7. User guide

7.1. Introduction

The manufacture of plastic articles from QUINN HIPS sheet normally involves secondary fabrication operations, including sawing, drilling, bending, decorating, and assembling. This guide covers the properties and characteristics of QUINN HIPS that need to be taken into account if secondary operations are to be performed successfully.

7.2. Fabricating

7.2.1. Machining guidelines

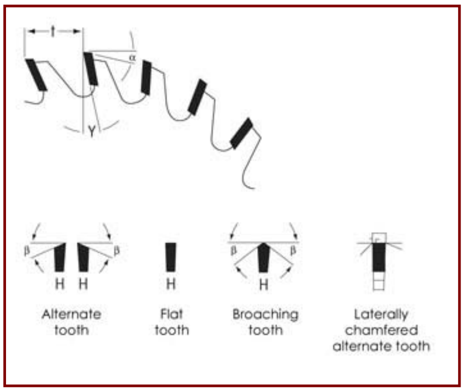
QUINN HIPS sheet can be worked with most tools used for machining wood or metal. Tool speeds should be such that the sheet does not melt from frictional heat. In general, the highest speed at which overheating of the tool or plastic does not occur will give the best results.
It is important to keep cutting tools sharp at all times. Hard, wear-resistant tools with greater cutting clearances than those used for cutting metal are suggested. High-speed or carbon tipped tools are efficient for long runs and provide accuracy and uniformity of finish.
Since plastics are poor heat conductors, the heat generated by machining operations must be absorbed by the tool or carried away by coolant. A jet of air directed on the cutting edge aids in cooling the tool and in removing chips.
Plain water or soapy water is sometimes used for cooling unless the trim scrap is to be reused.

7.2.2. Milling

Sheet manufactured from QUINN HIPS can be machined with standard high-speed milling cutters for metal, provided they have sharp edges and adequate clearance at the heel.

7.2.3. Sawing

Following types of sawing operations can be used to saw thermoplastic materials: band saw, circular saw and jigsaw as well as hand operated saws.
It is recommended that new or well-sharpened tools be used. At very high cutting speeds, the saw blade should be cooled with water or an alternative appropriate cooling emulsion.



Example of Sawblades

Sawing recommendations

Type of sawing	Band saw	Circular saw
Tooth distance	sheet thickness below 3 mm, 1 to 2 mm	8 to 12 mm
	sheet thickness 3 to 12 mm, 2 to 3 mm	8 to 12 mm
Clearance angle a	30 to 40°	15°
Rake angle Ψ	15°	10°
Tooth angle β	-	15°
Cutting speed	1200 - 1700 m/min	2500 - 4000 m/min
Feed speed	-	30 m/min

7.2.4. Routing

Routers with sharp two-flute straight cutters produce very smooth edges. They are useful for trimming the edges of flat or formed parts, particularly when the part is too large or irregular in shape for a band saw. Portable, overarm, and under-the-table routers work equally well. The plastic sheet should be fed to the router slowly to avoid excessive frictional heating and shattering. The router or plastic sheet, whichever is moving, must be guided with a suitable jig.
Compressed air can he used during the routing operation to cool the bit and aid in chip removal.

7.3. Forming Information

There are a number of ways to achieve the finished shape, which include using vacuum pressure to ***pull*** the sheet into the mould, using air pressure to ***push*** the sheet into the mould or a combination of the above with a mechanical aid, known as a "plug" to help the sheet conform to the mould shape. The most appropriate method will be determined by the complexity of the article being formed and also the depth of draw in ratio to the surface area of sheet.

7.3.1. Heating

QUINN HIPS sheet must be heated properly to ensure optimum moulding performance. Thick sheets will require more heat than thin sheets, but careful control of the heating cycle is vital to avoid burning or degrading the surface of thicker sheet. Sandwich, or two sided, heating is essential for sheets over 2 mm thick to ensure that the sheet is heated evenly throughout and without causing the surface to become overheated. For sheets over 6 mm in thickness it is strongly recommended that pre-heating of sheet is carried out, which will also provide higher quality formings.

