

SPIRO DRAW PROJECT

Target Age Group

Key Stage 4

Skills Learned

CAD, CAM, Design, Laser Cutting, Vacuum Forming, Finishing and Assembly

Outline of Project

In this project, the students design and make a "Spiro Draw" pattern making set. The outer frame of the Spiro Draw has a circular cut-out in its centre. This cut-out is machined with teeth.

A set of wheels is manufactured with varying numbers of matching teeth. (See "Advanced Content for the Brave" for further information on Spirograph geometry)

By adjusting the number of teeth on the gears, and the gears used for each drawing, different patterns can be drawn on a piece of paper.

To complete the project, a vacuum formed tray is manufactured to hold the Spiro Draw set along with pencil, rubber, sharpener etc. An MDF base is manufactured to secure the work to and provide a storage location for A5 paper.

The base is complemented by a line bent clear acrylic cover, giving a complete product.

An MDF base is manufactured to provide both a work surface and a storage location for A5 paper.

Materials to be provided to the Students

1 piece of 3mm MDF, cut to 430mm x 227mm* (Mould mounting board)

7 pieces of 3mm MDF, cut to 310mm x 210mm (Mould Layers)

1 piece of 3mm MDF, cut to 148mm x 210mm (A5 Base plate)

1 piece of HIPS (High Impact Polystyrene) or other suitable material 1.5mm thick, cut to 458mm x 254mm* (Vacuum Forming)

1 piece of acrylic 3mm thick, cut to 320mm x 470mm (Cover)

1 piece of acrylic 3mm thick, cut to 148mm x 148mm (Spiro Draw pieces)

Double Sided Sticky Pads

5 x No 8 x 20mm Woodscrews

* This is based on the C R Clarke 917/725 Vacuum Forming Machine. The dimensions may need to be altered for different makes or models of machine.

Equipment Requirements

Vacuum Forming Machine

Laser Cutter**

Strip Heaters

** We have used a Laser Cutter throughout this project. Depending upon availability, a Router or Milling machine could be used equally well.



SPIRO DRAW PROJECT

STEP 1

DESIGN THE SPIRO DRAW SHAPES (CAD)

The students should start with a blank outline of the piece of acrylic that they have. Firstly, they should draw a ring gear of a suitable size, which will be cut in the centre of the acrylic. This should start as a circle and then have a number of teeth added.

For initial projects, we recommend using the following tooth details:

No of Teeth = Outside Diameter of Ring Gear in mm

Tooth dimensions as shown in Diagram 1

Note that, when drawing the teeth, the centreline of each tooth must be perpendicular with the outer diameter of the circle. Therefore, the angle α on Diagram 1 will vary depending upon the diameter. Angle α can be calculated as:

$$(360/\text{No of Teeth}) + 60$$

Four holes 1mm diameter should be added to secure the surround and the insert of the Spiro Draw to the paper being patterned.

Next, within the ring gear, draw circles and add teeth to make the gears. Again, initially follow the tooth form shown in Diagram 1. Note the relationship between the number of teeth in the ring gear and the number of teeth in each gear. For example, a 50 tooth gear running in a 300 tooth ring gear will produce a six-sided shape ($300/50 = 6$). Should you choose an odd number of teeth (maybe $300/55$), the wheel will run for many revolutions before drawing over the same line. The number can be calculated by working out the Lowest Common Denominator (LCD) of the two numbers, i.e. the LCD of 55 and 300 is 3300. Dividing this number

(3300) by the number of teeth in the ring gear (300) gives the number of revolutions that will be completed before the pattern restarts, i.e. in this case 11 revolutions.

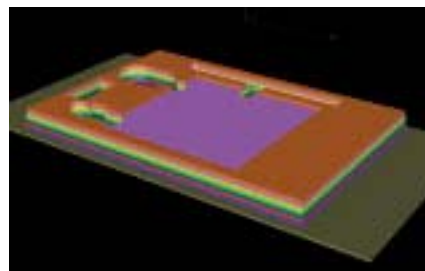
Suggestion: engrave your name, school logo or a pattern onto the face of the acrylic. Also engrave the number of teeth onto each gear.

Suggestion: Why limit yourself to round gears? How about elliptical or even polygon gears for an interesting effect?

