Hydrostatic Fluid Elements at ANSYS 13.0

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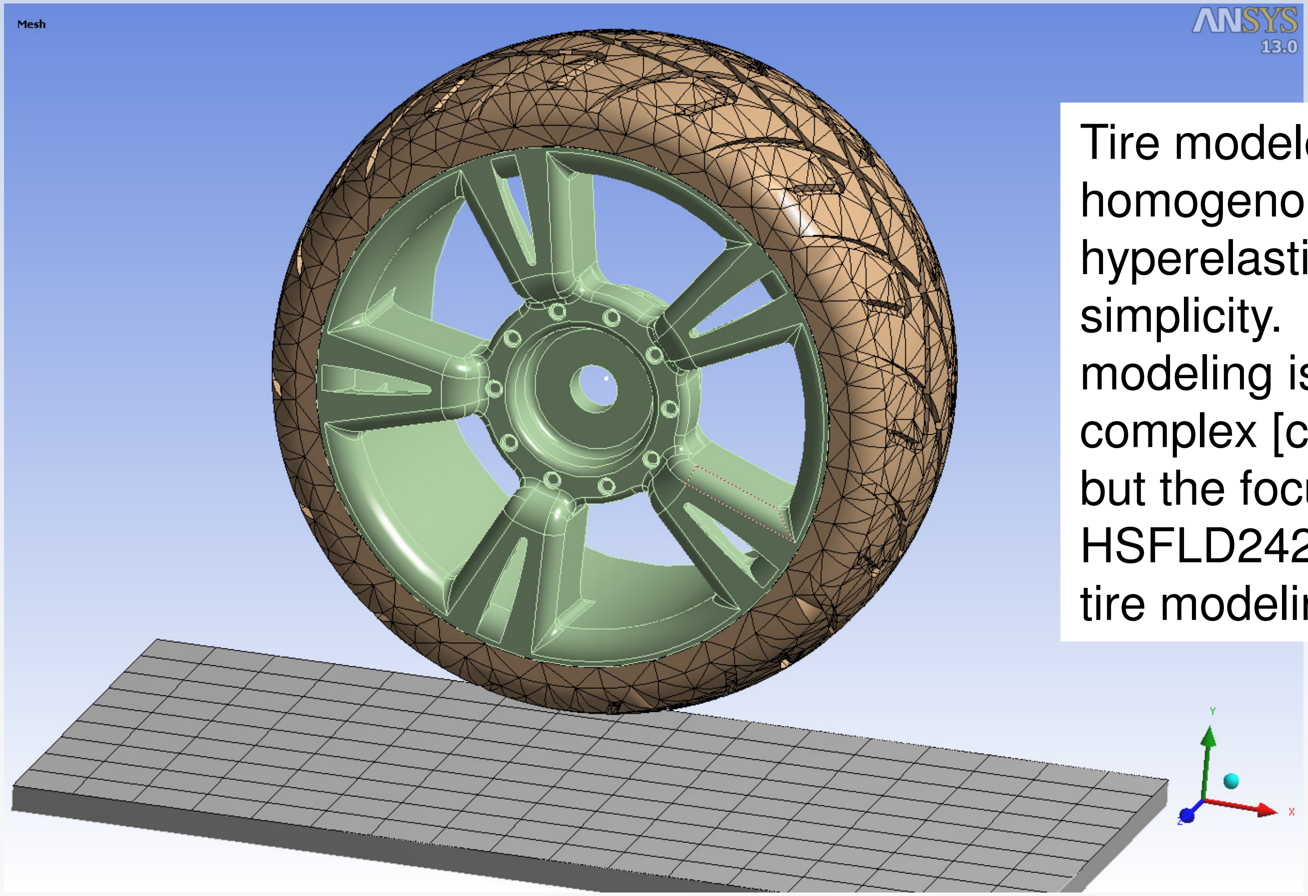
Overview

- **Two new *hydrostatic fluid elements*, HSFLD241 and 242, are introduced to model the effect of a trapped/enclosed gas or liquid**
  - As the volume or temperature changes, the pressure exerted on the structure will change
  - Not possible to do add this type of relationship accurately via APDL or user subroutines

