Teaching bolt group analysis using MATLAB

What is a bolt group?

Bolt group is a critical component in structures, which connects different components together and transfers forces from one member to the other. Bolt group can appear as different types and different patterns. Even experienced civil engineers have hard times when coming to bolt group designs.

Bolt group deforms under load, but they deform differently and carry different loads. When bolt group deforms, it intends to rotate purely at each instantaneous moment, which gives the engineer an excellent opportunity to perform bolt group analysis—That is to find the instantaneous center of the bolt group at each loading step and eventually the load carrying capacity of the bolt group.

However, the location of the instantaneous center is not obvious. An iteration process or a trial-error process is necessary to find it. Once the assumed location leads to equilibrated forces in all directions, a true instantaneous center has been found.

How MATLAB helps this process?

In old times, engineers typically use manual calculations to check and balance the forces with the assumed location of instantaneous center. If a wrong location is assumed, more calculations will be needed to correct it. Conversely, if we set up the problem in matlab, a search loop or an optimization algorithm could help performing the calculations and find the instantaneous center efficiently.

Motivating students to learn advanced numerical tools and verify their calculation and design results

I teach structural steel design to upperclassmen and graduate students at the North Dakota State University. Using MATLAB for steel design is typically not a favorable thing in Civil Engineering. However, there are many such cases that a hand calculation cannot be performed easily, such as a bolt ground under a combination of forces and moments.

In my class, I emphasize two things. The first is to implement the algorithm in a concise way, while the second is to verify the solution obtained, which usually involves a comparison of the computational results to data, or the results from one or more simplified bolt groups. Both of them are critical for complicated structural designs.

To implement the algorithm in a concise way, it is needed to know the mechanism of bolt group analysis as well as the matlab programming skills. To verify the code, it is necessary to determine whether our method provides the expected outcome in a closely related situation in which the outcome is already known. Compared to manual design processes, students will appreciate how much time could be saved and how efficient and neat the calculations could be. It is also worthy to let the students know that most of the work they put into the matlab code can be carried over to many other types of applications.

Summary

In my class, most students learned to use matlab and adopt verification to ensure that relatively complicated computations are correct. However, training to use the advanced numerical tool and verification are just as important and useful for freshmen and sophomores. For example, a student may simply be asked to solve a simple calculus problem (in a math or a science class) using both analytic and numeric tools. The student can learn the matlab programming and verify their answers obtained by Matlab with the analytic expressions in textbooks. As another example, a student could use the matlab tool to verify and develop these design tables in the Steel Design Manual. These exercises should build student confidence in computational skills and good habits in utilizing advanced numerical tools for engineering design.