HIMACS Thermoforming

HM2110

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Introduction

This section guides process, check points and wide technical knowledge about thermoforming fabrication with HIMACS products.

Overview

Thermoforming allows designers' and architects' ideal design with inspiration to come true. And, the material property of HIMACS sheets allows with specific controlled heat to thermoform HIMACS sheets into 2- or 3-dimensional forms, like shapes or other rounded applications, and curved walls. However, the technology of thermoforming is one of the most sophisticated fabrication techniques of HIMACS sheets. During this fabrication process many different parameters will have an influence to the results of the finished products. Although, fully guiding or proposing the proper thermoforming method for the all various applications having unique design is not possible, LX Hausys tried to share some basic technical knowledge about thermoforming in this section.

Visit our web site at www.lxhausys.com for the latest version of HIMACS fabrication guidelines.
Contact LX Hausys HIMACS territory manager or distributor of your market for specific questions and information.

1. Definition

Thermoforming means a deformation of thermoplastic material under the influence of heat with molds under suction, pneumatic pressure or vacuum. In other words, HIMACS sheets need proper heat, molds and pressure for thermoforming. And, there are a few constraints you should not do.

HIMACS sheets can be thermoformed to 2 or 3 dimensional shape. 2D shape thermoforming can be guided clearly in this section with the simplicity of 2D design. However, 3D thermoforming can't be guided clearly because of the diversity and complexity. Therefore, all guides and standards are addressed only for 2D shape thermoforming, and this information can be used as just a reference for 3D. Fabricator should do practice and simulation for success of 3D thermoforming.

2. Material Characteristics

There are some characteristics of HIMACS sheets influence at thermoforming work and the results.

2-1. Condition for deformation

HIMACS sheets are changed from rigid plate to flexible plate that can be deformed by heating under proper temperature and time. Therefore, the most important point to get successful thermoforming result without material breakage is using the proper heating condition.

The general heating temperature for 12mm thickness HIMACS sheets thermoforming is 155℃ ~ 175℃, and the time is 12minute ~ 30minute. However, these conditions should be optimized in detail considering the thickness of HIMACS sheet, workshop air temperature and the performance of each heating machine. On the other hands, too low temperature and too high temperature (204℃) will make failure at your thermoforming. **Never exceed 204℃ when you heating HIMACS sheets. It may occur color change, burn, breakage and durability down of products.** Follow the detailed thermoforming conditions below table.

Table. 2-1. Thermoforming conditions

Sheet Thickness	Heating Temperature	Heating Time
6 mm	155℃ ~ 175℃	6 ~ 20 minutes
12 mm	155℃ ~ 175℃	12 ~ 30 minutes

Meanwhile, the heated and deformed HIMACS sheets need proper cooling condition too. HIMACS sheets still can be deformed over 60℃, and too rapid cooling will make a cooling shock that may occur breakage at the sheets. **Therefore, thermoformed HIMACS sheets should be immobilized with the pressure on the mold until to reach 60℃ under room temperature for 40 ~60 minutes to avoid unexpected additional deformation and breakage.**

Note !

Thermoforming needs sensitive work process and conditions. And, there are lots of heating machines in the market, and each workshop has different working environments. Therefore, all conditions will not be guaranteed by LX Hausys, although there are efforts making a standard condition for thermoforming. Fabricator should simulate and find the optimized condition with your machines and workshop environments. It is the best way to get the best result.

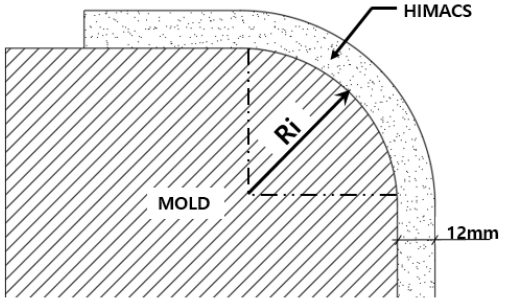
2-2. Limitation of deformation

In spite of wide realization performance through thermoforming for imaged and inspired design, HIMACS sheets have a few limitation for thermoforming. Thermoforming makes slight dimensional and visual change like thickness and color/pattern change. Too excessive bending makes cracks and tear on base sheet or chip of HIMACS sheets. When HIMACS sheets are bended to round shape through thermoforming, the thickness of bended part will be thinner than the original thickness, the pattern will be spread, and the color will be changed to white color calling "whitening effect". The smaller round and the darker color show more obvious whitening effect on HIMACS sheets. Therefore, fabricator should consider and follow the limitation of thermoforming with HIMACS sheets. Especially, darker and black color should be thermoformed with care. Refer to following fabrication standard for 2D thermoforming. But, as mentioned before, 3D thermoforming can't be guided clearly because of the diversity and complexity.

