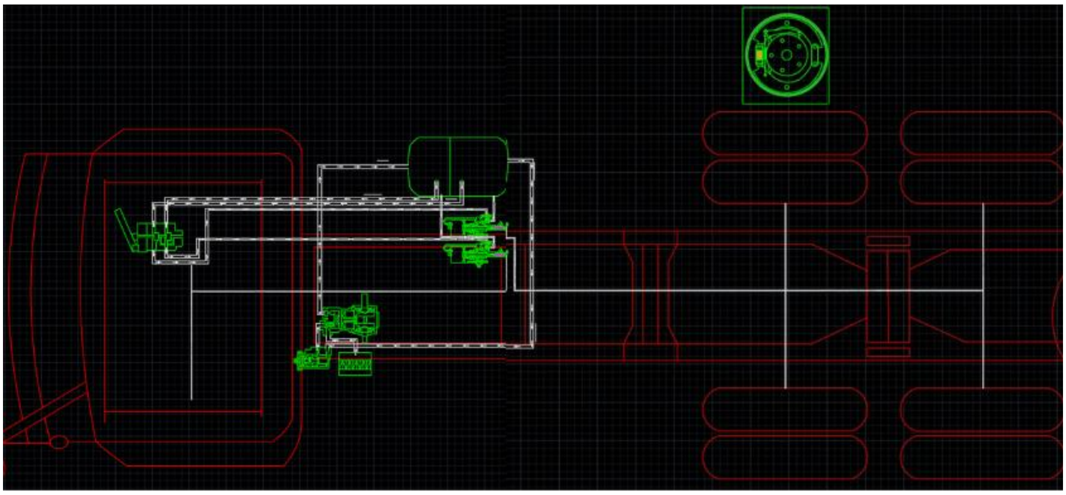
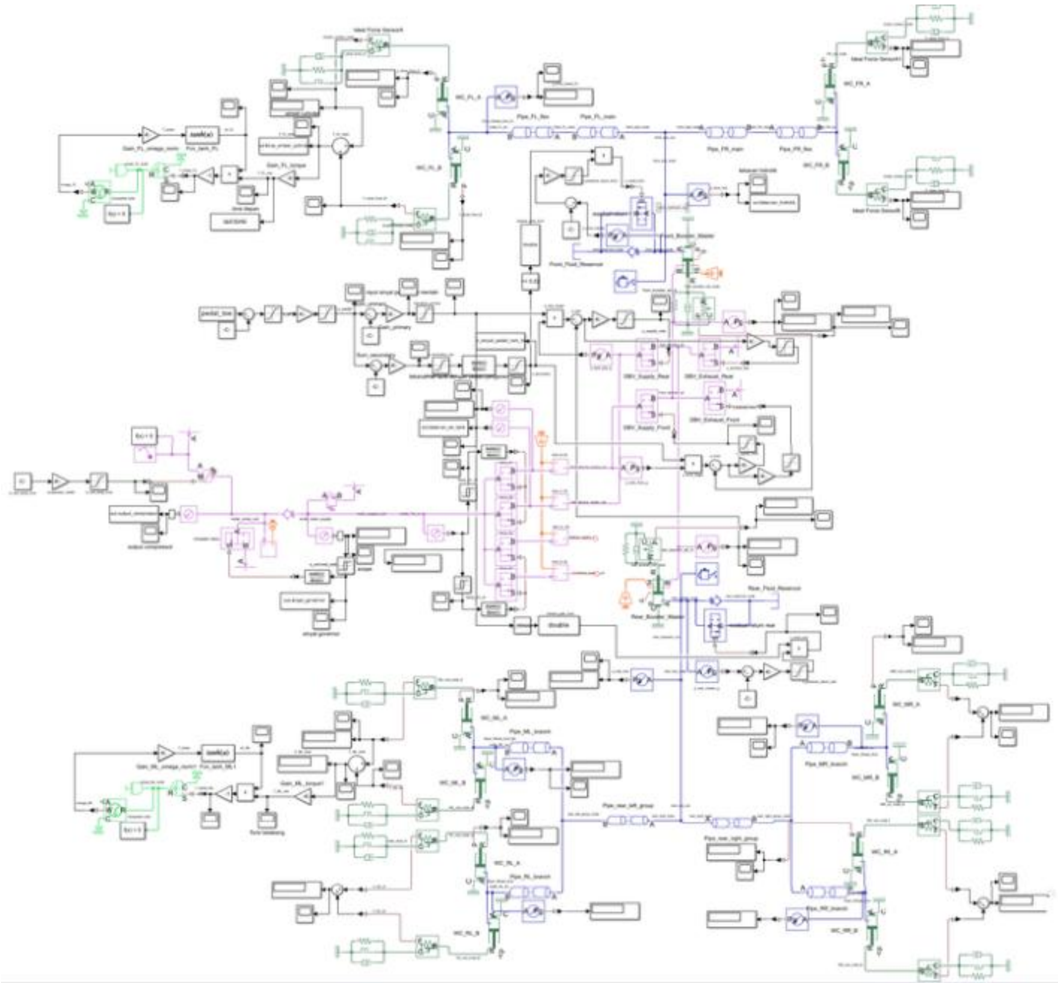
LAMPIRAN – LAMPIRAN

Lampiran 1. Pengukuran Komponen Dan Observasi Lapangan

Lampiran 2. Gambar Sistem Rem *AOH* Di Autocad



Lampiran 3. Pemodelan Sistem Rem *AOH* Di Matlab



Lampiran 4. Script Pemodelan Sistem Rem *AOH* Di Matlab

```
%%
%% aoh_fn517_final_init.m
% High-fidelity final-v1 parameter script
% Mitsubishi Fuso FN517 ML2 (6x2) MT
% Air-over-hydraulic service brake system
% Normal condition only, no fault injection
%
% Recommended workflow:
% 1) Run this script.
