are cheap, thin, flexible, come in plenty of sizes and therefore, have become an indispensable item in our daily lives for uses such as when shopping or disposing of garbage. However, insufficient side seal strength has become a serious problem in bag manufacturing, and as a result, research and development is being conducted daily to improve this strength.[1,2)]

The side sealing method is used in this study as a representative of the many bag-production methods. Bags manufactured with this method are used mostly for wrapping stationary and accessories. However, if the conditions during production, such as the temperature of the heat cutter or the number of shots (cutting speed: shot/min), are not optimal, then the weld can be either insufficient or excessive, which causes problems such as lines and pinholes in the exterior, and greatly affects the deterioration of the strength of the bag, in addition to the deterioration of strength of the weld. It is extremely important to

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reliably manufacture satisfactory products to control the occurrence of these issues. This study investigated factors such as the shape and material for the heat cutter used to cut and weld bags during production, and investigated the conditions during operations to help improve the bag strength (side seal strength) created by the side sealing method, and aims to optimize these factors as its ultimate objective.

This study includes strength tests for bags made by the side sealing method to examine the relationship between the breaking load and operating conditions. Finally, this study investigated methods to increase side seal strength using numerical analysis[3)].

2. Fundamental Items Related to Bag Manufacturing

2.1 The Side Sealing Method

Side sealing[4)] is one method of bag production that stacks 2 sheets of flat film such as

• CPP (Cast Polypropylene film) and

• OPP (Oriented Polypropylene film)

and cut/welds these sheets together at a specified width. CPP, OPP, and laminate are respectively, un-stretched polypropylene, biaxial stretched polypropylene, and CPP and OPP joined together. Figure 1 shows an example of a bag made using side sealing production method. The long side of the rectangular bag is the seal.

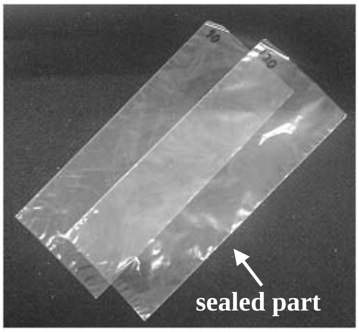


Fig.1 Example of a bag made using the side sealing production method

3. Practical Examination of Side Seal Strength

We investigated the cause and effect relationship between the manufacturing strength of side-sealed bags and each operating condition. Each operating condition means the film material[5)] (CPP, OPP, or laminate), thickness of materials (20～70 μm), preset heater temperature (430～440℃), shot number (cutting speed: 40～140 shot/min) and heat cutter material (stainless) .

3.1 Method

Five samples were collected from each of the 27 production machines and the collection date, manufacturing number, production machine number, preset heater temperature, shot number, material, maker name, and material thickness were recorded.

i) Three of the five sheets were evenly distributed to make the specimen (Figure 2).

ii) The specimen had both ends fixed using the same method as the standard stretch test and was stretched until it broke.

iii) The load at breaking point was designated as the breaking load. The breaking load and its shape (Figure 3) were recorded on each occasion.

3.2 Results

The relationship between the breaking load and the operating conditions is shown in Fig.4–Fig.8. Figure 2 shows the front and back of the bag referred to in the other figures. Also, the composite thickness of the laminate used in Figure 6 is the sum of the thicknesses of both the CPP and OPP films that were used to make it.

