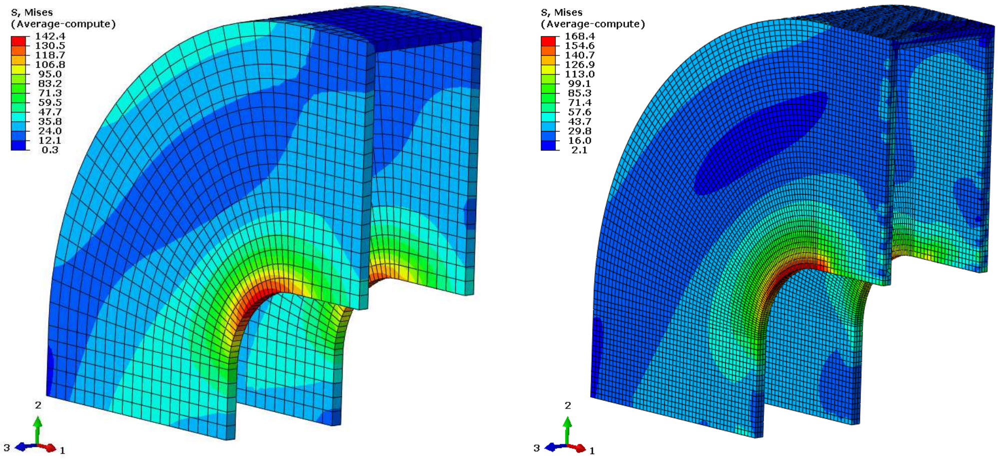

Figure 7.22. Left: Von Mises stress for the coarse model U-reinforcement; right: Von Mises stress for the submodel U-reinforcement.

7.4 The simulation of press fit couplings

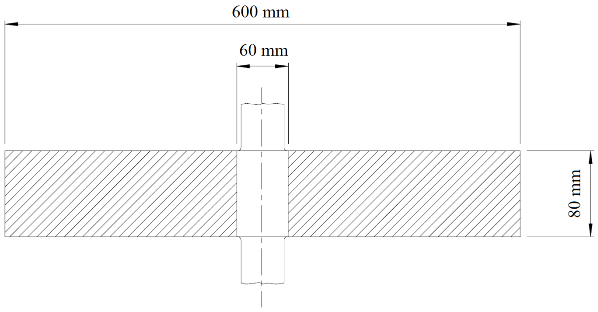

Figure 7.23. Press fit between shaft and flywheel; certain tolerances are required to ensure a stable fit, resulting in a maximum interference fit i = 0.025 mm.

Generally, in order to evaluate the stress state inside two elements coupled by means of shrinkage, Solid Mechanics relations are used, while typically, in order to solve a problem of contact between organs by means of the finite element method, in the past it was necessary to use the so-called "gap elements" that allow to reach the solution through iterative techniques, typical of the non-linear calculation. More modern and sophisticated calculation codes have introduced the possibility to manage the contacts through the surfaces of the elements, without the need to use the gap elements, more expensive in terms of modeling and more difficult to manage from several points of view.

However, to evaluate the stress state generated by a forced coupling it is possible to use a classical elastic-linear solver and simulate the interference by imposing on the shaft a thermal expansion corresponding to the given interference, and without employing contact surfaces or gap elements. Thus, with one exception that we will see later, shafts and hubs are here considered "glued" in the sense that at the interface they share the same nodes. In the following we will see some practical examples and where it will be possible we will compare the results obtained through the numerical method with those determined through the theoretical relations.

7.4.1 Shaft - Flywheel

Suppose we want to determine the pressure arising at the interface of the press fit between the two elements in figure 7.23. Let i = 0.025 mm be the maximum interference of the coupling. Taking advantage of axial symmetry, we choose to model the structure with axisymmetrical elements (see Chapter 1); figure 7.24 contains the mesh of the flywheel and the shaft section affected by the fit (note that the code used for this example assumes that the elements lie in the xy plane). To obtain an expansion on the diameter equal to i we will have to impose on the shaft a temperature that can be evaluated through the following relation:

$$T = \frac{i}{\alpha \cdot d}$$

being d the nominal diameter of the coupling and α the coefficient of linear thermal expansion, for which we can assume a convenient value: in fact we are not interested in the thermal problem, since the imposition of T is an artifice.

The important thing is that the T-α pair generates the given interference.

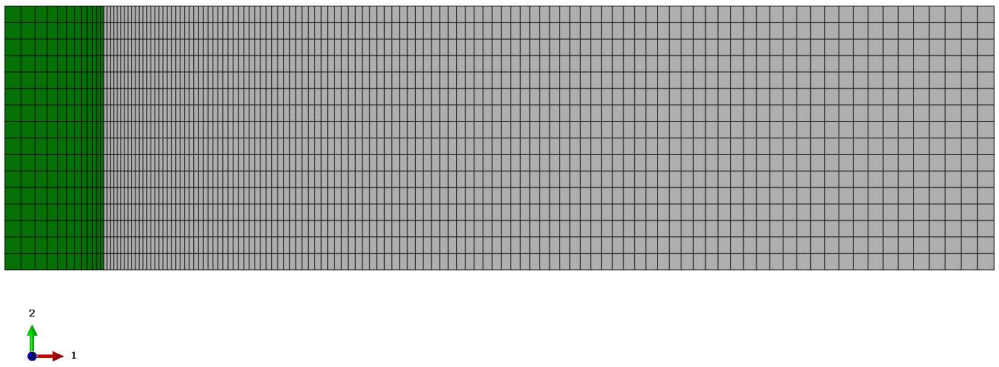

Figure 7.24. The axisymmetric finite element model: the shaft mesh is shown in green, and the flywheel mesh is visible in gray.

However, by doing so, we will also have an axial expansion component that is not present in reality. To avoid this effect there are two ways to proceed:

1. use elements that manage an orthotropic material (i.e. one that has different properties along orthogonal directions), thus being able to assign to it all the characteristics of steel and impose a zero thermal expansion coefficient in the direction in which expansion is to be avoided;
2. if no calculation program is available that allows the use of orthotropic elements, it is possible to counteract the axial expansion with a suitable compression force.

For this case we choose the first way while we reserve to illustrate the second one, less trivial, in a next example.

By assuming $\alpha = 0.00001$ °C^{-1} we have: