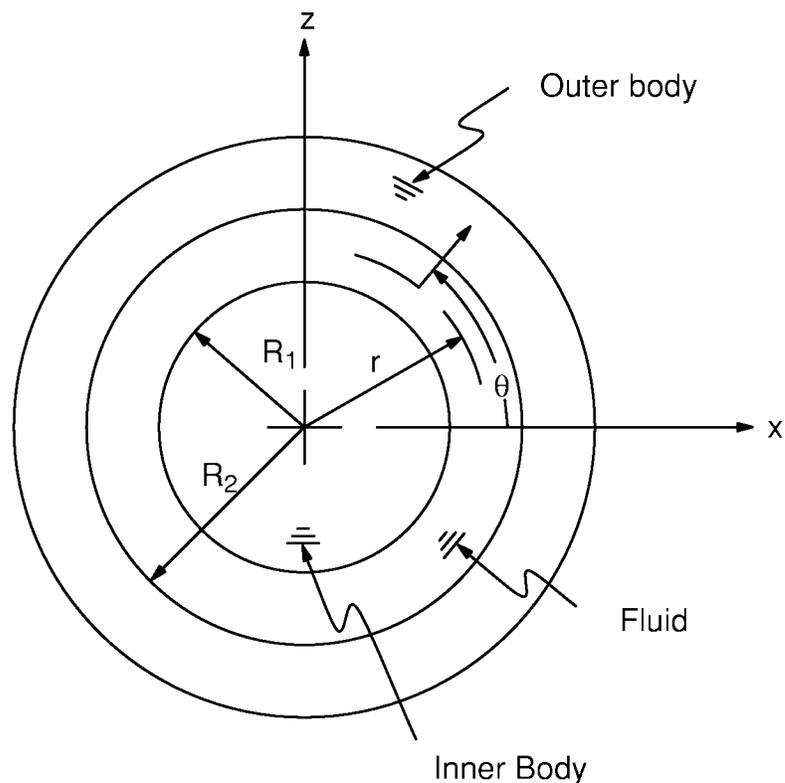


14.38 FLUID38 — Dynamic Fluid Coupling



Matrix or Vector	Shape Functions	Integration Points
Mass Matrix	$u = \left(\frac{C_1}{r^2} - C_2 \right) \cos\theta$ $w = \left(\frac{C_1}{r^2} + C_2 \right) \sin\theta$ (KEYOPT(3) = 0 only)	None
Damping Matrix	Not defined	None

Reference: Fritz(12)

14.38.1 Description

This element is used to represent a dynamic coupling between two points of a structure. The coupling is based on the dynamic response of two points connected by a constrained mass of fluid. The points represent the centerlines of concentric cylinders. The fluid is contained in the annular space between the cylinders. The cylinders may be circular or have an arbitrary cross-section. The element has two DOFs per node: translations in the nodal x and z directions. The axes of the cylinders are assumed to be in the nodal y directions. These orientations may be changed with KEYOPT(6).

14.38.2 Assumptions and Restrictions

1. The motions are assumed to be small with respect to the fluid channel thickness.
2. The fluid is assumed to be incompressible.
3. Fluid velocities should be less than 10% of the speed of sound in the fluid.
4. The flow channel length should be small compared to the wave length for propagating vibratory disturbances (less than about 10%), in order to avoid the possibility of standing wave effects.

14.38.3 Mass Matrix Formulation

The mass matrix formulation used in the element is of the following form:

$$[M_e] = \begin{bmatrix} m_{11} & 0 & m_{13} & 0 \\ 0 & m_{22} & 0 & m_{24} \\ m_{31} & 0 & m_{33} & 0 \\ 0 & m_{42} & 0 & m_{44} \end{bmatrix} \quad (14.38-1)$$