% 2) Build a new Simscape model using the guide file:
%       AOH_FN517_ML2_Final_Guide.md
% 3) Use the variable names below directly in block dialogs.
% 4) Validate subsystem-by-subsystem before enabling full vehicle dynamics.
%
% IMPORTANT:
% - This is a final-v1 engineering model, not a 100%% OEM digital twin.
% - Parameters are split into:
%     * verified public-seed data
%     * engineering assumptions
%     * tuning parameters
% - Keep baseline and final models as separate .slx files.

%% ----------------------------------------------------------------------
%% 0) Feature flags and model metadata
%% ----------------------------------------------------------------------
model_name = 'aoh_fn517_ml2_final_v1';

use_dryer_unloader_subsystem = true;
use_abs_normal_wrapper       = true;
use_vehicle_longitudinal     = true;
use_vdb_three_axle_body      = false;   % set true if Vehicle Dynamics Blockset is
available
use_residual_return_valve    = true;
```

```
use_pipe_inertia_initially   = false;   % keep false for first stable build

final_v1_notes = {
    'Public-seed data used where available';
    'Unknown OEM internals are represented using smooth engineering equivalents';
    'Rear tandem hydraulic routing is modeled as left/right groups split to middle and rear axle wheel-ends';
    'ABS wrapper is included in normal mode only (no modulation yet)'
    };

%% -------------------------------------------------------------------
%% 1) Global environment
%% -------------------------------------------------------------------
patm_Pa  = 101325;
patm_MPa = patm_Pa/1e6;
T_amb_K  = 293.15;

g_m_s2   = 9.81;
rho_air_kg_m3 = 1.20;

%% -------------------------------------------------------------------
%% 2) Vehicle data (public seed + engineering assumptions)
%% -------------------------------------------------------------------
% Public seed data
vehicle_name = 'Mitsubishi Fuso FN517 ML2';
drive_layout = '6x2';
m_chassis_kg = 5395;
m_gvw_kg     = 21000;
wheelbase_total_m = 5.450;
track_front_m = 1.885;
track_rear_m  = 1.815;
v_max_kph     = 96;
final_drive_ratio = 6.666;
```

```
tire_size_nom = '10.00-20-16PR';

% Engineering assumptions for 3-axle body geometry
x_axle_front_m  = 0.0;
x_axle_middle_m = 4.25;
x_axle_rear_m   = 5.45;

% Engineering assumptions for static load guesses (replace if scale data is available)
m_axle_empty_guess_kg = [2300; 1700; 1395];
m_axle_gvw_guess_kg   = [5200; 7900; 7900];

% Engineering assumptions for CG fitting
x_cg_empty_from_front_m = 2.20;
x_cg_gvw_from_front_m   = 3.10;
h_cg_empty_m = 1.05;
h_cg_gvw_m   = 1.30;

% Wheel / tire assumptions for longitudinal model
r_tire_loaded_m = 0.49;        % assumed for 10.00-20 tire under load
J_wheel_front_kg_m2 = 18;      % assumed
J_wheel_rear_kg_m2  = 24;      % assumed
mu_road_nom = 0.75;            % dry asphalt nominal assumption
