Project 1
Unit Number: 301023
Unit Name: Advanced Thermal and Fluid Engineering

Instruction

- Students will develop CFD programs to solve simple problems in this project.
- There are two parts in this project, each student needs to complete the work assigned in each part and submit a written report.
- The report must be in the format of Miscrosft Word file and submitted through vUWS. Reports in hard copy will not be accepted.

Note:

Plagiarism

Plagiarism is absolutely unacceptable. If plagiarism is suspected to be involved in a report, it will be reported to the school for further investigation.

Late submission

– If you submit a late assessment, without receiving approval for an extension of time, (see next item), you will be penalised by 10% per day for up to 10 days. In other words, marks equal to 10% of the assignment's weight will be deducted from the mark awarded.
– For example, if the highest mark possible is 50, 5 marks will be deducted from your awarded mark for each late day.
– Saturday and Sunday are counted as one calendar day each.
– Assessments will not be accepted after the marked assessment task has been returned to students.
– This is consistent with Clause 51 of the Western Sydney University's Assessment Policy - Criteria and Standards-Based Assessment.

- Submitting the report late due to your own internet connection problem will be treated as late submission without a valid reason. To avoid delay, you need to submit the report well before the due date.

Part one: Simple initial value problem

Assignment (please read the problem description before doing the assignment)

(1) Find out the equation of motion of the cylinder. The derivation procedure of the equation must be included in the report.
(2) Develop a numerical method for predicting the vibration of the cylinder. The procedure of deriving the numerical formula must be included in the report.
(3) Develop a MATLAB program for solving the problem. The MATLAB program code must be included in the report.
(4) Keeping the damping coefficient of c = 100 N·m/s, conduct numerical simulations for KC=2 to 20 with an interval of 2 and find out the variation of the power with the KC number.
(5) Keeping the KC number to be constant of KC=10, conduct numerical simulations for c=0 to 2000 N·m/s with an interval of 50 and find the variation of the power with c.
(6) In the report, show the time histories of the vibration for all the calculated cases.
(7) Discuss how KC and c affects the power generation.

Problem description

An energy extraction device includes a cylinder elastically mounted on a spring and the electricity generator. The cylinder vibrates only in a direction parallel to the flow and drives an electricity generator. The electricity generator extracts the energy from the cylinder in the same way as a damper. It is modelled as a damper with a damping constant c when the vibration is studied. The flow velocity is a combined steady and oscillatory flow

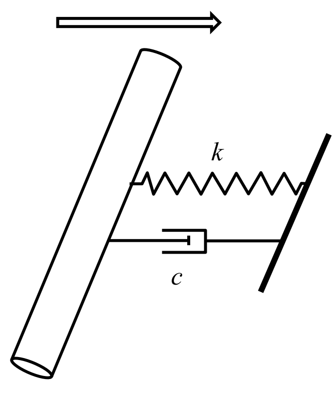
$$u(t) = U_0 + U_m \sin(2\pi t / T)$$

where U_0 is the steady flow velocity, U_m is the amplitude of the oscillatory flow velocity, T is the period of the oscillatory flow and t is the time.

The KC number is defined as

$$KC = \frac{U_\mathrm{m} T}{D}$$

Flow velocity u=U_0+$U_m$sin(ωt)



The electricity generator can modelled by a damper that extract energy from the motion of the cylinder with a constant damping constant of c. The structural damping is considered to be negligibly small. Considering the power given by the fluid should be the same as the power received by the damper, the power can also be calculated using the energy received by the electricity generator (damper) as:

$$\bar{P} = \frac{1}{nT}\int_t^{t+nT} cV^2 \mathrm{d}t$$

where P is the power of the system, F is the hydrodynamic force on the cylinder, V is the vibration speed of the cylinder. In the numerical simulation, if total computational time step is N, the power can be calculated by

$$\bar{P} = \frac{1}{N}\sum_{n=\mathrm{N_0}}^{\mathrm{N_0}+N}(cV^2)_{\text{at step n}}$$

Note, N_0 must be a step where the vibration has been fully developed. In addition, the time from step N_0 to N_0+N must be one or a few whole periods.