STEP 2

DESIGN THE STORAGE TRAY MOULD (CAD)

The students should start with a blank outline of the seven pieces of MDF that will form a mould for manufacturing the storage tray. Within each layer, the required cut-outs should be drawn for the Spiro Draw set, a pencil, eraser, pencil sharpener and some drawing pins. Diagram 2 gives some outline dimensions for a suitable tray layout.



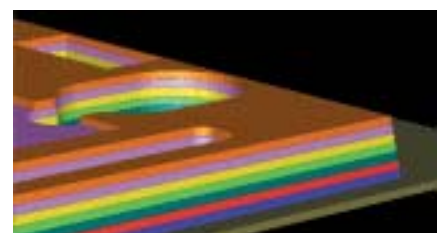
To help align the mould, make five holes in each layer, each a snug fit for a No 8 wood screw (around 4.1mm in diameter). Make the holes in the top layer only 1mm diameter. This will provide a pilot to guide the screw, while not showing on the final forming.

Remember to add ventilation holes of 1mm in diameter at this stage. These should be placed at the last points of evacuation (normally the bases of recesses etc) on the appropriate layers. On any layers below one with evacuation holes, place an aligning hole to allow this air to evacuate. Make these holes around 5mm in diameter to aid airflow and alignment.



When designing the layers ensure that each layer has a difference in size of 0.5mm on each edge (for 3mm MDF), to provide a draft angle to allow the forming to release. Working from the top layer down, any outer edges must increase in size on each layer. Conversely, any apertures must decrease in size.

Suggestion: Engrave the number of each layer onto the MDF. This will help with assembly later.



STEP 3

DESIGN THE BASE PLATE OF THE STORAGE TRAY MOULD

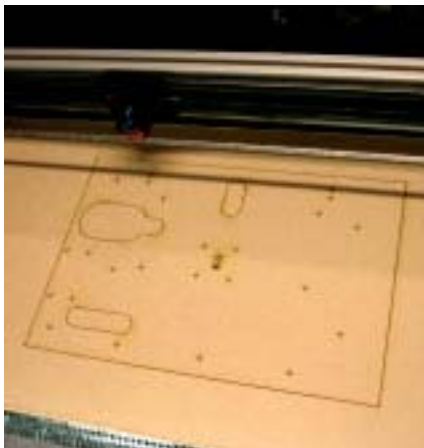
This will simply have a central hole of 6mm diameter to allow air to be evacuated, along with four holes to line up with the screw holes in the other mould layers.



STEP 4

CUT THE STORAGE TRAY (LASER CUTTER, ROUTER)

Load the material into the Laser Cutter. Download the programme. Set the machine at suitable power and speed settings and cut out the components.



STEP 5

CUT THE SPIRO DRAW (LASER CUTTER, ROUTER)

Load the material into the Laser Cutter. Download the programme. Set the machine at suitable power and speed settings and cut out the components.



STEP 6

ASSEMBLE THE MOULD (HAND SKILLS)

Countersink the underside of the securing screw holes. Place each layer in turn over the screws. Add PVA wood glue at any stage where the screws may not be sufficient, for example where there are thin rails of material. Fit the securing screws and tighten.



Place sticky pads onto the underside of the bottom mould layer, and stick to the base plate ensuring that the holes line up. This provides a gap for the air to be evacuated.



Finish any edges with fine glass paper and the mould is ready to use.



SPIRO DRAW PROJECT

STEP 7

VACUUM FORM THE TRAY (MACHINERY SKILLS)

Load the mould into the vacuum forming machine and form using 1.5mm HIPS.

Suggestion: Flocked or leathergrain material can be used for the tray to give a different feel to the forming.



STEP 8

TRIM THE VACUUM FORMING

Using a C R Clarke Profile Cutter, or similar tool, trim the base of the forming to leave a smooth edge.