Crr = 0.012;
CdA_m2 = 6.5;                  % assumed drag area
road_grade_deg = 0.0;

%% ---------------------------------------------------------------------
%% 3) Engine / compressor drive
%% ---------------------------------------------------------------------
% Public/manual seed for compressor on AOH truck family
comp_type = 'Water-cooled single cylinder';
d_comp_bore_m = 85e-3;
s_comp_m      = 60e-3;
```

```
Vdisp_comp_m3_per_rev  = pi/4*d_comp_bore_m^2*s_comp_m;
Vdisp_comp_cm3_per_rev = Vdisp_comp_m3_per_rev*1e6;   % ~340 cm^3/rev

% Drive assumptions
i_comp_to_engine = 1.00;       % assumed pulley / gear ratio
eta_vol_comp_nom = 0.88;       % tuning seed
eta_mech_comp    = 0.90;       % tuning seed
n_poly_comp      = 1.25;       % tuning seed
A_comp_in_m2     = pi/4*(16e-3)^2;
A_comp_out_m2    = pi/4*(14e-3)^2;

% Compressor input profile (driver / engine operation)
engine_idle_rpm = 800;
engine_cruise_rpm = 1400;

engine_speed_t_s = [0; 0.1; 12];
engine_speed_rpm_u = [engine_idle_rpm; engine_idle_rpm; engine_idle_rpm];
engine_speed_rpm = timeseries(engine_speed_rpm_u, engine_speed_t_s);

%% ----------------------------------------------------------------------
%% 4) Air dryer, governor, safety valve, main check valve
%% ----------------------------------------------------------------------
% Verified public seed data
V_dryer_purge_m3 = 1.6e-3;     % 1.6 L purge chamber
t_dryer_recycle_s = 50;        % required purge / recycle time
p_gov_hi_Pa = 890e3;
p_gov_lo_Pa = 760e3;
p_safety_Pa = 950e3;

% Main check valve after compressor
p_check_main_crack_Pa = 5e3;
p_check_main_full_Pa  = 20e3;
A_check_main_max_m2   = pi/4*(10e-3)^2;
Cd_check_main         = 0.72;
```

```
% Unloader / purge engineering representation
A_unloader_max_m2 = pi/4*(10e-3)^2;
A_purge_max_m2    = pi/4*(8e-3)^2;
Cd_unloader = 0.72;
Cd_purge    = 0.72;
gas_valve_leakage_fraction = 1e-4;
gas_valve_smoothing = 0.02;

% Safety valve area seed
A_safety_max_m2 = pi/4*(8e-3)^2;
Cd_safety       = 0.70;

%% ---------------------------------------------------------------------
%% 5) Reservoir pack and 4-way protection logic
%% ---------------------------------------------------------------------
% Verified public seed data
V_tank_A_m3 = 14e-3;
V_tank_B_m3 = 8e-3;
V_tank_C_m3 = 9e-3;
V_tank_D_m3 = 8e-3;

% Suggested mapping for final-v1
tank_A_role = 'reserve_aux_1';
tank_B_role = 'front_service_supply';
tank_C_role = 'rear_service_supply';
tank_D_role = 'reserve_aux_2';

A_tank_port_m2 = pi/4*(12e-3)^2;
p_tank_init_abs_Pa = patm_Pa + 780e3;    % initialize near mid-governor band
p_tank_init_abs_MPa = p_tank_init_abs_Pa/1e6;

% 4-way protection valve threshold seeds (engineering representation)
```

```
% Based on common spring-type multi-protection behavior and published service
ranges.