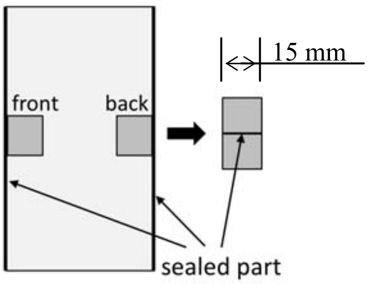


Fig.2 Specimen

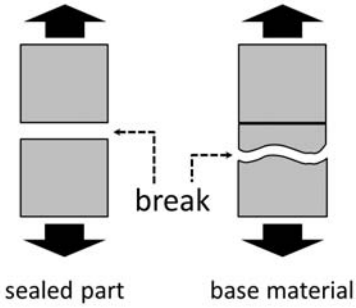


Fig.3 Schematic of break pattern

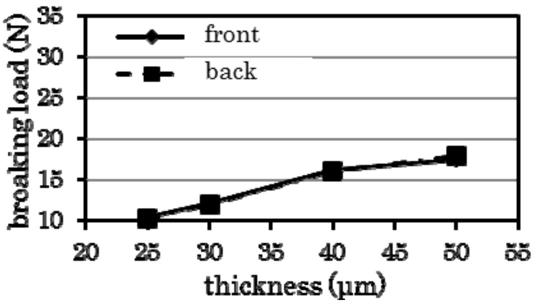


Fig.4 Relationship between breaking load and thickness in CPP film

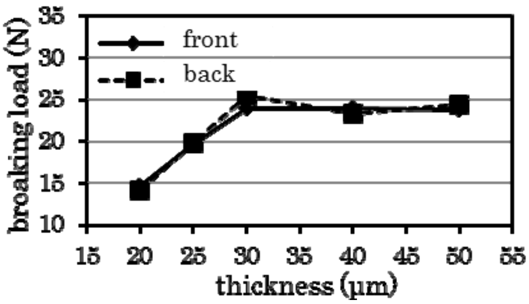


Fig.5 Relationship between breaking load and thickness in OPP film

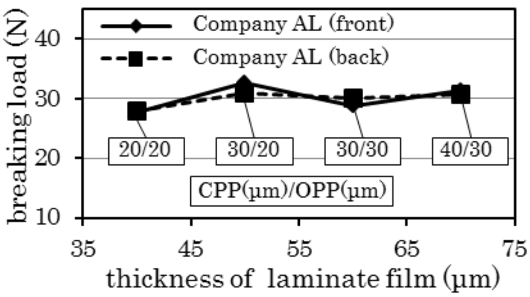


Fig.6 Relationship between breaking load and thickness in laminate film

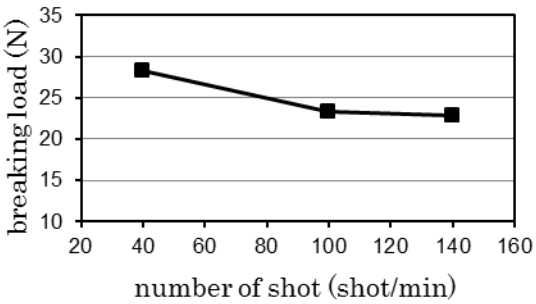


Fig.7 Relationship between breaking load and number of shot
(OPP film , thickness : 30μm, preset heater temperature : 430℃)

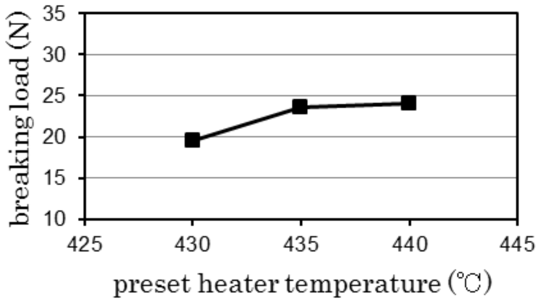


Fig.8 Relationship between breaking load and preset heater temperature (OPP film, thickness :30μm , number of shot :120shot/min)

4. Finite-Element Analysis of Two-Dimensional Non-steady Heat Conduction

This study examines the material and shape of the heat cutter in order to realize the stabilization the temperature at the tip of the cutter near the preset temperature of the heater because this stabilization is considered necessary for improving side seal strength. This study method calculates a numerical value based on a finite-element analysis of two-dimensional non-steady heat conduction[6, 7] that is modeled on actual operating conditions, then considers/examines effective shapes and materials for heat cutters based on those results. Figure 9 shows analysis models and boundary conditions. A preset heater temperature T=Tp (℃) is specified on the circumference. A heat pipe is known to have a high thermal conductivity of the longitudinal direction. We assumed that the temperature diffusivity in the xy plane is at the same level as copper. Further, when a heat cutter touches films, heat flow near the tip of heat cutter is modelled by giving a contact part a high heat transfer coefficient (assumed value). In addition, at other surface of heat cutter, convection to occur between external environment is considered.

