

Application of Metal Plasticity

Metal Plasticity – Lesson 5



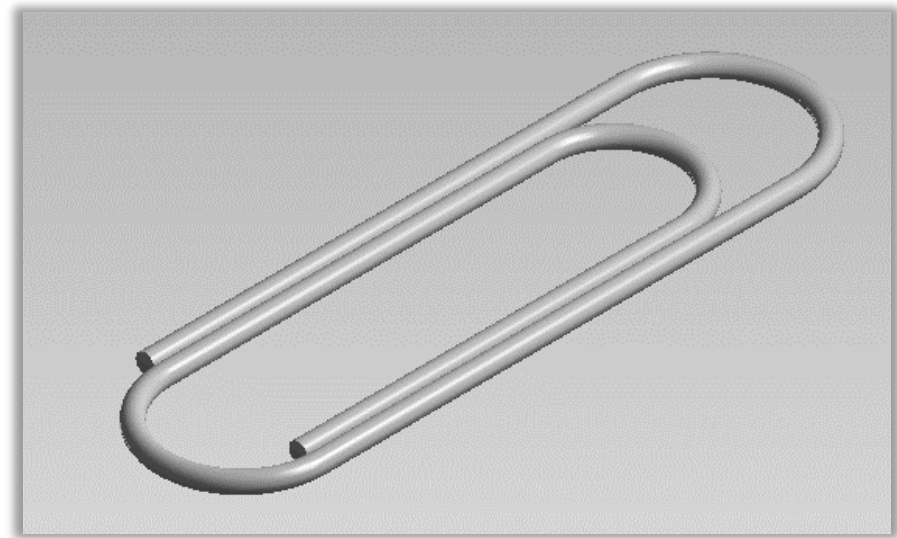
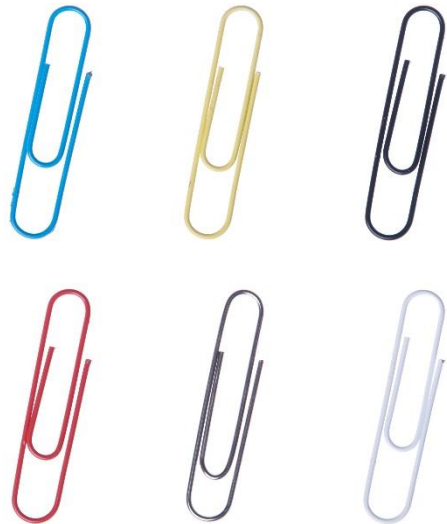
Paper Clip

We are all familiar with paper clips. They are usually made from steel wires. They use the elasticity in the wire along with friction between wire and paper to work for us in the office.



/ Paper Clip (cont.)

The elastic behavior in a steel wire is limited. What if we bend or pull hard on a paper clip? Will it be able to restore the original shape? Of course not. The steel wire easily reaches plasticity and the paper clip will stay at the deformed shape. Let's conduct an analysis of a paper clip to learn how plasticity is defined and how the material behaves in our model.

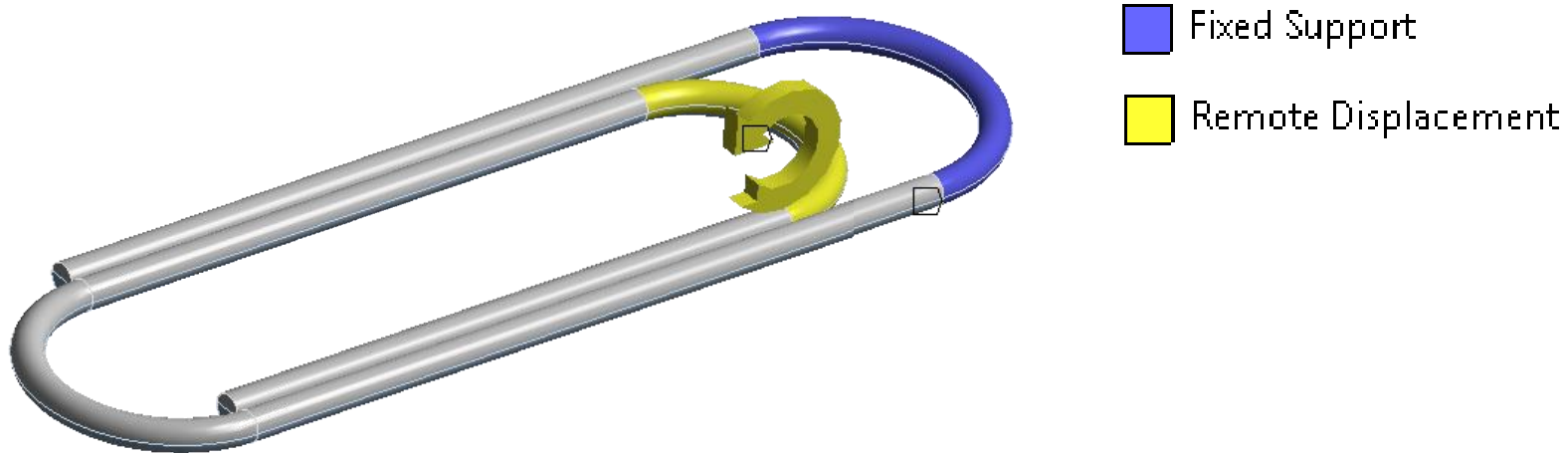


/ Paper Clip: Boundary Conditions

Boundary condition:

