Introduction to Contact

What is contact?

Why do we need to use it?

Solid Mechanics II – Capturing Complex Response

Contact

Ansys

Overview

- Introduction to Contact
- Types of Contact
- Calculation of Contact Forces
- Force Balancing in Contacts

Introduction to Contact

- When two bodies come in physical contact, they exert forces on each other.
- This is how they “detect” each other’s presence.
- Depending on how soft or hard both the materials are they may deform to some extent, so the contact forces are distributed over a small area.
- Capturing how this pressure is distributed in the area of contact is the main objective of contact formulation.
- This is important because behavior of materials at the interface is pivotal in assessing most designs.
- For instance, ergonomically it is comfortable to sit on a foam cushion as opposed to wooden or stone bench even though we exert the same force (body weight of person).
- This is because the foam cushion is softer and deforms so the same force is distributed over larger area and reduces contact pressure.

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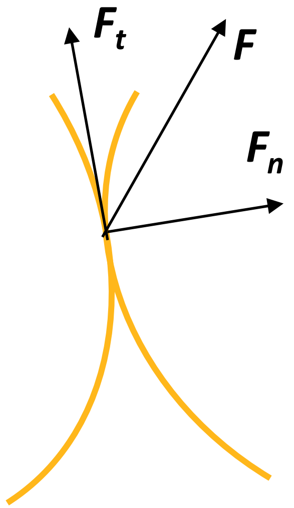
- The contact interaction between two bodies is also a form of a constitutive model.
- Material models such as Hooke's law describe what happens within a body whereas contact models describe what happens between the bodies.
- Contact is not automatically accounted for in the equations of motion, so it needs to be included in modeling the system.

Types of Contact

- There are several ways in which two bodies can interact with each other.
- Fundamentally, it boils down to how the forces are transferred in both normal and tangential directions at the point of contact.
- Force vector, F, at the point of contact can be resolved into normal and tangential components, F_n and F_t respectively.
- The normal component, F_n, tries to prevent bodies from penetrating into each other; the tangential component, F_t, tries to prevent bodies from sliding over each other.
- Depending on how this force vector resolves there are three types of contacts:

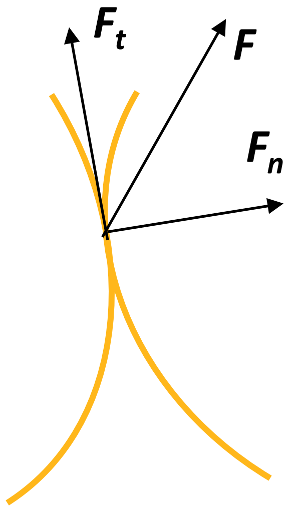
1. Bonded contact
2. Frictionless contact
3. Frictional contact



Bonded Contact

- In a bonded contact, the two surface interact in such a way that they neither separate from each other no they slide over each other.
- In other words, the normal and tangential forces are very strong, and they tend to resist any forces that tend to cause relative motion between them.
- So, one can say that both the forces tend to infinity as we apply more forces.

$$F_n \rightarrow \infty \qquad F_t \rightarrow \infty$$



- Such a contact does not exist in reality, but it is very helpful in approximating several situations such as welded joints, adhesive contacts, or even some bolted connections.

Frictionless Contact

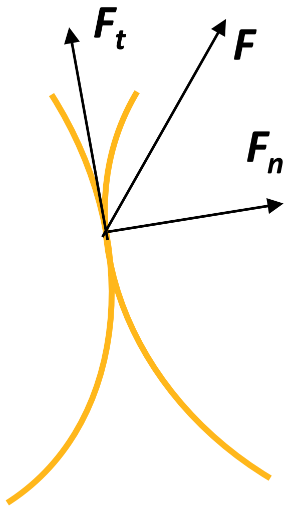
- In a frictionless contact, both the normal and the contact forces are treated differently.
- In normal direction, the surface can separate from each other, but they cannot penetrate into each other. So,

$$F_n = \begin{cases} 0, \text{ away from the surface} \\ F_n, \text{ into the surface} \end{cases}$$

- In tangential direction, the surfaces can slide over each other without any restriction. So,

$$F_t = 0$$

- Frictionless contact is also a rare occurrence, but most well-lubricated interfaces can be treated as frictionless.



