INTRODUCTION TO THERMOFORMING-

Local Line Bending

2

INTRODUCTION

Local line bending thermoplastic sheets has three stages:

1 Heating the sheet along the bend line to its elastic window using a strip heater.

Note: The best bends are produced when material is in its elastic state; the material retains enough tensile strength to maintain its form, producing uniform, aesthetically pleasing bends.

2 Folding the sheet, normally by hand, taking care to avoid contact with the heated area.

3 Securing the sheet in its folded position to cool, normally using some form of cooling jig.

HEATING A THERMOPLASTIC SHEET FOR LINE BENDING

As already mentioned in part 1, there are 3 types of strip heater commonly used for line bending:

1 Hot wire heaters

2 Radiant element or inconel sheathed element heaters

3 Contact heaters

In this section, we will look at each heater type in greater detail.

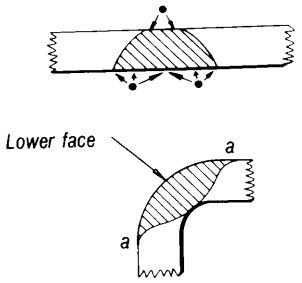
HOT WIRE HEATERS

Suitable for all thermoplastics, including PC, cast and extruded PMMA, PVC, PETG, ABS, PS, HDPE and PP.

When current passes through a resistance wire, every point along the length of the wire emits the same amount of heat.

If the wire is tensioned between two points then it will be straight between those points. The result is an extremely straight and uniform heat source. Add to this the ability to arrange wires alongside each other at distances as close as 1mm and you have the most ideal and versatile heating technique for bending thermoplastic sheets that has been developed to date. Lines as long as 3M can be heated with a negligable temperature differential along their length.

The amount of heat emitted can be controlled (by the voltage) so that material can be placed very close to the wire without burning. This has two benefits.



A typical hot wire heating configuration

Firstly, a very localised heating is achieved - similar to that produced by contact heating but without the contact.

Secondly, because most of the heat being generated is being used to heat the plastic, the rest of the machine remains relatively cool, removing the need for reflectors or water cooling. *(Note: water cooling can be used on a hot wire heater to reduce bowing along the bend line)*

Another advantage for clamping heaters is that the material can be clamped where it is cool, eliminating marks and blemishes.

Heat band widths can easily be controlled by arranging different numbers of wires along a bend line. In material over 3mm for example, bending times can be reduced and aesthetic properties enhanced if a wider heat band is applied to the outside of the bend. This can also help when making two opposing bends simultaneously in the same sheet.

RADIANT ELEMENT OR INCONEL SHEATHED ELEMENT HEATERS

Suitable for thermoplastics with a large elastic window, such as cast PMMA, PVC, PETG or ABS.

The heating element can have hot and cold spots along its length because of the way it is manufactured and the way it is fixed (brackets act as heat sinks).

When a sheet is heated parts of the bend line will be hotter than others. With a large elastic window this doesn't matter because the material will be elastic at say, 120˚C as well as 150˚C and fold just as well when parts of the bend line are at both temperatures.

If, however, the heating characteristics are mainly plastic, then some areas of the sheet will be ready to fold (ie. elastic) when others are too cool. By

the time the cool areas are hot enough to bend, the areas that were previously hot enough, will have become too hot (ie. plastic - or even worse, degraded) and deform when folded, spoiling the look of the bend.

The elements generally consume a lot of power and produce a lot of heat which has to be directed and controlled either by reflectors or water-cooled work supports (or both), to prevent too much of the sheet being heated.

Radiant elements can be fragile and expensive to replace.