Table. 2-2.Minimum inside radius for 2D

Sheet Thickness	Pattern	Minimum Inside Radius (Ri)
6 mm	Solid	Ri ≥ 20 mm
12 mm	Ultra Thermoforming Intense Ultra	Ri ≥ 6 mm
	Solid, Perna	Ri ≥ 50 mm
	Granite	Ri ≥ 60 mm
	Aurora	Ri ≥ 100 mm
	Others : Lucia, Marmo, Volcanics, Aster, Gravilla	Ri ≥ 200 mm

Fig. 2-1. Inside radius



2-3. Expanding and shrinking

HIMACS sheets expands or shrink according to heat change. The amount of expanded or shrunk size can be calculated. Refer to *'HM2070 HIMACS Site Inspection and Job Plan, part 2.Job plan'* for the accurate calculation if you need.

When you make molds and use machines, this expanding and shrinking should be considered. Unexpected deformed shapes may be happen at the edge if you use too small size of molds. Or, expanded sheets can interfere machines operation. Therefore, expanding and shrinking of HIMACS sheets should be considered through calculation or your experience before you start thermoforming.

2-4. Formulation change

Once heated HIMACS sheets never get back to the original formulation. It means that repetition of heating of HIMACS sheets is not allowed. The HIMACS sheets heated again will not have the original bending performance. It will be broken more easily, and the color will be changed obviously. **Never heat again HIMACS sheets, you can't get the satisfied result.**

Never heat and thermoform the seamed sheets. The seam line may get color change and/or tear by heat and pressure. Because, HIMACS adhesives may react at heat differently compare to HIMACS sheets. Therefore, seam line may be weaker point than original sheet against to heat and pressure for thermoforming.

Note !

- *Never oversell thermoforming of HIMACS sheets. The acceptable aesthetic level for the whitening effect is different to each customer. Specially, whitening effect of darker color and black color are more sensitive.*
- *Excessive and/or improper thermoforming will shorten the service life of your finished products, even if there were no visual defects immediately after the thermoforming. The micro cracks and formulation change by excessive and/or improper thermoforming will make problems during service life.*

3. Tools and Machines Required

The minimum tools and machines required are bellow.

- Heating machine, Forming machine (press or vacuum machine)
- Protective gloves with insulation
- Temperature meter, timer
- Molds
- And, temperature controlled workshop

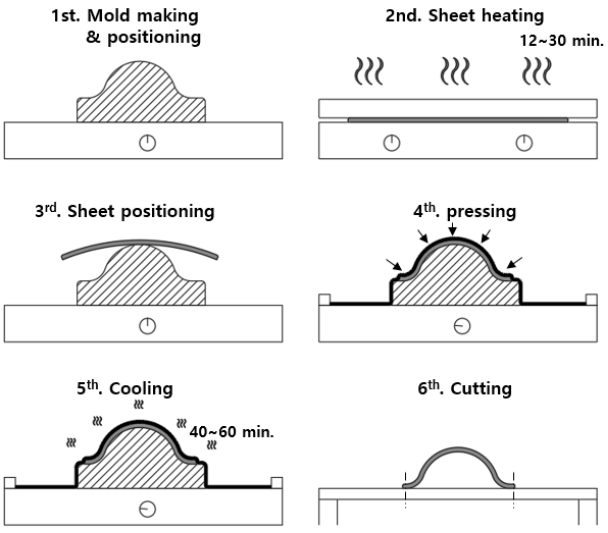
For more information refer to *'HM2060 HIMACS Tools and Accessories'*.

4. Thermoforming Process Basic

There are lots of machines and methods for thermoforming. However, the basic processes are similar. Please refer to the process below.

- Review drawing and prepare mold.
- Remove protect film, and cut HIMACS sheets in proper size
- Smoothen the edge of cut sheets by sanding.
- Heat the sheet, and place on the mold.
- Press the sheet with press machine or vacuum machine
- Leave the sheet under room temperature for 40~60 min.
- Cut the thermoformed shape in size.
- Join and finish.