Tire Inflation Example

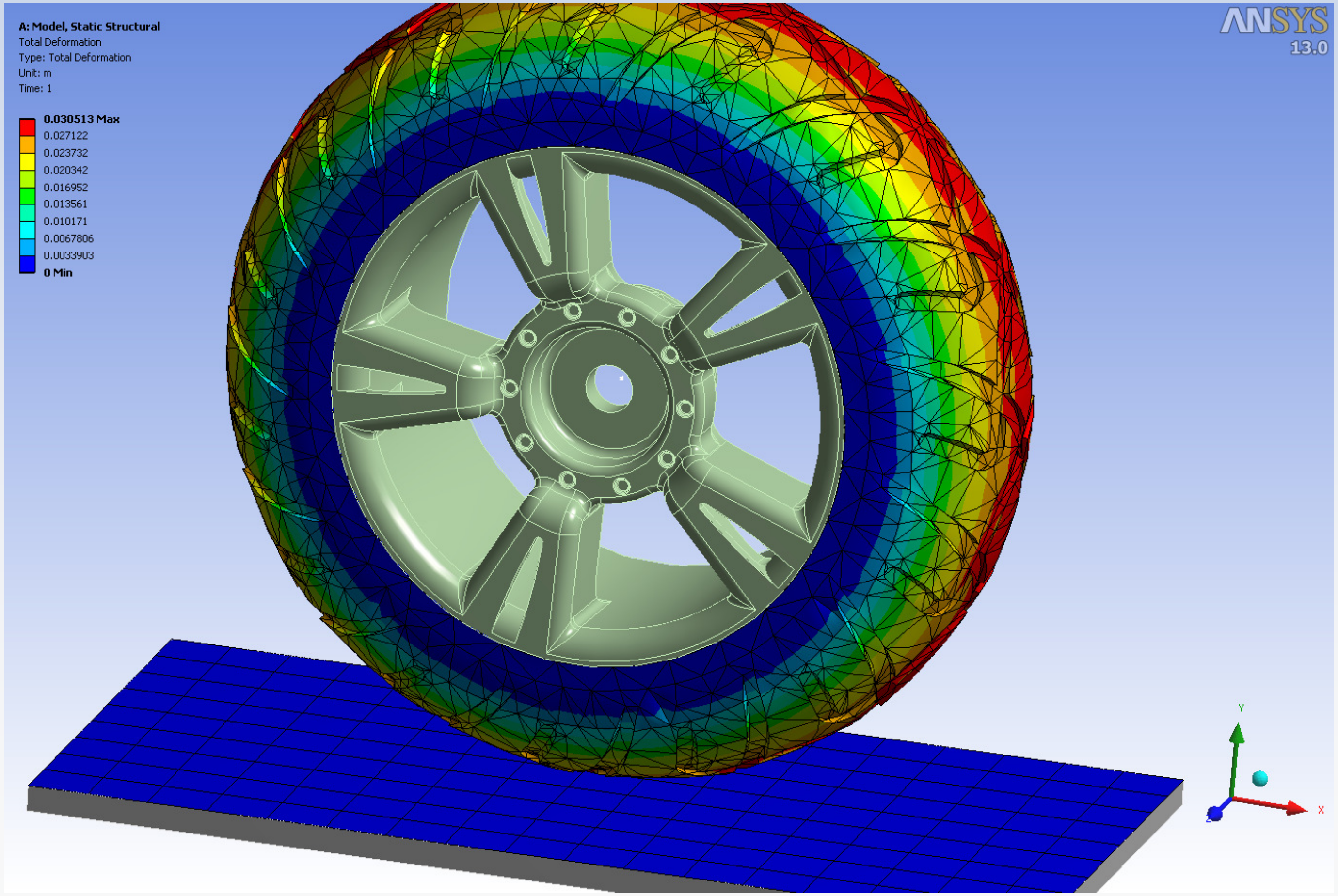
- **Original mesh (Autodesk Inventor model):**



Tire modeled as homogenous hyperelastic material for simplicity. (Real tire modeling is much more complex [composite] but the focus here is on HSFLD242 element, not tire modeling.)