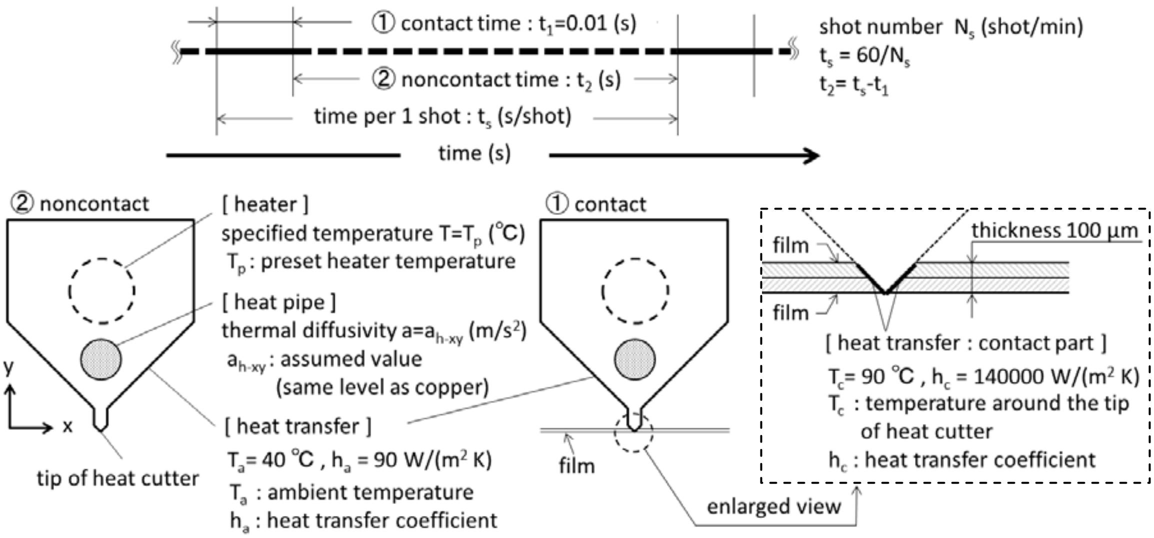


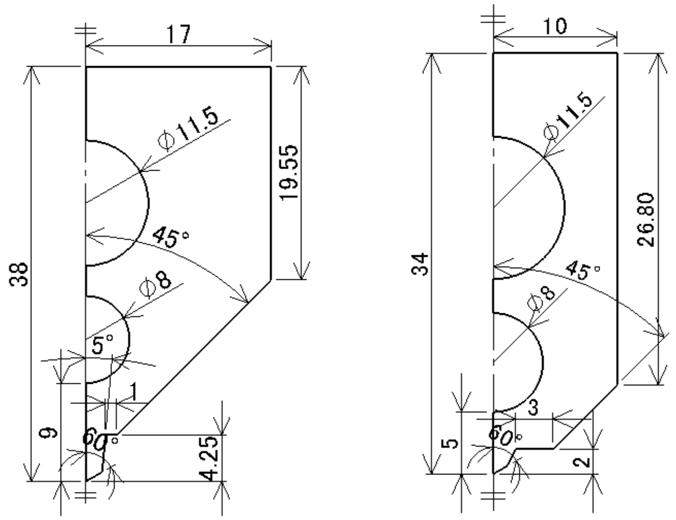
Fig.9 Analysis models and boundary conditions

4.1 Numerical Analysis based on Changes of Heat Cutter Material

We conducted an analysis of traditional stainless steel and die steel. The thermal conductivity for each material is shown in Table 1. The parameters, with the exception of thermal conductivity, were kept equal and the same shape and size were used (Figure 10(a)). Analysis were conducted for preset heater temperatures of 350°C, 400°C and 450°C with a shot number of 100 shot/min.