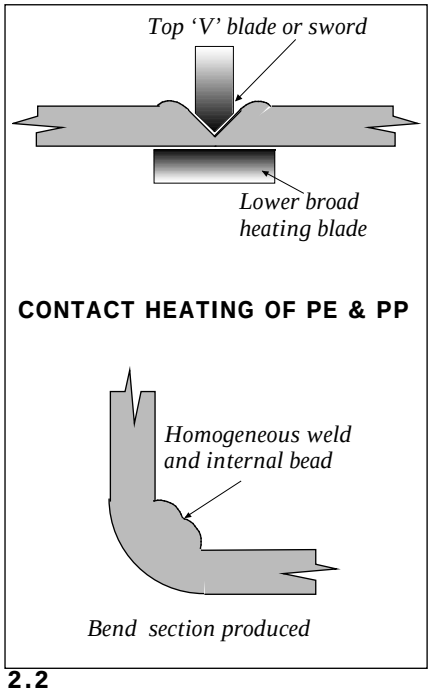
CONTACT HEATERS

Suitable for thermoplastics with a large elastic window, such as cast PMMA, PVC, PETG or ABS.

The material is heated by a blade or blades with integral heating elements, either mounted in groups on a machine or built as an individual and portable 'heating sword'.

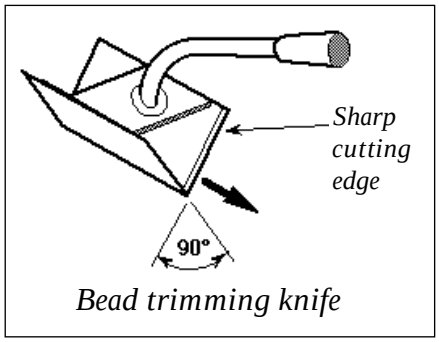
Contact heating is particularly useful for very thin material because it is very accurate - the heat goes exactly where you put it. Unlike thicker material, where a wide heat band is required, on thin material you only want to heat an area one or two millimetres wide and this can be governed very accurately by the section of the contact blade.

Generally we would say that only elastic materials are suitable because the blades will have a tendency to leave slight grooves in the sheet. Elastic material will recover its original shape using its plastic memory before it cools, whereas material in its plastic state will not recover and will be permanently blemished.



CONTACT HEATING OF PE & PP

Sometimes this can be an advantage, as in the case of PP and PE. To improve the speed of bending thick PP and PE sheets, a groove is sometimes routed on the inner face before bending. A 'V' shaped contact blade applied with enough force will form a groove during heating - removing the need for routing and speeding up the process even more.



Bead trimming knife

When the sheet is folded, the material that has been displaced either side of the 'V' shaped contact blade will fuse together, forming what looks like a weld and increasing the strength of the bend (this 'weld' can be trimmed off with a bead trimming knife immediately after forming if it is not wanted).

Note: Some form of PTFE coating is essential when contact heating PP to prevent the material sticking to the blades.

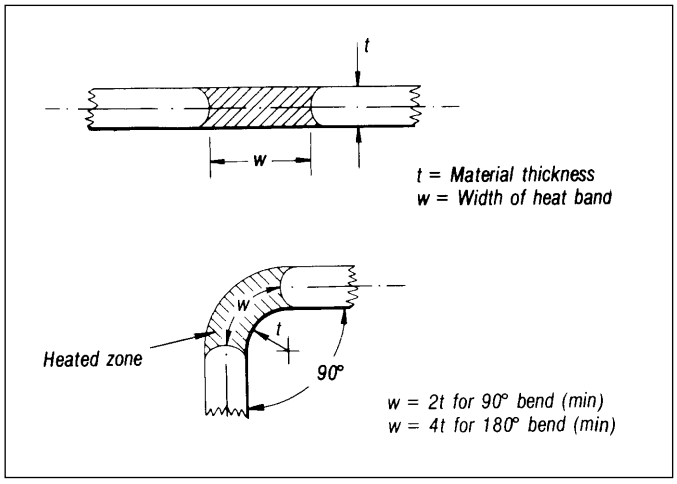
BEND CHARACTERISTICS

The style of a bend, depends mainly on the heat band width, which should be adjustable.