- The paper clip is held by one hand on the outer circular part. Use fixed support for the boundary condition.
- The inner circular part is bent by the other hand to a certain location and then released. Such a boundary condition is realized in two steps in our analysis.

- 1 Step 1: Use displacement control to apply 90° rotation.
- 2 Step 2: Release the displacement control. Let the paper clip recover freely.

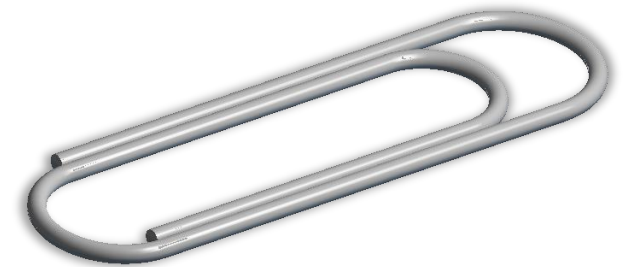
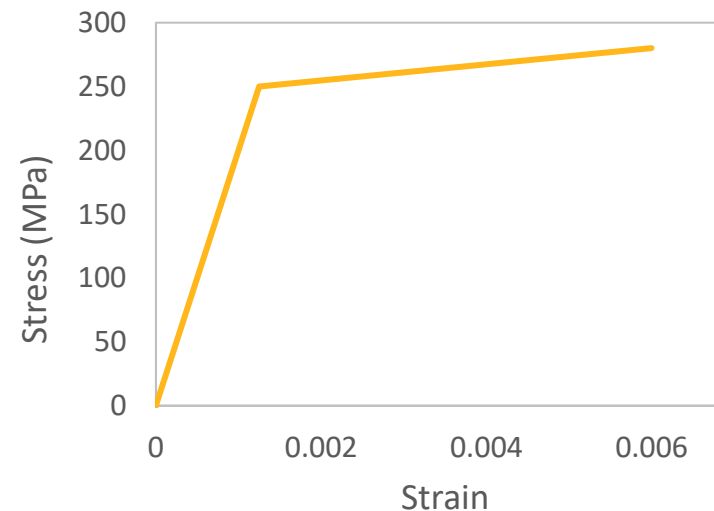


/ Paper Clip: Material Definition

The paper clip is made of steel wire. We will use a steel material model with metal plasticity.

