

Department of Systems Innovation

2021 Online Written Examination: Problems Designed to Test Ability of Logical Thinking Field 1: Structural mechanics, fluid dynamics, material mechanics, and designs

Question 1-1

There is a wide range of material selection when designing industrial products such as automobiles, ships, and aircraft. Therefore, the material selection is an important factor for determining the overall safety and overall performance of the industrial products. It is necessary to select appropriate materials after considering the product requirements under various constraints and characteristic features of each material.

- (1) In recent years, composite materials, such as carbon fiber reinforced plastics, in which two or more different materials are integrally combined, are increasingly used. The figure schematically shows an example of a composite material consisting of copper alloy (Cu) and mild steel (Fe). The composite is connected to rigid bodies at both ends of the composite that are restricted to move in the loading direction, so that both materials always have the same displacements. The original height (H) is 1.0 m and the respective total horizontal cross-sectional areas of Cu (A_{Cu}) and Fe (A_{Fe}) are 0.05 m^2 and 0.05 m^2 . Calculate the elongation of the composite when a tensile force of $P = 1.0 \text{ MN}$ is applied by using the mechanical properties given in the table. Note that the force of gravity and other body forces are not considered here.

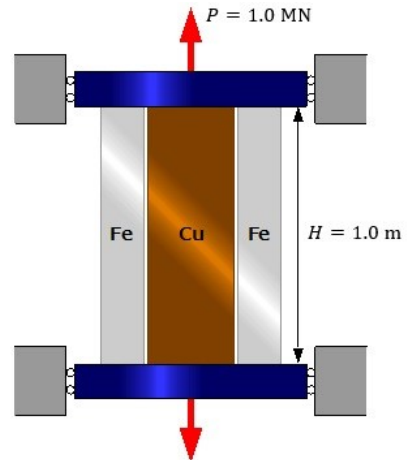


Figure Schematic of composite material consisting of copper alloy (Cu) and mild steel (Fe)

Table Mechanical properties of copper alloy (Cu) and mild steel (Fe)

Properties	Cu alloy	Mild steel
Young's modulus [GPa]	130	205
Yield strength* [MPa]	200	240

*In the case of copper alloy, the 0.1% proof strength is described instead of the yield strength.

- (2) Choose one industrial product either an automobile, ship, or aircraft, and list two or more material properties required for the structural materials that it is made of, excluding Young's modulus and yield strength. Then describe the experimental methods required for evaluating each property and the points to be considered in each evaluation.

Question 1-2

Vortex is one of the phenomena that occur in fluids. Humans have used the benefits of vortices but also suffered from them; thus, we must understand the nature of vortices and efficiently utilize them.

- (1) Consider an object placed in a uniform flow in the air, which can generate vortices behind it. In the case that the object is of a cylindrical shape, describe the state of the flow behind the object by considering the relation between inertial force and viscosity of the flow.
 - (2) Give an example of vortex phenomena behind object(s) which caused or can lead to accidents of mechanical products or structures. Also, describe the possible measures to prevent accidents.
 - (3) Describe the relation between accidents caused by vortices and the human society (e.g. impacts of accidents on society, or how society and technology have been advanced and developed after accidents). You may refer to the accidents answered in (2), or you can describe other accidents that are not related to (1) or (2).
 - (4) Give an example of the effective use of vortex phenomena and describe its mechanism. Note that the example is neither limited to mechanical products or structures, nor to the vortices mentioned in (1).
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