p_4w_open_21_22_Pa  = 590e3;
p_4w_close_21_22_Pa = 460e3;
p_4w_open_23_24_Pa  = 640e3;
p_4w_close_23_24_Pa = 520e3;

A_4w_max_m2 = pi/4*(8e-3)^2;
Cd_4w       = 0.72;
A_4w_leak_m2 = 1e-10;

%% ----------------------------------------------------------------------
%% 6) Brake pedal and dual brake valve (tandem treadle representation)
%% ----------------------------------------------------------------------
% Public seed data
pedal_freeplay_angle_deg = 3.5;
pedal_freeplay_toe_m     = 12e-3;

% Driver command representation
pedal_toe_eff_full_m = 45e-3;     % assumed effective toe displacement after free
play
pedal_lag_s          = 0.02;      % small smoothing lag
pedal_apply_rise_s   = 0.12;
pedal_release_fall_s = 0.15;

% Example brake event profile for first runs
pedal_toe_t_s = [0; 0.8; 1.0; 3.0; 3.2; 6.0; 6.15; 8.0; 8.2; 11.0];
pedal_toe_u_m = [0; 0; 38e-3; 38e-3; 0; 0; 22e-3; 22e-3; 0; 0];
pedal_toe = timeseries(pedal_toe_u_m, pedal_toe_t_s);

% Dual brake valve seeds
dbv_primary_deadband   = 0.06;
dbv_secondary_deadband = 0.08;
```

```
dbv_secondary_relay_gain = 0.25;   % front side assistance due to rear delivery pressure
p_rear_delivery_norm_ref_Pa = 800e3;
tau_dbv_secondary = 0.05;
tau_dbv_reg = 0.03;
tau_dbv_feedback = 0.05;

% Pressure regulation band

A_dbv_secondary_supply_max_m2 = 1e-4;
A_dbv_secondary_exhaust_max_m2= 2e-4;
A_dbv_secondary_port_m2 = 5e-4;   % harus lebih besar dari orifice area

Cd_dbv_secondary = 0.7;

dbv_leakage_fraction = 1e-4;
dbv_smoothing        = 0.02;
dbv_xT_choked         = 0.7;         % seed for gas directional valve if using sonic conductance / choked tuning
Cd_dbv               = 0.72;

% Spool offset seeds for overlapped near-closed behavior
dbv_primary_offset_PA  = -0.03;
dbv_primary_offset_AT  = -0.03;
dbv_secondary_offset_PA= -0.03;
dbv_secondary_offset_AT= -0.03;

% DBV Primary Rear - pressure regulating equivalent
A_dbv_primary_supply_max_m2  = 1e-4;
A_dbv_primary_exhaust_max_m2 = 2e-4;
p_dbv_band_Pa = 80e3;

A_dbv_primary_port_m2 = 5e-4;
```

```
Cd_dbv_primary = 0.7;

%% ----------------------------------------------------------------------
%% 7) Brake boosters (front and rear)
%% ----------------------------------------------------------------------
% Verified public seed data
d_boost_air_m      = 114.3e-3;
stroke_boost_air_m = 98e-3;
d_boost_hyd_m      = 22.2e-3;
stroke_boost_hyd_m = 95e-3;

A_boost_air_m2 = pi/4*d_boost_air_m^2;
A_boost_hyd_m2 = pi/4*d_boost_hyd_m^2;
ratio_boost_air_to_hyd = A_boost_air_m2 / A_boost_hyd_m2;

p_boost_start_Pa = 0.018e6;
p_residual_front_target_Pa = 30e3;
p_residual_rear_target_Pa  = 30e3;
p_residual_valve_band_Pa   = 50e3;
s_release_th = 0.02;

stroke_boost_common_m = min(stroke_boost_air_m, stroke_boost_hyd_m);

% Engineering seeds for dead volumes and ports
V_boost_air_dead_m3 = 120e-6;
V_boost_hyd_dead_m3 = 4e-6;
A_boost_air_port_m2 = pi/4*(10e-3)^2;
A_boost_hyd_port_m2 = pi/4*(4e-3)^2;

% Initial conditions
x_boost_front_init_m = 0.095;
x_boost_rear_init_m  = 0.095;
p_boost_air_init_abs_Pa = patm_Pa;
p_boost_hyd_init_abs_Pa = patm_Pa;
```

```
% Mechanical return and stop seeds
k_boost_return_front_N_m = 6.0e4;
k_boost_return_rear_N_m  = 6.0e4;
c_boost_front_Ns_m = 900;
c_boost_rear_Ns_m  = 900;

x_boost_stop_lower_m = 0;
x_boost_stop_upper_m = stroke_boost_common_m;

k_boost_stop_N_m = 2.0e7;
c_boost_stop_Ns_m = 2.0e3;
x_boost_stop_transition_m = 0.3e-3;

% Make-up and residual-return path seeds
A_makeup_rear_max_m2  = pi/4*(1.2e-3)^2;
A_resid_return_front_max_m2 = pi/4*(1.0e-3)^2;