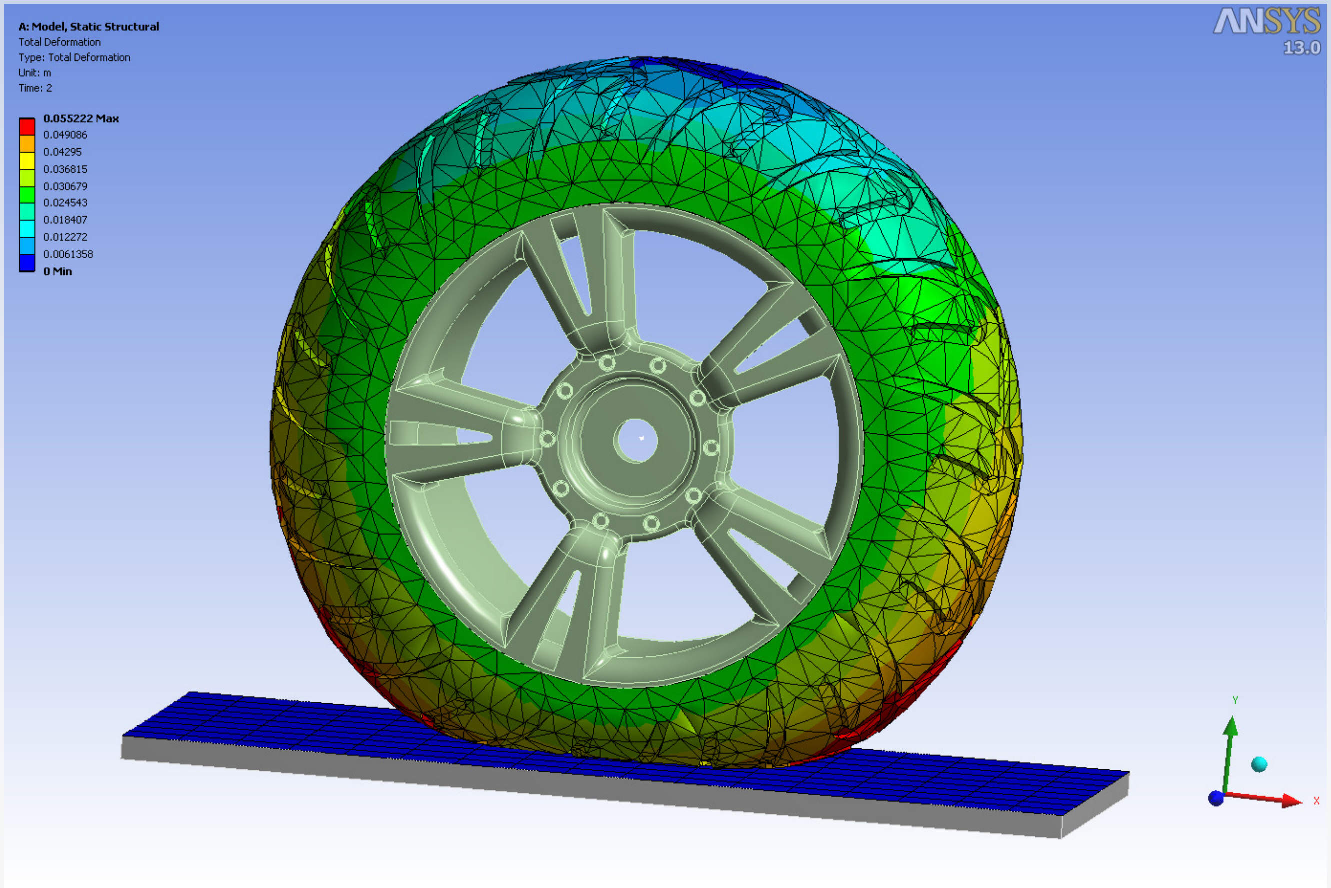
Tire Inflation Example (cont'd)