Table 1 Thermal conductivity for each material

material	stainless	die steel
thermal conductivity (W/m・K)	15	40



(a) conventional shape (b) prototype shape

Fig.10 Shape and size of heat cutter (1/2 model) (units: mm)

4.2 Numerical Analysis based on Changes of Heat Cutter Shape

The shape and size of the traditionally used heat cutter and the prototype heat cutter is shown in Figure 10. The heat cutters' physical properties (stainless) and operating conditions were kept equal and the analysis was conducted at a preset heater temperature of 400°C and a shot number of 100 shot/min.

4.3 Results of Numerical Analysis Based on Changes of Heat Cutter Material

The results of numerical analysis based on changes of the heat cutter material (transfer of heat in the tip of the heat cutter) are shown in Figures 11, 12 and 13.

The horizontal axis 'time' means the time passed since the start of operations (time passed since a heat cutter in a stable state began cutting) in order to calculate operation time simulations. The figures only show 0–20 s ; however, the actual numerical analysis calculated up to 60 s.

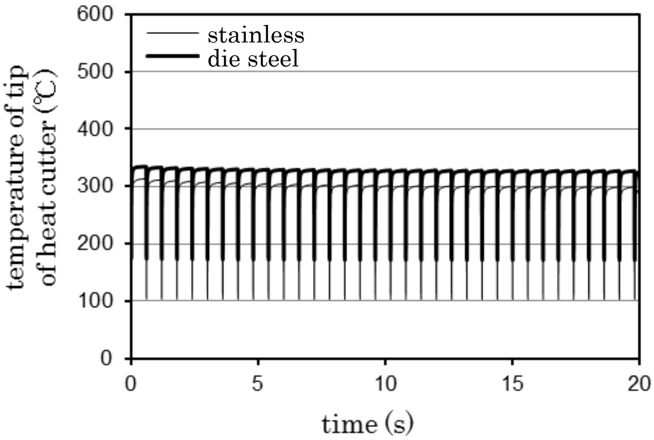


Fig.11 Temperature of tip of heat cutter (preset heater temperature 350°C)

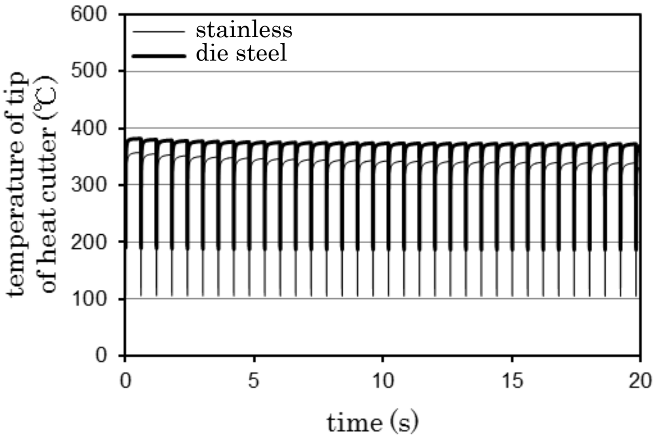


Fig.12 Temperature of tip of heat cutter (preset heater temperature 400°C)

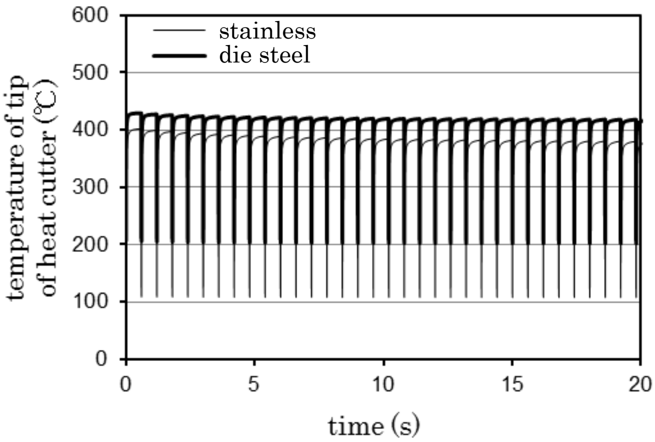


Fig.13 Temperature of tip of heat cutter (preset heater temperature 450°C)