A_resid_return_rear_max_m2  = pi/4*(1.0e-3)^2;

p_makeup_front_crack_Pa = 2e3;          % 2 kPa
p_makeup_front_full_Pa  = 10e3;         % 10 kPa
A_makeup_front_max_m2   = pi/4*(1.5e-3)^2;
A_makeup_front_leak_m2  = 1e-10;
A_makeup_front_port_m2  = pi/4*(2.0e-3)^2;
Cd_makeup_front         = 0.64;

x_resid_front_spool_max_m    = 1e-3;                % 1 mm
x_resid_front_spool_travel_m = 1e-3;                % 1 mm
A_resid_front_max_m2         = pi/4*(1.5e-3)^2;
A_resid_front_leak_m2        = 1e-10;
Cd_resid_front               = 0.64;
A_resid_front_port_m2        = pi/4*(2.0e-3)^2;

x_resid_rear_spool_max_m = 1e-3;
```

```
p_makeup_check_crack_Pa = 5e3;
p_makeup_check_full_Pa  = 20e3;
A_makeup_rear_port_m2   = pi/4*(2.0e-3)^2;
Cd_makeup_il = 0.70;
Cd_resid_il  = 0.70;

%% ----------------------------------------------------------------------
%% 8) Brake fluid and hydraulic reservoirs
%% ----------------------------------------------------------------------
% Public seed data: DOT3 brake fluid family
brake_fluid_spec = 'SAE J1703 / FMVSS No.116 DOT3';

% Engineering simple-property seeds for IL domain
rho_brake_kg_m3 = 1060;
nu_brake_m2_s   = 14e-6;
bulk_brake_Pa   = 1.7e9;
bulk_brake_GPa  = bulk_brake_Pa/1e9;

% Optional entrained-air tuning seed (if IL block setting supports it)
entrained_air_frac = 1e-4;

V_fluid_res_front_m3 = 0.5e-3;   % assumed front fluid reservoir share
V_fluid_res_rear_m3  = 0.5e-3;   % assumed rear fluid reservoir share

%% ----------------------------------------------------------------------
%% 9) Hydraulic pipes and line topology
%% ----------------------------------------------------------------------
% Pipe roughness
eps_pipe_m = 15e-6;

% Front circuit assumptions
L_pipe_front_main_m = 3.2;
L_pipe_fl_flex_m    = 0.6;
L_pipe_fr_flex_m    = 0.6;
```

```
D_pipe_front_rigid_m= 4.0e-3;
D_pipe_front_flex_m = 3.0e-3;
Leq_front_local_m   = 0.8;

% Rear circuit assumptions
L_pipe_rear_left_group_m  = 4.8;
L_pipe_rear_right_group_m = 4.8;
L_pipe_ml_branch_m = 0.9;
L_pipe_mr_branch_m = 0.9;
L_pipe_rl_branch_m = 1.6;
L_pipe_rr_branch_m = 1.6;
D_pipe_rear_rigid_m = 4.0e-3;
D_pipe_rear_flex_m  = 3.0e-3;
Leq_rear_local_m    = 1.2;

% Initial hydraulic pressures in pipes
p_front_line_init_abs_Pa = patm_Pa;
p_rear_line_init_abs_Pa  = patm_Pa;

%% ---------------------------------------------------------------------
%% 10) ABS normal-mode wrapper (pass-through)
%% ---------------------------------------------------------------------
u_abs_inlet_norm  = 1;
u_abs_outlet_norm = 0;

A_abs_inlet_max_m2  = pi/4*(2.0e-3)^2;
A_abs_outlet_max_m2 = pi/4*(1.5e-3)^2;
abs_leakage_fraction = 1e-4;
abs_smoothing = 0.02;
Cd_abs = 0.70;

V_abs_low_pressure_chamber_m3 = 5e-6;   % optional placeholder if used

%% ---------------------------------------------------------------------
```

```
%% 11) Wheel-end hydraulic actuators and shoe mechanics
%% ----------------------------------------------------------------------
% Verified public seed data
d_wc_front_m = 36.51e-3;
d_wc_rear_m  = 38.10e-3;
D_drum_front_m = 0.320;
D_drum_rear_m  = 0.320;
w_lining_front_m = 0.120;
w_lining_rear_m  = 0.140;
t_lining_m = 0.012;

% Shoe-level representation
% Front 2-leading: 2 single-acting shoe actuators per wheel-end
% Rear dual 2-leading: 2 single-acting shoe actuators per wheel-end
n_front_shoe_act_per_wheel = 2;
n_rear_shoe_act_per_wheel  = 2;

A_wc_front_shoe_m2 = pi/4*d_wc_front_m^2;
A_wc_rear_shoe_m2  = pi/4*d_wc_rear_m^2;

% Total hydraulic areas implied by this shoe-level representation