Fig. 4-1. Thermoforming process basic



5. Molds Preparation

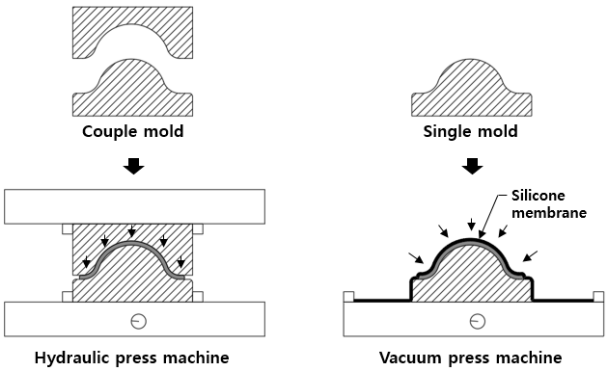
Review drawings, and plan to make molds. That is the first and most important step to success thermoforming with HIMACS sheets. Some shapes and size may not possible in one piece because of sheet size and/or machine capacity. Sometimes the mold may be used only one time for a project, or used for long term with repetitive forming. And, mold accounts for a significant portion of the thermoforming cost. Therefore, consider as many factors as addressed in this section for high quality and cost reduction.

5-1. Mold types

Mold types are different according to the press machine type for forming and the structure of mold itself.

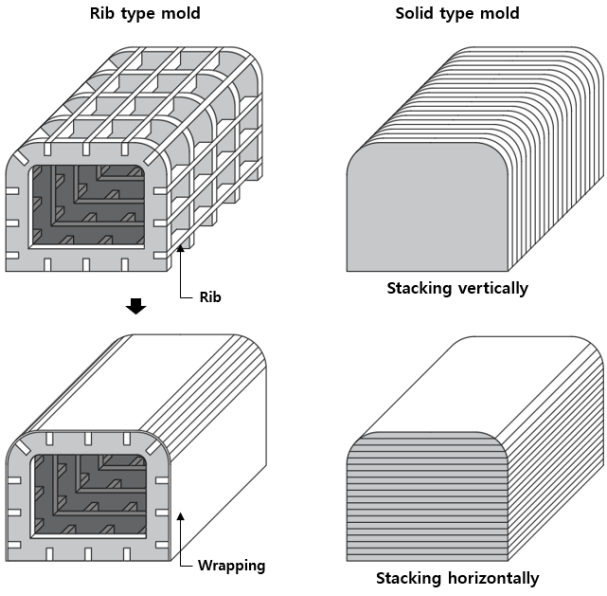
Couple molds (male/female molds) are used for forming by hydraulic press machine or manual method. Single mold is used with the vacuum forming machine. Couple molds are not recommended for complex 3D shapes. However, couple molds are useful if the molds have been proven successfully for frequent repetitive forming. A large volume of small wash basin is a good example of using couple molds. Thermoforming through single mold and vacuum machine is proper to manufacture large shapes and more accurate shapes.

Fig. 5-1. Mold type by press method



There are two types of mold according to the structure of molds. One is a rib type (hollow type), and another one is solid type. The rib type mold can be made through assembling MDF or metal rib.

Fig. 5-2. Mold type by structure



The rib type mold is useful for big shapes, and easy to handle with the lightweight. However, it needs skilled assembling technique for accurate shape and structure strong enough.

Solid mold is proper for higher pressure forming as is stronger against to the pressure than rib type mold. Vertically stacked mold is easy to make simple 3D shape with 3 axis motion CNC machines, but it not recommended for long shape because of the deflection by pressure. Horizontally stacked mold is useful for complex 3D shape with over 5 axis motion CNC machines.

5-2. Mold material

Metal, wood and high-density foam that can withstand pressure are used as mold materials. Material should be carefully considered to reduce cost and time waste. For example, metal is the best material if you need high repetitive forming works for long term, or wood is the best material if you need only one time forming.

Metal is proper material for a large volume shape for long term use with repetition. Although, the cost is higher and time is longer for the mold production, metal mold serve long term service life and stable shape/finish quality without deformation if it has successfully manufactured. The thermal conductivity and thermal capacity should be considered. These property of metal can cool the thermoformed HIMACS sheets too rapidly, and it may lead to breakage or tear of HIMACS sheets. Therefore, slow cooling technique should be applied to the metal mold.

