# Twisting plate study

## Concepts involved:

### 1) Metal Plasticity

In physics and materials science, **plasticity** (also known as **plastic deformation**) is the ability of a solid material to undergo permanent deformation, a non-reversible change of shape in response to applied forces. For example, a solid piece of metal being bent or pounded into a new shape displays plasticity as permanent changes occur within the material itself. In engineering, the transition from elastic behavior to plastic behavior is called yielding.

For many ductile metals, tensile loading applied to a sample will cause it to behave elastically. A proportional increment in extension accompanies each increment of the load. When the load is removed, the piece returns to its original size. However, once the load exceeds a threshold – the yield strength – the extension increases more rapidly than in the elastic region; now, when the load is removed, some degree of extension will remain.

### 2) Hardening Rules

The hardening law, also known as hardening rules, describes how the yield surface changes under plastic deformation. The hardening rule governs the change in material strength as the plastic material deforms. The change in material strength can also be thought of as a change in the geometry or position of the yielding surface. The developed yield surface is often called the loading surface

#### Isotropic hardening

The isotropic hardening is the simplest way to model strain hardening, and it sets the yield surface to increase in size but remains the same shape due to plastic straining, which means the yield surface remains uniform (without any distortion or translation), but expands with increasing stress.

The yield surface expands uniformly in all directions with the plastic flow. The value of isotropic hardening is directly related to the amount of strain.

Isotropic hardening is related to the accumulated dislocation structure and expands the yield surface of a material under plastic deformation

#### Kinematic Hardening

In kinematic hardening, the yield surface is allowed to translate in stress space with no change in size or shape, meaning the yield surface remains the same shape and size but translates in the direction of yielding.

An initially isotropic plastic behavior is no longer isotropic after yielding (kinematic hardening is a form of anisotropic hardening).

Kinematic hardening is one of the hardening rules that describes the material's behavior after reaching the yield surface.

## Simulations:

### 1) Defining materials for Elastic and Plastic metal

Properties of Outline Row 3: Copper Alloy

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Property | Value | Unit | | |
| 2 | Material Field Variables | Table | | | |
| 3 | Density | 8300 | kg m^-3 | | |
| 4 | Isotropic Secant Coefficient of Thermal Expansion | | | | |
| 6 | Isotropic Elasticity | | | | |
| 7 | Derive from | Young's Modulus and... | | | |
| 8 | Young's Modulus | 1.1E+11 | Pa | | |
| 9 | Poisson's Ratio | 0.34 | | | |
| 10 | Bulk Modulus | 1.1458E+11 | Pa | | |
| 11 | Shear Modulus | 4.1045E+10 | Pa | | |
| 12 | Bilinear Isotropic Hardening | | | | |
| 13 | Active Table | Plastic | | | |
| 14 | Yield Strength | 100 | MPa | | |
| 15 | Tangent Modulus | 1300 | MPa | | |
| 16 | Tensile Yield Strength | 2.8E+08 | Pa | | |
| 17 | Compressive Yield Strength | 2.8E+08 | Pa | | |
| 18 | Tensile Ultimate Strength | 4.3E+08 | Pa | | |
| 19 | Compressive Ultimate Strength | 0 | Pa | | |

*Fig: Plastic behavior*

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|---|---|---|---|---|---|
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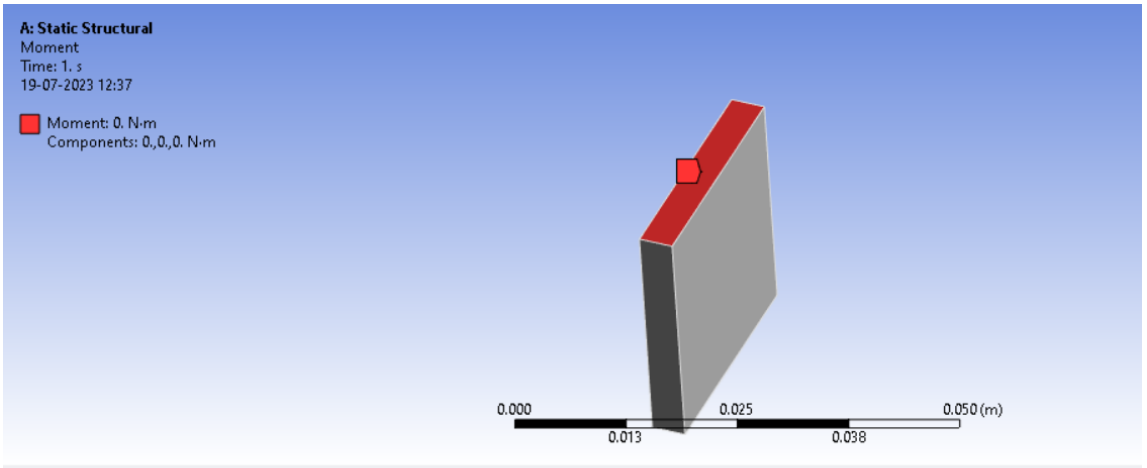
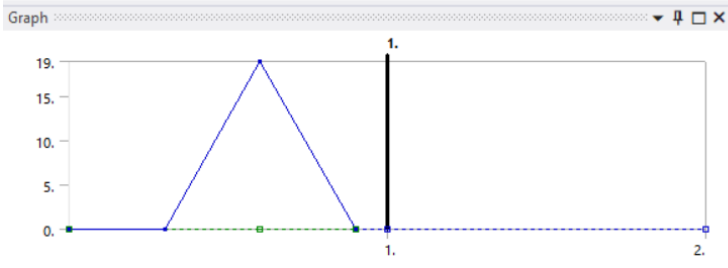
| 15 | Compressive Ultimate Strength | 0 | Pa | | |