A_front_total_axle_m2 = 2 * n_front_shoe_act_per_wheel * A_wc_front_shoe_m2;  % FL + FR
A_rear_total_tandem_m2= 4 * n_rear_shoe_act_per_wheel * A_wc_rear_shoe_m2;   % ML/MR/RL/RR

% Travel / dead volume seeds
stroke_wc_front_shoe_m    = 1.2e-3;
stroke_wc_rear_shoe_m     = 1.4e-3;
V_wc_front_shoe_dead_m3   = 0.6e-6;
V_wc_rear_shoe_dead_m3    = 0.8e-6;
x_wc_rear_init_m          = 0;
p_wc_rear_init_abs_Pa     = patm_Pa;
```

```
% Nominal adjusted clearances / take-up assumptions
x_takeup_front_nom_m = 0.20e-3;

% Contact / shoe-seat stiffness for hard stop based take-up
k_contact_front_N_m = 2.0e8;
c_contact_front_Ns_m = 2.0e3;
x_contact_transition_front_m = 0.05e-3;

k_contact_rear_N_m = 2.5e8;
c_contact_rear_Ns_m = 2.5e3;
x_contact_transition_rear_m = 0.05e-3;

% Shoe compliance after contact
k_front_shoe_N_m = 1.0e7;
c_front_shoe_Ns_m = 500;
k_rear_shoe_N_m  = 1.0e7;
c_rear_shoe_Ns_m = 400;

%% ---------------------------------------------------------------------
%% 12) Brake torque model
%% ---------------------------------------------------------------------
% Engineering effective friction radii
R_drum_front_m = D_drum_front_m/2;
R_drum_rear_m  = D_drum_rear_m/2;
R_eff_drum_front_m = 0.160;
R_eff_drum_rear_m  = 0.180;

% Lining friction and servo factors
mu_lining_nom = 0.35;
K_servo_front = 1.85;   % tune using deceleration and balance
K_servo_rear  = 2.10;   % rear dual 2-leading generally stronger
omega_tanh_eps_rad_s = 0.5;

% Optional fade placeholders (inactive in normal final-v1)
```

```
use_brake_fade = false;
mu_fade_slope_per_K = 0.0;
T_brake_ref_K = T_amb_K;

%% ----------------------------------------------------------------------
%% 13) Vehicle longitudinal model tuning seeds
%% ----------------------------------------------------------------------
% If using a custom longitudinal body
vehicle_test_mode = 'GVW';   % 'empty' or 'GVW'

switch lower(vehicle_test_mode)
    case 'empty'
        m_vehicle_sim_kg = m_chassis_kg;
        x_cg_from_front_m = x_cg_empty_from_front_m;
        h_cg_m = h_cg_empty_m;
        m_axle_guess_kg = m_axle_empty_guess_kg;
    otherwise
        m_vehicle_sim_kg = m_gvw_kg;
        x_cg_from_front_m = x_cg_gvw_from_front_m;
        h_cg_m = h_cg_gvw_m;
        m_axle_guess_kg = m_axle_gvw_guess_kg;
end

% Simple aerodynamic / rolling resistance seeds
rho_air_env_kg_m3 = rho_air_kg_m3;

%% ----------------------------------------------------------------------
%% 14) Simulation input scenarios
%% ----------------------------------------------------------------------
sim_t_stop_s = 12.0;

% Normal straight-line braking scenarios
scenario_list = {
    'air_charge_idle_no_brake';
```

```
    'single_apply_38mm_toe';
    'second_apply_22mm_toe';
    'gvw_straight_line_brake'
    };

% Derived normalized pedal helper
% Use in Simulink:
%   x_eff   = max(0, pedal_toe - pedal_freeplay_toe_m)
%   u_pedal = min(max(x_eff/pedal_toe_eff_full_m,0),1)

%% ---------------------------------------------------------------------
%% 15) Suggested Simscape nominal values
%% ---------------------------------------------------------------------
simscape_nominal_pressure_air_Pa   = 1.0e6;
simscape_nominal_pressure_hyd_Pa   = 1.0e7;
simscape_nominal_displacement_m    = 1.0e-3;
simscape_nominal_velocity_m_s      = 1.0e-2;
simscape_nominal_torque_Nm         = 5.0e3;
simscape_nominal_force_N           = 1.0e4;

%% ---------------------------------------------------------------------
%% 16) Derived checks and summary
%% ---------------------------------------------------------------------
