A Synthesis Module for Designing Shallow Bistable Arches in COMSOL®

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INTRODUCTION: For arbitrarily curved arches with fixed–fixed boundary conditions (see Fig. 2), the initial profile h(x) and the deformed profile w(x) are taken as the weighted combinations of the buckling mode shapes of a straight fixed–fixed column. Arch-profiles obtained from such a choice of basis set are kinematically admissible and tend to show bistability.

Figure 1. Schematic of a bistable gripper in the closed Configuration

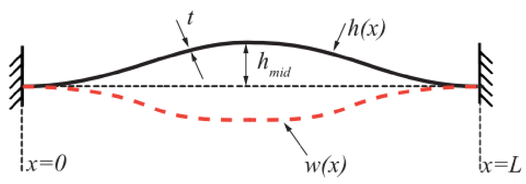

Figure 2. Fixed–fixed bistable arches with arbitrary initial profile

COMPUTATIONAL METHODS: By taking Ai and ai as the unknown weights corresponding to the i^{th} buckling mode shape, the normalized as-fabricated profile *H(X)* and the normalized deformed shape *W(X)* are written as

$$H(X) = \frac{h(XL)}{h_{mid}} = \sum_{i=1}^{\infty} a_i W_i(X)$$

$$W(X) = \frac{w(XL)}{h_{mid}} = \sum_{i=1}^{\infty} A_i W_i(X)$$

Where,

$$W_i(X) = \begin{cases} 1 - \cos(M_i X), & i = 1,\ 3,\ 5\ldots \\ 1 - 2X - \cos(M_i X) + 2\dfrac{\sin(M_i X)}{M_i}, & i = 2,\ 4,\ 6\ldots \end{cases}$$

$$M_i = \begin{cases} (i+1)\pi, & i = 1,\ 3,\ 5\ldots \\ 2.86\pi,\ 4.92\pi,\ 6.94\pi\ldots, & i = 2,\ 4,\ 6\ldots \end{cases}$$

Deriving equations for Bilateral relationship of shallow Bistable arches, and Implementing it in COMSOL® to make it an app.

$$a_1 = A_1 \frac{\sum_{i=1}^{\infty} \frac{M_1^2 A_i^2}{M_i^2} - 2\sum_{i=1}^{\infty} A_i^2 - \frac{1}{3Q^2}}{\sum_{i=1}^{\infty} \frac{M_1^2 A_i^2}{M_i^2}}$$

Where,

$$A_i = \frac{a_i}{1 - \frac{M_1^2}{M_i^2}\left(1 - \frac{a_1}{A_1}\right)}$$

COMSOL®'s 'Mathematics' physics and Optimization Module was used to solve the equations mentioned above and to find the constants A_i and a_i respectively.

The Application: When user enters the specified points for his required toggled profile of a Fixed-fixed arch, the COMSOL® solves the aforementioned equations and gives the as-fabricated profile of the bistable arch. The comparison of the two states of the Bistable arch. Screenshots of the solved problem showing the solved equations, normalized expressions is as shown in figure 3 and the overall COMSOL®'s application window is shown in figure 4.

