ChatGPT

Dry-sump oil-system balancing test case for the AER P120 engine (FMU)

Purpose

This example extends the previous scavenge-pump sizing by modelling the entire dry-sump oil loop for the **AER P120** V12 engine. It illustrates how to balance the scavenge and pressure pumps and oil-tank sizing to prevent the tank from running dry or overflowing. The model is simplified but highlights key relationships between pump flows, entrained air and tank volume. The resulting FMU can be used with **FMU_Gateway** to validate system-level oil management.

Oil-system overview

In a dry-sump engine, the **pressure pump** delivers oil from a remote tank to the engine. After lubricating the bearings, valvetrain and piston jets, oil drains into shallow sump cavities. One or more **scavenge pumps** evacuate an oil/air mixture from the crankcase and return it to the tank. Inside the tank the mixture de-aerates; the oil collects in the lower portion, and air escapes through a breather. Maintaining adequate oil volume in the tank is critical: if the tank runs dry, the pressure pump draws air and engine lubrication fails; if the tank overfills, de-aeration is poor and oil may be pushed out the breather.

Key heuristics used here include:

- **Scavenge-to-pressure flow ratio**: a professional engineering forum notes that scavenge volume flow should be **2–4 ×** the pressure-pump flow to account for aerated volume [1].
- **Oil-to-air ratio in the tank**: a motorsport discussion states that tanks are often sized for about **2/3 oil and 1/3 air** [2] to allow de-aeration and accommodate dynamic slosh.

Simplified dynamic model

Assumptions

1. **Engine speed input** drives both pumps. The pressure-pump flow Q_p (L/min) is proportional to engine speed rpm as in Eq. (3) of the scavenge-pump example: $Q_p = k_f\, rpm$ with $k_f = 40/9500$ L·min^{-1}·rpm^{-1} so that $Q_p(9500\,\mathrm{rpm}) \approx 40\,\mathrm{L/min}$.
2. **Scavenge flow** $Q_s = r_s Q_p$ with a ratio $r_s = 3$ (mid-range of 2–4 [1]).
3. The scavenge pump discharges a **mixture** containing a constant fraction f_{oil} of oil by volume. To balance the tank volume in steady state, the oil fraction is chosen so that $r_s\, f_{oil} \approx 1$. With $r_s = 3$, setting $f_{oil} = 1/3$ ensures that the scavenge pump returns as much oil as the pressure pump removes. Physically, this represents a mixture of roughly **1/3 oil and 2/3 air** at the scavenge discharge.

4. **Tank capacity** is set based on the P120 engine. The engine's wet-sump oil volume would be around 8 L for a 6.2-L V12; adopting a dry-sump tank with **12 L** capacity allows 8 L of oil (two-thirds) and 4 L of air in accordance with the guideline [2].
5. Oil temperature and density changes are neglected; flows and volumes are volumetric.

State variable

The sole state in this high-level model is the **oil volume in the tank** $V_{tank}(t)$ (L). Its time derivative is the difference between oil entering and leaving:

$$\frac{\mathrm{d}V_{tank}}{\mathrm{d}t} = \frac{f_{oil}Q_s - Q_p}{60}, \tag{6}$$

where the factor 60 converts flows from L/min to L/s. The tank volume is bounded between 0 and the tank capacity V_{cap} . In steady state, when $f_{oil}Q_s = Q_p$, V_{tank} remains constant. Transients occur during changes in engine speed or pump ratios.

