Introduction to Mechanical Engineering BMEGEVGAG01

DEPARTMENT OF HYDRODYNAMIC SYSTEMS
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1. Measurement of revolution number, moment of inertia and friction torque

Theoretical questions

1. Measurement devices for revolution number (tachometer, Jacquet indicator, stroboscope Electric speed indicator).

2. The definition of moment of inertia, moment of inertia of a material point, a ring, and a cylinder.

3. Sketch of the measurement rig for measurement of *n(t)* diagram. (What will be measured with what type of device and how?)

4. How can be determined the moment of inertia with the help of physical pendulum?

5. How can be the friction torque determined with the help of *n(t)* diagram?

6. The definition of reduced length and its formula.

7. Definition of mathematical and physical pendulum, the formula of time period.

8. Give three revolution number measurement device, which work in different way. Emphasise the operation principle.

Problems

1. How much torque should be used to rotate the rotor of the motor if the moment of the inertia of the rotor is $\Theta=4\cdot10^{-4}$ kg·m^2 and $\varepsilon=5$ rad/s^2 angular acceleration is desired?
Give the answer in Nm. *($2\cdot10^{-3}$ Nm)*

2. Determine the moment of inertia of a material point with a mass of m = 20kg moving in a circle with a radius of r = 200mm. Give the answer in kg·m^2. *(0.8 kg m^2)*

3. What is the time period of the mathematical pendulum whose length is L = 150cm. Give the answer in s. *(2.46 s)*

4. An electric motor rotates with the nominal revolution number of n = 2800 rpm. What is the angular velocity of the motor? Give the answer in rad/s. *(293.2 rad/s)*

5. The angular velocity of an electric motor increases during $\Delta t=5$s from $\omega_1=100$ rad/s to $\omega_2=150$ rad/s. What is the angular acceleration of the motor? Give the answer in rad/s^2 respect to the proper sign (positive by acceleration, negative by deceleration). *(10 rad/s^2)*

2. Measurement of torque and efficiency (balance machines)

Theoretical questions

1. What is the aim of the idle run measurement? Torque equilibrium equation of the balance generator in idle run.
2. How can we measure the useful and the inlet power for a balance generator? How can we calculate the efficiency?
3. How can we measure the useful and the inlet power for a balance motor? How can we calculate the efficiency?
4. Draw a sketch of the measurement rig! Describe and define what, and how can we measure it?
5. Define what is the nominal power and load factor?

Problems

1. Problem: Data from a measurement of a balance motor are as follows: The revolution number $n = 1440\ f/min$, the balancing weight $m = 1340\ g$, arm length $k = 75\ cm$. Under the given revolution number, the balancing weight in idle run is $m_0 = 0{,}02\ kg$. The measured voltage is $U = 220\ V$, the current is $I = 12{,}1\ A$. How much is the balance motors useful and inlet power in this given operation point?

2. Problem: Data from a measurement of a balance generator are as follows: The revolution number $n = 2880\ f/min$, the balancing weight $m = 850\ g$, arm length $k = 60\ cm$. Under the given revolution number, the balancing weight in idle run is $m_0 = 0{,}02\ kg$. The measured voltage is $U = 220\ V$, the current is $I = 4{,}15\ A$. How much is the balance generator useful and inlet power in this given operation point?

3. Problem: The nominal power of a balance generator is $P_N = 1400\ W$, its mechanical power is $P_{mech} = 1150\ W$ while its electric power is $P_{vill} = 1380\ W$. Calculate the balance motor efficiency and load factor.

4. Problem: The nominal power of a balance motor is $P_N = 2000\ W$, its mechanical power is $P_{mech} = 1100\ W$ while its electric power is $P_{vill} = 650\ W$. Calculate the balance motor efficiency and load factor.

3. Measurement of a mobile generator

Theoretical questions

1. Draw the indicator diagram of a four-stroke Otto-engine, and explain its main steps.
2. Draw the sketch of the carburetor and explain its operation.
3. Show the formulae and dimensions for the load factor, the efficiency, the specific fuel consumption, the useful and input power of the aggregate.
4. Show the formula for the average efficiency.
5. Show the formula for the average load.