The m values are dependent upon the KEYOPT(3) value selected. For KEYOPT(3) = 0 (concentric cylinder case):

$$m_{11} = m_{22} = M (R_1^4 + R_1^2 R_2^2) \quad (14.38-2)$$

$$m_{13} = m_{31} = m_{24} = m_{42} = -M (2R_1^2 R_2^2) \quad (14.38-3)$$

$$m_{33} = m_{44} = M (R_1^2 R_2^2 + R_2^4) \quad (14.38-4)$$

where:

$$M = \frac{\pi L \rho}{R_2^2 - R_1^2} \text{ (Mass/Length}^4\text{)}$$

ρ = fluid mass density (input as DENS on **MP** command)

- R_1 = radius of inner cylinder (input quantity R1 on **R** command)
 R_2 = radius of outer cylinder (input quantity R2 on **R** command)
 L = length of cylinders (input quantity L on **R** command)

Note that the shape functions are similar to that for PLANE25 or FLUID81 with MODE = 1. The element mass used in the evaluation of the total structure mass is

$$\pi L \rho (R_2^2 - R_1^2).$$

For KEYOPT(3) = 2, which is a generalization of the above cylindrical values but for different geometries, the m values are as follows:

$$m_{11} = M_{hx} \quad (14.38-5)$$

$$m_{13} = m_{31} = - (M_1 + M_{hx}) \quad (14.38-6)$$

$$m_{33} = (M_1 + M_2 + M_{hx}) \quad (14.38-7)$$

$$m_{22} = M_{hz} \quad (14.38-8)$$

$$m_{24} = m_{42} = - (M_1 + M_{hz}) \quad (14.38-9)$$

$$m_{44} = M_1 + M_2 + M_{hz} \quad (14.38-10)$$

- where:
- M_1 = mass of fluid displaced by the inner boundary (Boundary 1) (input quantity M1 on **R** command)
 - M_2 = mass of fluid that could be contained within the outer boundary (Boundary 2) in absence of the inner boundary (input quantity M2 on **R** command)
 - M_{hx}, M_{hz} = hydrodynamic mass for motion in the x and z directions, respectively (input quantities MHX and MHZ on **R** command)

The element mass used in the evaluation of the total structure mass is $M_2 - M_1$.

The lumped mass option (**LUMPM,ON**) is not available.

14.38.4 Damping Matrix Formulation

The damping matrix formulation used in the element is of the following form:

$$[C_e] = \begin{bmatrix} c_{11} & 0 & c_{13} & 0 \\ 0 & c_{22} & 0 & c_{24} \\ c_{31} & 0 & c_{33} & 0 \\ 0 & c_{42} & 0 & c_{44} \end{bmatrix} \quad (14.38-11)$$

The c values are dependent upon the KEYOPT(3) value selected. For KEYOPT(3) = 0:

$$c_{11} = c_{33} = C\Delta x W_x \quad (14.38-12)$$

$$c_{13} = c_{31} = -C\Delta x W_x \quad (14.38-13)$$

$$c_{22} = c_{44} = C\Delta z W_z \quad (14.38-14)$$

$$c_{24} = c_{42} = -C\Delta z W_z \quad (14.38-15)$$

where: $C = \frac{f \rho L R_1^2 (R_1^2 + R_2^2)}{3(R_2 - R_1)^3}$ (Mass/Length)

W_x, W_z = estimate of resonant frequencies in the x and z response directions, respectively (input quantities WX, WZ on **RMORE** command)

f = Darcy friction factor for turbulent flow (input quantity F on **R** command)

$\Delta x, \Delta z$ = estimate of peak relative amplitudes between inner and outer boundaries for the x and z motions, respectively (input quantities DX, DZ on **R** command)

For KEYOPT(3) = 2, the c values are as follows:

$$c_{11} = c_{33} = C_x \Delta x W_x \quad (14.38-16)$$

$$c_{13} = c_{31} = -C_x \Delta x W_x \quad (14.38-17)$$

$$c_{22} = c_{44} = C_z \Delta z W_z \quad (14.38-18)$$

$$c_{24} = c_{42} = -C_z \Delta z W_z \quad (14.38-19)$$

where: C_x, C_z = flow and geometry constants for the x and z motions, respectively (input quantities CX, CZ on **RMORE** command)