p_boost_theoretical_full_air_Pa = ratio_boost_air_to_hyd * 930e3;
p_boost_theoretical_full_air_MPa = p_boost_theoretical_full_air_Pa/1e6;

V_front_per_shoe_per_mm_mL = A_wc_front_shoe_m2 * 1e-3 * 1e6;
V_rear_per_shoe_per_mm_mL  = A_wc_rear_shoe_m2  * 1e-3 * 1e6;

V_front_per_wheel_per_mm_mL = n_front_shoe_act_per_wheel *
V_front_per_shoe_per_mm_mL;
V_rear_per_wheel_per_mm_mL = n_rear_shoe_act_per_wheel *
V_rear_per_shoe_per_mm_mL;
```

```
V_front_total_axle_per_mm_mL = A_front_total_axle_m2 * 1e-3 * 1e6;
V_rear_total_tandem_per_mm_mL = A_rear_total_tandem_m2 * 1e-3 * 1e6;

fprintf('\n=============================================
====================\n');
fprintf(' FN517 ML2 AOH FINAL-V1 PARAMETER SUMMARY\n');
fprintf('==============================================
==================\n');
fprintf('Vehicle                : %s (%s)\n', vehicle_name, drive_layout);
fprintf('Model stop time        : %.1f s\n', sim_t_stop_s);
fprintf('Vehicle mass mode           : %s (%.0f kg)\n', vehicle_test_mode,
m_vehicle_sim_kg);
fprintf('Wheelbase total        : %.3f m\n', wheelbase_total_m);
fprintf('Track (front / rear)   : %.3f / %.3f m\n', track_front_m, track_rear_m);
fprintf('\n');
fprintf('Compressor displacement: %.1f cm^3/rev\n', Vdisp_comp_cm3_per_rev);
fprintf('Governor hi / lo            : %.0f / %.0f kPa\n', p_gov_hi_Pa/1e3,
p_gov_lo_Pa/1e3);
fprintf('Safety valve           : %.0f kPa\n', p_safety_Pa/1e3);
fprintf('Tank pack total                          : %.1f L\n',
(V_tank_A_m3+V_tank_B_m3+V_tank_C_m3+V_tank_D_m3)*1e3);
fprintf('Tank pack split        : %.0f + %.0f + %.0f + %.0f L\n', V_tank_A_m3*1e3,
V_tank_B_m3*1e3, V_tank_C_m3*1e3, V_tank_D_m3*1e3);
fprintf('\n');
fprintf('Booster air area       : %.6f m^2\n', A_boost_air_m2);
fprintf('Booster hyd area       : %.6f m^2\n', A_boost_hyd_m2);
fprintf('Booster area ratio     : %.2f : 1\n', ratio_boost_air_to_hyd);
fprintf('Theoretical P_hyd @930kPa air: %.2f MPa\n',
p_boost_theoretical_full_air_MPa);
fprintf('\n');
fprintf('Front WC dia           : %.2f mm\n', d_wc_front_m*1e3);
fprintf('Rear WC dia            : %.2f mm\n', d_wc_rear_m*1e3);
fprintf('Front shoe area        : %.6f m^2\n', A_wc_front_shoe_m2);
fprintf('Rear shoe area         : %.6f m^2\n', A_wc_rear_shoe_m2);
```

```
fprintf('Front wheel volume/mm  : %.2f mL\n', V_front_per_wheel_per_mm_mL);
fprintf('Rear wheel volume/mm   : %.2f mL\n', V_rear_per_wheel_per_mm_mL);
fprintf('Front axle volume/mm   : %.2f mL\n', V_front_total_axle_per_mm_mL);
fprintf('Rear tandem volume/mm : %.2f mL\n',
V_rear_total_tandem_per_mm_mL);
fprintf('\n');
fprintf('Drum diam front/rear   : %.0f / %.0f mm\n', D_drum_front_m*1e3,
D_drum_rear_m*1e3);
fprintf('Effective radius f/r   : %.3f / %.3f m\n', R_eff_drum_front_m,
R_eff_drum_rear_m);
fprintf('mu lining nominal      : %.2f\n', mu_lining_nom);
fprintf('Servo gain front/rear  : %.2f / %.2f\n', K_servo_front, K_servo_rear);
fprintf('=================================================
==================\n\n');

%% ----------------------------------------------------------------------
%% 17) Front wheel-end actuators (FL / FR)
%% ----------------------------------------------------------------------
% Public seed: front wheel cylinder bore
d_wc_front_single_m = 36.51e-3;

% Hydraulic actuator seeds per wheel-end
A_wc_front_single_m2      = pi/4*(d_wc_front_single_m)^2;
stroke_wc_front_single_m  = 1.2e-3;
V_wc_front_single_dead_m3 = 0.8e-6;
x_wc_front_init_m         = 0;
p_wc_front_init_abs_Pa    = patm_Pa;

% Mechanical compliance per wheel-end
