Popular Science Abstract: Implementation of inverse motion form finding in commercial software

Sean Mooney

June 2018

When an object is built using the exact dimensions of its desired geometry, the object may deform into an unwanted shape when a load is applied. However, the inverse motion form finding formulation can be used to calculate the manufacturing shape that will result in its desired geometry after a load is exerted on the object. This Masters dissertation investigates how to easily apply the inverse method through implementation in commercial software.

When an object is loaded with a force or pressure, the object will deform. The magnitude of the deformation will vary depending on factors such as the material of the object and the magnitude of the load. In general, the deformation of the object will be in the same direction as the direction of the applied load. Therefore, the geometry of an object is in its loaded state may differ from its intended shape. For example, if our object is a straight beam that is sticking out of a wall and a weight is hung from the end of the beam, the beam will bend downwards, as illustrated in Figure 1. This deformation can be calculated through a numerical solution method known as the finite element method (FEM), which can quite easily be done with various commercial software.

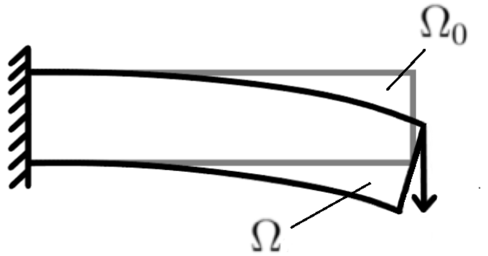

Figure 1: *Illustration of the forward motion form finding formulation. The deformed shape, Ω, is obtained from the forward motion solution procedure with the rectangular box as the design geometry.*

To mitigate the deformation of the object in its loaded state, changes can be made such as using a different material or making the object, in our case a beam, thicker to increase its stiffness. However, if the shape of the object in its loaded state is of major importance, these changes to the design may not be sufficient. They will reduce the deformation, but a small deformation will inevitably occur.

This master's dissertation suggests another approach to obtain the desired shape of the object in its loaded state. Instead of manufacturing the object in the same shape as it was designed, a backwards approach known as inverse motion form finding is used. This method calculates the shape in which the object should be manufactured to obtain the desired shape it was designed to have when loads are applied. In the case of the beam, this would mean that instead of manufacturing a straight beam that bends slightly downwards when the weight is hung from the end, the beam can be manufactured slightly bent upwards so that when the weight is applied, the beam bends down to obtain its perfectly straight shape, as illustrated in Figure 2.

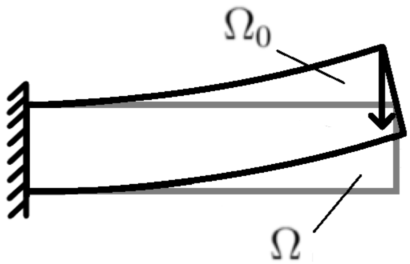

Figure 2: *Illustration of the inverse motion form finding formulation. The undeformed shape, Ω_0, is obtained from the inverse motion solution procedure with the rectangular box as the design geometry.*

To the author's knowledge, this inverse motion concept is not yet available in commercial software. Therefore, the scope of this Master's thesis has been to implement inverse motion form finding in commercial software. By doing so, this computational tool becomes easy to use by making it possible to create a geometry, perform the calculations and view the results, all within a single software framework. In addition, the implemented model can be used as a base for further research so that the implementation can be further developed to handle a larger range of problems.

A design similar to our previous beam example was created with the implemented inverse model. As shown in Figure 3, a straight beam is held in place in one end, marked with "A", and a downward force is exerted on the other end of the beam, marked with "B". With the inverse model, the manufacturing shape is calculated, as shown in Figure 4. The color scale in figure 4 show the deformation of the beam from the shape in Figure 4 to the shape in Figure 3 in meters, such that the blue end where beam is held in place has not moved and the red end where the load is exerted has had a large deformation.

The paper also suggests different applications in which the inverse motion form finding model could be utilized. This shows that the inverse motion form finding model is not only applicable to a narrow selection of applications, but can be used in a large variety of products including both technologically advanced designs and everyday objects.

