Wall Shear Stress Contour Plot in ANSYS Fluent Simulation

Description: Contour plot of WSS (Wall Shear Stress) around the airfoil profile

Keyword: *Aerodynamics, CFD, ANSYS, Simulation, WSS, Shear Stress, Airfoil*

What is Wall Shear Stress

Mathematically speaking, WSS is defined as –

$$\tau_w = \mu \left. \frac{\partial u_t}{\partial n} \right|_{wall}$$

Where $\boldsymbol{\mu}$ is dynamic viscosity, $\boldsymbol{u_t}$ is the tangential velocity, and $\boldsymbol{n}$ is normal to the wall

WSS is the tangential force per unit area that a fluid exerts on a wall. In the context of our study, airflow applies a tangential force to the wing surface, causing stress to be developed. This is a paramount metric in computational fluid dynamics, as the value of WSS have massive implication in Fluid-Structure Interaction (FSI) for an object experiencing forces due to fluid flow. Notably,

- **Fatigue and Material Stress:** Imagine an aircraft experiencing Mach 2 flow over it. WSS determines how much fatigue the aircraft is experiencing at each point of the surface of that wing. This is critical in designing as miscalculation in WSS may cause the aircraft to fail in extreme conditions. This is particularly true if your design must go through many cycles – as repeated shear can lead to erosion, wear and tear.
- **Deformation:** A flexible wall (turbine blades, blood vessels) experiences tangential stress along pressure due to the fluid flow they are dealing with. This leads to deformation of the wall. If WSS is not calculated properly, engineered solutions will induce deformation at critical point that may result in failure of operation.
- **Skin Friction Drag:** WSS is the silent induced or skin friction drag. It is paramount to consider WSS for calculating drag characteristics for your design. All CFD solvers take WSS into account while measuring critical aerodynamic values like Cd.

To sum up, both pressure and shear stress impacts your simulation (and later, impacts your design decision). While pressure (Cp) shows how hard the fluid is ‘pressing’ the structure, shear stress elucidates how hard the flow is ‘dragging’ the structure.

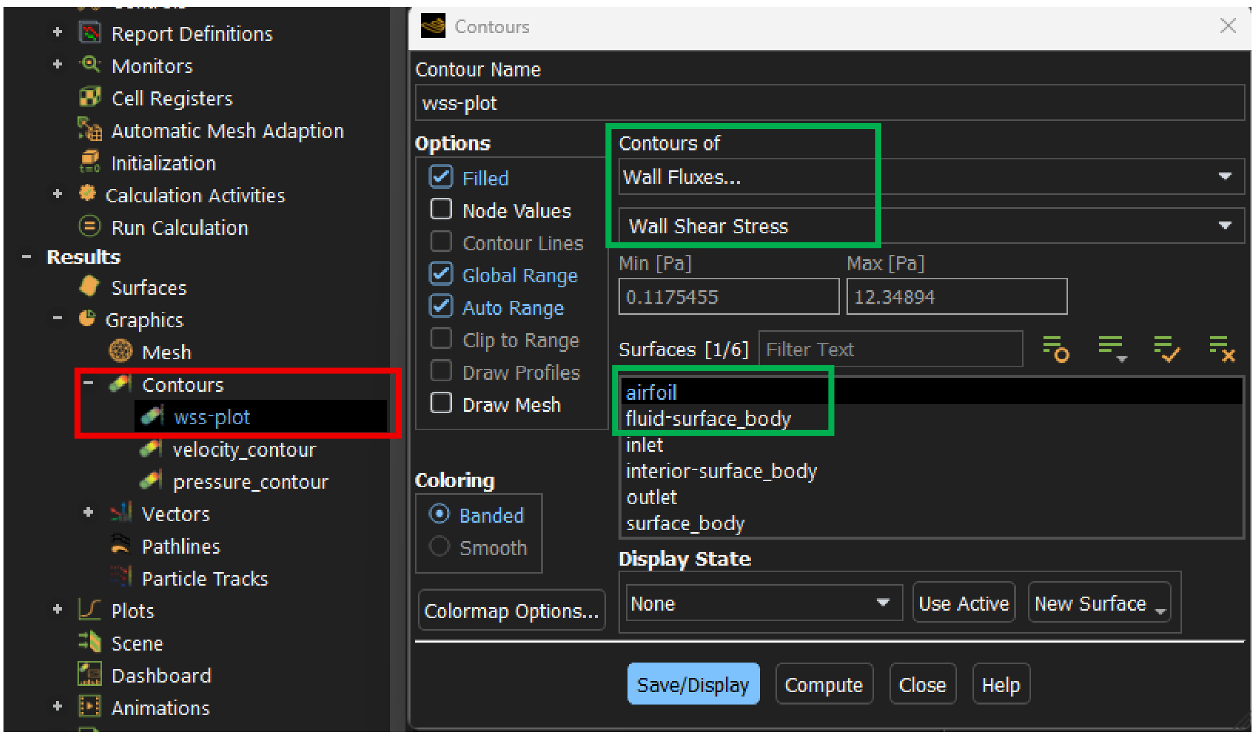
Important MESH Parameter for WSS

WSS plot (and contour) is very sensitive to the **y^+** value. It is important to keep this value under 1. But for our study (provided you have properly developed the meshing), the **y^+** value is already below 1 and we don’t need to concentrate too much on it.

Now that is out of the way, let us plot the WSS contour in the solution, shall we?