- **Step 1 – Inflate tire (~1 bar):**



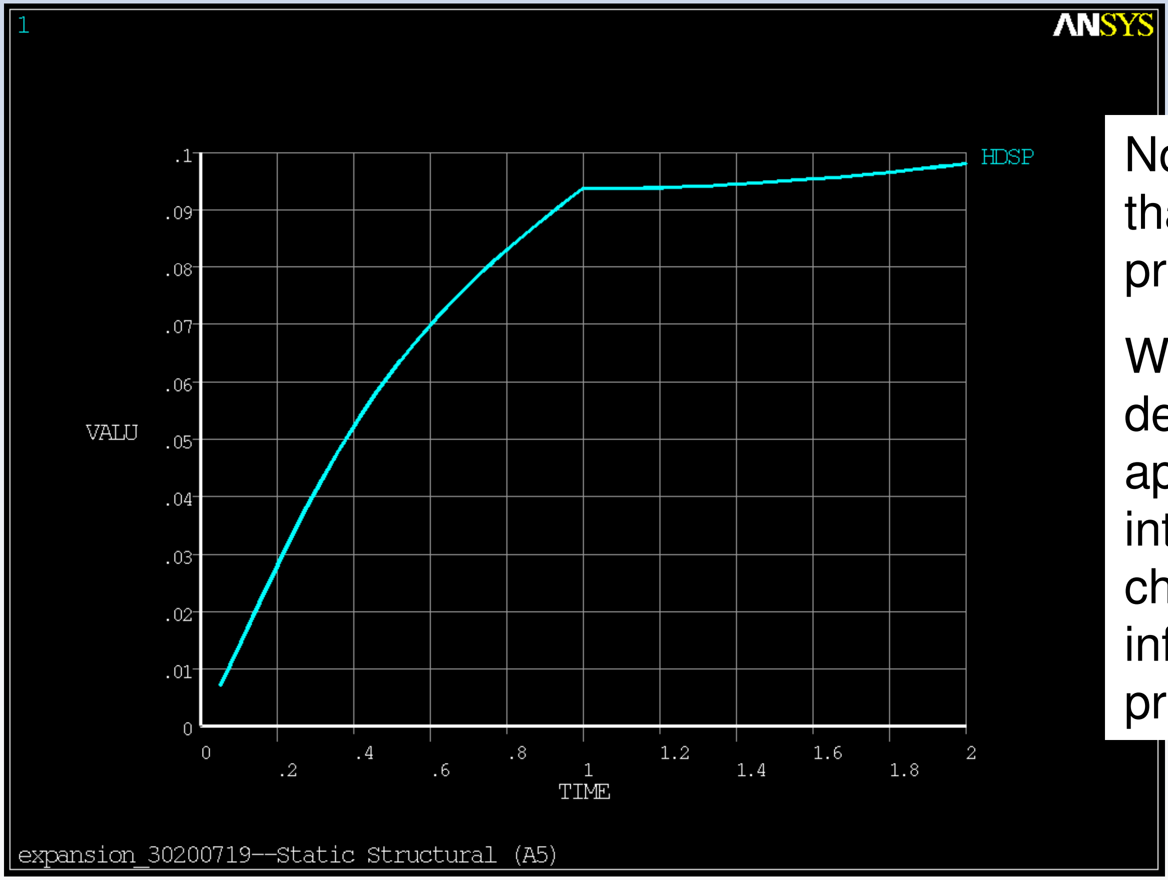
Tire Inflation Example (cont'd)

- **Step 2 – Push tire on rigid road:**



Tire Inflation Example (cont'd)

