3.2 Averaged and un-averaged contours

An important aspect concerns the plotting of the quantities that can be done by requesting them averaged in the nodes or not. Generally, in a finite element model, each node is connected to more than one element; since the state of stress within each element is obtained through the shape functions (see Appendix B) in an approximate way, it is legitimate to expect that the value of the stress calculated in a given node is different in the different elements that have that node in common (we emphasize that this does not apply to displacements, because it is precisely from the nodal displacements that strains and stresse are derived). It is clear that the better the model, the smaller the difference in values, as we will see in Chapter 6. Post-processing software is generally capable of plotting both averaged and un-averaged quantities. Comparing figures 3.1 and 3.2, which show the longitudinal stress contour for the classical beam (modeled with plane stress elements) clamped at one end and loaded in bending and shear at the other, the differences between the averaged results at the nodes (figure 3.1) and the non-averaged ones (figure 3.2) can be seen; let's pause to analyze them.

The first obvious thing is that on the scale of values the maximum and minimum coincide in the two cases: this tells us that the maximum and minimum are certainly found in nodes to which a single element belongs; we know that this is so because of the way the beam is constrained and loaded. The maximum and minimum are located in the clamped section, at the extrados and intrados respectively. And to these two points correspond in fact nodes to which only one element is connected. The second aspect concerns the contour of the isostress lines at the boundary between two colors: in the averaged case the lines have a continuous pattern and there are no "jumps" between one element and another, while in the un-averaged case the isostress lines appear "serrated", presenting strong discontinuities in passing from one element to another.

Not only: if the post-processor in use allows it, it is helpful to "click" on the nodes to get the corresponding value of the plotted quantity with the precision of the calculation program. In the averaged case the value will be unique, otherwise the numbers provided in correspondence of a node will be equal to the number of elements that belong to that node. A test that is always worth doing is to perform the average calculation by hand, starting from the non-averaged data, and verify the correspondence with the averaged value calculated by the post-processor.

It is not possible to say a priori which of the two systems is better because both have advantages and disadvantages. For example, the unaveraged plotting allows us to evaluate at a glance the quality of the mesh: in fact, the more evident are the discontinuities of the stress contours, the worse is the quality of the mesh, indicating that at least it could be worth evaluating a refinement of the mesh (we will see this aspect better in Chapter 6). However an averaged plotting for our example allows us, by clicking on the neutral axis nodes, to establish that actually there the longitudinal stress is zero, as we know from Solid Mechanics; an unaveraged plotting instead provides four almost identical values, two positive and two negative, not making immediately evident the absence of stress.

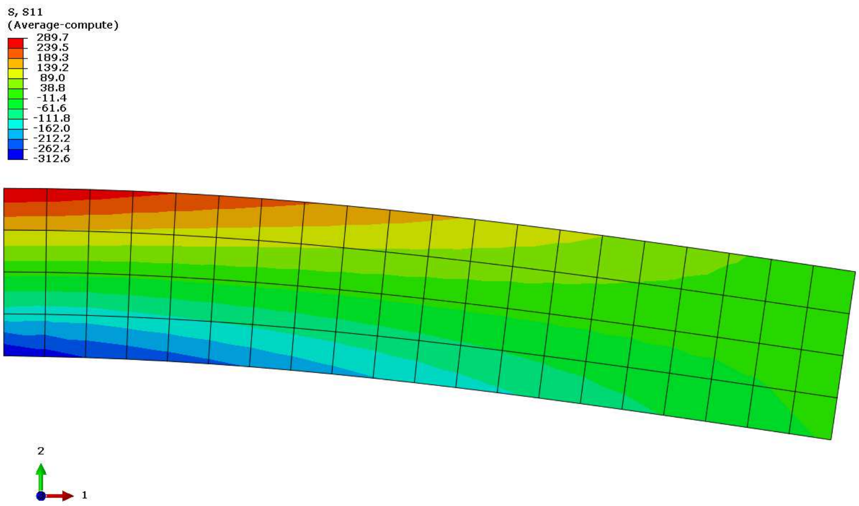

Figure 3.1. Longitudinal stress contour (averaged across nodes).

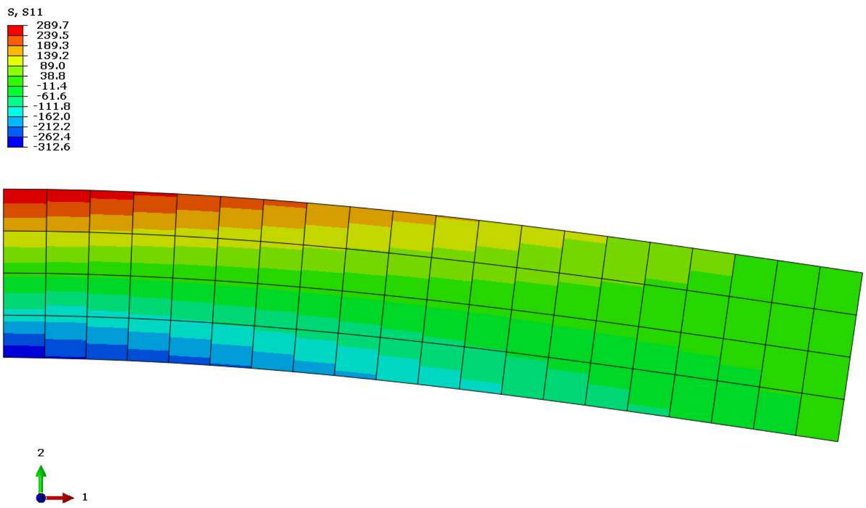

Figure 3.2. Longitudinal stress contour (unaveraged across nodes).

Clearly whenever there is a variation of thickness in shell elements (but it is also true for plane stress elements) it is necessary to avoid looking at the averaged values, since on the boundary the part with greater thickness would lower the stress values of the one with lesser thickness, thus hiding possible structural problems.

A last aspect consists in knowing how the post-processor behaves towards the derived quantities: for example the Von Mises equivalent stress is not always calculated by the calculation code, but it can clearly be determined within the post-processing programs, starting from the stress tensor. But how is the averaging argument applied? That is, is the plotted value the average of the Von Mises stresses or is it the Von Mises stress of the average of the tensor values? We leave the answer to this question to the more willing readers.