Generally, wood based materials (MDF, plywood, hardwood) are used as the most favorite and useful material with low cost and easy/rapid production. But, wood grain makes pattern on the thermoformed surface of HIMACS sheets. And, wood is weak at moisture and has limited longevity. Therefore, wood mold needs additional finish process and careful handling and storage. These weak points can be a little bit improved through applying aluminum filled epoxy paint to the surface of the mold. And, store wood mold in dry, room temperature space without direct sun light.

High-density polyurethane foam is easier to handle with lightweight than steel and wood. Although, the cost is a bit expansive than wood, high-density polyurethane foam has a lots of strong points as mold material. However, this material needs highly skilled technique to operate high tech machine like 5 axis motion CNC machine when you produce mold. It cannot be manufactured by hand work, and it needs knowhow to make air path on the surface of mold as high-density polyurethane foam is not porosity. This material is not suitable for hydraulic press machine and manual thermoforming.

There are no limitation as a material for mold if the material can serve the proper performance that you need without any dangerous factors to people and nature.

5-3. Mold size

Mold should be made in proper size. Sometimes, the big size product needs to be separated into several small molds. Refer to following check points to decide the molds size. Mold size should not exceed any size that mentioned below.

- Factory manufactured HIMACS sheets size
- Working bed size of heating machine and press machine
- Maximum size that you can handle in your workshop
- The moving path from your workshop to site

On the other hand, mold should be larger than the final shape size after thermoforming. Mold size should able to accept followings.

- The extra sheet size for cutout in accurate size after thermoforming.
- The expanded sheet size by heat during thermoforming

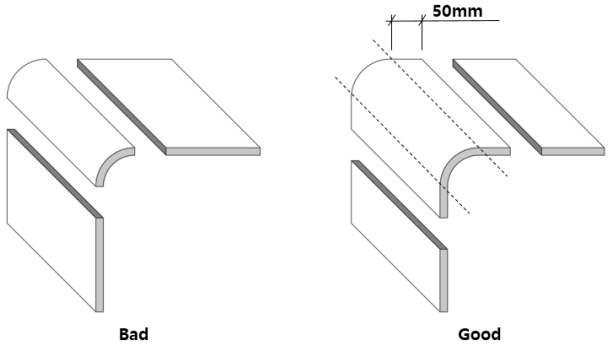
5-3. Mold shape

Professionally skilled techniques through experience considering the property of HIMACS sheets are needed to make good mold. Good mold means the mold that can make correct shape purposed and can work with easy handling. There is no sole standard to make molds as the suitable condition are different for each design of shape. Therefore, fabricator's personal experiences are the best knowledge to make mold. However, LX Hausys tried to address basic common guides that can help to make good mold in this section. Please refer to following several guides. And, never allow to make mold that excess the deformation limit of HIMACS sheets.

Corner distance

It is not easy to make perfect seams through joining round parts or round and flat parts as the cutting angles are different and clamping is difficult. Therefore, consider to leave minimum 50mm of flat part from round part when you make mold for easy seaming.

Fig. 5-3. Corner Distance



Angle for release

A deep shape formed over male mold will shrink as it cools, and then the formed piece will stick on the mold with high pressure. As a result, the release of formed piece will be difficult. Therefore, the mold needs proper positive angle for easy release. Leave more than 5 degree of positive angle. Refer to 'Fig. 5-4. Positive angle'. If the deep shape does not have positive angle, consider mold separation.

Negative angle shape is not recommended for mold. Negative angle shape can't be formed through couple molds because of the interference between molds. Although, vacuum forming machine can make negative shape, the release of formed shape is not possible, and the formed shape will not be correct. The best method for shape with negative angle is separate the shape into several molds and join the formed pieces. Refer to 'Fig. 5-5 Negative angle'.

