

Application of trigonometry in design and manufacturing of tooling in the industry

Introduction:

The main project in my year in the industry was to semi-automate one of the assembly lines at PEI-Genesis. PEI-Genesis is the fastest connector assembler in the world and the assembly line that I was meant to semi-automate was called Amphe-Lite. Connectors in general are made of two essential parts, a shell and an insulator.

There are various methods of retention between a shell and an insulator. Some are achieved by using a combination of adhesives and compressive forces and some are achieved by purely using adhesives.

The description of the challenge:

Adhesives are used in Amphe-Lite products to retain the insulator within the shell. There are three different adhesives that need to be applied between the shell and the insulator in the appropriate locations. This essay focusses on the application of the first adhesive only.



The first adhesive is applied on the shoulder inside the shell. This had been done manually before the start of my project. Many of the failures from this production line were caused by the incorrect application of the first adhesive. The failures were caused by an inconsistent application of the adhesive, application to the incorrect location and not having enough adhesive on the shoulder. Now that the process had to be done by the robot, an appropriate tool had to be designed to replicate and significantly improve the manual process by eliminating all the causes of failure.



Figure 1 - The difference of the angle of nozzle entry between the largest size and the smallest size

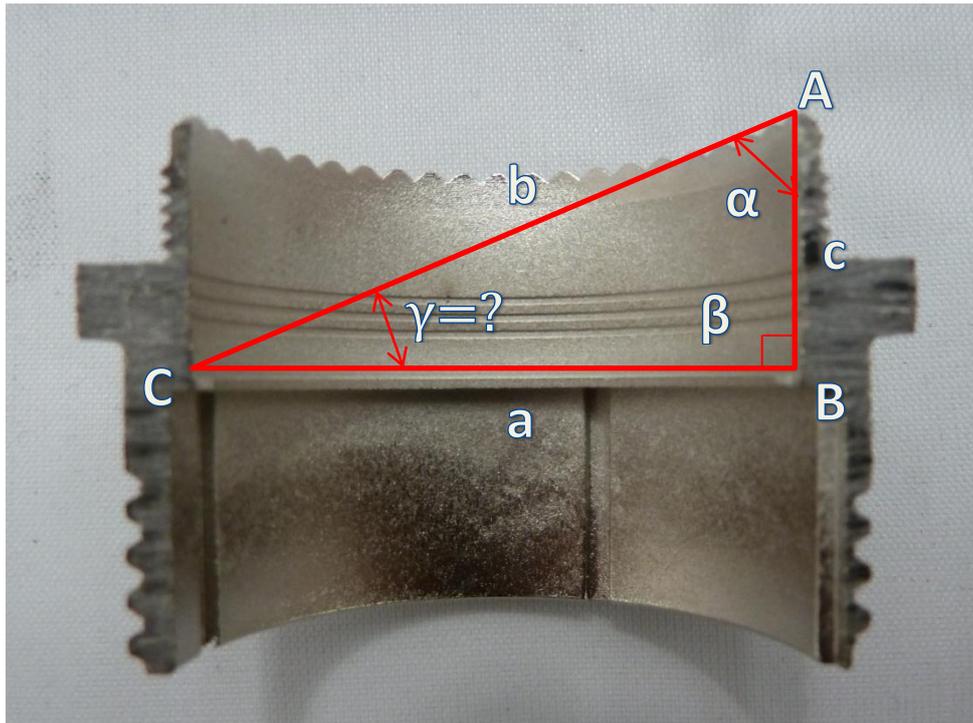


Figure 2 - Graphical representation of the mathematical problem

I was interested in finding the value of γ by using the following available values:

Variable	Value
a	12.08 mm =< a <= 33.35 mm
c	14.81 mm
β	90°

Sine rule:

$$\frac{\sin \alpha}{a} = \frac{\sin \beta}{b} = \frac{\sin \gamma}{c}$$

As β was already available, the part of the Sine equation that I was interested in was:

$$\frac{\sin \beta}{b} = \frac{\sin \gamma}{c}$$

The four variables in this equation are b, c, β and γ . I was interested in finding the value of the variable ' γ '. In order for me to do that, I first had to find the value of b.

This was easily found by using the Cosine rule:

$$a^2 + c^2 - ac \cos \beta = b^2$$

$$\beta = 90^\circ$$

$$\cos 90^\circ = 0$$

$$a^2 + c^2 = b^2$$

$$b = \sqrt{a^2 + c^2}$$

Now that the value of 'b' was found using the equation $b = \sqrt{a^2 + c^2}$, it was possible to find the value of γ using the below formula:

$$\frac{\sin \gamma}{c} = \frac{\sin \beta}{b}$$

$$\sin \gamma = \frac{c \sin \beta}{b}$$

$$\gamma = \sin^{-1}\left(\frac{c \sin \beta}{b}\right)$$

I substituted in the value of b into the equation:

$$\gamma = \sin^{-1}\left(\frac{c \sin \beta}{\sqrt{a^2 + c^2}}\right)$$

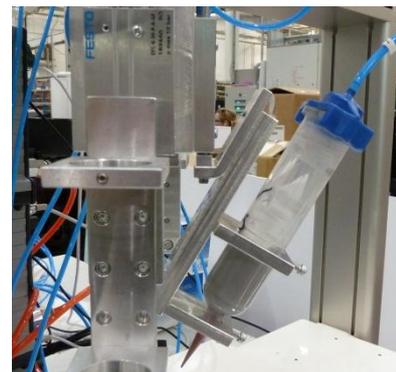
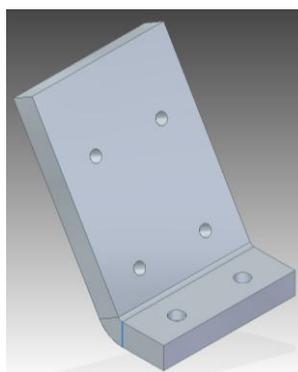
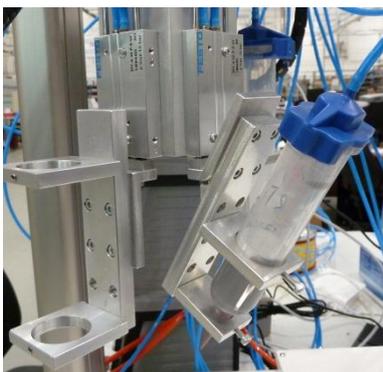
Using the above formula it was possible to find the maximum and the minimum value of γ , although I was only interested in finding the maximum value of γ (the angle of entry for the smaller connectors)¹. If the barrel's tip could access the shoulder inside the smaller connector it would imply that it could also easily access the shoulder on all the larger connector sizes.

$$\gamma = \sin^{-1}\left(\frac{c \sin \beta}{\sqrt{a^2 + c^2}}\right)$$

$$\gamma = \sin^{-1}\left(\frac{14.81 \cdot \sin 90^\circ}{\sqrt{12.08^2 + 14.81^2}}\right)$$

$$\gamma = 50.79^\circ$$

Now that I knew the angle of the barrel's tip can be anywhere between 50.79° and 90° , I had to choose an appropriate angle between the two limits for the tool. Since 50.79° was the bottom value, the value of 60° was chosen for the bend angle of the tool.



¹ Please refer to figure 1.