

simplifying the interpretation of the results. Today this should not be necessary anymore because the graphical software, as we said, can perform these operations on the data they read in.

4.2 Averaged and non averaged contours

An important aspect concerns the results plotting that can be done averaging them to the nodes or not. Generally in a finite element model any node belongs to more than one element; as the stress status inside each element is obtained by means of the shape functions (see also Appendix B) in an approximate way, it is not surprising if the stress value calculated for an arbitrary node is different for all the elements that share that particular node (we highlight that this is obviously not true for displacements, because it is exactly from the nodal displacements that strains and stress are evaluated). It is clear that as much the model is “good” as less the differences in the values will be, as we will see in Chapter 7. Post processing software are generally able to plot the results in both averaged and non averaged formats. Comparing figures 1 and 2, which illustrate the longitudinal stress contour for the classic beam (modeled with plane stress elements) clamped to one end and loaded by a shear force to the other end, it is possible to look at the differences present between averaged results (figure 1) and non averaged ones (figure 2); let us analyze them.

The first relevant thing is that on the coloured band the maximum and minimum values are coincident in the two cases: this tells us that the maximum and the minimum stresses are certainly located in nodes that belong to one element only; from the way the beam is loaded and constrained we know that this is true: maximum and minimum values are located in the clamped section, at the extrados and at the intrados respectively. And to these two points two nodes that belong to a single element correspond. The second aspect concerns the flow of the isostress lines at the boundary of two colours: in the averaged case these lines have a continuous flow and no steps can be noticed among the elements, while in the non averaged case the isostress lines appear discontinuous and present some steps among adjacent elements.

Moreover if the post processor in use allows the user to click on the nodes to query for the results it is useful to do it in order to retrieve the values calculated by the program. In the averaged case the value obtained by clicking will be unique, while in the other case the number of the results obtained will be equal to the number of the elements that share the clicked node. A test that will always be worth to do consists in calculating the averaged value by hand, starting from the non averaged data, and then verifying their correspondence with the averaged value calculated by the post processor.

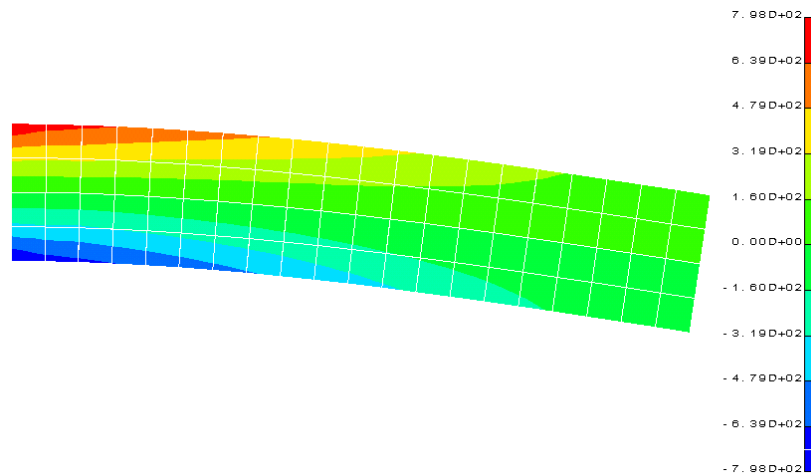


Figure 1. Longitudinal stress contour (averaged at the nodes).

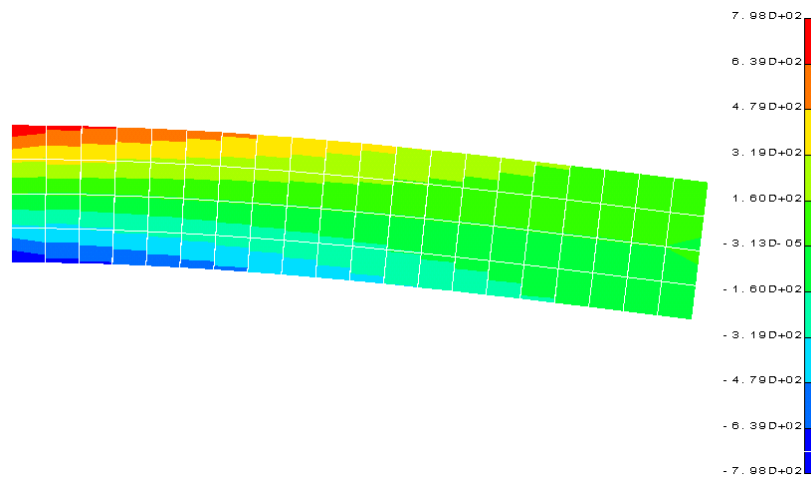


Figure 2. Longitudinal stress contour (not averaged at the nodes).

It is not possible to tell which of the two ways is the best because both of them present some advantages and some disadvantages. For example the non averaged plot allows to evaluate immediately the mesh quality: in fact the more evident the stress contour discontinuities are the worse the mesh quality is, thus indicating that some refinement should be taken into account (as we will see in Chapter 7). Nevertheless on the other hand an averaged plot for our simple example will allow us, by clicking on the neutral axis nodes, to establish that in these locations the longitudinal stress is equal to zero, as we expect from Solid Mechanics theory; a non averaged plot gives

four values that are almost identical in their magnitude, two positive and two negative, thus somehow hiding the null stress.

Clearly each time in a model a thickness variation is present in shell elements (but this is true also for plane stress elements) it is necessary to avoid averaged results, because at the boundary nodes the thicker part will tend to lower the stress value of the thinner part, thus hiding some possible structural integrity problems.

The last aspect concerns the behaviour of the post processor with respect to the derived quantities: for example the equivalent Von Mises stress is generally calculated by the finite element program, but it can also be evaluated by post processing software, starting from the stress tensor. But how is the concept of the average applied? In other words, is the plotted value the average of the Von Mises stresses or is the Von Mises stress calculated from the averaged tensorial values? We will leave the readers' willingness the answer to this question.

4.3 The reference coordinates system

The choice of the reference system with respect to which the results have to be plotted is crucial and it depends on various factors: the finite element code in use, the type of elements with which the model has been built, the post processor.

As we said in § 4.1 generally finite element codes give the user the possibility to choose, before the analysis is started, in which coordinates system the nodal displacements have to be calculated. Nevertheless the same thing can be said also for stress or internal forces; for example generally the stresses for shell elements are calculated in the element reference system, while for brick elements these are evaluated in the global reference system.

Therefore when using a post processing software attention to these details must be paid. Let us have a look to what can happen, still considering the beam clamped and loaded by a shear force, when the same quantity is plotted in two different reference systems.

Figure 3 shows the non averaged contour in the x direction of the global reference system, while figure 4 reports the stress in the y direction of the element reference system (local); as in this example the two directions are coincident, the two plottings should be equivalent. Nevertheless for the second case an irregularity can be well observed; a strong discontinuity, more evident than what can be expected from a non averaged contour. In this simple case it is very easy to understand what happened: for some reason (maybe due to some manual modifications to the mesh, i.e. a cancellation of an element and its subsequent recreation) the element located in the discontinuity region has a different orientation with respect to all the others. In the first case, as the quantity has been plotted in the global reference system, the post processor has read in the value from the solver and then recalculated it, thus producing a correct plotting regardless the element orientation; in the second case the post processor has simply reported what it has read from the solver, without performing any other operation.