Fig. 5-4. Positive angle

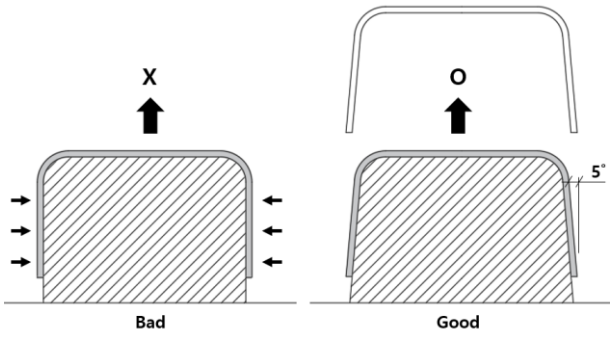
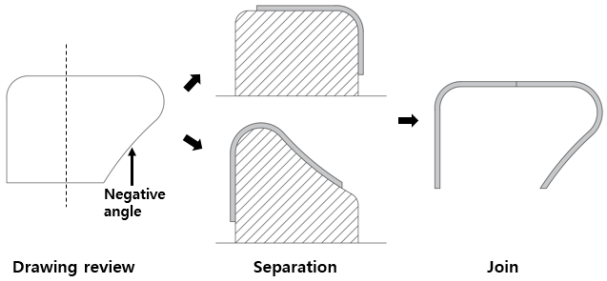


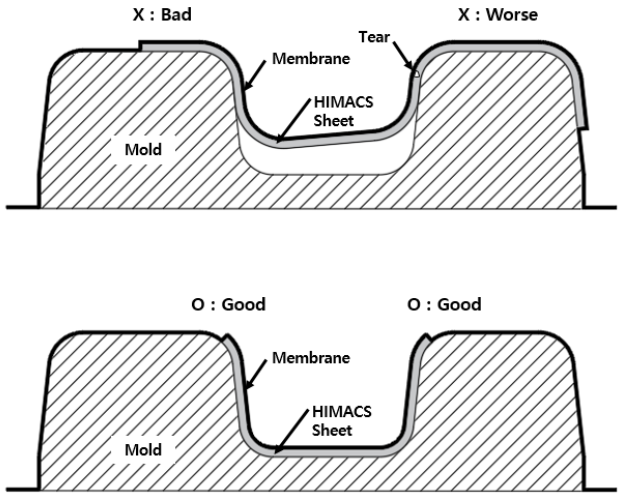
Fig. 5-5. Negative angle



Preventing interference

Any kind of interference that inhibits sheet moving on the mold during thermoforming should be prevented, and it should be considered when making molds. For example, when you make deep shape using female mold and vacuum forming machine, if some parts of sheet are caught by membrane and mold, the sheet will not fully move into the mold. And, the result is incorrect shape and/or tear of sheet. Review drawing, imagine the result, and then do not allow this kind of interference when making mold. Mold separation can be solution. The more complex needs the more mold separation.

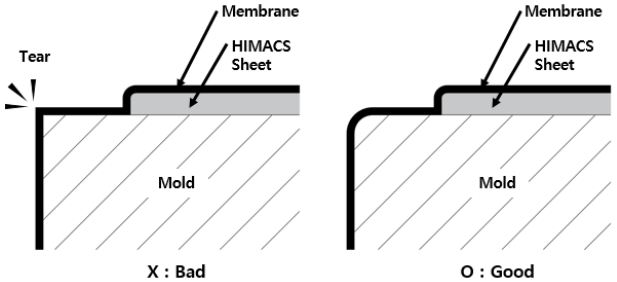
Fig. 5-6. Interference



Finish

The surface of mold should be smooth, and not allowed any residue. Smooth surface will reduce your additional sanding works. And, the edges of mold that contact to membrane should be rounded to prevent the tear of membrane. The larger round edge is the better.

Fig. 5-7. Mold Edge



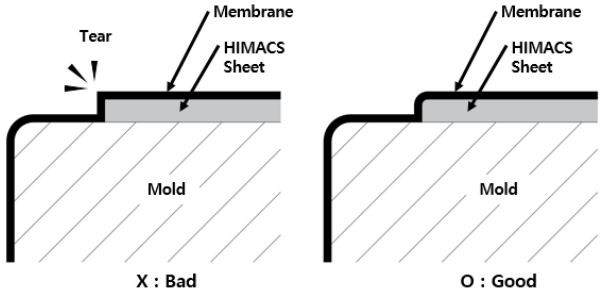
5-4. Mold Positioning

- Put the mold on the forming machine before heating sheets.
- Center is the best positon for even press.
- Do a pressing simulation to check.
- If there is no problem, the mold preparation has done.

