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Task 0: Pre-assignment

MEC-E1070 Selection of Engineering

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TABLE OF CONTENTS

1 TASK 0_1 COMPOSITES

Composite materials are a composition of two or more materials. The aim is to benefit from the best properties of the combined materials. The three most known engineering composite materials are fiberglass, carbon and Kevlar composite materials.

Fiber-reinforced composites are usually used in areas where the weight of the component is critical. Carbon, glass and Kevlar fiber-reinforced composites can usually be found in aerospace, automotive and sports applications. Fiberglass has wider use cases because of its lower price. All of the previously mentioned composite materials generally offer a good weight to strength ratio, but more complex manufacturing than conventional metal alloy parts.

1.1 MATERIAL EXAMPLES

Carbon fiber composites are used in for example, sports cars to replace aluminium or sheet steel panels because carbon fiber composite panels can provide similar strength at a much lighter weight.

Kevlar (aramid) composites are used in components which require lightweight and high resistance to impact and cracking. For example, they are widely used to manufacture parts requiring impact resistance such as bulletproof vests, boats and helmets.

Glass fiber composites are used in also in applications which require lightweight, but necessarily do not require the same strength as aramid or carbon fiber composites. Glass fiber composites are also more cost effective. As an example, glass fibre composites are also used in many aircraft and aerospace applications such as outer panels of some passenger planes.

2 TASK 0_2

2.1 FRACTURE TOUGHNESS

Fracture toughness measures how resistant a material is to crack propagation. There are several different measurements for fracture toughness. They usually include a notched specimen loaded in different configurations. One widely used test method is the Charpy impact test in which the specimen is impacted with a pendulum of known height and weight. The pendulums height after the impact can be used to calculate the energy transferred to the fracture event. The other common test is the three-point bending test using a notched specimen.

2.2 TRANSPARENCY

In optics transparency is only regarded within the wavelengths of the visible spectrum. The materials are split in to three main categories. Materials which absorb all the visible light are called *opaque*. Materials which transmit some light are called *translucent*. Materials which transmit light well enough to see through clearly are called *transparent*. Transparent materials also have a sub-set of materials which transmit light almost perfectly and they a have an additional title of *optical quality*.

2.3 SPECIFIC HEAT CAPACITY

The specific heat capacity is defined by the amount of energy needed to raise the temperature of 1 kg of a material by one degree Celsius. This is done with a devices called calorimeters. There are various measurement methods depending on the substance being measured.

2.4 Thermal conductivity

Thermal conductivity represents the rate at which heat is conducted through a solid. It is measured by heating a solid from the other side and measuring the heat conductivity from the warmer side of the solid to the colder side.

2.5 Electrical conductivity

Electrical conductivity is defined as a inverse number of electrical resistivity.

Electrical conductivity = 1 / Electrical resistivity

2.6 Flammability

Flammability is measured in different standards depending on the materials. The most common standards used are UL94-rating for plastics and LOI rating. Below is listed the corresponding values between LOI and UL-94 at 1,6 mm thickness.

Flammability rating	LOI % (limiting oxygen index)	UL-94 rating (1.6 mm nominal thickness)
Highly flammable	< 20	Unclassified or HB
Slow-burning	20–25	HB
Self-extinguishing	26–49	V-2, V-1, V-0, 5VA and 5VB
Non-flammable	> 50	Exceeds all UL94 ratings

2.7 Maximum operating temperature

For my carbon fiber composite material search I was able to only find maximum service temperatures which displays the maximum temperature that can be used for that material for an extended period without significant problems. There is no universal test for this, because it is highly dependent on the used material and is usually reported by the manufacturer.

2.8 CO_2 footprint

CO_2 footprint describes the amount of CO_2 created per kg to manufacture a kilogram of the material. It can also be described as how many MJ of energy is used to manufacture one kilogram of the product. In Granta the values are estimated from different sources and can be used as a approximation.

2.9 Coefficient of thermal expansion

Coefficient of thermal expansion describes how much a material expands when heated. Depending on the material, temperature range and application linear coefficients of expansion can be used. For other materials and difficult applications more complex methods are used.

2.10 Toxicity

I could not find a property of toxicity in the material datasheets other than a warning in the material datasheet.

2.11 Typical values for the composite material group

Fracture toughness	6 – 30 MPa · $m^{1/2}$
Transparency	Opaque - Transparent
Specific heat capacity	1 J/(kg·°C)
Thermal conductivity	0,42 – 2,6 W/(m·°C)
Electrical conductivity	$2,46\cdot10^{-21}$ – 0,0013 %IACS
Flammability	Non-flammable – Highly flammable
Maximum operating Temperature	157 – 287 °C
CO2 footprint	6 – 50 kg/kg
Coefficient of thermal expansion	9-16 µm/m·°C
Toxicity	Not specified

2.12 Material properties comparison between Level 2 and Level 3

The composite materials I chose vary a lot between levels 2 and 3. This is mainly because composite material properties are difficult to simplify because of the wide availability of different fabrics, different resins, different layups and with different curing procedures.

	Carbon fiber, woven prepreg, biaxial layup	Epoxy 0 continuous HS carbon fiber, quasi-isotropic layup
Fracture toughness	26,4 – 32,3 MPa · $m^{1/2}$	6,12 – 20 MPa · $m^{1/2}$
Transparency	Opaque	Opaque
Specific heat capacity	890 – 1000 J/(kg·°C)	902 – 1004 J/(kg·°C)
Thermal conductivity	1,06 – 3,79 W/(m·°C)	1,28 – 2,6 W/(m·°C)
Electrical conductivity	$1,31\cdot10^{-4}$ – 0,0013 %IACS	Not specified

The results look quite similar even though the comparison is between a prepreg and epoxy resin infused carbon fiber panel. Especially the specific heat capacity and thermal conductivity are quite similar the biggest variation is in the fracture toughness, but this is probably due to the different layup and layer amount.

3 Task 0_3

English	**Suomi**	**German**
Fracture toughness	Brottseghet	Bruchzähigkeit
Transparency	Läpinäkyvyys	Transparenz
Specific heat capacity	Ominaislämpökapasiteetti	Spezifische Wärmekapazität
Thermal conductivity	Lämmönjohtavuus	Wärmeleitfähigkeit
Electrical conductivity	sähkönjohtavuus	elektrische Leitfähigkeit
Flammability	Syttyvyys	Entflammbarkeit
Maximum operating Temperature	Maksimi käyttölämpötila	maximale Betriebstemperatur
CO2 footprint	Hiilijalanjälki	CO2-Fußabdruck
Coefficient of thermal expansion	lämpölaajenemiskerroin	Ausdehnungskoeffizient
Toxicity	Myrkyllisyys	Toxizität