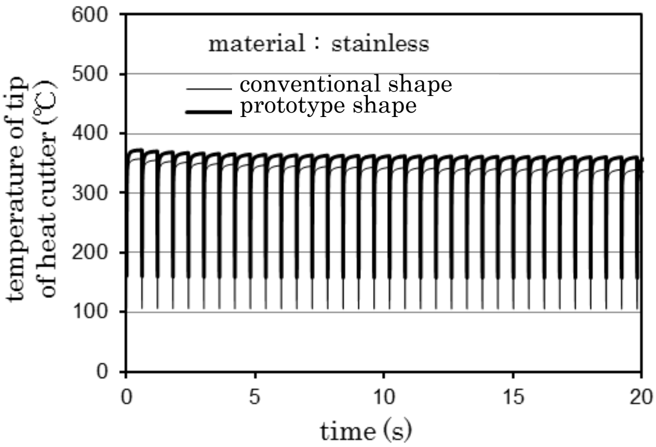


Fig.14　Transfer of heat in tip of heat cutter

4.4　Numerical Analysis based on Results of Changes of Heat Cutter Shape

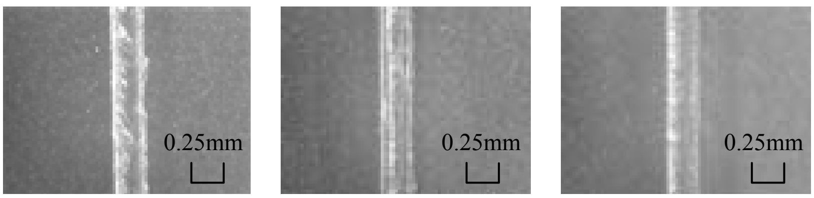
Figure 14 shows the numerical analysis based on the results of changes of heat cutter shape shown in Figure 10.

5. Discussions

5.1　Discussions of Test Results

1) Figure 4 shows that the breaking load increases with an increase in the thickness of the CPP film. All the CPP tests broke in the base material. This is because the film itself has a lower breaking load than the seal section. Therefore, we believe there is a proportional relationship between breaking load and thickness of a film.

2) Figure 5 shows that the breaking load tends to increase with an increase in the thickness of the OPP film but that it becomes almost fixed after a thickness of 30 μm. This is because the base material breaks down at thicknesses less than 30 μm, however seal breakage occurs at 30μm and higher. As shown in Figure 15, the seal width is not dependent on the film thickness and it could be considered that the breaking load is roughly the same because the seal width is fixed.



(a)30μm　(b)40μm　(c)50μm

Fig.15　Seal thickness for each OPP film thickness

3) As shown in Figure 6, we were able to confirm that increases in the composite thickness of laminate do not affect the breaking load, which remains roughly the same.　This information appears to coincide with

the OPP trend because the breaks all occurred in the seals. There is a slight rise compared to the OPP film, which may be caused by the other film, CPP; however, confirmation of this requires further investigation.
4) Figure 7 shows that an increase in shot number is accompanied by a decrease in breaking load. This is a result of a reduction in the contact time between the film and the heat cutter as the shot number increases, which leads to an insufficient supply of heat during cutting/welding. Finally, an increase in the shot number causes an increase in the number of contacts with the film and other materials (there is a rubber roll underneath the film), which contributes to a reduction of heat from the tip of the heat cutter and as a result, causes insufficient joins.
5) There is a general trend of the breaking load increasing with an increase of preset heater temperature. A similar trend is shown in Figure 8. Since the break pattern in OPP film with 30μm thickness occurs within the seal, it can be concluded that an increase in the preset heater temperature improves the strength of the seal.