Problems

1. Problem: During a $t = 40\ min$ interval with a load factor $x = 0.8$ a mobile aggregator (with nominal power $P_N = 1500\ W$) consumed $V = 0.4\ litres$ fuel, which has a heating value $H_b = 43.6\ MJ/kg$ and density $\rho_b = 740\ kg/m^3$. Calculate the efficiency. ($\eta = 0.223$)

2. Problem: A mobile aggregator (with nominal power $P_N = 1500\ W$) produces $(P_u)_1 = 750\ W$ for $t_1 = 20\ min$, then $(P_u)_2 = 1200\ W$ for $t_2 = 40\ min$. For the first period, the efficiency is $\eta_1 = 15\%$, while for the second it is $\eta_2 = 25\%$. Calculate the average efficiency and load. ($x_{ave} = 0.7$ and $\eta_{ave} = 0.216$)

3. Problem: A mobile aggregator (with nominal power $P_N = 1500\ W$) is operating for $t = 20\ min$ with load factor $x = 0.5$. Durint its operation it consumes $m = 0.2\ kg$ fuel, which has a heating value $H_b = 43.6\ MJ/kg$. Calculate the specific fuel consumption. ($b = 0.8\ kg/kWh$)

4. Problem: A mobile aggregator (with nominal power $P_N = 1500\ W$) is operating for $t = 40\ min$ with load factor $x = 0.7$ and efficiency $\eta = 25\%$. Calculate the mass of the consumed fuel, which has a heating value $H_b = 43.6\ MJ/kg$. ($m = 0.26\ kg$)?

4. Measurement of characteristics of a flow through water heater

Theoretical questions

1. Bernoulli equation and Bernoulli enthalpy: and explain the physical meaning of the equation parts!
2. Draw the sketch of the measurement rig, and explain the measurement (heat up curve)!
3. Which terms of the total enthalpy can be neglected, explain the physical meaning of the simplifications!
4. Explain the operation of the following temperature measurements: glass thermometers, manometric thermometer, bimetallic temperature gauge, thermocouple.
5. Draw the sketch of the measurement rig, and explain the measurement (steady state temperature-mass flow rate)!

Problems

1. Problem: The volumetric flow rate of a water heater is 0.1 l/s (the density of the water is 1000 kg/m^3 and its specific heat capacity is 4187 J/(kg °C)). The lumped mass of the water heater of 0.5 kg. What is the time after the stationary state is reached?

2. Problem: The volumetric flow rate of a water heater is 0.5 l/s (the density of the water is 1000 kg/m^3 and its specific heat capacity is 4187 J/(kg °C)). The lumped mass of the water heater of 0.5 kg, and the temperature difference between the outflowing and inflowing water is 50 °C. 5 s after the machine is turned on, what if the temperature difference between the outflowing and inflowing water?

3. Problem: During a 20 s time interval, 0.5 l water flows through a water heater with 1 kW electric power. (the density of the water is 1000 kg/m^3 and its specific heat capacity is 4187 J/(kg °C)). The temperature of the inflowing water is 15 °C. In the stationary operational state of the machine, what is the temperature of the outflowing water?

4. Problem: The volumetric flow rate of a water heater is 0.05 l/s. What should be the electric power of the heater to raise the temperature of the water by 10 °C? (the density of the water is 1000 kg/m^3 and its specific heat capacity is 4187 J/(kg °C))

5. Measurement of pressure

Theoretical questions

1. U-tube equilibrium equation at positive gauge pressure measurement.
2. U-tube equilibrium equation at measurement of vacuum.
3. Explain how a Bourdon-tube manometer works, make a sketch.
4. Make a sketch of the device used for the Bourdon gauge calibration and explain how it works.
5. Volume metering tank. How it is used for measurement of volume flow rate?
6. Explain how to use an orifice plate. (sketch, operating principle)

Problems

1. Problem:

Find the absolute pressure at location "A" of the vertical pipe shown in Figure 1. The pressure is measured by a mercury filled U-tube manometer! a=150 mm; h=100 mm; ρ_{water} = 1000 kg/m^3; ρ_{Hg}=13600 kg/m^3. The atmospheric pressure is 10^5 Pa (110899 Pa).

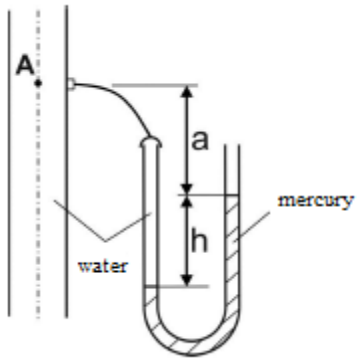


Figure 1.

2. Problem:

Find the absolute pressure at location "B" of the vertical pipe shown in Figure 2. The pressure is measured by a mercury filled U-tube manometer! b= 120 mm; h= 50 mm; ρ_{water} = 1000 kg/m^3; ρ_{Hg}=13600 kg/m^3. The atmospheric pressure is 10^5 Pa (92152 Pa).