6. Sheet Preparation

- HIMACS sheets should be stored 24 hours under room temperature before thermoforming, if the sheets have been stored and/or transported under cold weather. The size change from expanding to shrinking of cold sheets is big, and the big size change is a big risk point during thermoforming.
- Remember protect film should be removed before heating.
- Inspect the sheet according to 'HM2050 HIMACS Quality Inspection'.
- Cut the sheet to the appropriate size considering shrinking, expanding, and trimming. HIMACS sheets can shrink about 5% to 7% during the thermoforming process. Material to be thermoformed should be oversized by at least 25mm and up to 7% of overall dimensions to allow for this shrinkage.
- Sand or rebate the edges and corners of sheet to minimum 1.5mm radius. These rounds will protect membrane and sheet material from tear.

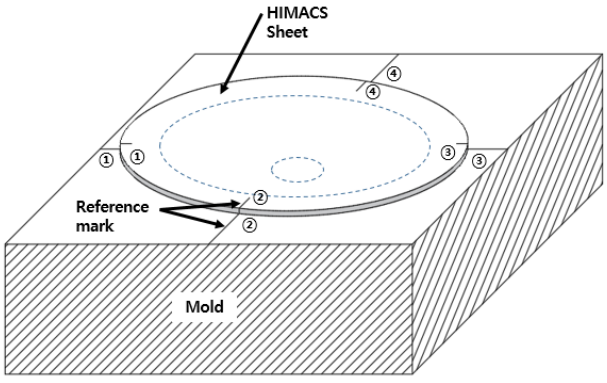
Fig. 6-1. Sheet edge



Useful Tip !

- Mark minimum 3 points of reference points with pencil on the both sheet and mold. This reference points will help to put and align the heated sheet on the correct position quickly, and avoid the thermoforming fail.

Fig. 6-2. Reference mark example



- The extra size for thermoforming should be added into your estimate for the project. The loss rate of thermoforming are very larger than general fabrication. However, you can down the loss rate though your thermoforming knowledge and skills.

7. Heating

The most important factor for successful heating is following the guide and giving uniform heating to entire sheets.

- Refer to '2-1. Condition for deformation' in this section before start heating.
- Control the work shop air temperature into room temperature (15℃ to 25℃). Uniform environment is the best way to get stable quality from heating as well as forming.
- Make sure the oven is clean. Dirt, residue and stain on the surface of heating plate make defects on sheet after heating.
- Heat the oven up to target temperature.
- Put sheet in the center of oven, when the temperature of oven has reached and stable at target temperature. Do not put the sheet in the oven before reaching the target temperature. .
- **Use protect clothes and tools when you handle heated sheet. The heated sheets are hot, flexible and slippery. Never attempt to handle heated large sheet by a single person.**
- Put out the sheet when reached the time set, and transfer the sheet to the mold.

Useful Tip !

- *When heating small piece of sheet using platen heating machine, use helper piece to keep the gap between top plate and bottom plate.*
- *Thermoforming may make slight color change to HIMACS Sheets. Heating flat part as well as thermoformed part can be a solution to match the color of each part.*

8. Forming

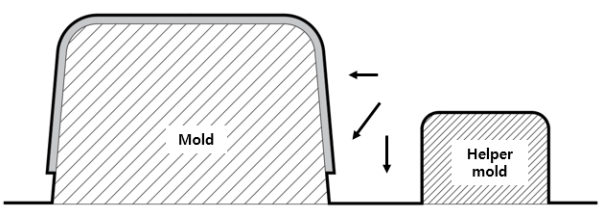
Forming should be done quickly before the heated sheet get start harden. Therefore, all before processes should be done clearly. For example, sheet should be properly heated, mold should be on positon, and any obstacles are not allowed in the path of heated sheet from oven to forming machine.

- Place the heated sheet on the mold and align it at the correct position through reference mark.
- Start pressing.
- If you use vacuum pressing machine, assist machine pressing using hands pressing on the membrane, and pull the membrane to avoid wrinkles at the beginning of pressing.
- Leave the sheet for cool down. Do not release the sheet from mold and pressing should be continued until the sheet temperature reaches to 60℃. Never attempt quick cooling. It will make cooling shock to lead cracks.

Useful Tip !

If there are too much wrinkles, or the formed shape is not correct, because of too larger membrane than mold, put helper mold near the original mold when forming.

Fig. 8-1. Helper mold



9. Trimming and Finishing

Most of the thermoformed sheets need to be trimmed in precise dimension after forming. And, the cutting angle for join is very important as well as size to make perfect seam and shape. Therefore, the trimming method for thermoformed sheets should be carefully planned when you design mold.