The heat band width determines the radius of the bend, and can be roughly calculated using the formulas below:

90˚ bend: Heat band = 2 x inner radius [inner radius must be greater than sheet thickness]

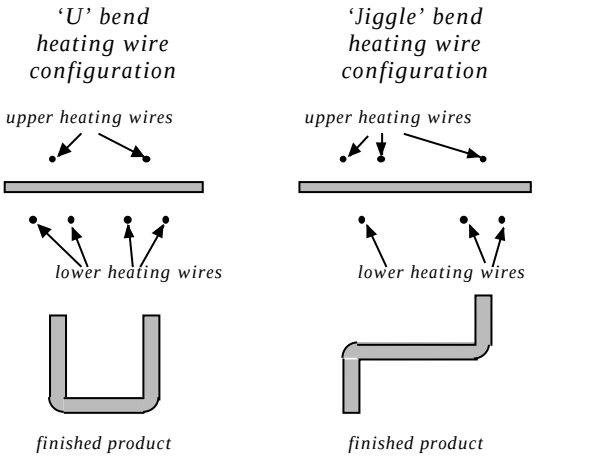
180˚ bend: Heat band = 4 x inner radius [inner radius must be greater than sheet thickness]



There is no limit to the radius you can give a bend but, large radii only work well with materials that can be folded in their elastic state.

DOUBLE SIDED HEATING

Heating a sheet from both sides can cut the heating time almost in half. Double sided heating with hot wire heaters also enables control of the



bend characteristics and produce opposing bends in single sheets simultaneously.

BENDING THE SHEET

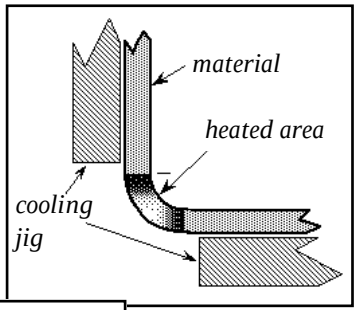
Folding is normally done by hand. There are strip heaters on the market that are equipped with folding apparatus but these are expensive. The folding work of most fabricators involves complex designs and large volumes, so the pieces are folded and loaded onto cooling jigs by hand.

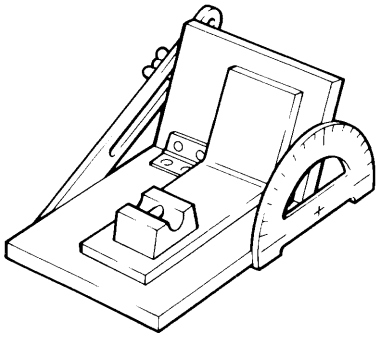
The bend must never be touched when it is hot, even if you are wearing gloves. When it is hot, even if it is only in an elastic state, a sheet is vulnerable to pressure marks from hands and fingers. A hot sheet can be slightly tacky and dirt and fibres can stick to the heated line.

COOLING THE SHEET

Most fabricators use wooden or composite board cooling jigs, some of them designed to be loaded with 50 pieces or more, held in place with soft jawed clamps if necessary.

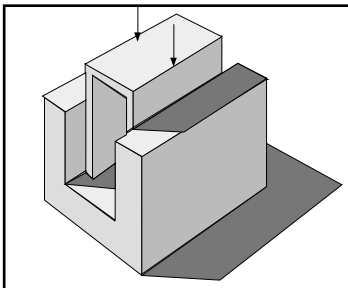
When designing a cooling jig, it is important to remember that the heated bend should not come into contact with any other surface to avoid