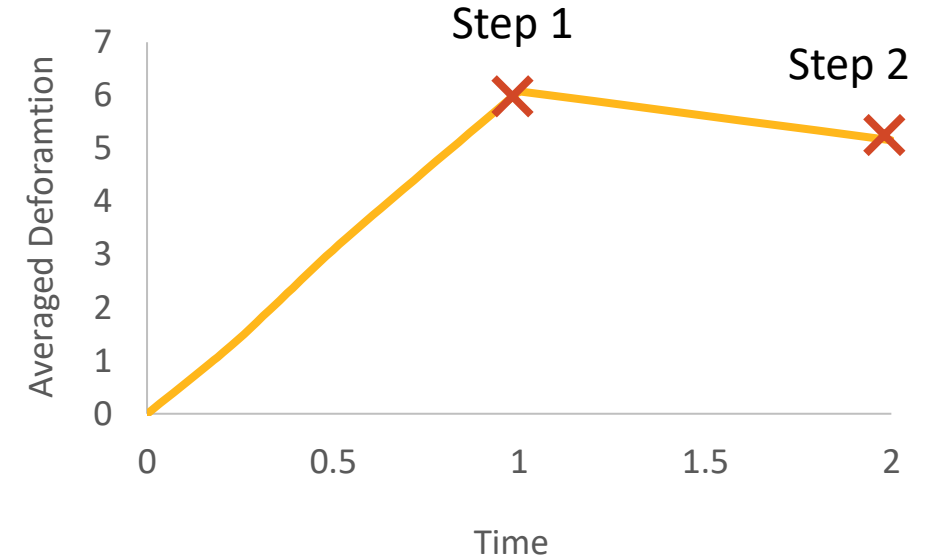
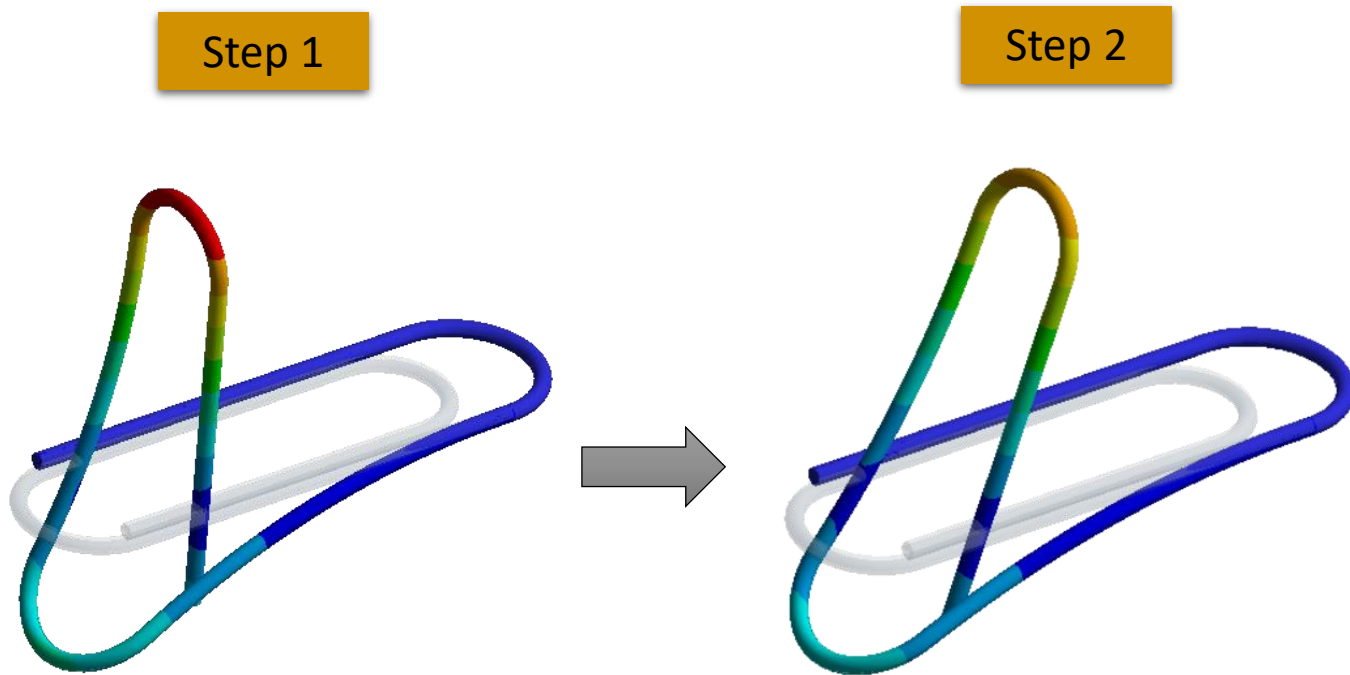
- The steel material yields when von Mises stress reaches 250 MPa.
- The hardening mode of the steel material is isotropic bilinear hardening. The hardening modulus is 1450 MPa.

Material	Steel
Young's Modulus (MPa)	2E+05
Poisson's Ratio	0.3
Yield Stress (MPa)	250
Hardening Modulus (MPa)	1450