5.2 Results of Two-Dimensional Non-steady Finite-Element Analysis

1) From Figures 11, 12, and, 13, die steel can be considered stable because it is more flexible to changes in the temperature zone (the belt-shaped region, in the figures that forms as the maximum and minimum temperatures, which generated as the temperature in the tip of the heat cutter fluctuates each cycle, changes over time). In addition, we enlarged the temperature transfer of the vicinity after 60 s, and determined the maximum and minimum temperatures, as well as their difference (dT) as shown in Figure 16. Each preset heater temperature is shown in a separate graph in Figure 17. Figure 17 shows that the die steel has higher maximum and minimum temperatures and a smaller difference (dT) compared to stainless steel. The results also show that regardless of increasing the preset heater temperature, if stainless steel comes in contact with the film, its temperature will lower to around 100°C, but the temperature of die steel will not lower to that same degree. This shows that using materials with high thermal conductivity for the heat cutter reduces the change in temperature in the tip of the heat cutter, which contributes to stable operation.

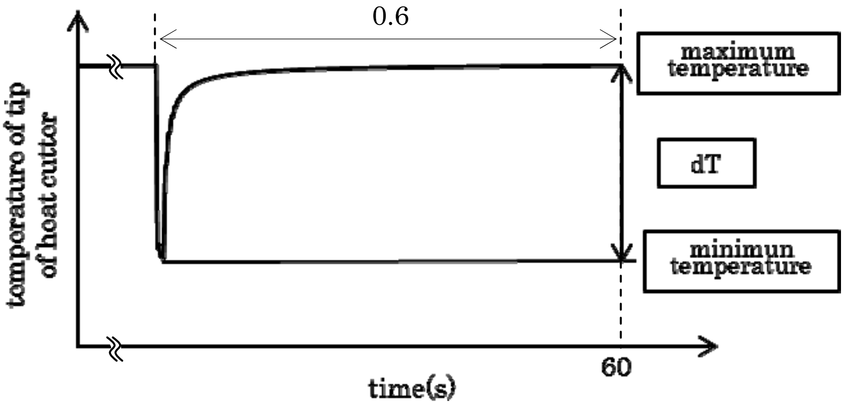


Fig.16 Method to determine maximum temperature, minimum temperature, and dT

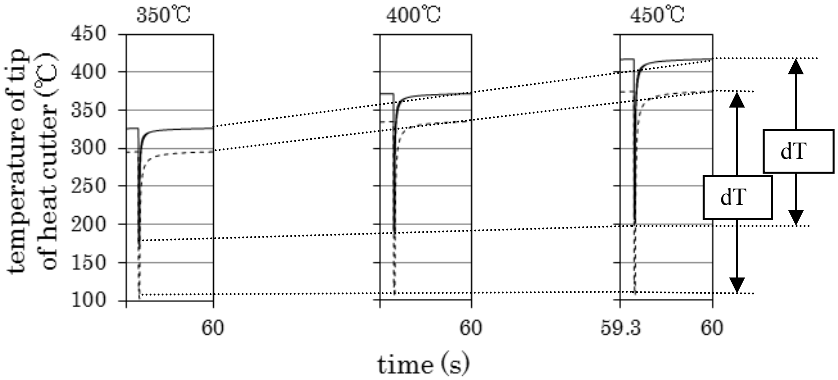


Fig.17 Temperature of a neighboring heat cutter tip after 60 s

2) Figure 14 shows that the prototype shape can be considered stable because the changes in the temperature zone are more flexible. In addition, Figure 18 shows that dT decreases as the maximum and minimum temperature increase, which results in improvements in the characteristics related to temperature stability in the tip of the heat cutter.

Thus, the prototype shape showed favorable results; however, the prototype shape used in this study was designed based on the improvement areas, below.

Plan A: The shaded section (1) in Figure 19 removes heat from the heater and obstructs heat transfer to the tip of the heat cutter.