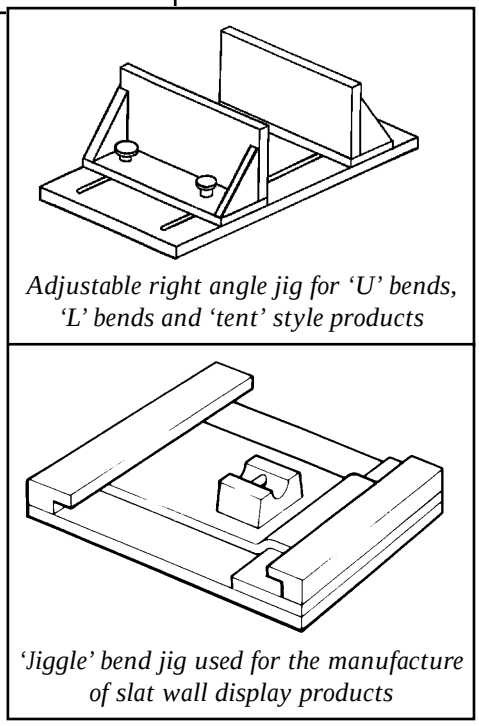


Adjustable 'protractor' jig to set angles

blemishes. The beauty of TP line bending is that only the bending line is flexible so in fact, a jig can be nothing more than four nails in a board that stop the four corners of an angled sheet from splaying apart. But most fabricators have more complex requirements and invest a good deal of time designing jigs that will do the job cleanly and efficiently.



A dedicated 'U' bend jig accurately controls the outside dimensions



Adjustable right angle jig for 'U' bends, 'L' bends and 'tent' style products

'Jiggle' bend jig used for the manufacture of slat wall display products

Small returns which would be impossible to fabricate by hand can be made by placing the heated edge of the sheet into a slot and then folding the rest of the sheet back against the jig.

DISTORTION

Distortion can be a problem for fabricators. Multiple bends in close proximity, bends in narrow sections or bends near the edges of sheets all suffer from buckling during heating and bowing along the bend line when cool.

The problem arises because the line of heated material expands whilst the cool material either side of it does not.

During heating this can cause distortion which can be restricted by clamping the sheet.

When the sheet is folded, the bend line cools and contracts after it has become rigid again. This produces a bow as the bend line pulls the two ends of the sheet together.

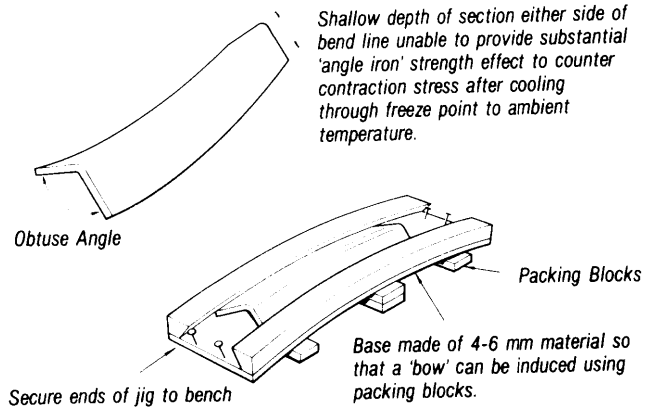
COUNTER BOWING

The effects of bowing can be reduced in a number of ways:

1 Keep bends well spaced and away from edges - if there is plenty of material either side of the bend it helps to restrict its movement.

2 Use minimum width heat lines.
3 Use water cooled heater beams to reduce the heated area.
4 Clamp in a straight cooling jig and anneal.
5 Cool in a counter bowed cooling jig.

A counter bowed cooling jig incorporates a bow in the opposite direction to the one expected in the material, the stresses induced in the bend line due



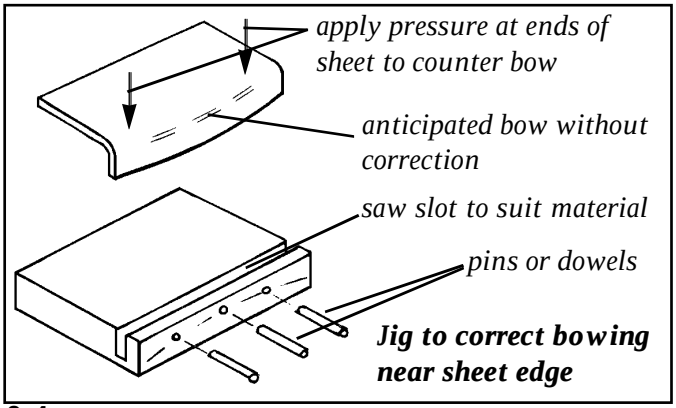
A long shallow item with little depth of section either side of the bend line to oppose stress

to heating should pull the bend straight when removed from the jig.