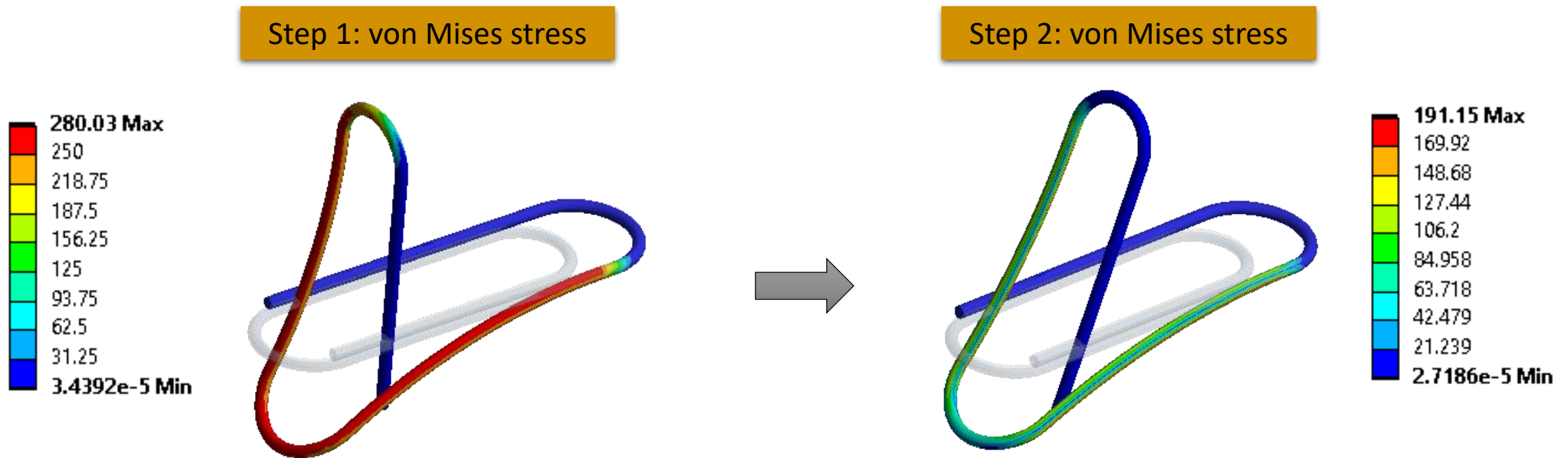
Paper Clip: Deformation

The paper clip deformed a lot in the first step. After the displacement control was released, the deformation returned a small amount. The rest of the deformation in the paper clip is caused by plasticity of the steel material.



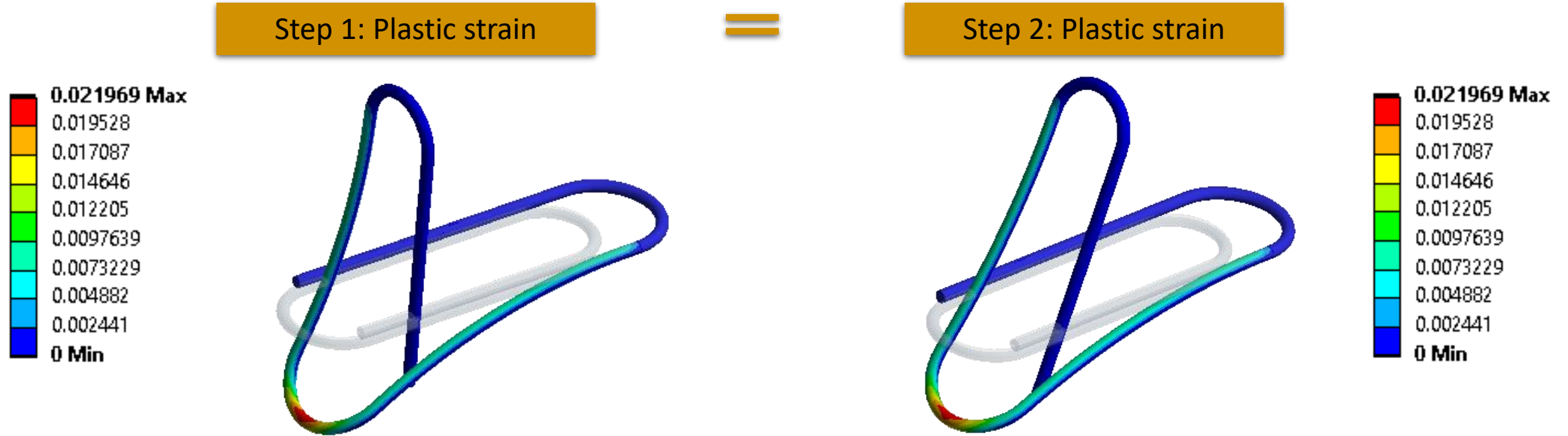
Paper Clip: Von Mises Stress

At the end of step 1, the von Mises stress of a large part of the paper clip exceeds the yield stress of 250 MPa. After the displacement control is released, the von Mises stress is decreased to below 250 MPa.