*Fig: Elastic behavior*

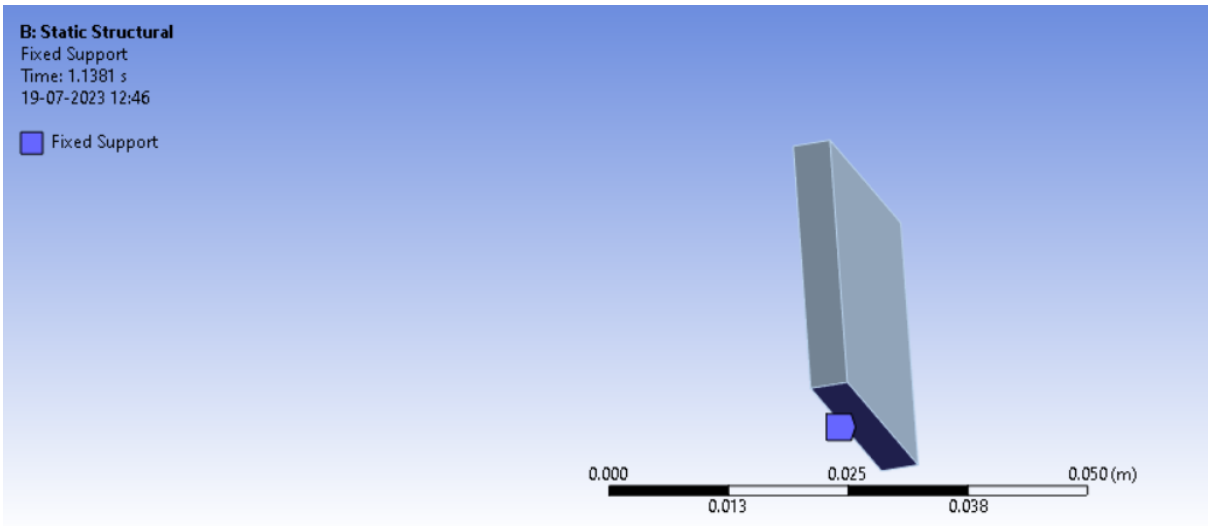
## 2) Defining Boundary Conditions




Tabular Data

| | Steps | Time [s] | X [N·m] | Y [N·m] | Z [N·m] |
|---|---|---|---|---|---|
| 1 | 1 | 0. | = 0. | = 0. | 0. |
| 2 | 1 | 0.3 | 0. | 0. | 0. |
| 3 | 1 | 0.6 | = 0. | = 0. | 19. |
| 4 | 1 | 0.9 | = 0. | = 0. | 0. |
| 5 | 1 | 1. | = 0. | = 0. | = 0. |
| 6 | 2 | 2. | = 0. | = 0. | = 0. |
| * | | | | | |