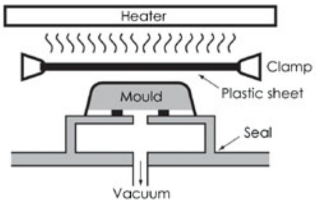
7.3.2. Thermoforming

Guidelines for processing QUINN HIPS

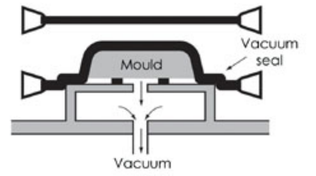
Sheet temperature	95-150°C
Mould Temperature	55-90°C
Demould	immediately after the part becomes cool
Shrinkage	0.5 – 0.6%

There are a number of different techniques used in thermoforming QUINN HIPS, but all use the same basic method of the application of heat and pressure to achieve a finished shape.
Thermoforming, sometimes known as vacuum forming, typically uses a clamp to hold sheet in place while it is heated and then, when softened, a mould is placed next to the sheet whilst the air is evacuated, by a vacuum pump. This causes the sheet to be forced into the shape of the mould, and once the sheet has cooled down, the finished article can be removed and worked on further as required.
This technique can be used to make articles as diverse as refrigerator liners, through to simple signs with limited depth.

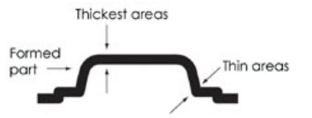
7.3.3. Drape forming



(A) Clamped, heated plastic can be pulled over the mould, or the mould can be forced into the sheet.



(B) Once the sheet has formed a seal around the mould, a vacuum is drawn to pull it tightly against the mould surface.



(C) Final wall thickness distribution in the moulded part.

Drape forming is similar to straight vacuum forming except that after the QUINN HIPS sheet is framed and heated, it is mechanically stretched, and a pressure differential is then applied to form the sheet over a male mould. In this case, however, the sheet touching the mould is close to its original thickness. It is possible to drape-form items with a depth-to-diameter ratio of approx. 4 to 1; however, the technique is more complex than straight vacuum forming. Male moulds are easier to build and generally cost less than female moulds; however, male moulds are more easily damaged. Drape forming can also be used with gravitational force alone. For multi-cavity forming, female moulds are preferred because they do not require as much spacing as male moulds.

7.3.4. Matched-mould forming

Matched-mould forming is similar to compression moulding in that heated QUINN HIPS sheet is trapped between male and female dies made of wood, plaster, epoxy or some other material.
Although they cost more, water-cooled matched moulds produce more accurate parts with close tolerances.

7.3.5. Pressure-bubble plug-assist vacuum forming

The pressure-bubble plug-assist vacuum forming technique can be used when QUINN HIPS sheet is to be formed into deep articles that must have good thickness uniformity. The sheet is placed in a frame and heated, and controlled air pressure is used to create a bubble. When the bubble has been stretched to a predetermined height, the male plug-assist (normally heated) is lowered to force the stretched sheet into the cavity. Plug speed and shape can be varied for improved material distribution; however, the plug is made as large as possible so that the plastic material is stretched close to the shape of the finished product. The plug should penetrate 75 to 85% of the mould cavity depth. Air pressure is then applied from the plug side while a vacuum assist is being drawn on the cavity. The female mould must be vented to allow the escape of trapped air.

7.3.6. Plug-assist pressure forming

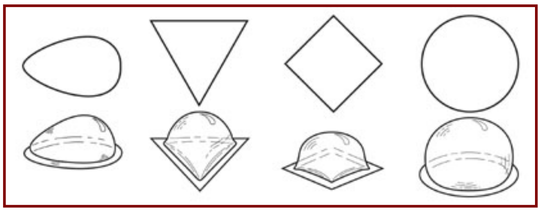
Plug-assist pressure forming is similar to plug-assist vacuum forming in that a plug forces the hot QUINN HIPS sheet into a female cavity. Air pressure applied from the plug then forces the plastic sheet against the walls of the mould. Plug design and plug speed can be varied to optimize material distribution.

7.3.7. Plug-assist vacuum forming

Corner or periphery thinning of cup- or box-shaped articles can be prevented by use of a plug-assist to mechanically stretch and pull additional plastic material into the female cavity. The plug should be 10 to 20% smaller than the mould and should be heated to just under the forming temperature of the sheet. Once the plug has forced the hot sheet into the mould cavity, air is drawn from the mould to form the part.
Plug-assist vacuum forming and plug-assist pressure forming (see previous section) allow deep drawing and permit shorter cooling cycles and good wall thickness control. Both processes require close temperature control and are more complex than straight vacuum forming.

7.3.8. Free forming

In free forming, air pressures of about 2.76 MPa can be used to blow a hot QUINN HIPS sheet through the silhouette of a female mould. Air pressure causes the sheet to form a smooth bubble-shaped article. Since only air touches each side of the pad, there will be no mark-off unless a stop is used to form a special contour in the bubble.