- **Plot of hydrostatic pressure in tire:**

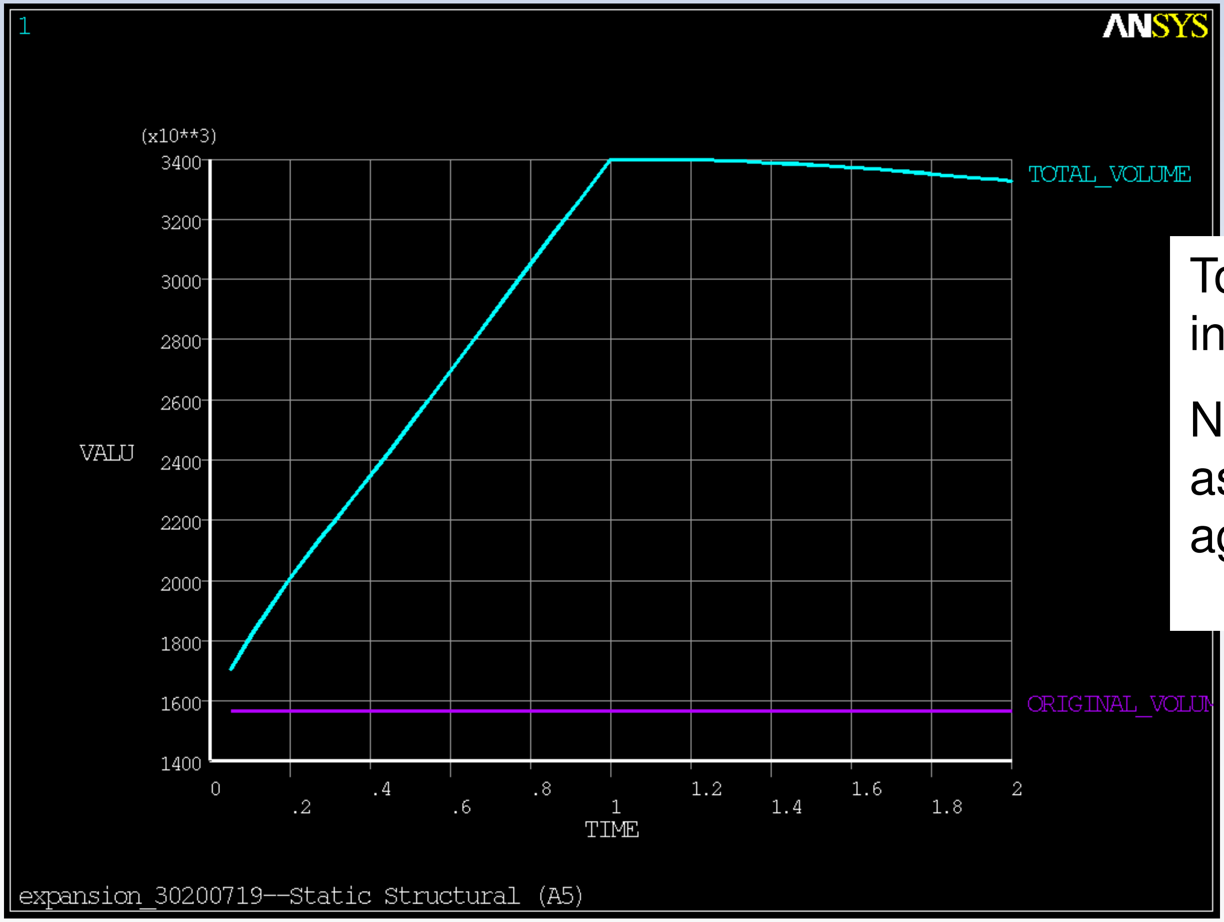


Note from this graph that hydrostatic pressure is not constant.

We could not accurately depict this by just applying constant internal pressure since change in volume influences change in pressure.

Tire Inflation Example (cont'd)

- **Plot of total volume of air in tire:**



Total vs. original volume in tire shown here.

Note volume changes as tire is pushed against rigid floor/road.

Motivation

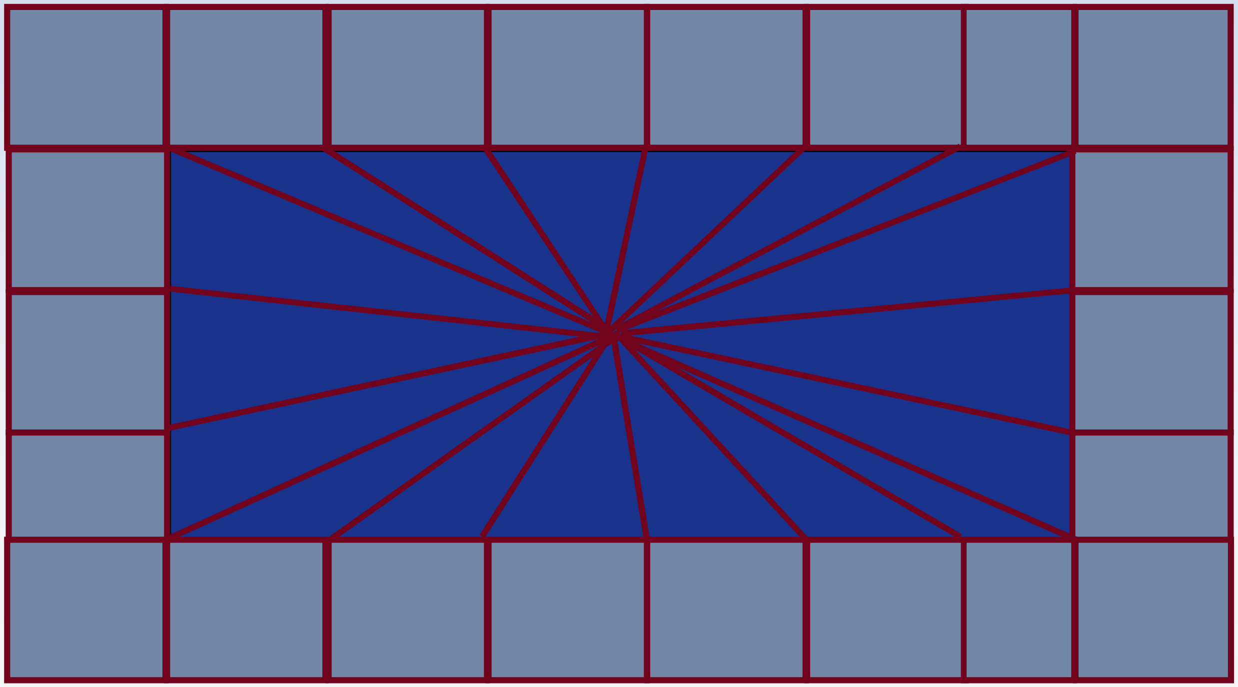
- **Why introduce a new element?**
  - Provide an element to model gas or liquid trapped in structure. Regular contained fluid element FLUID79/80 not sufficient for this since it has linear stiffness relationship
  - This new hydrostatic fluid element does not require the inside fluid to be 'meshed' in a typical sense, so more efficient