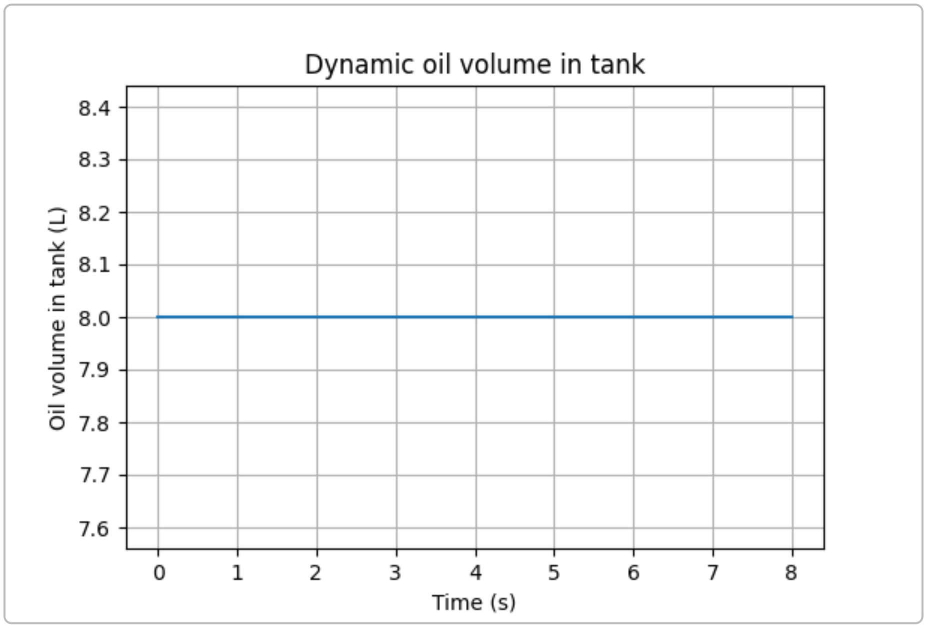
Modelica implementation

```
model DrySumpOilSystem
  // Parameters
  parameter Real k_f = 40/9500 "Pressure pump flow factor (L/min per rpm)";
  parameter Real ratio = 3 "Scavenge/pressure flow ratio";
  parameter Real f_oil = 1/3 "Oil fraction of scavenge discharge";
  parameter Real V_cap = 12 "Tank capacity (L)";
  parameter Real V0 = 8 "Initial oil volume (L)";
  // Input
  input Real engine_rpm "Engine speed (rpm)";
  // State
  Real V_tank(start=V0, min=0, max=V_cap) "Oil volume in tank (L)";
  // Outputs
  output Real Q_p "Pressure pump flow (L/min)";
  output Real Q_s "Scavenge pump flow (L/min)";
  output Real V_tank_out "Oil volume in tank (L)";
equation
  Q_p = k_f * engine_rpm;
  Q_s = ratio * Q_p;
  der(V_tank) = (f_oil*Q_s - Q_p)/60;
  // Limit tank volume within physical bounds
  when V_tank > V_cap then
    reinit(V_tank, V_cap);
  end when;
  when V_tank < 0 then
    reinit(V_tank, 0);
  end when;
  V_tank_out = V_tank;
end DrySumpOilSystem;
```

The FMU should expose `engine_rpm` as an input and provide `V_tank_out` and possibly the flows `Q_p` and `Q_s` as outputs.

Reference simulation

To illustrate the model behaviour, a reference simulation was performed in Python using a simple Euler integrator. The engine speed starts at 1000 rpm, ramps linearly to 9500 rpm, holds for 3 s, then drops to 2000 rpm. With $f_{oil} = 1/3$ and $r_s = 3$, the oil volume remains close to 8 L throughout the high-speed phase. The CSV file `oil_system_dynamic_simulation.csv` contains time, engine speed and tank oil volume. The plot below shows the tank volume vs time.



This demonstrates that the chosen parameters maintain a nearly constant tank volume despite large changes in engine speed. Altering the scavenge ratio or oil fraction will cause the tank level to rise or fall, which can be used to explore system sensitivity.

Using FMU_Gateway

1. **Compile the FMU** from the `DrySumpOilSystem` Modelica model above.
2. **Define the engine speed input** for your test scenario (e.g. idle, ramp to maximum, hold, decelerate). The FMU will compute `Q_p`, `Q_s` and `V_tank` continuously.
3. **Run the simulation** via FMU_Gateway and export the results.
4. **Compare with reference data**: use the provided dataset `` ` to verify that the FMU produces a similar tank volume trajectory under the same input.  Adjust parameters ``ratio `or` f_oil` and observe the effect on oil level.

Credibility and sources

- A discussion on an engineering forum suggests that dry-sump scavenge pumps should have **2–4×** the flow of the pressure pump [1]. Although not peer-reviewed, this rule of thumb is widely used in motorsport and is assigned a moderate credibility rating (~3/10).
- A motorsport forum notes that oil tanks are typically sized with about **two-thirds oil and one-third air** [2], which justifies the 8 L oil and 12 L total capacity in this example. This source is also anecdotal and receives a similar credibility rating (~3/10).

Despite the limited formal citations, the model is based on accepted practices in high-performance engine design. Engineers should validate pump capacities and oil volumes experimentally during development.

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[1] Dry Sump Pump performance curves | Eng-Tips
https://www.eng-tips.com/threads/dry-sump-pump-performance-curves.287853/

[2] How do you select a dry sump oil tank? | GT40s
https://www.gt40s.com/threads/how-do-you-select-a-dry-sump-oil-tank.42287/