How to use symmetry and anti-symmetry boundary conditions

SolidWorks Express, Tech Tips

Introduction

Sooner or later you will encounter an analysis where you need more computer memory and/or CPU speed that you can obtain. Therefore you should get familiar with methods for using efficient modeling techniques. One method of efficiently using finite element (FE) modeling is to exploit the planes of symmetry or anti-symmetry in an assembly or a part being analyzed. When we take advantage of symmetry, we need to model only a portion of the actual structure to reduce the analysis run time and memory required The lines or planes of symmetry or anti-symmetry in a FE model can be simulated by providing proper restraints to the symmetrical faces or edges. To model symmetry or anti-symmetry, the geometry and the restraints must be symmetric about a plane. The loads must be either symmetric or anti-symmetric. Both symmetry and anti-symmetry restraints are discussed in detail in the following sections for structural models.

Symmetry and anti-symmetry restraints

In solid mechanics, the general rule for a *symmetry* displacement condition is that the *displacement vector component perpendicular to the plane is zero* and the *rotational vector components parallel to the plane are zero*. For an anti-symmetry condition the reverse conditions apply (*displacements in the plane are zero; the rotation normal to the plane is* zero).

For solid models using solid finite elements, the symmetry or anti-symmetry restraints are restricted to only translational displacements. This is because the solid models are modeled only with either TETRA4 (low) or TETRA10 (high) quality elements in COSMOS®, which do not have rotational degrees of freedom. Consider a plate simply supported at both ends subjected to symmetric loading as shown in Figure 1.
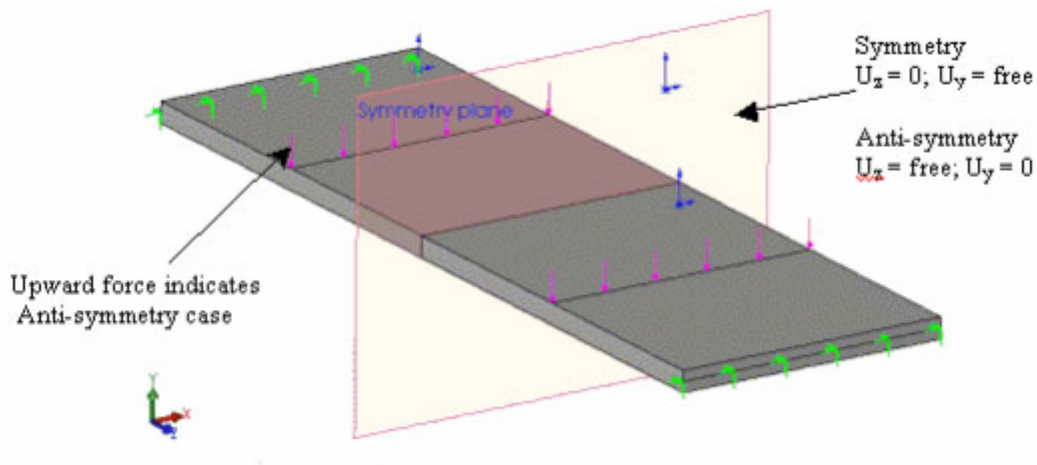

Symmetry
$U_z = 0$; U_y = free

Anti-symmetry
U_z = free; $U_y = 0$

Upward force indicates
Anti-symmetry case

Figure 1 Solid model with displacement (U) symmetry or anti-symmetry plane

For this model the symmetry restraints on the symmetry plane are Uz = 0; Uy = free and the anti-symmetry restraints are Uz = free; Uy = 0. (Note that the z direction is normal to the cut face). The displacement response, including rotations, of a full plate due to symmetry and anti-symmetry loading are shown in Figure 2 below. It can be seen that at the plane of symmetry, the applied displacement restraints are not violated. The identical results for a half symmetry model would be obtained using the same restraint conditions at the symmetry plane.
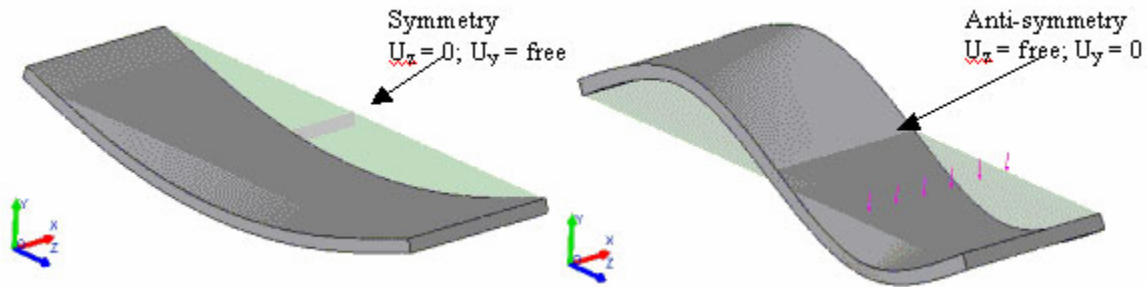