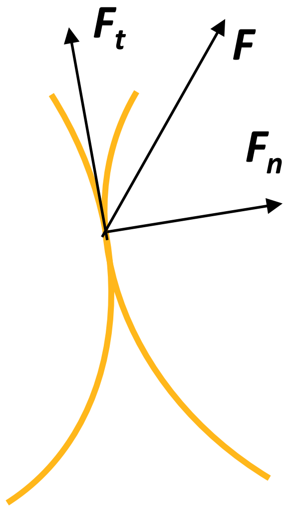
Frictional Contact

- Frictional contact is the most commonly seen contact type.
- Normal force component is same as that of frictionless contact.

$$F_n = \begin{cases} 0, & \text{away from the surface} \\ F_n, & \text{into the surface} \end{cases}$$

- Tangential force is not zero, instead it is a function of the normal force.
- Most commonly used is Coulombs law of friction which states that the frictional force is directly proportional to the normal force.

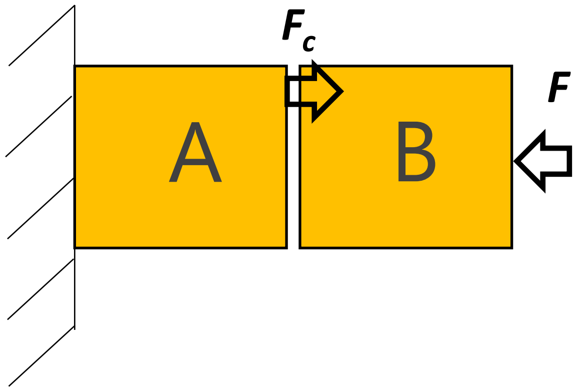
$$F_t = \mu F_n$$



Frictional Force Balancing in Contact

- Contact force must be sufficient to counter the external load that is forcing the bodies to penetrate into each other.
- When the two forces balance each other out, they're in a state of equilibrium.

$$(F - F_c) = M.a$$



- Proper calculation of contact force at all the points of contact is important to balance the applied force and to prevent penetration of one body into the other.
- What happens when contact forces are not calculated properly?

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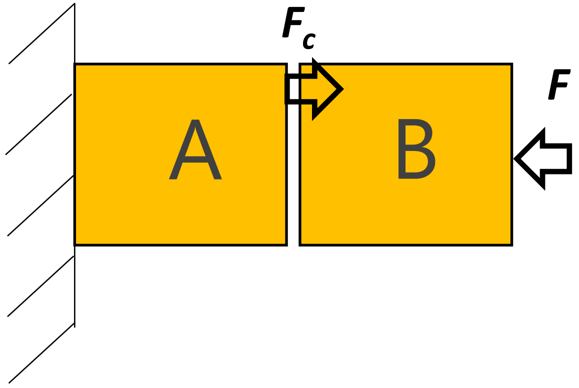
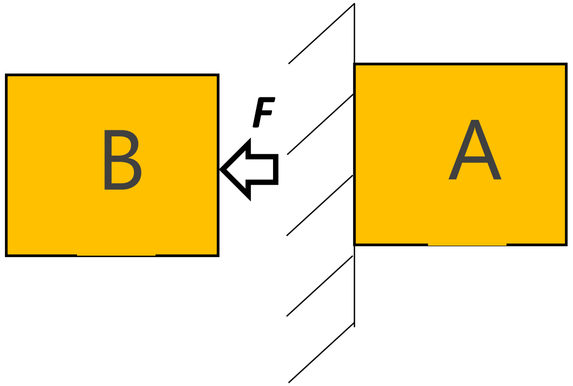
- Case 1: Contact force is zero
- No force to balance the applied load, F.

$$F = M.a$$

- Object ***B*** passes through object ***A*** without any restriction.
- Failure of contact!





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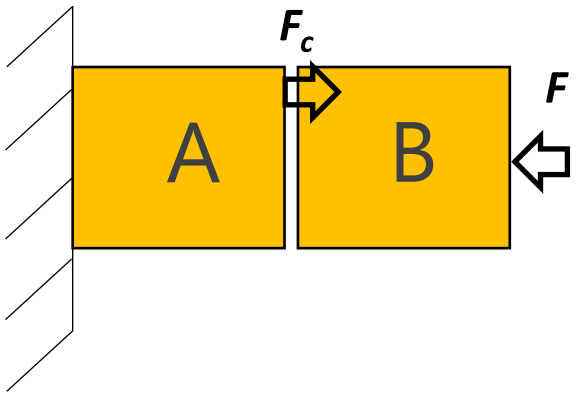
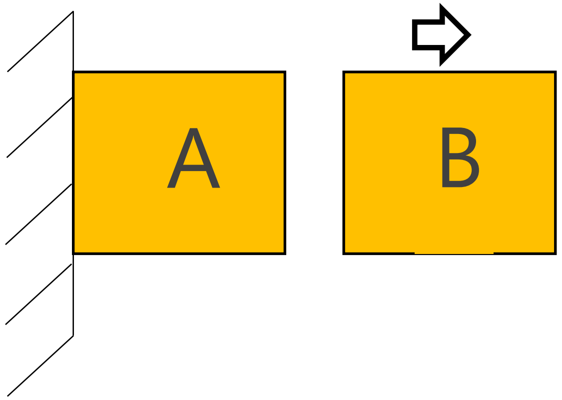
- Case 2: Contact force is more than applied force
- Forces don't balance each other out and there'll be net acceleration.
- Difference between the two forces is negative so object B is slammed away after impact (like billiard balls).