STEP 9

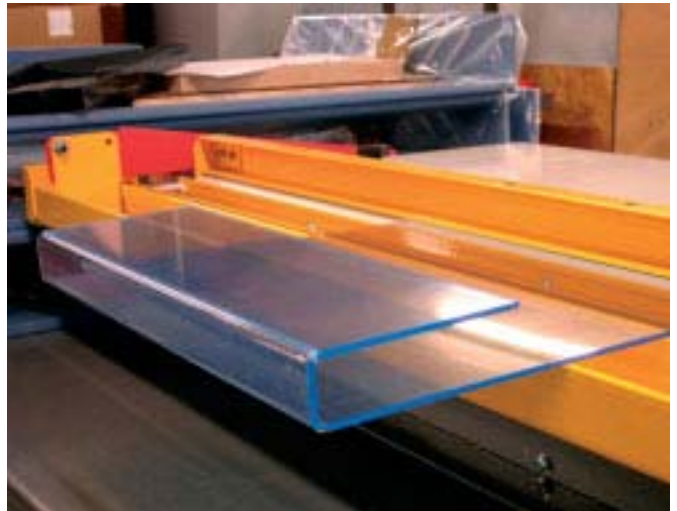
MAKE THE BASEBOARD

This is a pre-cut piece of MDF to suit A5 paper. There is no need to do anything more to this other than sand the edges smooth. However, an engraved pattern can be made on it if desired.

STEP 10

MAKE THE ACRYLIC COVER

Heat and fold the acrylic to the dimensions in Diagram 3. If using a C R Clarke 1000 or 1220 Hot Wire Strip Heater, two folds can be done in each operation. For other machines folds will need to be done singly.



Pack your Spiro Draw into the tray. Fill with A5 paper, place the MDF base under the tray and slide the cover over. Your Spiro Draw set is ready to use!

ADVANCED CONTENT FOR THE BRAVE

If the radius of fixed circle is R , the radius of moving circle is r , and the offset of the pen point in the moving circle is O (Figure 1), then the equation of the resulting curve is defined by:

$$x = (R+r)\cos(t) - (r+O)\cos(((R+r)/r)*t)$$

$$y = (R+r)\sin(t) - (r+O)\sin(((R+r)/r)*t)$$

Where $t = \text{angle}$

(0,1,2,3,4,5,...359,360) etc. These are the parametric equations for the curves. Mathematicians call this path an epicycloid. The rest of the world calls them Spiro Graphs.

For correct meshing of the spirograph it is essential that the size of the teeth on the moving circle are the same as the size of teeth on the fixed circle. One measure of size is the circular pitch, p , the distance between adjacent teeth around the pitch circle thus;

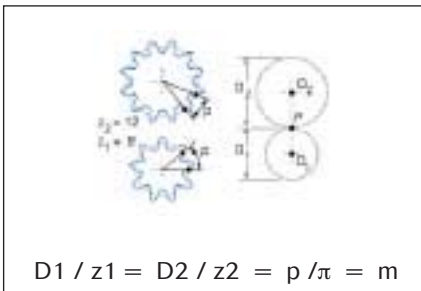
$$p = \pi D/z$$

where z is the number of teeth on a gear of pitch diameter D .

The SI measure of size is the module;