Note on Fluid Elements

- **This element should not be confused with other fluid elements in ANSYS:**
  - Unlike contained fluid elements or acoustic elements, this new hydrostatic fluid element has no free surface effects. Not meant to model sloshing.
  - Not meant for damping effects or acoustic wave propagation.
  - This element is meant to model pressure loading by enclosed fluid/gas

Element Topology

- **This is a triangular (2D) or pyramid (3D) element with one pressure node:**



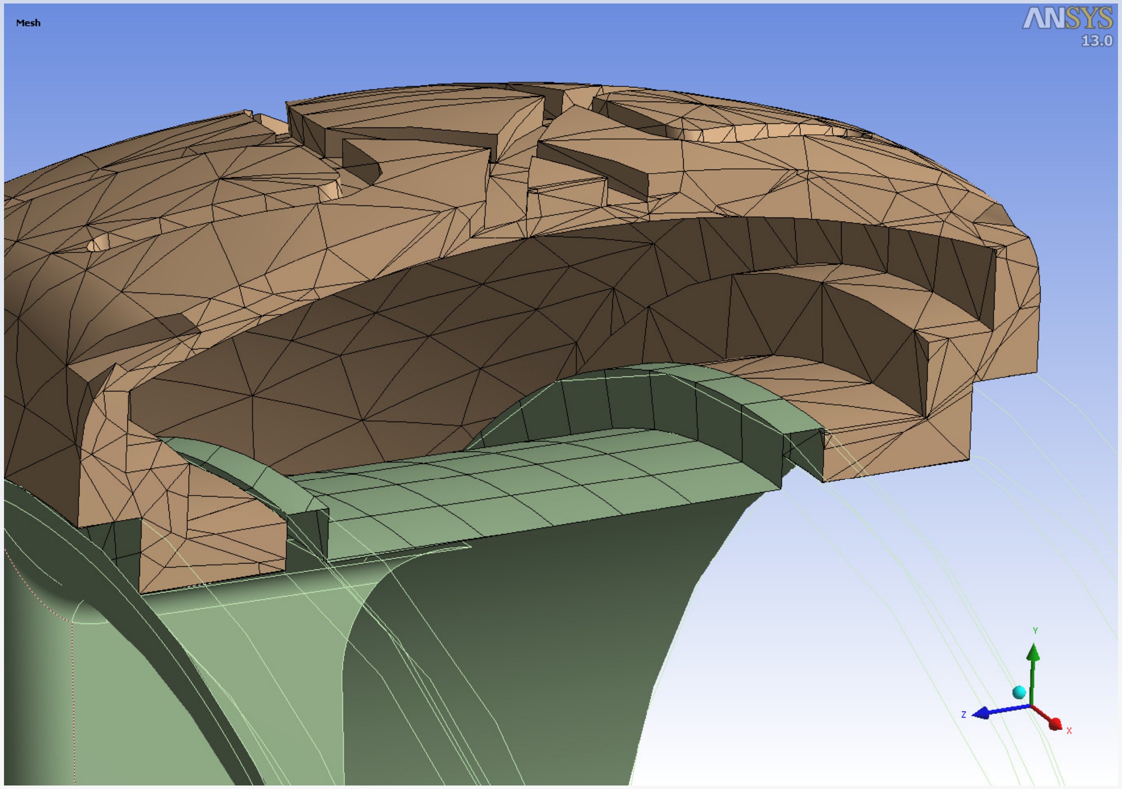
Here, the grey quad elements can be thought of as the solid structural elements.
The dark blue triangular elements are the HSFLD241 elements.
Pressure node at center.

Element Topology (cont'd)

- As shown in the previous slide, the hydrostatic fluid elements 'fill up' the volume by 'connecting' the structural element faces with the 'pressure node'
- This is how the 'volume' of the cavity is calculated – simply by adding up the volume of the hydrostatic fluid elements
- When HSFLD24x elements share a single pressure node, their 'pressure' and 'total volume' are shared.