$$(F - F_c) = M.a < 0$$

- Impact type of contact!





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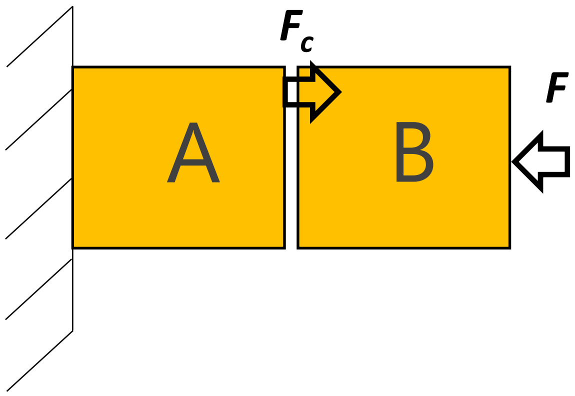
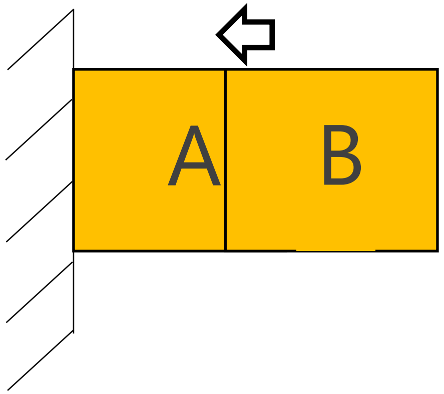
- Case 3: Contact force less than applied force.
- Forces don’t balance each other out and there’ll be net acceleration.
- Difference in forces is positive to object B continues to penetrate into object A.
- Magnitude of difference would determine if object B passes completely or only partially.

$$(F - F_c) = M.a > 0$$

- Either failure or inaccurate contact!





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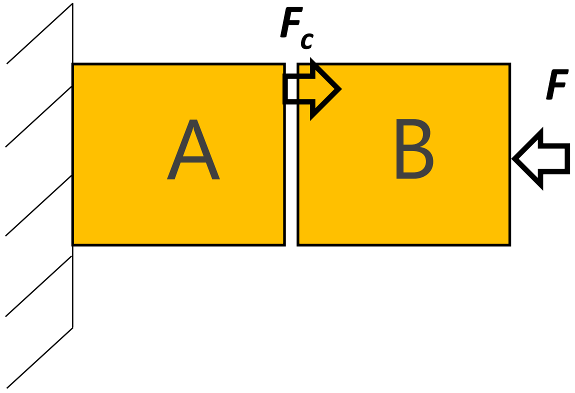
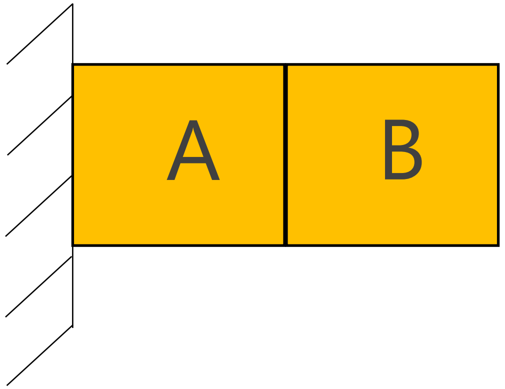
- Case 4: Contact force is equal to applied load.
- Both the forces balance each other out.
- Net acceleration is zero – equilibrium.



$$(F - F_c) = M.a = 0$$

- Proper contact established!



Calculation of Contact Forces

- The contact forces at interface of two different bodies depends on several factors such as:
  - Material of both the bodies
  - Shape and topology of the two bodies
  - Kinematics of the interacting bodies
  - Etc.,
- Accurate calculation of contact forces is crucial in capturing contact behavior.
- There are several ways of modeling these types of contact and each of them have both advantages and disadvantages.

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