Figure 2 Symmetry (left) and anti-symmetry deflections

For shell elements, in addition to the translational restraint a rotational restraint also needs to be applied along the edge of the symmetry. Figure 3 shows the shell model and the associated symmetry and anti-symmetry restraints.
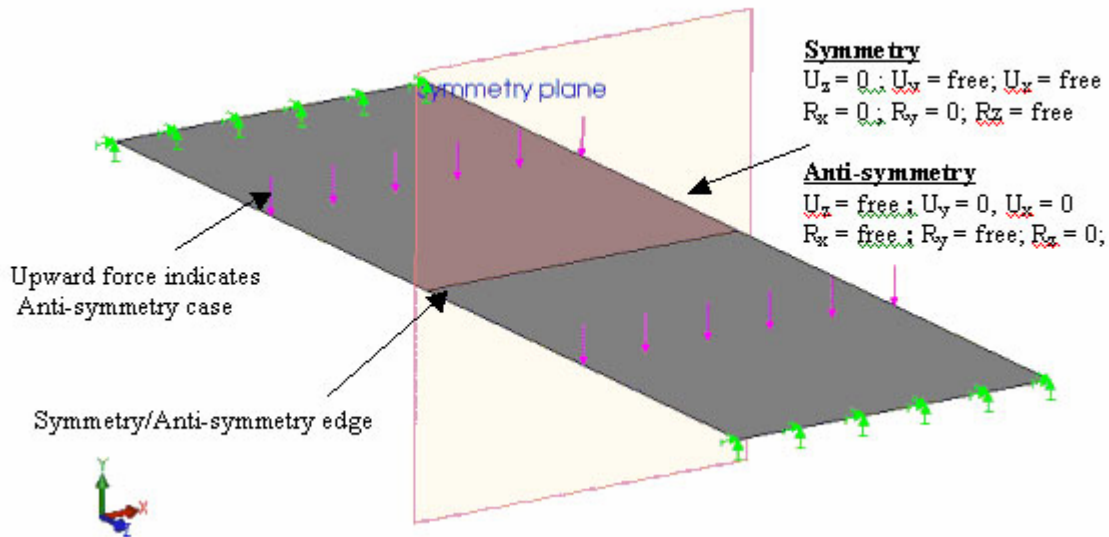

Figure 3 Shells involve rotation (R) constraints as well

Frequency and buckling response
In the previous discussion, the tacit assumption was that under symmetric loads, a symmetric structure with symmetric restraints will respond symmetrically, and with anti-symmetric loads, will respond anti-symmetrically. For buckling or frequency response of a symmetric structure, this is not always the case. Care should be taken when using the symmetry/anti-symmetry restraints for frequency and buckling analysis. Symmetry restraints for a half or quarter model yield only symmetry modes and anti-symmetry restraints will only give the anti-symmetry modes. So on the

symmetry plane or edge, the analysis needs to be repeated for every possible combination of symmetry and anti-symmetry restraints.

For example, if you were asked to find all the natural modes and frequencies for a symmetric plate and if you use a quarter model, then one needs to run the frequency study for this quarter plate four times with the following set of restraints on the symmetry planes.
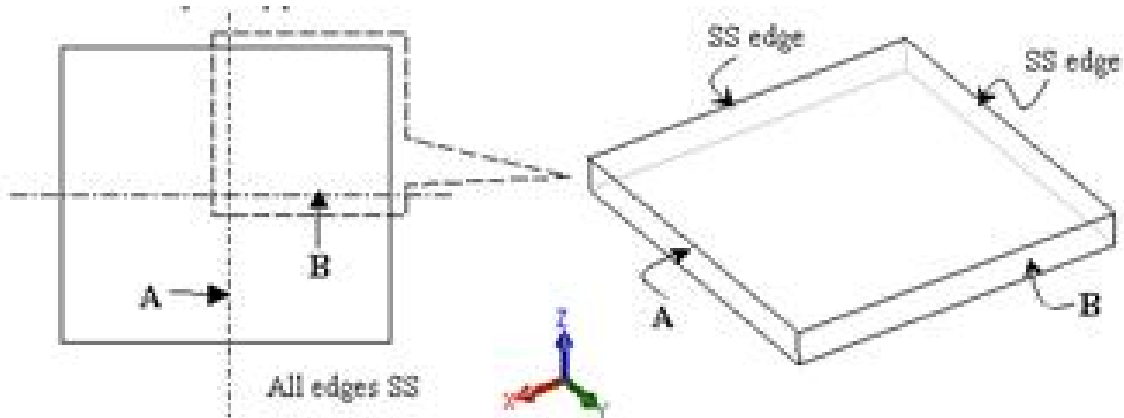

Figure 4: Four sided simply supported plate with symmetry planes

	Restraint type on A	Restraint type on B
1	Symmetry	Symmetry
2	Anti-symmetry	Anti-symmetry
3	Anti-symmetry	Symmetry
4	Symmetry	Anti-symmetry

Four runs of frequency study need to be run for each of the four restraint cases on the A & B Symmetry planes as shown above. The frequencies obtained from each run put together will form a complete set. For buckling, the lowest (positive) buckling factor obtained from all four studies will define the buckling load. This procedure can be applied to any type of restraint and geometry as long as the symmetry plane or edge can be identified.

Conclusion
By taking advantage of symmetry or anti-symmetry, the size of the analysis domain can be reduced, at least by a factor of two. The reduction in analysis domain could mean the difference between keeping the analysis in-core, and swapping in and out of memory during the analysis. Or, a finer mesh can be used in the reduced analysis domain resulting in a more accurate analysis than a coarsely meshed full model with a comparable node and element count. This is where the real payoff is for taking advantage of symmetry conditions.