Plan B: By reducing the length (L) represented by the thick line in Figure 19, namely the heat pipe, reducing distance between the tips of the heat cutter (heater – distance between tips of the heat cutter) improves temperature recovery of the heat cutter.

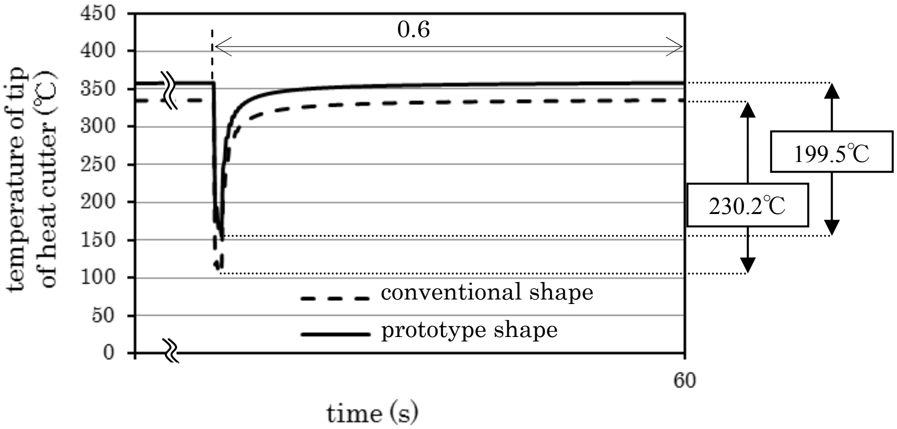


Fig.18 Temperature of a neighboring heat cutter tip after 60 s

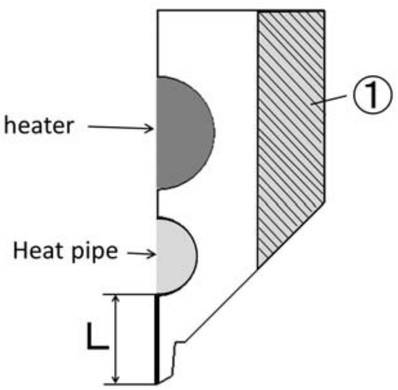
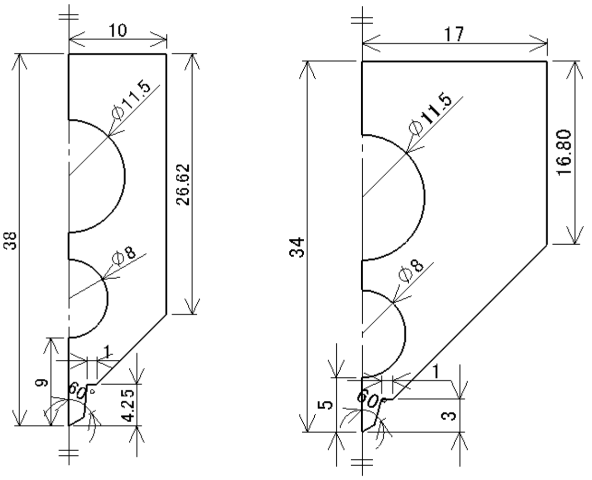


Fig.19 Improvement areas for the conventional shape



(a) plan A (b) plan B

Fig.20 Shape and size of heat cutter (1/2 model)

In order to examine the type of effect the two improvement areas have on the temperature in the tip of the heat cutter, analysis was conducted on only Plan A with prototype shape A (Fig.20 (a)), and on only Plan B with prototype shape B (Fig.20 (b)).

The results are shown in Figures 21 and 22.

