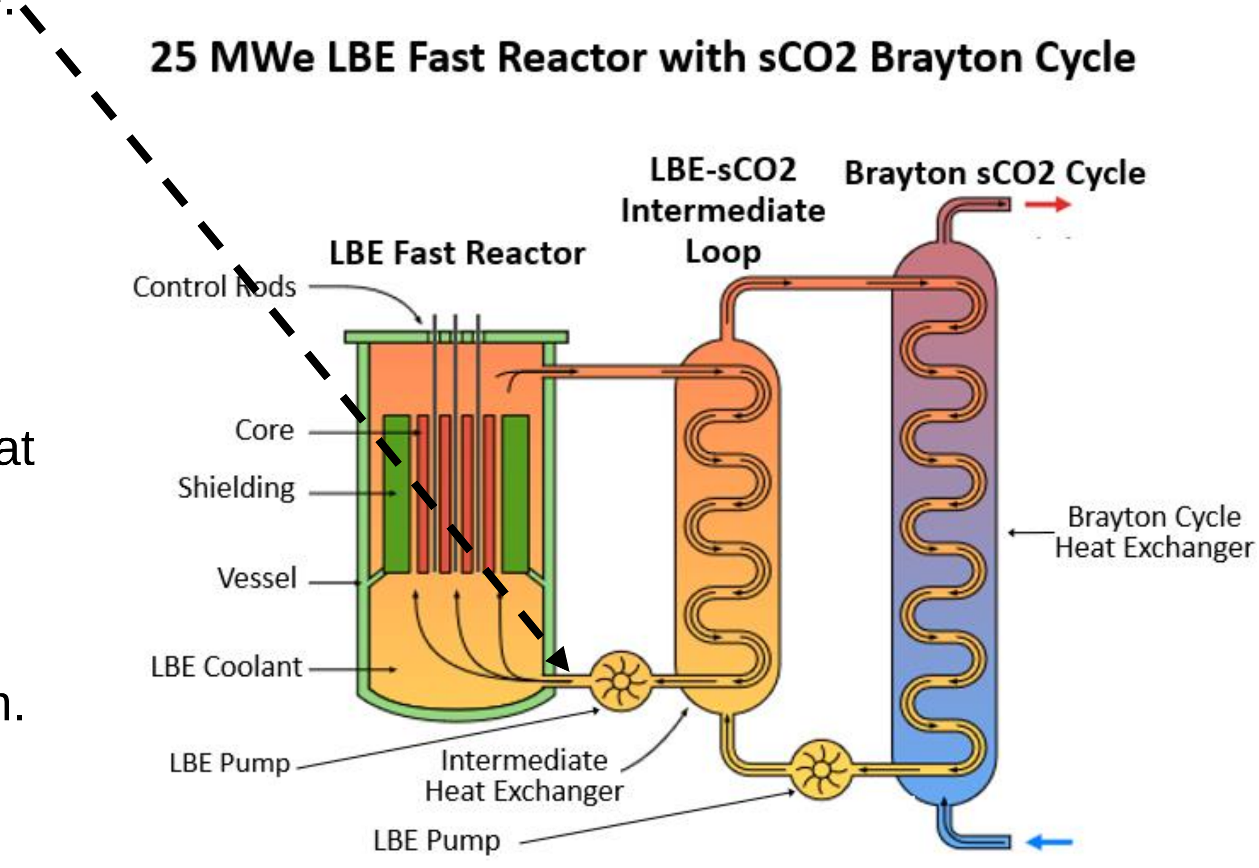
Calculation of Eddy Scales for a Small Modular Reactor

- Suppose you want to model a small modular reactor (SMR) inlet pipe.
- You want to compare different coolant fluids: He, water, and lead bismuth eutectic (LBE).
- For the sake of an “apples to apples” comparison, assume that only the coolant fluid differs.
- P=5.7e5 Pa, T=400 K, u=5.5 m/s, and D=0.1 m.
- This time, the LIKE algorithm is used.



Lucky for us, this example is already coded in Matlab file “Yplus_LIKE_Eddy_Scales__BOOK_Version.m”.

Calculation of Eddy Scales for an SMR

From file "Yplus_LIKE_Eddy_Scales__BOOK_Version.m"

%%% Another LIKE example for Book, Chapter 3. 11/03/2017.

