How to Check Another Engineer's Calculation

Donald L. Goddard PhD PE,

Checking a calculation done by another engineer can be one of the most important responsibilities of your engineering career. After you give your approval of the calculation, very few people will question its accuracy because it was done by an engineer and "its been checked!" An error will be that much harder to find and lives could depend on it. Your checking of the calculation could well be the last major safety hurdle the work will have to pass. Obviously, this is not a trivial matter.

1. Where to Start? Start with an Overview.

If you are going to check a calculation, you must first know what you are dealing with. You will need to obtain an overview of what the calculation is trying to determine. Hopefully the preparer has included a statement of purpose. If he or she has not included an overview, perhaps you should consider rejecting the calculation since, without a purpose, the results might be misused. Suppose for instance that an engineer is calculating the diameter to be used for a rifle bullet. If the purpose of the calculation is to determine what the ballistic flight performance of such a bullet might be, an approximation that causes the answer to be 0.1 mm too large probably won't make much of a difference. On the other hand, if the calculation is being performed to determine what size bullet to use in a particular rifle, an error of .1 mm too large could result in the gun blowing up and killing the user. It is best to understand what is being calculated and to what purpose the information is to be put.

2. Consider the Assumptions.

Once you know the objective of a calculation, you can consider whether the assumptions are appropriate. The reason for making many assumptions is to make the calculations simpler or more efficient. Attention needs to be paid to whether the assumptions are likely to produce a sufficiently accurate answer.

Accuracy may not be the only item to consider. In some cases, the assumption may be simply wrong. Inappropriate assumptions such as neglecting the mass of some item, assuming that a fluid is inviscid, assuming frictionless contact, etc. may result in a meaningless answer.

A truly difficult call on assumptions may be the problem that arises when the calculation is sufficiently complex that it is not clear what the consequences of a particular assumption will be on the answer. It may make the calculation easier, but it may be virtually impossible to determine what the effect is without doing the calculation twice.

3. Consider the References.

The references must be considered carefully. Some reviewers seem to act as if the use of recently published sources automatically makes the results somehow superior. This is usually a problem arising out of the "publish or perish" syndrome. However, the use of "good old classics" can be as bad.

Legal acceptability is a special problem to be dealt with. In some cases, the calculations must be prepared to a particular code. So if a pressure vessel must be designed to the ASME Boiler and Pressure Vessel Code, referencing other sources may make the work easier and produce a satisfactorily accurate answer, but the calculation will be useless until code compliance is demonstrated.

Perhaps the most vicious pitfall with references is the failure to carefully check what is being referenced. If a reference cited for a formula for estimating the yield strength of metal is not checked, including the rules for applying the formula, the point might be missed that the formula is invalid for cold worked material, or perhaps it doesn't apply to a particular class of alloys.

A related problem is that sometimes the source is just plain wrong. A text book listed the Young's modulus of steels as about $2*10^{11}$ Pascals and the shear modulus as $.84*10^{11}$ Pascals and Poisson's ratio as 0.19. While all these values are consistent with the formula relating the three and the Young's modulus is right, any practicing mechanical engineer should know that Poisson's ratio for steel is about .3 which would yield a shear modulus of about $0.77*10^{11}$ pascals. This is the reason that engineers should be doing the checking.

4. Examine the Drawings and Diagrams.

It can easily be disastrous if the calculation is entirely correct but it is performed on the wrong part. A careful analysis on a bolt to assure adequate strength and fatigue resistance can be meaningless if in fact the wrong bolt is analyzed or the bolt geometry is correct but a different material is specified in the notes on the correct drawing. Getting the correct drawings is a special case of checking the references.

Once the correct drawing has been obtained, measurements must be carefully checked to be sure that there is no confusion of items like shank length and shank diameter of a bolt with the thread length and thread diameter. A good understanding of the drawing should be obtained before proceeding with the actual checking of the computations.

5. Computational Method.

There are two key facets to be considered in assessing the appropriateness of the computational method.

A• The engineering theory of the method must be checked for appropriateness. For example if Castigliano's method is being used to determine a deflection, this can only be considered appropriate if all the criteria for the method are met (e.g. are deflections small, is the system linear elastic, etc.).

B• The mathematics of the method must be checked for appropriateness. For example if a time dependent differential equation is being solved by a Runge-Kutta method, has a small enough time increment been used or is it in fact too small? Too large an increment, and the numeric approximation is not close enough; too small, and round off error destroys the accuracy. With numerical methods, will the mathematical method converge in a stable manner to a solution over the entire region of interest defined by the parameters?

6. Replication of the Results of the Calculation.

There are two general approaches to verifying that a calculation has been executed correctly.

A• Direct replication is perhaps the most common procedure at this point if all the preceding concerns have been satisfied. A simple careful step-by-step replication of the computation is carried out. For most hand calculations, this will be the method used.

B• Indirect replication of the calculation is not necessarily an alternate to direct replication but it can be, and is extremely valuable in most cases. You may be familiar with an alternate method of calculating the same result in some problems. For instance, a numeric evaluation rather than a direct evaluation of a particularly difficult integral may be used, or perhaps and entirely different method to calculate a deflection of a particular component offers advantage. If the results come out the same or similar, the confidence level that there is no error in the computation can be high, (but deceptive if an error has been missed in the inputs).

7 What is Failure, and Have all the Credible Failure Modes Been Considered.

Many if not most computations directly or indirectly involve consideration of failure modes. In many cases, the emphasis on a particular failure mode causes the real problem to be neglected. One common, simple example is forgetting to calculate fatigue life and only bothering with calculation to assure staying below yield or ultimate stress. More subtle failures can occur, such as inserting a high strength screw into a threaded cast iron hole. The load distribution going mostly into the first turn or two of the female thread can cause a progressive failure of the female thread regardless of the length of engagement.

8. Is the Result Reasonable?

This step should be taken at both the start and end of the computational process. Any result, which appears unreasonable, should set off alarms on the part of the checker. Even when each step of the calculation seems correct, an unreasonable answer suggests that there may be a subtle error that has been missed.

Sometimes a result that appears unreasonable based on previous experience is in fact correct, but in such cases, the you should track down why. What odd combination of input parameters is responsible for this result? Finding the reason why will add to your confidence level and in some cases open a whole new realm of possibilities for a shrewd observer.