that there was something not correct in the model and therefore the decision to use the model of figure 8.39.

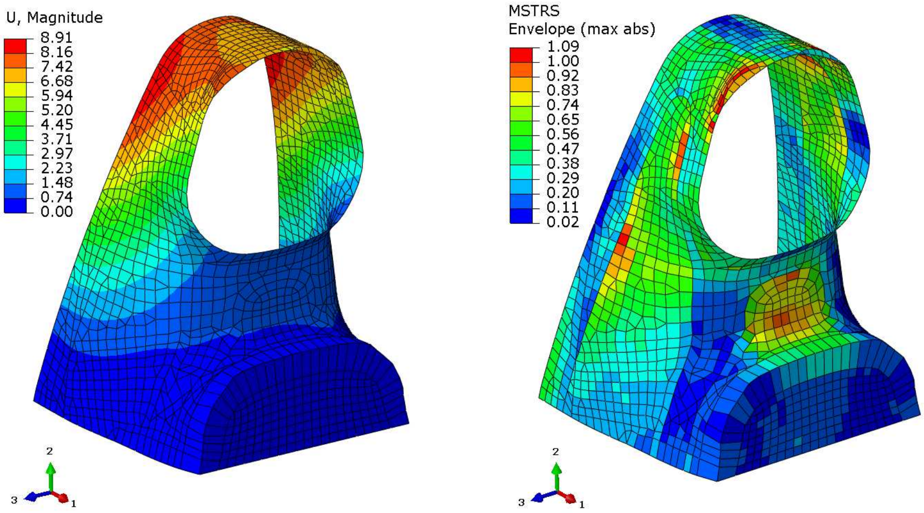

Figure 8.42. Results of the model with continuum shell elements. The Failure Index value according to the maximum stress criterion is shown on the right (see Chapter 10) [201].

The continuum shell element model, as mentioned, was built by extruding the elements of the shell model: the load was applied in the same way and the layup was adapted to the element type, converting the actual thicknesses of the sheets into percentages of the total thickness, as required. The obtained results are contained in figure 8.42.

In terms of displacement the differences from the shell model are minimal (about 3%), while the differences in terms of Failure Index are substantial: 35%.

This model would have predicted the start of failure at 68% of the load (1/1.47 = 0.68), a value that would never have led to the decision to risk the test and would instead have suggested reinforcing the structure.

More ahead in the Chapter we will see an other example, always drawn from the Formula One world, where once again a shell model has lead to wrong conclusions: in that case a model with continuum shell elements would not have produced better results and it is therefore adopted a more extreme modeling solution, as we will illustrate.

8.9 "Zone based" and "ply based" methods

8.9.1 Introduction

In the examples preceding the RollHoop one we always had to manage a unique laminate, i.e. equal in every part of the various bars. Instead, as it can be seen from figures 8.38 and 8.39, in the RollHoop model we have three different zones with different properties and to manage these differences there are two methods: "zone based" and "ply based". Let's see what these are.

8.9.2 Zone based method

As the name suggests, this method is based on zones, i.e. each zone will have its own specific property to describe the laminate: ply type, material, thickness and orientation. Until some time ago this was the only method for managing a structure made of composite; however, it is clear that, if the zones are numerous, the management of the different properties can become difficult and a source of errors; and it can happen to arrive at many dozens of areas, if we think that each local addition of reinforcement plies alters the zone to which it refers, creating the need to generate a new property (if then the reinforcement ply is applied across two or more existing properties things become even more complicated). It is precisely the modification phase of a previously generated zone-based laminate that creates the greatest difficulties. Take the RollHoop as an example: if we want to add a general sheet, i.e. one that covers the entire structure, we will have to modify the three properties, taking care to insert it in the correct position, which will not be the same for all zones, given that each zone has a different number of sheets and may already have other local reinforcement sheets. With three properties the matter is still manageable, but if we imagine having to operate on the frame of figure 1.34, where each color indicates a different zone, we realize the difficulty.

8.9.3 Ply based method

Here then the developers of pre-processors have made available the ply based method, with which the laminate in the model is created exactly as if it were built physically, i.e. by laying the sheet on the area to which it belongs; this is done by creating sets of elements that will constitute the sheet and assigning to it the properties (material, thickness, orientation) that belong to the sheet itself. It will therefore happen that a particular element can be part of different sets, because that element can "belong" to more than one sheet. In this way the elimination or introduction of sheets (general or local makes no difference) does not force the structural engineer to modify individual properties. Perhaps it is useful to underline the fact that the calculation codes need anyway to have as input the properties as if they were created with the "zone based" method: it will be the pre-processor that, starting from the "ply based" information, will reconstruct after each modification of the laminate the properties in an appropriate way, and in a totally transparent way to the user, when it will generate the input file.

8.9.4 Zone based vs ply based

It goes without saying that every medal has its downside: if the ply based method reduces the time of preparation and modification of the model and almost eliminates errors, it is also true that, when the model created with this system should be exported to a different calculation code (for example to be passed to the final customer or to a supplier) through its input file, we realize that the properties would be imported as if the "zone based" method had been used, in fact recreating all the difficulties. The translation then becomes at least tricky and care must be taken in trying to reconstruct the "ply based" system, using the definition of the original laminate (generally exportable in ASCII format) and the sets used to build the laminate in the original model. In conclusion, in the experience of the writer, the "ply based" method is by far the best choice, especially when the structure is being sized and, not knowing what the final layup will look like, there are many changes to be made.

8.10 More about 3D elements

As mentioned earlier, in this paragraph we see another case where the shell model produced erroneous results that led, as in the case of the RollHoop, to component failure during bench type approval testing.

The part we are talking about is the so-called Upper Wishbone of the rear suspension of a Formula One car, of which figure 8.43 shows a partial view of a finite element model from the early 2000s.

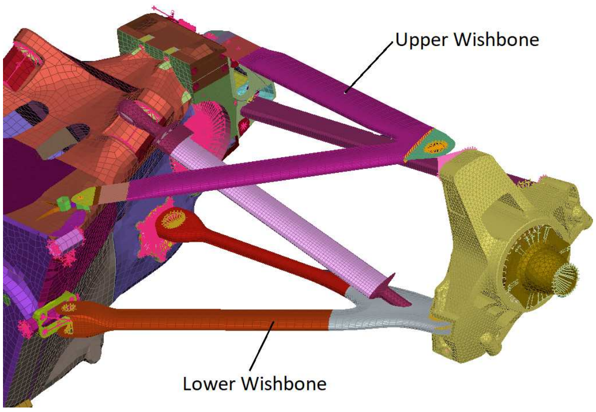

Figure 8.43. Finite element model of the rear end of a Formula One car.

Without going into details, we will say that wishbones are components that connect the wheel group to the car body and that, therefore, must allow the relative movement, called shaking.

Traditionally, ball joints are used to allow this movement. Over time, some designers have thought of replacing the ball joints with other elastic elements, called flexures, which would allow the shaking of the suspension, at the same time reducing the mass and increasing the stiffness of the assembly. These flexures then see significant axial loads (both tensile and compressive) and deflections (in both directions) due to shaking; in order to meet the stiffness requirement, which is also accompanied by the stability requirement (see Chapter 5), the flexures cannot be too thin. And this poses a new problem to the structural engineer called to size them (also choosing the materials to be used - strictly composite) and to decide the stacking sequence and the orientation of the sheets: what type of element to use?

Figure 8.44 shows the Failure Index contour (maximum stress criterion, see Chapter 10) for the upper wishbone under the worst of the predicted loading and shaking conditions.