%%% Gas, water, and LBE cooled reactor example.

%%% Fluid = He, water, or lead-bismuth eutectic (LBE). (User specifies the fluid below, based on the three choices).

flow = 0;   %%% Flow is internal.

lambda = 0.0; %%% lambda = surface roughness, m.

P = 5.7e5;

P_refprop = P/1000.0; %101.3 kPa = 101,300 Pa (refprop requires kPa input)

T_fluid = 400;

T_film = T_fluid;

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%%%%%%% Choice 1, a call for He gas properties %%%%%%%

```
[U_sound rho_liq k_liq mu_liq Cp_liq Pr beta] =
    refpropm('ADLVC^B','T',T_fluid,'P',P_refprop,'helium');
nu = mu_liq/rho_liq;
```

%%%%%%% Choice 2, a call for liquid water properties %%%%%%%

```
[U_sound rho_liq k_liq mu_liq Cp_liq Pr beta] =
    refpropm('ADLVC^B','T',T_fluid,'P',P_refprop,'water');
nu = mu_liq/rho_liq;
```

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%%%%% Choice 3, a call for the LBE molten metal properties %%%%%

```
%%% Choose value for i_fluid=4 (LBE selection in function "NaPbBiLBE_FUNC").
%%% Note: if using another molten metal, then Na=1, Pb=2, and Bi=3.
%%% Otherwise, insert the necessary molten metal properties manually.
i_fluid = 4;          %%% Choice of fluid. Default = 0, which will induce abort.
i_matprop = 1;   %%% Choice of method to calculate the material properties.
                        %%% 1 = Function call for Na, Pb, Bi, or LBE properties.
if i_matprop == 1
    %%% Call function "NaPbBiLBE_FUNC" to obtain the fluid material properties.
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%% How function "NaPbBiLBE_FUNC" works:
    %%% values=values(i_fluid, T)= array with fluid temperature, T_fluid.
    %%% [rho, beta, Cp_liq, mu, k, Pr, nu, alpha] = output from function NaProperties07142015.
    %%% i_fluid=values(1);   %%% Choice of fluid. Na=1, Pb=2, Bi=3, and LBE=4
    %%% T = values(2);       %%% T=T_fluid, the fluid temperature.
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    values = [i_fluid, T_fluid]
    [rho_liq, beta, Cp_liq, mu_liq, k_liq, Pr, nu, alpha_liq] = NaPbBiLBE_FUNC(values);
    nu = mu_liq/rho_liq;
end
```

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And finally, the remaining input to solve the problem:

```
u_fluid = 5.5;
%%%Ma = u_char/U_sound; %%% Mach number calculation
D_pipe = 0.1;
```

- **At this point, run the Matlab file, and the output is printed out almost instantaneously!**
- **Key output for the He, H_2O, and LBE pipes are shown in the next three slides, respectively.**

Calculation of Eddy Scales for an SMR

Reynolds number = 1.55e+004
Prandtl number = 6.62e-001

Max. mean turbulence velocity = 6.88e+000 m/s
L_e/x_char = 1.52e+001

Wall friction C_f or f = 6.89e-003
Wall friction velocity (u*) = 3.23e-001 m/s
Wall shear = 7.14e-002 kg/m-s2

y at y+=1 = 1.10e-004 m
y at y+=7 = 7.70e-004 m
y at y+=30 = 3.30e-003 m

Turbulent kinematic viscosity = 1.66e-003 m2/s
Ratio of turb. and kinematic visc. = 4.68e+001
Turbulence intensity = 3.52e-002
Specific turbulence kinetic energy = 5.62e-002 m2/s2
Eddy dissipation (epsilon) = 1.71e-001 m2/s3

Kolmogorov eddy size = 7.15e-004 m
Kolmogorov eddy velocity = 4.97e-002 m/s
Kolmogorov eddy time = 1.44e-002 s

Taylor eddy size = 1.08e-002 m
Taylor eddy velocity = 1.94e-001 m/s
Taylor eddy time = 5.57e-002 s

Integral eddy size = 7.00e-003 m
Integral eddy velocity = 2.37e-001 m/s
Integral eddy time = 2.95e-002 s

