

# ALE and Fluid-Structure Interaction in LS-DYNA

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## Workshop Models

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## 1. Taylor bar impact

`taylor.k` is a quarter model of a Taylor bar impacting a rigid wall. The Taylor bar is used in experiments to determine strain rate effects in metals. The input deck is set up for a Lagrangian analysis.

- Run the model as it is and examine the results. Write down required CPU time and the maximum effective plastic strain.
- Add necessary keyword cards to run the model with ALE smoothing and 1st order advection. CPU time and plastic strain?
- Switch to 2nd order advection and re-run the model. CPU time and plastic strain?
- Try to modify `*CONTROL_ALE` to make the model run faster. CPU time and plastic strain? How did you modify the input deck?

## 2. One-dimensional advection test

`advection.k` is a Lagrangian model of a bar that has been deformed plastically at one end. The input deck can be modified to simulate constant flux of material through a fixed Eulerian mesh. By transporting material through the mesh, one can study the how well the advection schemes preserve the shape of state variable fields (in this case plastic strain).

- Run the model as it is.
- Switch to an Eulerian formulation and 1st order advection and observe how the plastic strain field distorts as it travels through the bar.
- Switch to 2nd order advection and re-run the model. Compare the results to the previous run. Comments?

## 3. Channel

`channel.k` models a viscous fluid flowing through a pipe. The model is one element thick (plane strain).

- Run the model as it is. Plot the pressure time history for different elements. Make contour plots of the pressure. An analytical solution suggests a linear pressure drop along the pipe.

- Lower the inlet flow velocity by one and two orders of magnitude. Look at the pressure time history and distribution. What happens? Why?

#### 4. Underwater explosion

`underwater.k` is a plane strain model of a high explosive detonating in water. It is Lagrangian and it can be run with two different mesh densities (different include files).

- Run the model as it is, with the different mesh densities. Pick a few locations in time and space where you check the pressure in the model. Plot the energy balance stored in `glstat`.
- Add appropriate keyword cards and run the models in an Eulerian mode, with 1st order advection. Evaluate the pressure at the same time and locations as in the Lagrangian models and plot the energy balance.
- Switch to 2nd order advection and re-run the models.

Compare the results from the different simulations. Any comments? Looking at CPU time and at results, is it worth using 2nd order advection?

#### 5. Bar impacting water surface

`quadrature.k` models a bar impacting a water surface. The FSI card needs to be defined carefully to avoid leakage.

Add appropriate keyword cards to make it a single material and void or a multi-material model. For the coupling, try 1, 2 and 3 quadrature points. Look at the results and comment.

#### 6. Sloshing

`lag.k` and `ale.k` are Lagrangian and ALE sloshing models, respectively.

- Run `lag.k` as it is. Why does the fluid motion slow down?
- Modify the input to prevent the viscous behavior. What did you do? Re-run the model.
- Repeat the previous steps for `ale.k`. Eventually the motion still slows down? Why?

## 7. Bird strike

`bird.k` is a small, idealized, bird strike model. Add ALE and FSI keyword cards. Use element formulation 11 or 12. Try different ALE mesh motion techniques (`PRTYPE=3` and `PRTYPE=4`).

## 8. Initial volume fraction

`cylinder_impact.k` contains an Eulerian mesh and a rigid plate. Use the keyword `*INITIAL_VOLUME_FRACTION_GEOMETRY` to define a metal cylinder inside the mesh. Assign the cylinder an initial velocity and let it impact the rigid plate.

## 9. Energy compensation in FSI

`energy_comp.k` models an elastic thin-walled sphere that is filled with a pressurized gas. Hoop stresses in the sphere,  $\sigma$ , balance the internal and external gas pressures,  $p_i$  and  $p_e$ .

$$\sigma t = \frac{(p_i - p_e)D}{4}$$

$D$  is the sphere diameter and  $t$  is the wall thickness. Based on the amount and state of the injected gas, the expected sphere diameter at equilibrium should be  $D = 10.8 \text{ cm}$ .

- Run the model as it is. Notice the leakage.
- Try leakage control `ILEAK=1`. What happens?
- `ILEAK=2` compensates for energy added in the leakage control. Any difference?

## 10. Forging

`mat102_euler.k` and `mat102_lagrange.k` are Eulerian and Lagrangian models of a forging operation (plane strain). Compare the punch force running the two models. It is output in `bndout` for the Lagrangian model and it can be obtained in the Eulerian model by using the keyword `*DATABASE_FSI`.

## 11. Stagnation pressure

`stagnation.k` models a water jet impacting a rigid plate. The stagnation pressure,  $p$ , should be approximately

$$p = \frac{1}{2}\rho v^2$$

where  $\rho$  is the density of the water and  $v$  is the jet velocity. Use this relationship to define an appropriate user defined penalty stiffness for the fluid-structure interaction.

- Run the model with the user defined penalty stiffness. Check the penetrations. Plot the contact pressure stored in `dbfsi`.
- Add damping to the fluid-structure interaction. Does the damping influence the oscillations in the contact pressure?

## 12. Point source

`point_source.k` is a model of a 20l tank that is filled with an ideal gas. The initial gas density, temperature and the heat capacities are set to  $\rho_0 = 1 \text{ kg/m}^3$ ,  $T_0 = 300 \text{ K}$ ,  $c_v = 700 \text{ J/kgK}$  and  $c_p = 1000 \text{ J/kgK}$ , respectively.

The keyword command `*SECTION.POINT.SOURCE.MIXTURE` is used to shoot in more gas into the tank.

- Study the input deck and try to figure out the amount of energy,  $W$ , that is generated by the point source. (Hint:  $\dot{W} = \dot{m}c_pT$ , where  $\dot{m}$  is the mass flow rate and  $T$  is the stagnation temperature.)
- Based on the energy added, what should the final pressure be in the tank? You can use the relation  $p = (\gamma - 1)e$  that is valid for the simple gas model used in the example.  $\gamma = c_p/c_v$  and  $e$  is the specific internal energy of the gas.
- Run the model and verify that the final pressure is correct. You can view the distribution of the generated gas by applying a fringe of history variable #1 in LS-POST. The temperature is stored in history variable #9.