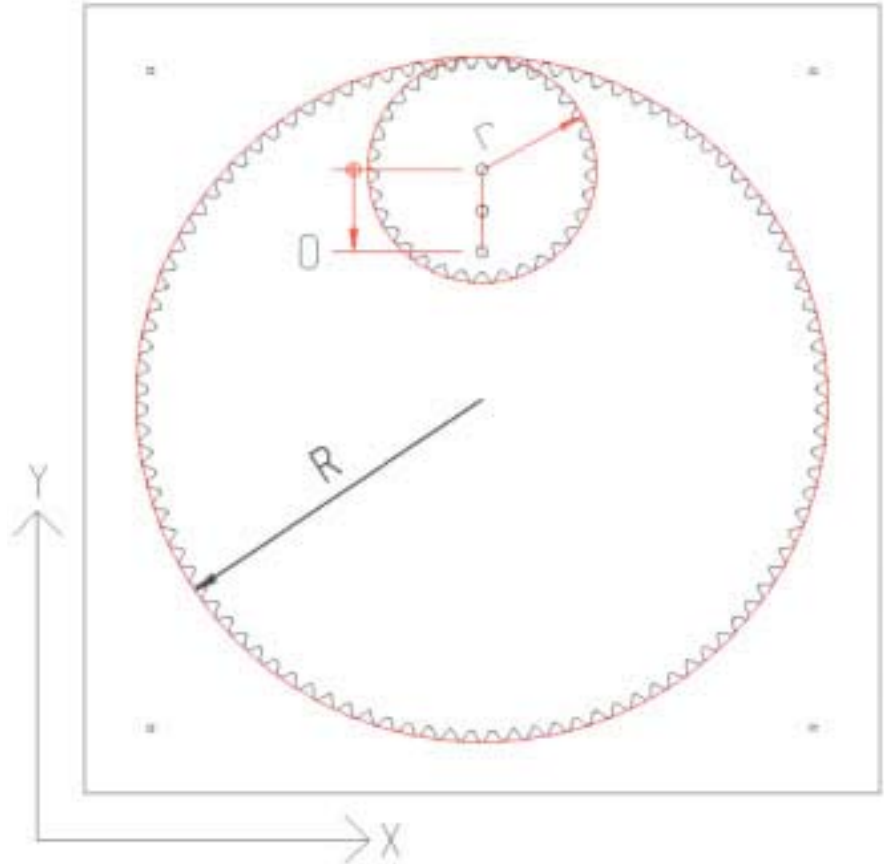
$$m = p/\pi$$

which should not be confused with the SI abbreviation for metre. So the geometry of the moving circle and the fixed circle must be such that:



$$D1 / z1 = D2 / z2 = p / \pi = m$$

...that is the module must be common to both gears.



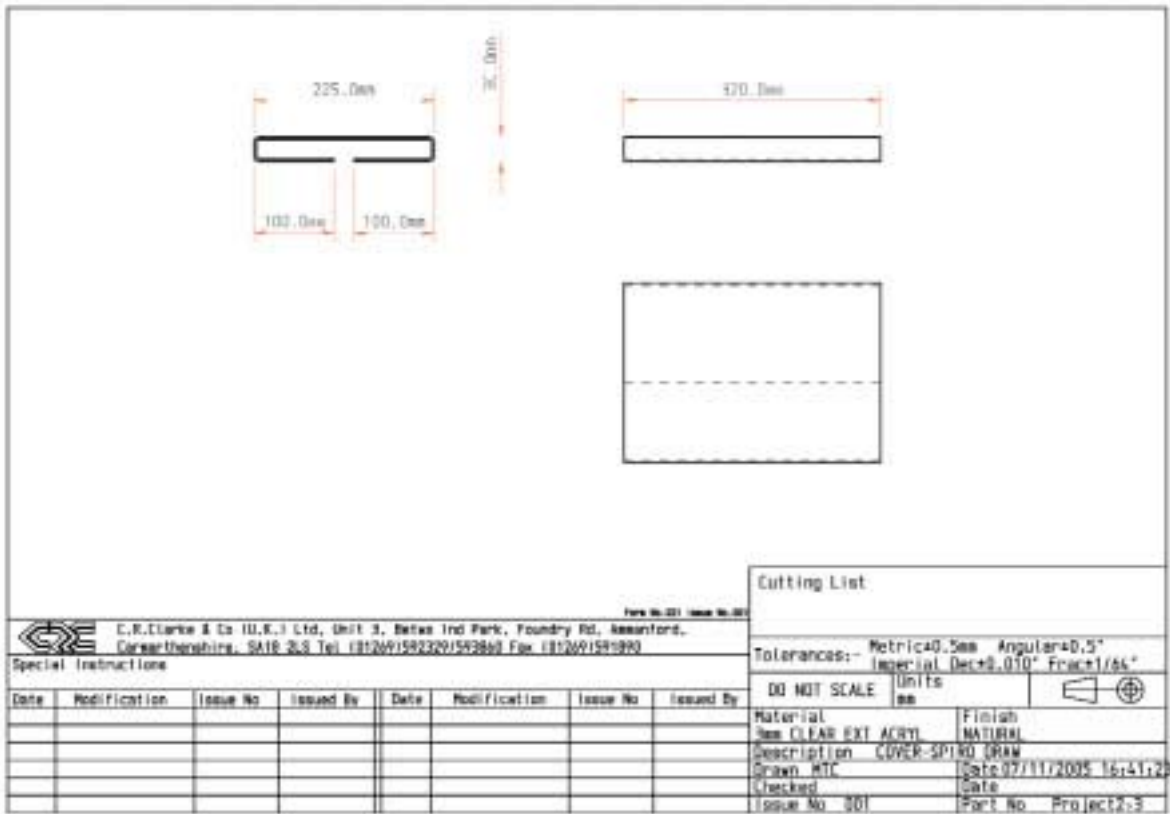


Diagram 3