Paper Clip: Plastic Strain

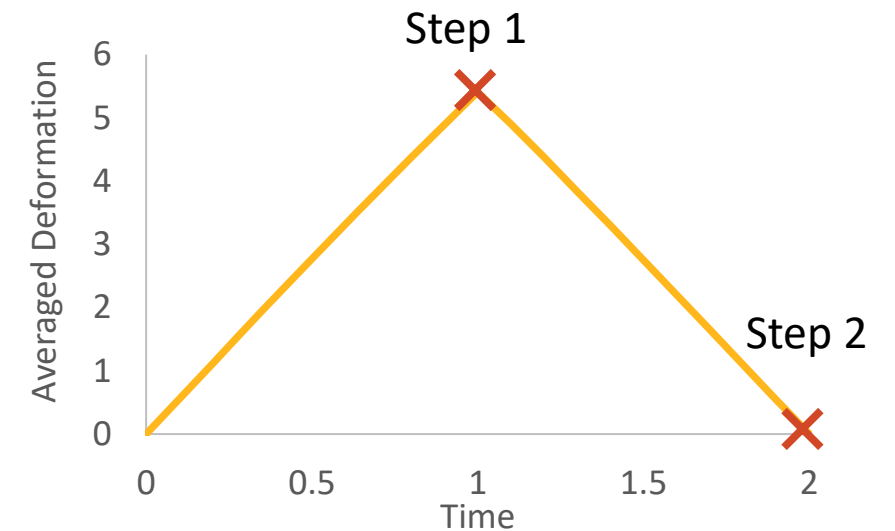
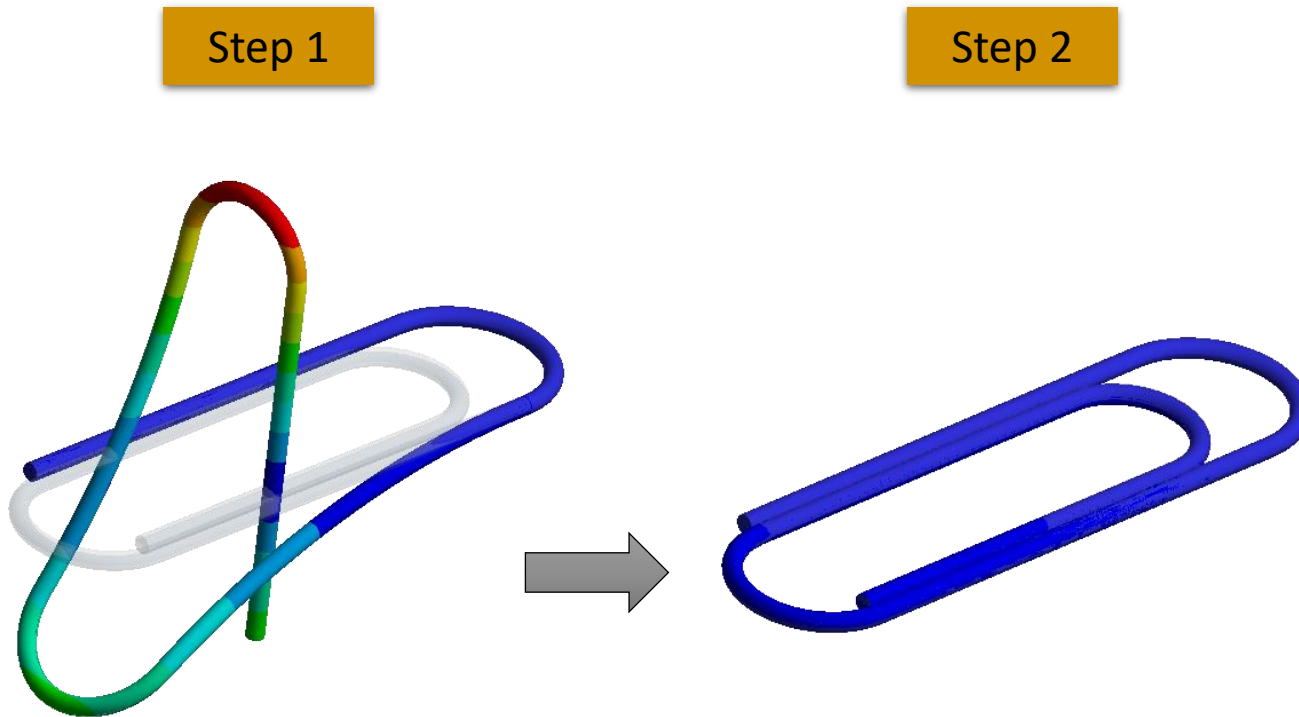
Plastic strain is a direct indicator of plasticity. At the end of step 1 and at the end of step 2, the paper clip has exactly same plastic strain. This is because plastic deformation is not recoverable.



Paper Clip: Elastic Material

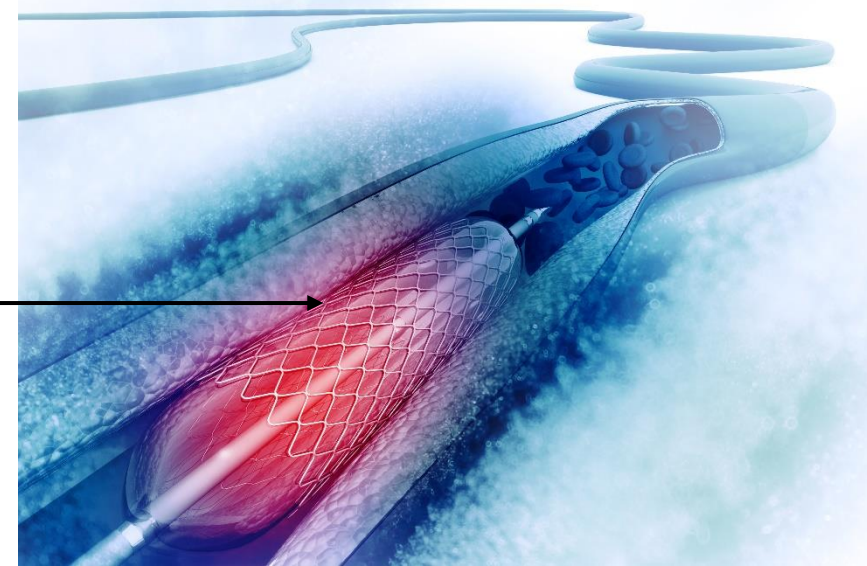
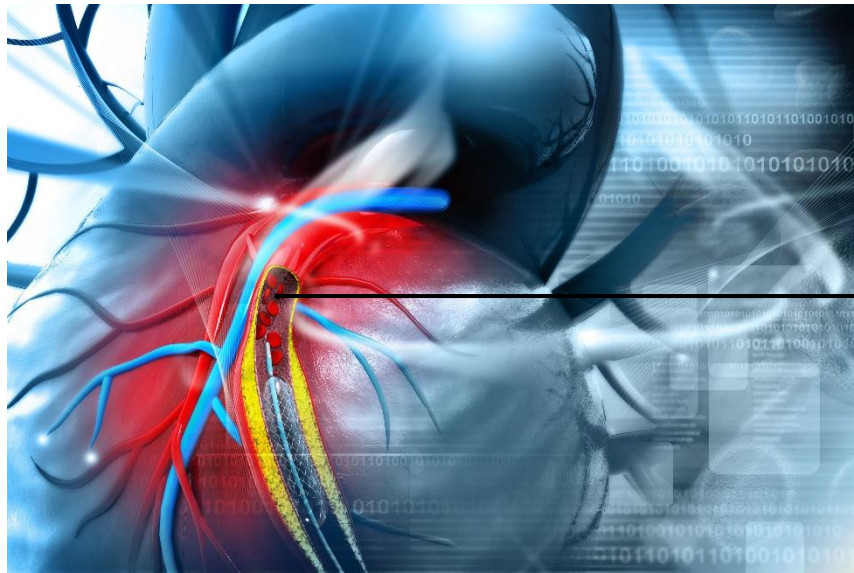
What if we solve this problem with elastic material?