It is best to establish counter-stress measurements by experiment - a good place to start might be to measure the bow on a piece of material bent on a normal cooling jig and take if from there.

When producing multiple bends in close proximity there is a tendency for the stress produced by each bend to accumulate and compound the distortion which becomes progressively worse (if the bends are done one at a time).

It is better to use a multiple bending heater to make all the bends simultaneously so that the piece only picks up the distorting stresses from a single heating cycle.



Jig to correct bowing near sheet edge

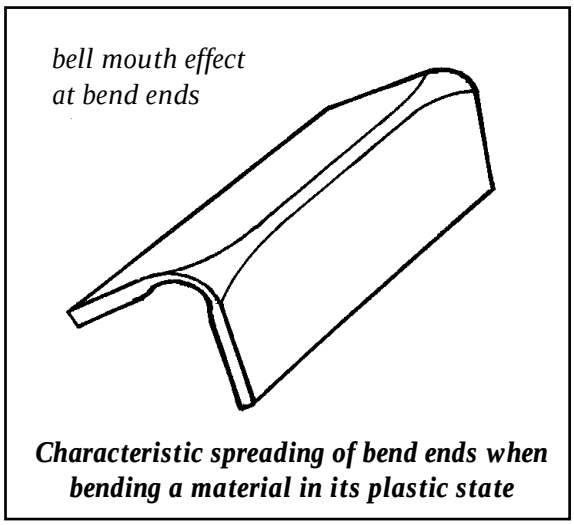
PS & PP

As already mentioned, bending TP's in their plastic state can lead to unsightly bends and 'bell mouth' ends - particular problems for materials like PS and PP - so following are a few things that can help.

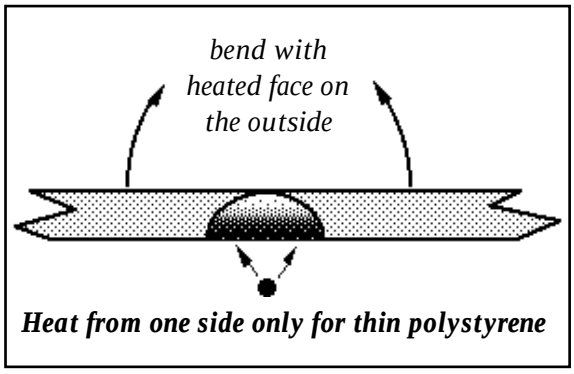
Avoid large radius bends; keep the heat band width to a minimum.

Heat from one side and keep the heating time as short as possible so that a very small area of the top face becomes flexible and hopefully, remains elastic.

Bend with the heated side outwards and a sharp, well defined bend with a minimum radius should be produced. (PP can be bent like this but, bending it the opposite direction works just as well, as a bead of material builds up on the inside of the bend in the same way as if it had been contact heated).



Characteristic spreading of bend ends when bending a material in its plastic state



Heat from one side only for thin polystyrene

C.R.Clarke
& Company (UK) Limited
Betws Industrial Park, Ammanford, Carms. SA18 2LS.
Tel: +44 (0)1269 593860 Fax: +44 (0)1269 591890
Email: sales@crclarke.co.uk Internet: www.crclarke.co.uk
C.R.Clarke & Company (US) Inc.
4407 Vineland Road, Suite #D5, Orlando, FL.32811
Tel: 1 800 676 7133 Fax: 1 407 648 1905