7.3.9. Demoulding

Once formed into the correct shape the part must be cool enough to be removed from the mould, without losing its shape, or sticking. The sheet needs to be at least 10°C below the Vicat softening point of the sheet, to allow the part to become rigid enough to withstand handling. Sufficient time must be allowed, as cooling sheet too rapidly can cause thermal stress, with consequent loss of physical properties

7.3.10. Finish Trimming

Once the part has cooled and been removed from the forming equipment, it is usual for the edge of the sheet to be trimmed off, leaving the finished part ready for subsequent work. Depending on volumes of parts, trimming can be done with shears, band saws or routing machines, or for large volumes it may be necessary to use clicking presses, machined cutting forms or steel rules, to speed the process.

7.4. Assembly

QUINN HIPS sheet can be fabricated into a variety of shapes and articles with solvent, cement (a polymer dissolved in a solvent), or adhesive bonds. In general, when the surfaces to be joined are irregular, a cement is preferred over a solvent.
Solvents and cements are not the best choice when bonding QUINN HIPS sheet to other thermoplastics. Adhesives, including cyanoacrylates, two-part acrylics and hot melts, are more effective when bonding QUINN HIPS to dissimilar plastics and can be used to bond QUINN HIPS to itself.

7.4.1. Assembly guidelines

The following guidelines should be observed when bonding QUINN HIPS sheeting:

- The sheet edges must be clean and free from contamination.
- The surfaces must be smooth and accurately aligned.
- A solvent or cement must be sufficiently active to soften the mating surfaces for some flow to occur when pressure is applied.
- When using solvents in QUINN HIPS sheet assembly, it is advisable that the work area be climate controlled with low humidity to minimise joint 'whitening'. If this is not possible, the addition of 10% glacial acetic acid to the solvent or use of a slower curing cement-type bond is suggested.
- Fixture pressure must be maintained to prevent movement of the joint until it is solid.
- Good ventilation is required when working with solvents. Exposure levels must be controlled according to OSHA guidelines.

7.4.2. Bonding techniques: solvents, cements and adhesives

Small articles with flat surfaces can be joined by placing the pieces together and applying the appropriate bonding agent (solvent, cement, or adhesive). Care should be taken to ensure that the joints are uniformly coated; a solvent can be effectively applied with a needle applicator. The assembly should be clamped into position until the bond is set. When larger articles are to be solvent bonded, it is best to immerse the joining surfaces in a solvent bath until the material is softened and then clamp them into position until the bond has set. A constant level of solvent immersion should be maintained in a shallow pan with a support pad, screens, and other means to ensure part-to-part uniformity.
Several solvents, cements, and adhesives provide strong bonds when used in QUINN HIPS sheeting fabrication operations:

Material	Bond type
Methyl Ethyl Ketone (MEK)	Solvent
Methylene Chloride	Solvent
Mixture of PS in a 50/50 mixture toluene/MEK (300g PS/1000g mixture)	Solvent
Super Glue	Cyanoacrylate Adhesive

7.5. Finishing

7.5.1. Sanding

QUINN HIPS sheet is best sanded wet to avoid the frictional heat build-up that is characteristic of dry sanding techniques. If water coolants are used, the abrasive lasts longer and the cutting action increased. Progressively finer abrasives are used: for example, rough sanding with 80-grit silicon-carbide would be followed by finer sanding with 280-grit silicon-carbide, wet or dry. The final sanding may be with 400 or 600-grit sandpaper. After the sanding is finished and the abrasives removed, additional finishing operations may be required.

7.5.2. Joining

A standard woodworking jointer-planer will produce an accurately aligned and good quality finished edge on QUINN HIPS sheeting. Carbide or high speed blades, which have a longer life, will provide a uniform finish as well.

7.5.3. Filing

When many thermoplastics, including QUINN HIPS, are filed, a light powder that tends to clog some files is produced. Therefore, aluminium Type A, shear-tooth, or other files that have coarse, single-cut teeth with an angle of 45° are preferred.

7.5.4. Printing

QUINN HIPS sheeting can be printed with conventional equipment; however, the ink does not penetrate a plastic as it does with paper and cloth and is therefore subject to damage by abrasion. This can be minimised by applying a light coat of clear lacquer over the printing.

There are a number of different methods used when printing on plastics including letterpress, letterflex, dry offset, offset lithography, rotogravure, stencilling, and screen process. In silk screening, the ink is spread on a fine metallic or fabric screen onto the product, and a squeegee is used to force the ink through the screen on the sheet.

Since each application may require a different type of ink, it is suggested that an ink manufacturer be consulted for recommendations.