- The paper clip goes back to the original configuration after such a large deflection. In reality, this will not happen for a paper clip.



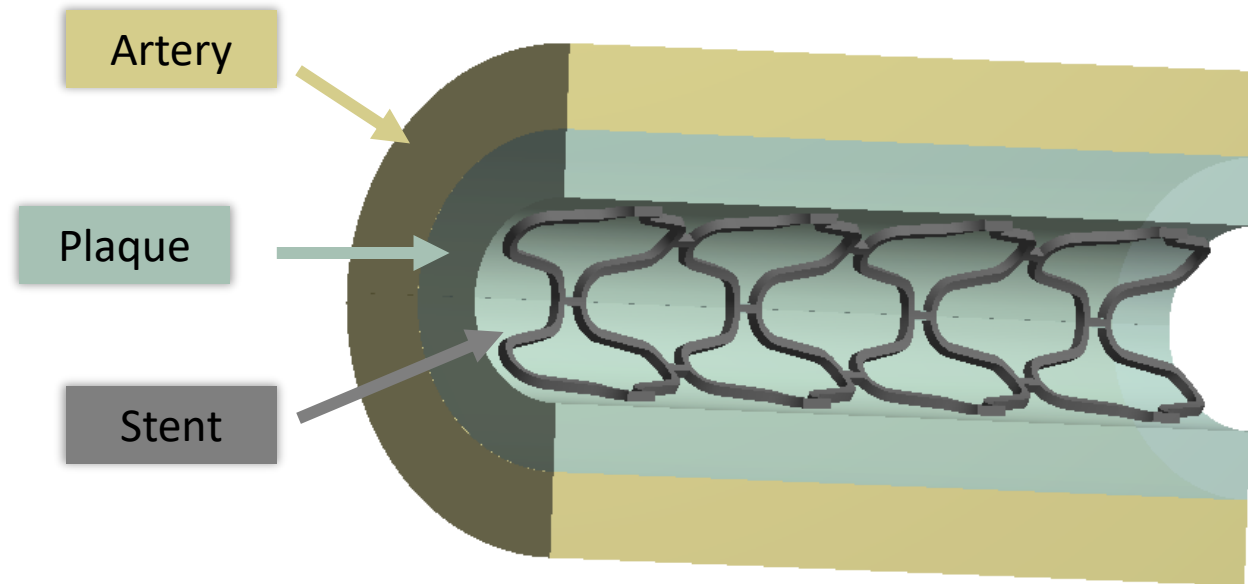
/ Cardiovascular Stent

A cardiovascular stent is a tiny wire mesh tube. It opens a clogged artery and is left there permanently. Once the stent is inserted into the artery at the right location, the physician will expand the inner balloon of the stent, which deforms the metal stent mesh to its expanded size. Cardiovascular stents are now used in more than 90% of percutaneous coronary intervention procedures.



/ Cardiovascular Stent (cont.)

A cardiovascular stent is usually made of metal, e.g., stainless steel. Because of metal plasticity, the stent can stay in the expanded size in an artery after the balloon is removed. Here, we create a mechanical simulation of the procedure: a stent is expanded in the artery and is left without further support.