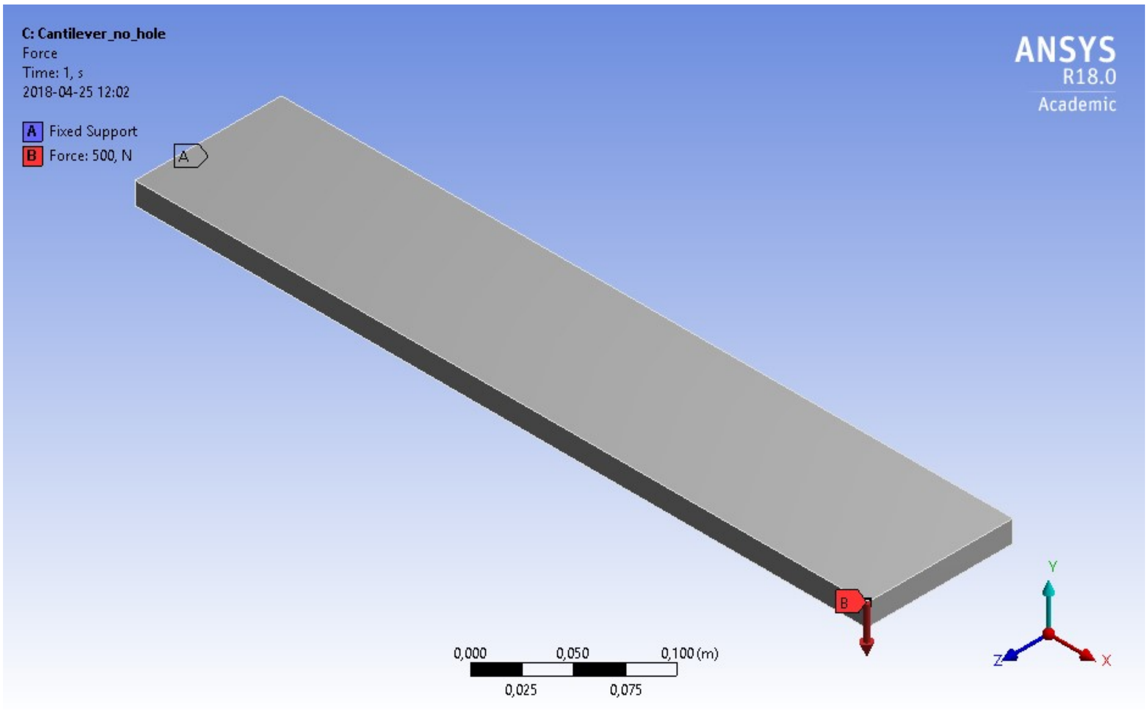

Figure 3: *The desired shape of the beam after deformation due to loading.*

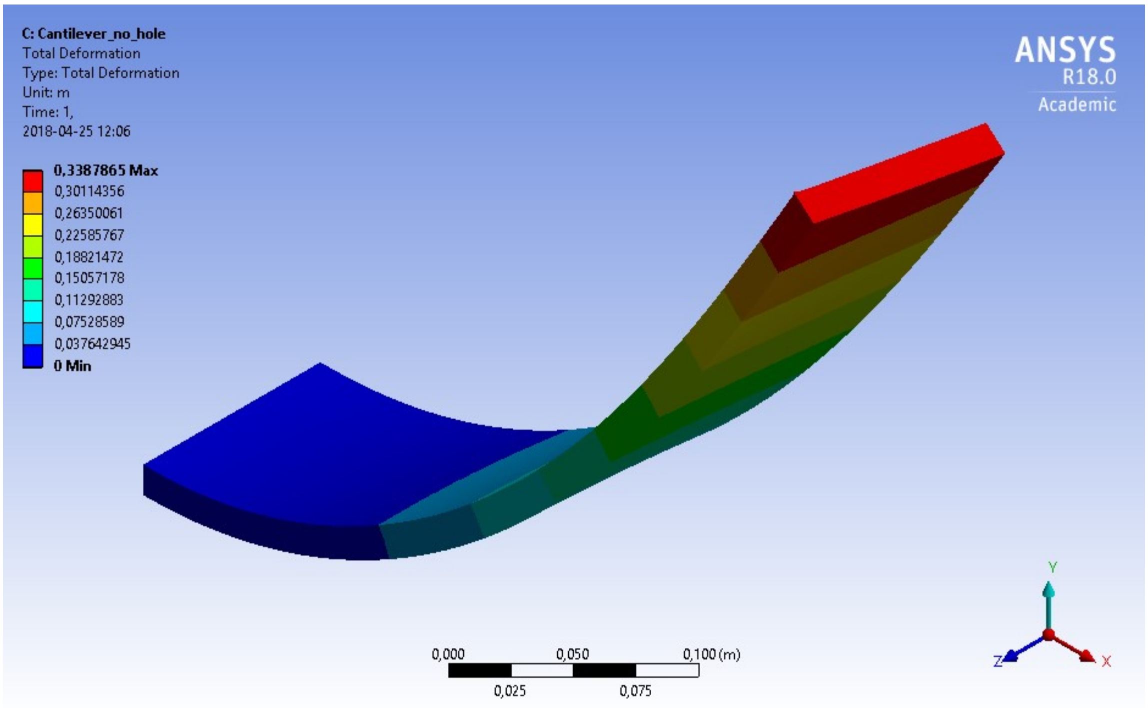

Figure 4: *The calculated undeformed manufacturing shape of the beam.*