You can trim most of simple 2D & 3D shapes with hand held router. But, sometimes complex 3D shapes need high-tech CNC machine and/or fully skilled fabricator. Irregularly curved shapes are the examples.

Sometimes mold can be used for trimming after forming, but this case mold can get unexpected damages by trimming. To make the mold only for trimming can be solution if you need to reuse the forming mold without damage. If you need thermoforming only once, you can consider several methods for trimming, and the mold can be used as support structure itself.

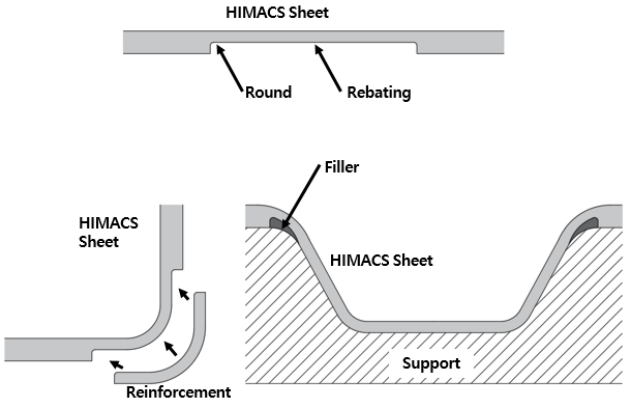
More careful sanding is needed for thermoformed sheet. And, use sandpaper with soft backing materials. Refer to 'HM2100 HIMACS Finishing(Sanding and Polishing)

10. Thinning for Thermoforming

When you make small rounds that exceed the limitation of deformation in 'Table. 2-2.Minimum inside radius for 2D', generally joining small pieces fabricated by router is recommended. However, the case that joining is not possible and/or allowed, thermoforming through thinning the thickness of HIMACS sheet is an idea. However thinning parts are weak points that should be fully reinforced and supported.

- Thin the HIMACS sheet with router.
- Do not allow square corner after rebating the thickness. The square corner make cracks during service life.
- Make the surface thinned soothe.
- Do thermoforming.
- Reinforce, fill and support the thin parts.

Fig. 10-1. Thin thermoforming



11. Summary for Development

- Habituate to make detailed plan for thermoforming process for each project before start, and record the condition and result. It will help to develop your thermoforming skill.
- Remember the condition and performance of each HIMACS sheets for thermoforming, and do not exceed the basic condition and limitation in this section. Too low or too high temperature is not recommended. Do not try to make shapes exceeding the limited minimum radius.

- Do not apply the guide for minimum radius of 2D shape to 3D shape. The guide can be used for 3D shape as reference hint only. The result of thermoforming for 3D shapes are depend on the complexity of the shape.
- Use recommended machines only. For example, do not use heating method that can't make uniform heating. Generally, platen heating oven is most efficient heating machine type.
- Find the best thermoforming condition of your machines and workshop. And, try to keep the best condition. For example, the temperature of workshop should be controlled as room temperature during thermoforming, and the heating time and temperature can be balanced through the performance of you heating oven.
- If you want to grow up the efficiency of your workshop for thermoforming, you can consider to add one more forming machine than heating oven, because heating process needs shorter time than forming and cooling process. The workshop with two forming machines and one heating oven can make two times amount of thermoforming products compare to the workshop with one forming machine and one heating oven.
- Another way to improve the efficiency of thermoforming is making good mold. There is not the only correct way to make good mold. However, fabricator should have training to make good mold. Skill for mold designing and making will help the make balance between cost, efficiency and quality.
- Choose proper material for mold as characteristics of the project.
- Choose proper type for mold as your forming machine
- Mold dividing is very important technique for efficiency. If you try to make huge shape through only one mold, the mold will have worse handling and you can't make detailed part correctly, because you can't get enough forming time. The other hands, if you divide the shape into too many molds, it will need too much additional works like join and sanding, and is not easy to join the many pieces into correct shapes. Therefore have self-training to make proper dividing through works.
- Follow the succeeded process strictly.
- Find the changed points of machines, molds, environment and any factor that related your thermoforming work if you failed thermoforming although you followed the process that constantly succeeded. It will give you more improved thermoforming technique.

Referenced documents

'HM2050 HIMACS Quality Inspection'

'HM2060 HIMACS Tools and Accessories'

'HM2070 HIMACS Site Inspection and Job Plan'

'HM2100 HIMACS Finishing(Sanding and Polishing)'

- End of Document -