Eddy frequency (omega) = 3.39e+001 1/s
Kolmogorov eddy frequency = 6.95e+001 1/s
Taylor eddy frequency = 1.79e+001 1/s
Integral eddy frequency = 3.39e+001 1/s

Calculation of Eddy Scales for an SMR

Reynolds number = 2.36e+006
Prandtl number = 1.36e+000

Max. mean turbulence velocity = 6.88e+000 m/s
Entrance length = 5.33e+000 m
L_e/x_char = 5.33e+001

Wall friction C_f or f = 2.41e-003
Wall friction velocity (u*) = 1.91e-001 m/s
Wall shear = 3.42e+001 kg/m-s2

y at y+=1 = 1.22e-006 m
y at y+=7 = 8.56e-006 m
y at y+=30 = 3.67e-005 m

Turbulent kinematic viscosity = 7.97e-004 m2/s
Ratio of turb. and fluid kinematic visc. = 3.42e+003
Turbulence intensity = 1.69e-002
Specific turbulence kinetic energy = 1.30e-002 m2/s2
Eddy dissipation (epsilon) = 1.90e-002 m2/s3

Kolmogorov eddy size = 2.86e-005 m
Kolmogorov eddy velocity = 8.16e-003 m/s
Kolmogorov eddy time = 3.51e-003 s

Taylor eddy size = 1.26e-003 m
Taylor eddy velocity = 9.30e-002 m/s
Taylor eddy time = 1.36e-002 s

Integral eddy size = 7.00e-003 m
Integral eddy velocity = 1.14e-001 m/s
Integral eddy time = 6.15e-002 s

Vortex shedding frequency = 1.15e+001 1/s
Eddy frequency (omega) = 1.63e+001 1/s
Kolmogorov eddy frequency = 2.85e+002 1/s
Taylor eddy frequency = 7.37e+001 1/s
Integral eddy frequency = 1.63e+001 1/s

Calculation of Eddy Scales for an SMR

Reynolds number = 1.78e+006
Prandtl number = 5.14e-002

Max. mean turbulence velocity = 6.88e+000 m/s
L_e/x_char = 4.97e+001

Wall friction C_f or f = 2.51e-003
Wall friction velocity (u*) = 1.95e-001 m/s
Wall shear = 4.00e+002 kg/m-s2

y at y+=1 = 1.58e-006 m
y at y+=7 = 1.11e-005 m
y at y+=30 = 4.75e-005 m

Turbulent kinematic viscosity = 8.30e-004 m2/s
Ratio of turb. and fluid kinematic visc. = 2.69e+003
Turbulence intensity = 1.76e-002
Specific turbulence kinetic energy = 1.41e-002 m2/s2
Eddy dissipation (epsilon) = 2.15e-002 m2/s3

Kolmogorov eddy size = 3.42e-005 m
Kolmogorov eddy velocity = 9.02e-003 m/s
Kolmogorov eddy time = 3.79e-003 s

Taylor eddy size = 1.42e-003 m
Taylor eddy velocity = 9.68e-002 m/s
Taylor eddy time = 1.47e-002 s

Integral eddy size = 7.00e-003 m
Integral eddy velocity = 1.19e-001 m/s
Integral eddy time = 5.90e-002 s

Eddy frequency (omega) = 1.69e+001 1/s
Kolmogorov eddy frequency = 2.64e+002 1/s
Taylor eddy frequency = 6.81e+001 1/s
Integral eddy frequency = 1.69e+001 1/s

Calculation of Eddy Scales for an SMR

Coolant	Integral Eddy Size (m)	Taylor Eddy Size (m)	Kolmogorov Eddy Size (m)
Helium	**7.00E-03**	**1.08E-02**	7.15E-04
Water	7.00E-03	1.26E-03	2.86E-05
LBE	7.00E-03	1.42E-03	3.42E-05

Notice, we rightfully expect:

$\ell_o > \lambda > \eta$

$\tau_{\ell_o} > \tau_\lambda > \tau_\eta$

$v_{\ell_o} > v_\lambda > v_\eta$

$Re_h > Re_{\ell_o} > Re_\lambda > Re_\eta$

So why is the He Taylor eddy scale larger than the integral scale?

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