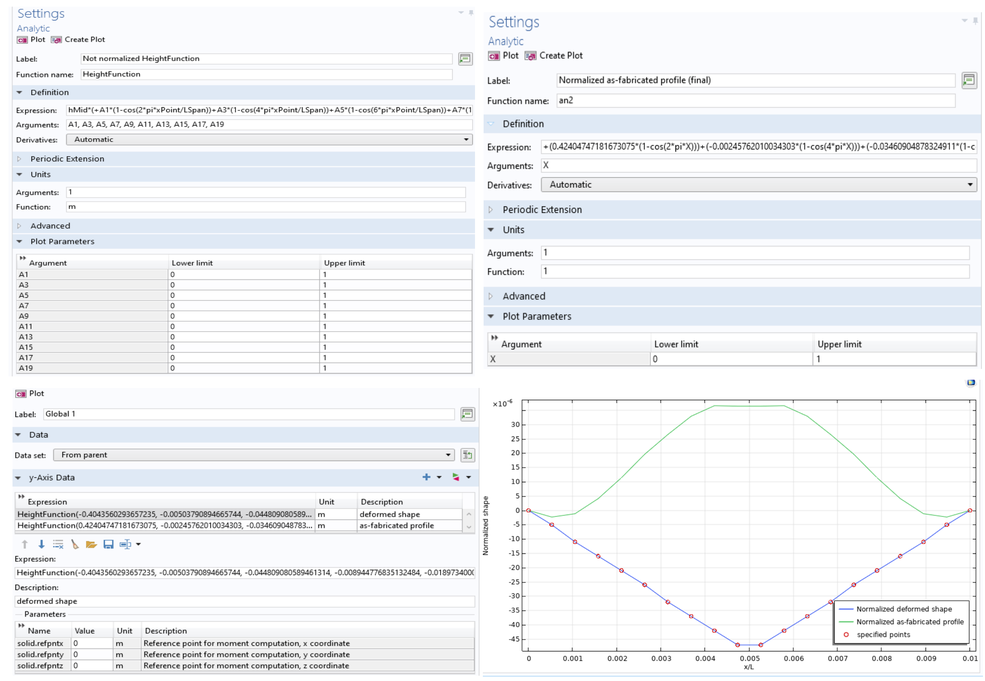

Figure 3. Screenshots of the app showing different features of the application

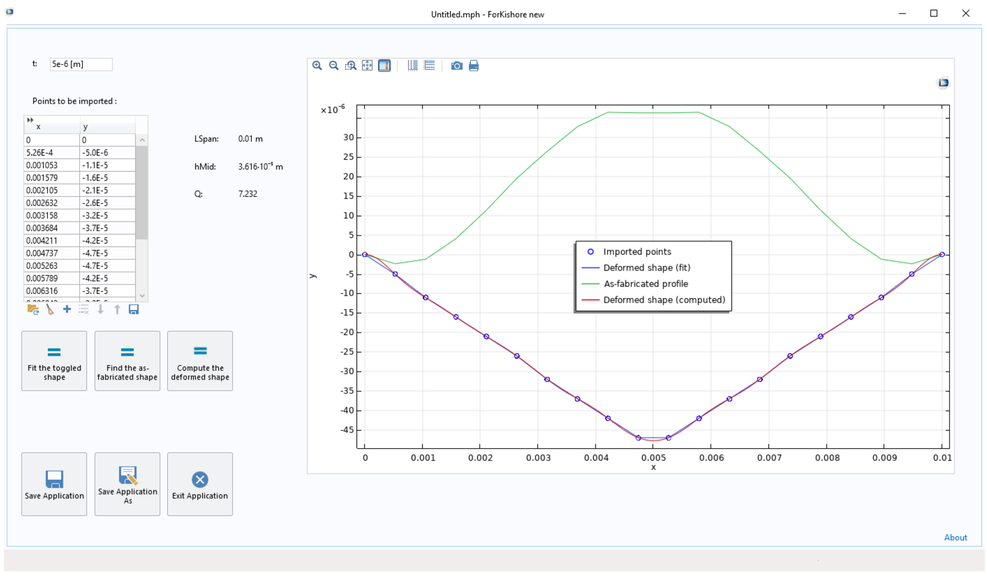

Figure 4. Screenshot of the app showing the overall application window

CLOSURE: An application in COMSOL® is developed by implementing the Bilateral relationship equations for shallow bistable arches having fixed-fixed boundary conditions. The developed COMSOL®'s app. gives the stress-free 'as-fabricated' shape of the shallow bistable arch when the coordinates of the required 'stressed toggled profile of the arch is given. Also, COMSOL®'s FEA solution is compared with the obtained analytical result as shown in figure 4.

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REFERENCES:

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