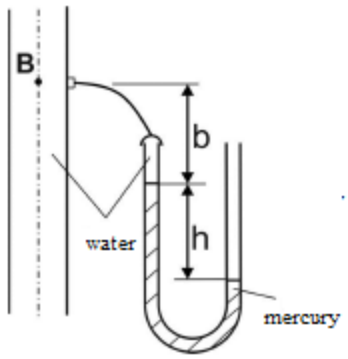


Figure 2.

3. Problem:

Calibration of a Bourdon gauge. The mass of the plunger extending into the oil filled cylinder is 1 kg, and the cross section area of the plunger rod is 2 cm^2. Calculate the gauge pressure induced in the oil cylinder by adding a disk of 2 kg on the top of the plunger! (147150 Pa)

4. Problem:

The volume flow rate was measured by a metering tank. The level rise was 100 m, and the time taken for rising was 41.21 seconds. The constant of the tank is α=0.1086 dm^3/min. Calculate the volume flow rate in units of dm^3/min! (15.81 dm^3/min)

6. Measurement of pressure losses of pipes and elbows

Theoretical questions

1. Write the lossless Bernoulli equation and explain the physical meaning of the equation parts!

2. Write the lossless Bernoulli equation and write down the conditions under which it is valid! Write three conditions!

3. Define the loss coefficient for a pipe element (generally)! On what parameters does it depend? Write at least three parameters!

4. Draw the sketch of the measurement test rig!

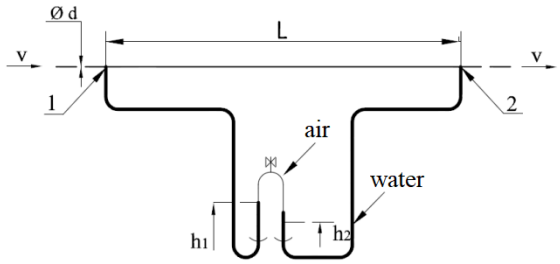
5. Describe the process of the measurement!

6. How do you calculate the shape loss coefficient of a pipe element?

Problems

Problem 1.

In a straight pipe section, water flows at speed v. As shown in the figure, pressure taps 1 and 2 are formed, the resulting pressure difference Δp is directed to a reversed "U tube" manometer. (The density of the air is negligible.) The manometer positions are h_1 and h_2. Length of test section is L, and pipe inner diameter is d.

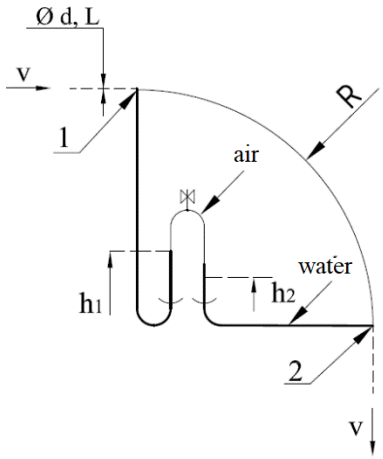


a. What is the pressure drop (Δp_{12}) on the length L? (*883 Pa*)
b. What is the friction factor λ? (*0.0303*)

Data: ρ_{water}=1000 kg/m^3, h_1= 1.450 m, h_2= 1.360 m, v = 1 m/s, L=1.75 m, d=0.03 m, g = 9.81 m/s^2

Problem 2.

In a pipe, water flows at average velocity v. As shown, at the beginning and at end of the bend, pressure taps 1 and 2 are formed. The resulting pressure difference Δp, is directed to a reversed "U tube" manometer. (The density of the air is negligible.) The manometer positions are h_1 and h_2. The length of the curved section is L, the inner diameter of the pipe is d, the friction factor is λ.



a. What is the pressure drop (Δp_{12}) between the pressure taps? (*324 Pa*)
b. What is the shape loss coefficient for the elbow ζ_{shape}? (*0.3743*)

Data: ρ_{water}=1000 kg/m^3, h_1= 2.345 m, h_2= 2.312 m, v = 0.9 m/s, L = 0.55 m, d = 0.022 m, λ=0.017, g = 9.81 m/s^2

Problem 3.

In a 0.5" (0.5 inch) inner diameter water flows in a pipe with average velocity v. (1 inch = 25.4 mm.) The pipe is filled with a 16-liter tank in 75 seconds.

a) What is the inner surface A of the pipe? *(0.000126677 m^2)*
b) What is the average velocity v in the pipe? *(1.684 m/s)*