k_wc_front_N_m  = 1.0e7;
c_wc_front_Ns_m = 600;

% Hard stop seeds
x_wc_front_stop_lower_m      = 0;
```

```
x_wc_front_stop_upper_m      = stroke_wc_front_single_m;
k_wc_front_stop_N_m          = 2.0e7;
c_wc_front_stop_Ns_m         = 2.0e3;
x_wc_front_stop_transition_m = 0.2e-3;

%% ----------------------------------------------------------------------
%% 18) Rear wheel-end actuators (ML / MR / RL / RR)
%% ----------------------------------------------------------------------
% Public seed: rear wheel cylinder bore
d_wc_rear_single_m = 38.10e-3;

% Hydraulic actuator seeds per wheel-end
A_wc_rear_single_m2      = pi/4*(d_wc_rear_single_m)^2;
stroke_wc_rear_single_m  = 1.4e-3;
V_wc_rear_single_dead_m3 = 0.8e-6;

% Nominal adjusted clearance / take-up assumption
x_takeup_rear_nom_m = 0.20e-3;

% Mechanical compliance per wheel-end
k_wc_rear_N_m  = 1.0e7;
c_wc_rear_Ns_m = 400;

% Hard stop seeds
x_wc_rear_stop_lower_m      = 0;
x_wc_rear_stop_upper_m      = stroke_wc_rear_single_m;
k_wc_rear_stop_N_m          = 2.5e8;
c_wc_rear_stop_Ns_m         = 2.5e3;
x_wc_rear_stop_transition_m = 0.05e-3;

%% ----------------------------------------------------------------------
%% Compressor equivalent using Controlled Mass Flow Rate Source (G)
%% ----------------------------------------------------------------------
% Normal compressor mass flow
```

```
m_dot_comp_normal_kg_s = 0.004;      % kg/s, nilai awal tuning

% Compressor health factor
compressor_health_normal = 1.0;      % normal
compressor_health_70     = 0.7;      % kemampuan turun 30%
compressor_health_50     = 0.5;      % kemampuan turun 50%
compressor_health_30     = 0.3;      % kemampuan turun 70%

% Pilih kondisi awal
compressor_health = compressor_health_normal;

% Safety limit untuk command flow
m_dot_comp_min_kg_s = 0;
m_dot_comp_max_kg_s = 0.008;

% Governor pressure
p_gov_hi_Pa = 890e3;     % cut-out, gauge pressure
p_gov_lo_Pa = 760e3;     % cut-in, gauge pressure

% Safety valve
p_safety_Pa = 950e3;

% Optional: restriction/check valve after compressor equivalent
A_comp_out_restr_m2 = 1e-4;
Cd_comp_out_restr   = 0.7;

%% ---------------------------------------------------------------------
%% Fault 2 - Valve blockage menggunakan Local Restriction (G)
%% ---------------------------------------------------------------------
A_fault_valve_open_m2 = 1e-4;     % luas bukaan normal/sehat
A_fault_valve_min_m2  = 1e-8;     % luas minimum, sebagai leakage kecil
A_fault_valve_port_m2 = 1.131e-4;     % luas port A dan B
Cd_fault_valve        = 0.70;     % discharge coefficient
```

```
valve_health_normal = 1.00;
valve_health_30     = 0.70;      % penyumbatan 30%, bukaan tersisa 70%
valve_health_50     = 0.50;      % penyumbatan 50%, bukaan tersisa 50%
valve_health_70     = 0.30;      % penyumbatan 70%, bukaan tersisa 30%

% Pilih tingkat penyumbatan
valve_health_fault = valve_health_70;

% Luas bukaan restriction saat fault
A_fault_valve_cmd = A_fault_valve_open_m2 * valve_health_fault;

%% ---------------------------------------------------------------------
%% Fault 3 - Air tank leakage
%% ---------------------------------------------------------------------
leak_cmd_normal = 0;
leak_cmd_fault  = 1;

A_tank_leak_small_m2  = 1e-7;   % bocor kecil
A_tank_leak_medium_m2 = 5e-7;   % bocor sedang
A_tank_leak_large_m2  = 2e-6;   % bocor besar

% Pilih tingkat kebocoran
A_tank_leak_max_m2 = A_tank_leak_small_m2;

A_tank_leak_port_m2 = 5e-4;
Cd_tank_leak = 0.70;
tank_leak_smoothing = 0.02;
tank_leak_leakage_fraction = 1e-6;

% End of script
```