The hydrodynamic force on the cylinder can be predicted by the Morison equation

$$F_{\text{water}} = \underbrace{C_A m_{\text{d}} \frac{\mathrm{d}V_{\text{r}}}{\mathrm{d}t}}_{F_{\text{inertia}}} + \underbrace{\frac{1}{2}\rho C_D A_p |V_{\text{r}}| V_{\text{r}}}_{F_{\text{drag}}}$$

where $V_r=u-V$ is the velocity of the flow relative to the cylinder, C_A and C_D and inertia and drag coefficients, respectively, m_d is the displaced fluid mass and A_p is the projected area. The calculating parameters are listed in the table below.

Table 1 Parameter table

Note: In the table, the number j stands for the last digit of your student ID. For example, if your student ID is 2345673, 10+j = 13.

Amplitude of the oscillatory flow velocity, U_m	$1+\frac{j}{10}$ m/s
Steady flow velocity U_0	$0.1\times U_m$ m/s
Diameter of the cylinder, D	10+j cm
Length of the cylinder, L	1 m
Mass of the cylinder, m	50 kg
Density of the water, ρ	1024 kg/m^3
Stiffness of the spring (total), K	200 N/m
Damping coefficient (total), c	See the assignment
Added mass coefficient (assume to be constant)	1
Drag coefficient (assume to be constant)	1.8

Note: Stable vibration can be achieved only if the simulated time is long enough.

Part two: One-dimensional convection diffusion problem

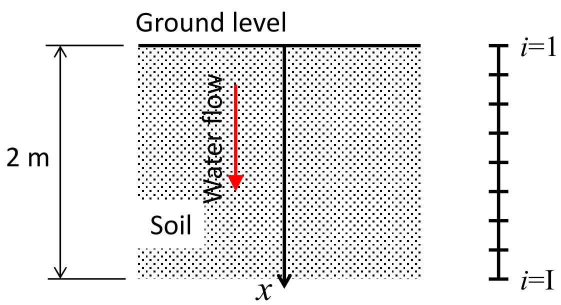
Assignment (please read the problem description before doing the assignment)

- Develop a finite difference method (FDM) formula for solving the equation. The procedure of deriving the FDM formula must be included in the report.
- Develop a MATLAB program and use this program to do the simulation and answer the following questions. Divide the soil depth into 200 cells when solving the problem numerically. You must attach the MATLAB program in your report.
- If α=0.0002 m^2/s, find out when the temperature at the depth of 1.5 m reaches 25°C.
- If the temperature at the depth of 1.5 m reaches 25°C is defined as $T_{1.5}$, do the simulations for α in the range of 0.0002 m^2/s to 0.001 m^2/s with an interval of 0.0001 m^2/s and discuss how α on $T_{1.5}$ and why.

Problem description

Note: *In the paragraph below, the number j stands for the last digit of your student ID. For example, if your student ID is 2345673, 10+j = 13.*

The water on the ground flows into the soil through the pore space of the soil (the space between soil particles). The flow velocity is very small of 0.002×(1+j) m/s and it does not change along the vertical direction. Initially, the temperature is (10+j) °C in the whole soil volume (including soil and the water in the soil). The temperature of the water on top of the ground level is 30°C and remains constant. The warm water moves into the soil and increases the temperature in the soil.



A coordinate x is defined and its origin is on the ground level and pointing downwards. The governing equation is the convection diffusion equation

$$\frac{\partial T}{\partial t} = -u\frac{\partial T}{\partial x} + \alpha\frac{\partial^2 T}{\partial x^2}$$

where

T is the temperature in the soil

t is the time

u is the water flow velocity

α is the heat diffusion coefficient (the influence of the soil has been considered).

Boundary condition is T=30°C at the top boundary and $\frac{\partial T}{\partial x} = 0$ at the bottom boundary (at x= 2 m).