Element Topology (cont'd)

- **Consider the case of the tire shown earlier. Cross-section is shown below:**

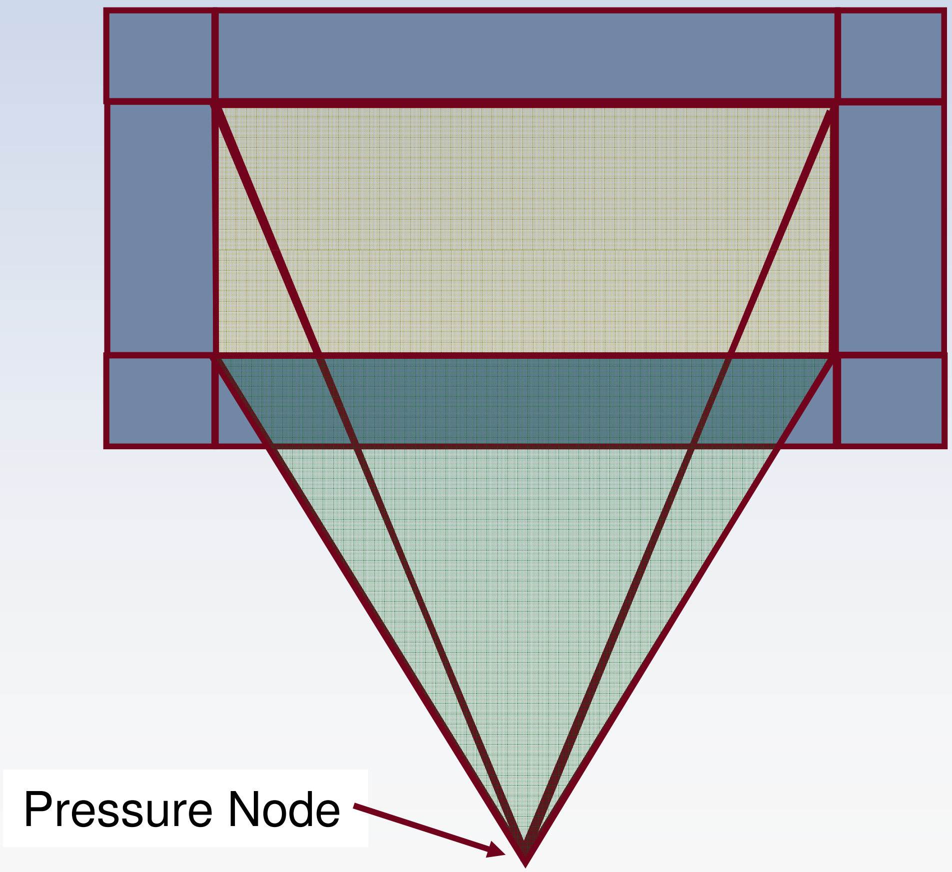


Element Topology (cont'd)

- **There should be only a single 'pressure node' in the previous case.**
  - It is not possible to have a single pressure node in a toroidal volume
  - Consequently, the pressure node for the example will lie *outside* of the actual fluid volume. Both positive and negative volumes will be created to produce the correct total volume

Element Topology (cont'd)

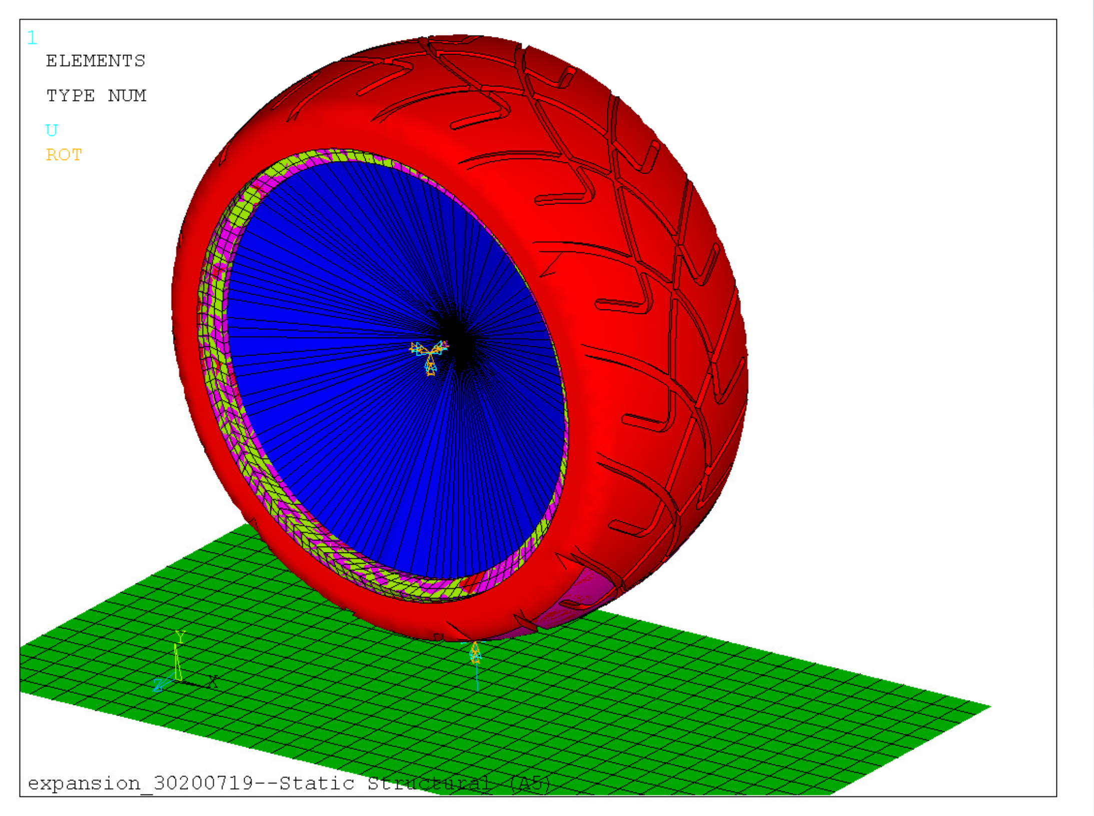
- **Positive and negative volumes shown below:**