Plotting WSS in Solution of ANSYS Fluent

Consult the following screenshot –

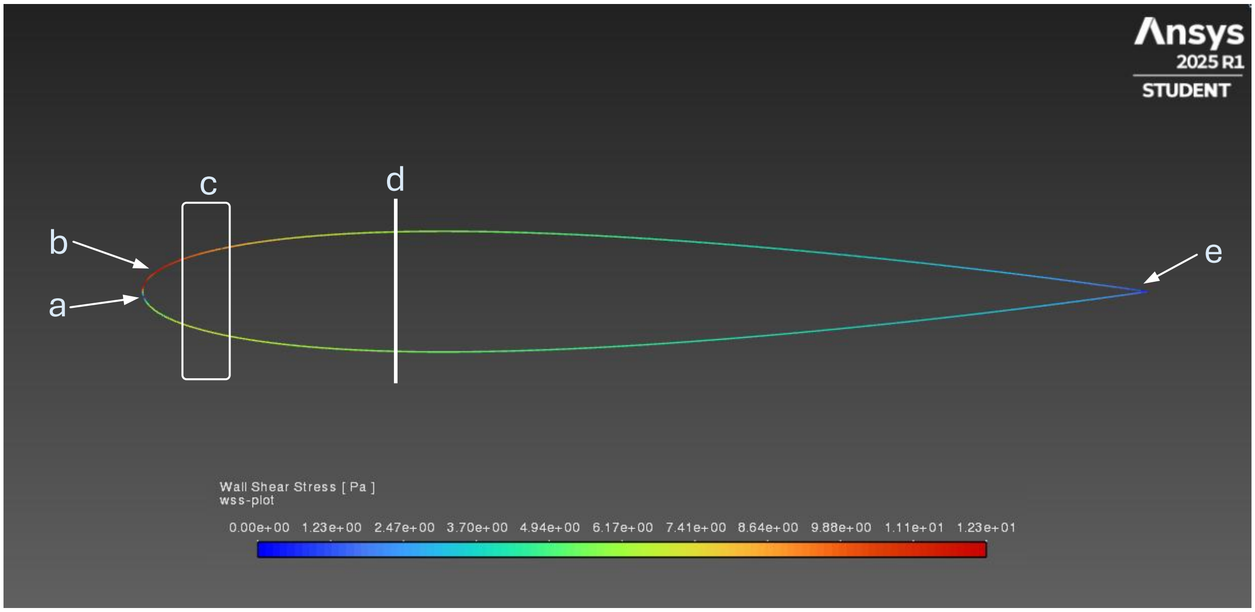


In the result tab, right click on ‘Contour’ and hit ‘New’. In the pop-up menu, make sure the green marked options are selected. Leave the rest as is. If your ANSYS version has something different as default, change them to match the screenshot.

Hit Save/Display and we are done.

Time to dissect WSS. Let us see what that airflow did to our poor airfoil!

WSS Contour Discussion



Here are some conclusion we can come to after consulting the image shown above –

a. **Blue Dot:** That is the stagnation point. It is consistent with our other solutions. This is where the flow halts (equals to 0) and therefore, there are no tangential stress in this region. The blue dot is slightly below the chord line, a tell-tale sign that the flow hits the airfoil at an angle. Again, consistent with our simulation setup (AoA = 2°).
b. **Rapid Rise at the Top Surface:** Indicates the initial boundary layer acceleration. This area shows a higher velocity gradient, resulting in higher shear stress. The fluid is getting 'pulled' faster in this region and thus, exerting higher tangential stress.
c. **Top Surface Sees More Gradual Fizzling Out:** Again, consistent with our other solutions. The flow is 'zipping past' the top curvature faster. There is more friction drag in the top surface compared to the bottom.
d. **Boundary Layer Maturing:** After the initial velocity acceleration, the flow starts to mature beyond this point. There are less shear stress in both top and bottom surface. It is clear from this observation that the first 1/3rd of the airfoil experiences the most shear stress along the wall.
e. **Trailing Edge Behavior:** The shear stress converges at the TE that shows there are no abrupt separation of the flow. This means, there are no stall condition present for our simulation. Additionally, please see the text in the red box below for some further evaluation for the trailing edge WSS behavior.

Slight Asymmetry at the Trailing Edge
At the trailing edge, the top surface exhibits slightly higher wall shear stress than the bottom. This indicates a marginally stronger tangential (viscous) force acting along the upper surface, likely due to a thinner boundary layer or ***delayed pressure recovery****. While both surfaces converge toward minimal shear at the exact trailing tip (as expected due to diminishing velocity gradients near the edge), this slight asymmetry reflects the residual effect of flow acceleration and deceleration induced by the 2° angle of attack. It can also hint at incipient separation tendencies being more probable on the bottom surface under more aggressive conditions.*

So, what do they all mean, from an engineering perspective?

It is clear from the WSS contour plot that the maximum sheer stress is developed at the 'b' region. Consulting the legend at the bottom, we can confidently conclude the maximum value of shear stress the structure will develop under the simulation protocol of fluid flow (angle of attack, flow velocity). This value is essential to keep in mind when designing the model and choosing what material to be used for construction. Additionally, region 'e' shows us that there will be no stall condition at these parameters for our model.

Now, we can make some informed decisions during the design phase.

Cheers!

Omar Saif
CFD Enthusiast
October 8, 2025