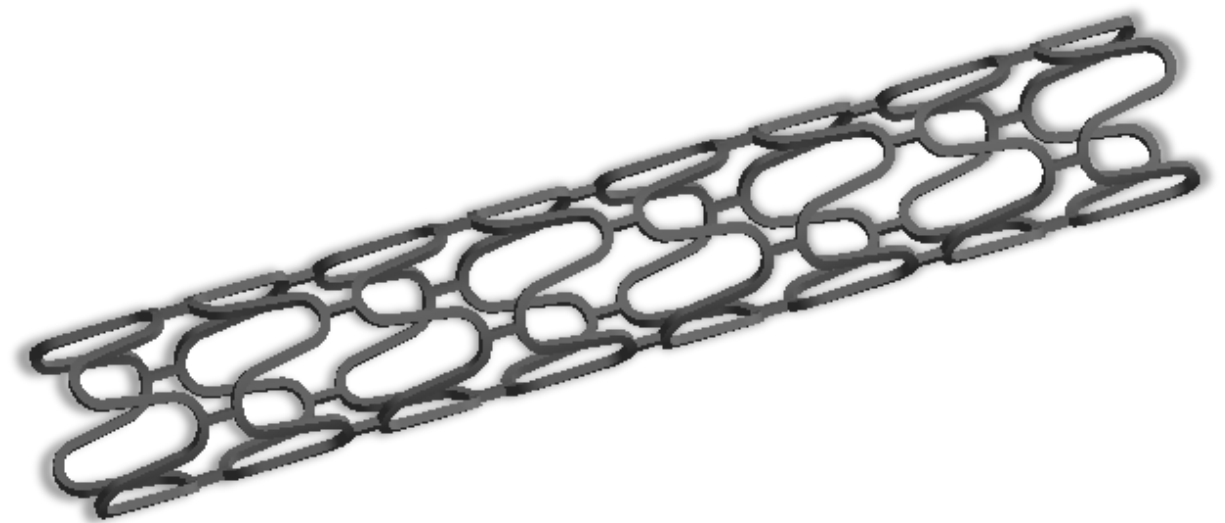


/ Cardiovascular Stent: Materials

Two different material models are used in this analysis, linear elasticity and plasticity.

- The artery and plaque materials are modeled as linear elasticity materials.
- The stent part is modeled as standard stainless steel SS316 with bilinear hardening.

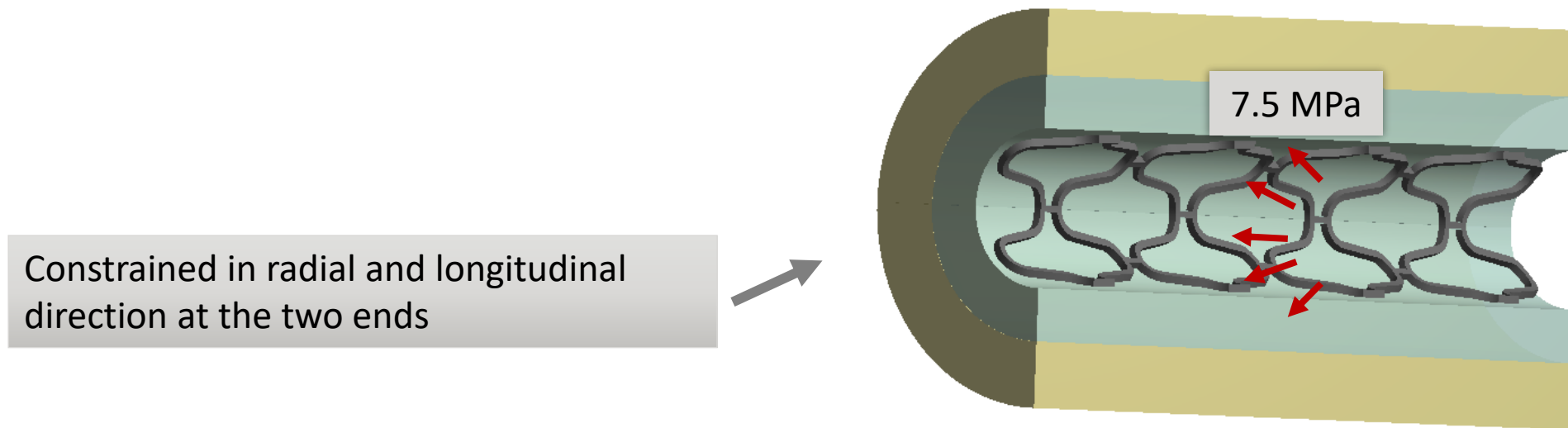
Material	SS316
Young's Modulus (MPa)	2E+05
Poisson's Ratio	0.3
Yield Stress (MPa)	285
Hardening Modulus (MPa)	1145