# 3) Results

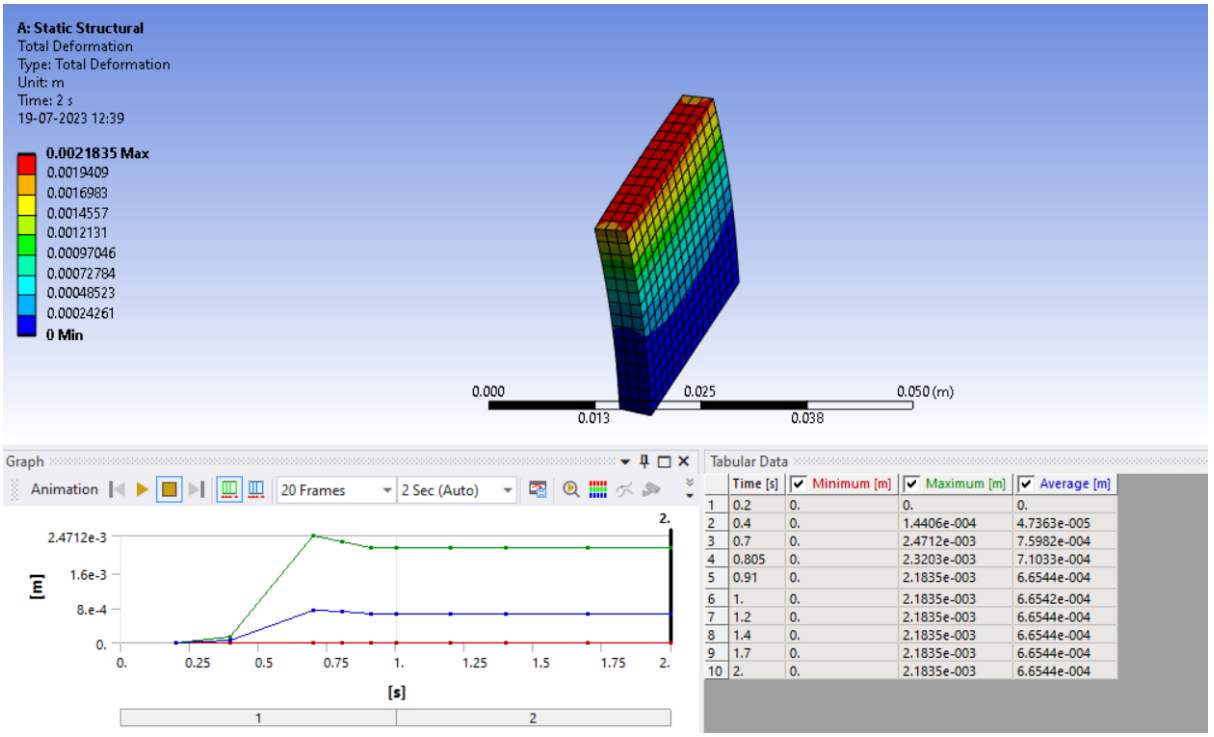



*Fig: Plastic deformation*

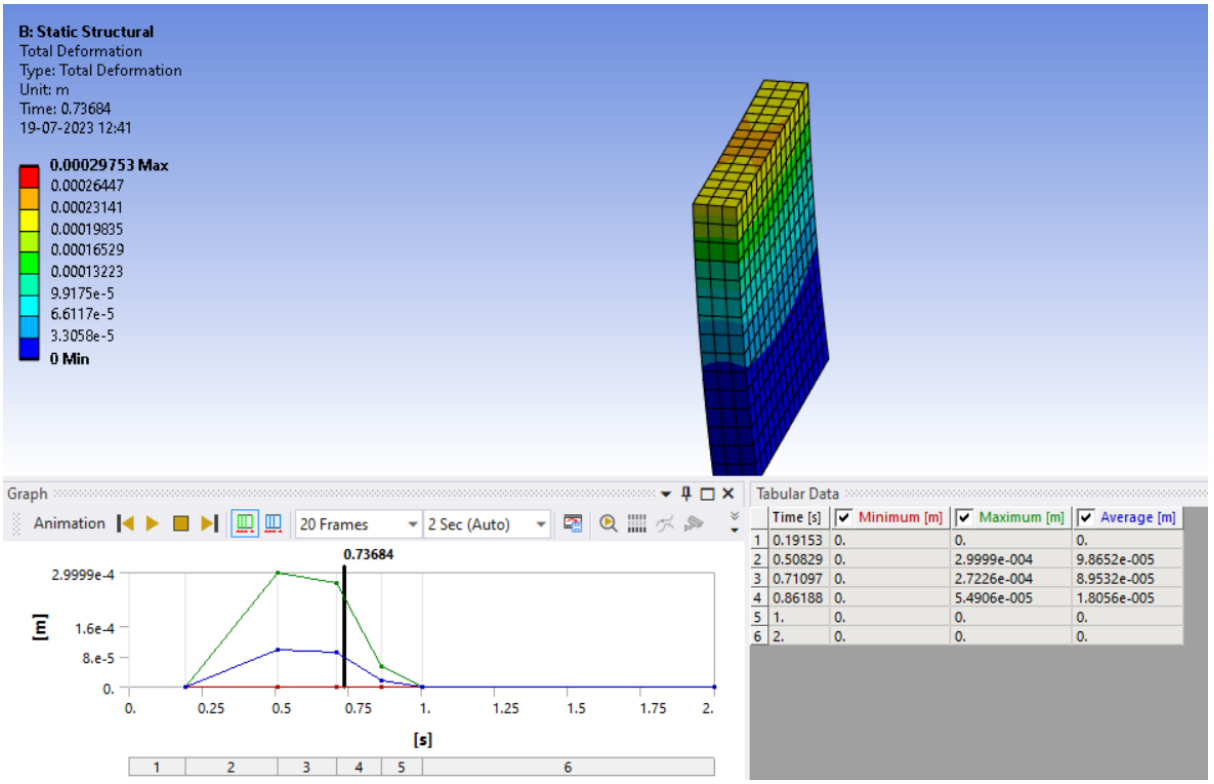



*Fig: Elastic Deformation*

## 4) Conclusions:

Upon a cyclic loading, if the moment or force goes beyond a certain limit, the material suffers from a permanent deformation, but if the properties are defined as elastic, then the plate suffers from zero deformation, as shown in the figure.