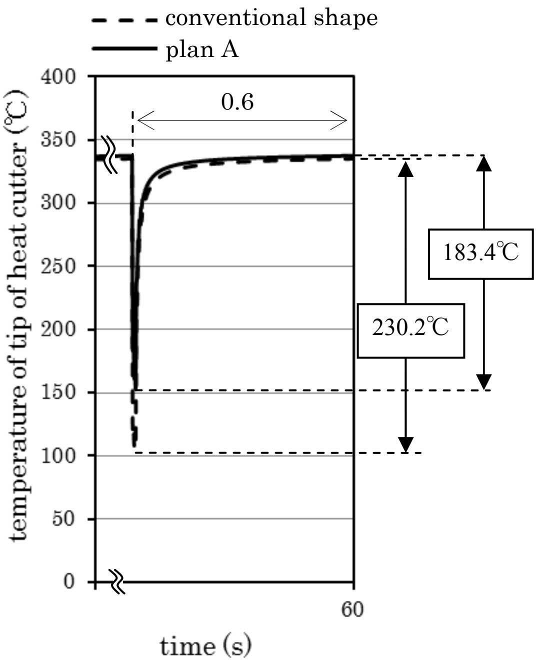


Fig.21 Temperature of a neighboring heat cutter tip after 60 s

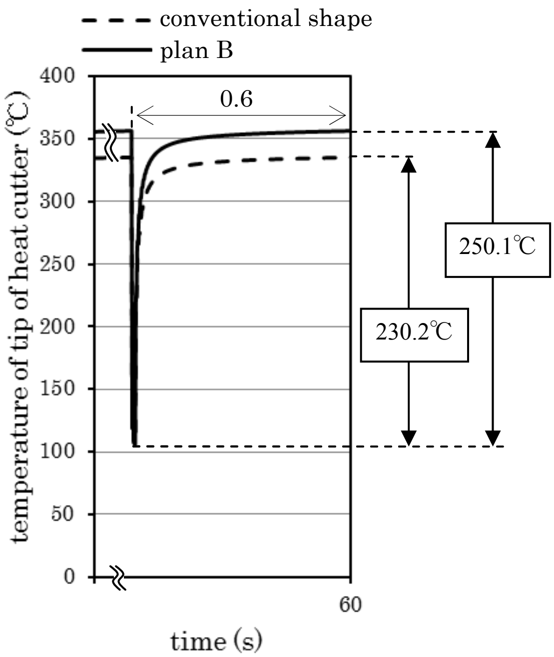


Fig.22 Temperature of a neighboring heat cutter tip after 60 s

In Figure 21, the maximum temperature of prototype shape A is relatively unchanged but the minimum temperature is approximately 50°C higher. This is because part (1) on Figure 19 was removed, which reduced wasteful diffusion of heat and suppressed a decrease in temperature in the tip of the heat cutter.

In Figure 22 the minimum temperature of prototype shape B is relatively unchanged but the maximum temperature is approximately 20°C higher. This is because the length (L) in Figure 19 was shortened, which reduced the amount of time taken for the heat to reach the tip of the heat cutter and increased the speed of temperature recovery in the in the tip of the heat cutter.

6. Conclusion

This paper covers a practical investigation of side seal strength and a numerical analytical study on the shape and material used in heat cutters with the objective of improving the strength (side seal strength) of bags manufactured using the side sealing method. The main conclusion remarks are as follows:

1) The breaking load of CPP film increases with an increase of thickness.
2) The breaking load of OPP film increases with an increase of thickness until 30 μm, after which the breaking load remains mostly steady.
3) The breaking load of laminate film remains mostly steady with an increase of composite thickness but there is a possible trend of a slight increase. Further research required.
4) The breaking load decreases as shot number increases.
5) The breaking load increases with an increase in preset heater temperature.
6) Confirmed that thermal conductivity greatly influences the temperature in the tip of the heat cutter by changing the thermal conductivity and conducting a finite-element analysis on the heat cutter's two-dimensional non-steady heat conduction. In addition, the use of materials with high thermal conductivity in heat cutters reduces temperature change in the tip of the heat cutter, which contributes to stabilizing operations.
7) Conducted a thermal conductivity analysis and refined future prototype selections by studying heat cutter forms that have the possibility to improve the temperature in the tip of the heat cutter.

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