Cardiovascular Stent: Boundary Conditions

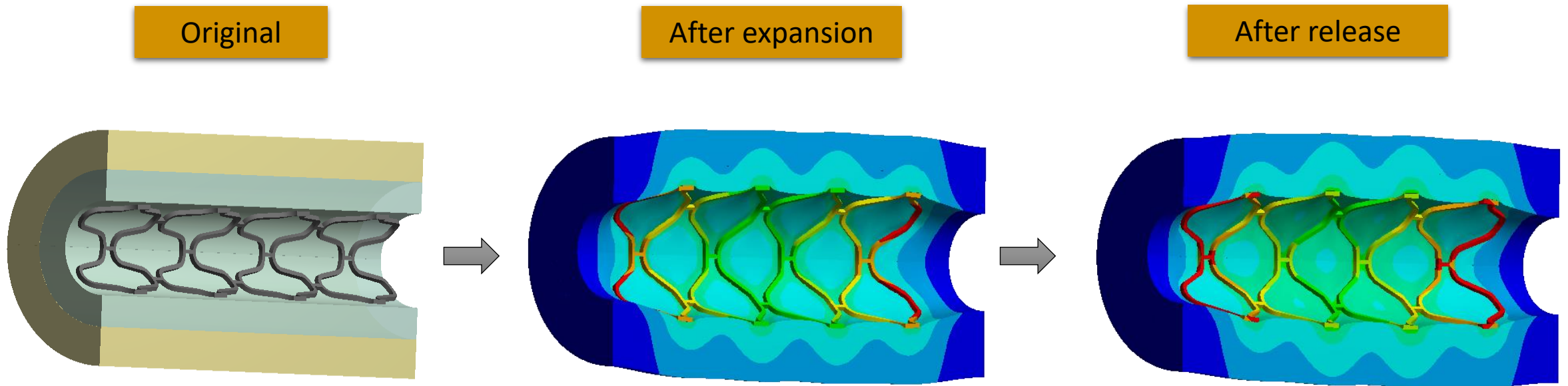
The artery and plaque parts (two circular parts) are constrained at the two ends in radial and longitudinal directions. On the inner surface of stent, a pressure is applied to expand the stent in the radial direction. After reaching 7.5 MPa, the pressure is released. The stent is expected to shrink.

- 1 Step 1: A pressure of 7.5 MPa is applied to the stent in the radial direction.
- 2 Step 2: Remove the pressure. Let the stent recover freely.



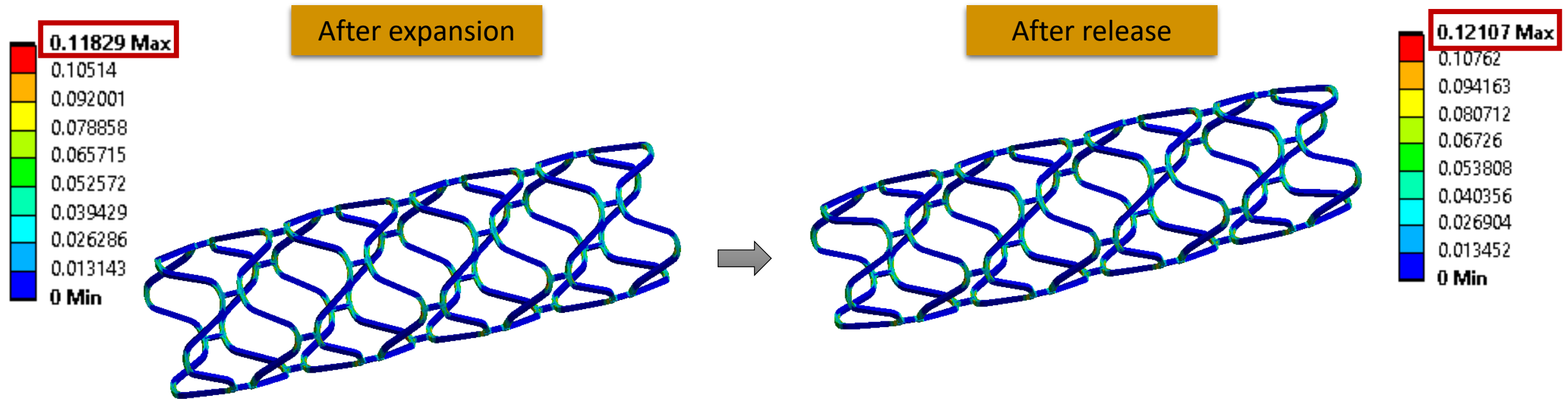
Cardiovascular Stent: Deformation

The reason that the stent should be made of a material exhibiting plasticity is that in the procedure, we want the stent to hold the expanded shape after the pressure from balloon is removed, so that the blood can flow freely in the artery. Based on the results, we can see the stent recoil a little bit in step 2 when pressure is removed, but the radius of the artery is indeed increased permanently after the procedure.



Cardiovascular Stent: Plastic Strain

Because the artery and plaque are made of elastic materials, in the process of recoil these two parts would like to return to their original shapes, and this will lead to push back load to the stent. For some area of the stent, the plastic strain starts to grow in the opposite direction. This makes the accumulated plastic strain increase from the results.



 **Ansys**