Assume that the grey represents quad elements with a cavity in the middle.
The HSFLD241 elements are triangular elements created from the element faces in the cavity to the 'pressure node'.
The light brown is positive volume. The green is positive volume + negative volume which cancels to zero. Total volume therefore is the volume of the cavity.

Element Topology (cont'd)

- **Resulting HSFLD242 of previous example shown in dark blue below:**



Element Topology (cont'd)

- **Element characteristics:**
  - Pressure node (node "Q") has HDSP DOF, along with translational DOF
  - Other nodes (on structural element face) have translational DOF only
  - Temperature is applied to pressure node only via "BF" command
  - Mass flow rate or prescribed pressure imposed on pressure node via "F" or "D"

Material Properties

- **Hydrostatic fluid element material:**
  - Compressible liquid (TB,FLUID,,,LIQUID):
    - Give bulk modulus, CTE, initial density
  - Ideal gas law (TB,FLUID,,,GAS):
    - PV=nRT type of relationship. Input initial density. Reference pressure (real constant), reference temperature (TREF or MP,REFT), TOFFST.
  - General PV relationship (TB,FLUID,,,PVDATA)
    - Total pressure-total volume via TBPT
  - Incompressible fluid (KEYOPT(6)=1)

Element Behavior

- **The hydrostatic fluid element calculates new pressure based on change in volume**
  - The pressure load is then applied to the structural elements to which it is attached
  - With deformation, volume may change. New density, pressure, etc. calculated
- **By its very nature, this element is *nonlinear*. Be sure to activate large deflection effects (NLGEOM,ON)**

Other Features

- **One can ‘connect’ two cavities with FLUID116**
  - Activate “PRES” DOF for HSFLD24x
  - Connect cavities with FLUID116 (new KEYOPT(1)=3)
  - Now, flow between cavities will be captured

Other Features

- **Mass of fluid:**
  – The HSFLD24x elements provide a stiffness matrix and pressure loading. KEYOPT(5) can control how the fluid mass is calculated, either based on volume (which neglects negative volume elements) or surface area (which is applied to both positive or negative volume elements)

Points to keep in mind

- **Points to remember:**
  - Depending on geometry, one may end up with ‘negative volume’ elements
    - Consider ‘tire’ case earlier. A single pressure node would exist outside of tire ‘torus’. Negative volume is OK in this case, so total volume is correct.
    - 1 warning message will be printed, just to let user know that negative volume elements are present. For the tire case shown earlier, such a warning message *is to be expected*.

Points to keep in mind (cont'd)

– If HSFLD24x elements not connected anywhere (like a 'rigid' surface not modeled), be sure to constraint translational DOF

Points to keep in mind (cont'd)

- Loading label is "DVOL" (F,,DVOL). This is *mass flow rate*. However, reaction 'force' DVOL is *volume change rate*. Must postprocess mass flow rate as element table (NMISC,5 = MFLO). This is specific to this element, where "input force" and "reaction force" are not the same (related by density)
- DOF label is "HDSP", not "PRES", so don't get confused with other 'fluid' elements. Can specify "D" or "IC" with HDSP label. This is relative pressure (to reference pressure).

Points to keep in mind (cont'd)

- Use ESURF to generate these elements with 'pressure node' specified as argument. Be careful when using with shell elements – ensure that shell element normal is aligned correctly, or use ESURF,,REVERSE to flip them.
- Always check initial/original volume (element table output) to ensure that elements were created correctly.

Where to find more information

- **MAPDL Help, *Structural Analysis Guide*, Chapter 19 is devoted to HSFLD24x:**