Engine Operating Physics

14.00 days **MOT/PHYM-E**

Overview

AUDIENCE

Engineers and technical staff from design department, testing department wishing to improve their knowledge on following items: engine operation, physics of engines, components design.

PURPOSE

This course provides a deeper knowledge on engine operating physics, under the mechanical aspects, air loading, fuel injection, ignition, exhaust gas after-treatment.

LEARNING OBJECTIVES

Upon completion of the course, participants will be able to:

calculate real flow sections in the cylinder head, in EGR circuits or any other fluid circuit,

understand and apply the calculation formulae used during dyno bench tests,

analyze some test results on emissions and efficiency,

analyze the component damage and failure causes,

understand the language and the tools used to analyze vibrations.

PREREQUISITE

No prerequisites for this course.

WAYS AND MEANS

Many exercises simulating reveryday situations in every chapter.

Agenda

WEEK 1 — 3.50 d

Engine thermodynamic operating (1.5 days)
History.
Thermodynamics basic knowledge: first and second principles, engine efficiency limits. Internal energy, enthalpy, entropy. Ideal gas equation. Laplace equation. Thermodynamic cycles, Beau de Rochas cycle.
Compressor isentropic efficiency.
Engine architecture - Performance and efficiency parameters (2 days)
Geometric parameters: bore, stroke, volumetric ratio, timing diagram.
Effective mean pressure: MEP, MFP, MIP.
Real cycle, differences with theoretical cycle.
Global efficiency: analysis using the 4 efficiencies and setting parameter influence.
Fuel/air ratio, volumetric efficiency: calculation of the main engine parameters at stabilized rpm.
Adaptation to the vehicle: Willans line.

WEEK 2 — 3.50 d

Engine mechanics (1.5 days)
Acyclism
Determine the movements of stresses due to gas pressure in the parts.
Stresses caused by gas pressure and inertia stresses, impact of the conrod spacing on acyclisms.
Acyclism consequences and solutions to limit their impact on the powertrain.

Balancing
Inertia stresses caused by the rotating weight and the alternative weight.
Calculation of rotating and alternating inertia forces.
Timing: description of the different valve control types, lift law, valve timing.
Air loop (2 days)
Link between loading and performances. Fluid mechanics.
Air loading.
Variable timing: presentation of the main technologies and their applications.
Turbocharging: operating, technology, mapping, adaptation process.

WEEK 3

3.50 d

Combustion (2 days)
Air and fuel. Heating value. Ignition equation. Stoichiometric quantity. Equivalence ratio. Specific energy of an air/fuel mixture. Application exercise.
Gasoline combustion: flame front propagation, influence of turbulence; influence of the burning rate (HLC) and of the combustion timing (CA 50) on the efficiency; exhaust gas composition depending on the equivalence ratio; calculation of specific emissions, abnormal combustions (knock, pre-ignition, rumble).
Diesel combustion: self-inflammation delay, pre-mixture and diffusion flames, formation of pollutants (PM, NOx, HC, CO). Common-rail injection systems; swirl number, EGR.
Fuels (1 day)
Fuels groups: fuel main required properties for engine operating (heat value, volatility), octane and cetane ratings, Diesel fuel resistance to cold, sulfur content, …
Manufacturing process of fuels in a refinery.
Biofuels: fuels-ethanol mixtures, vegetable oils, fatty acid esters.
Exhaust gas after-treatment (0.5 days)
Structure and operating of oxidation catalysts (Diesel) and trifunctional ones (gasoline). Starting, efficiency. Ageing mechanisms. OSC (Oxygen Storage capacity). Oxygen probe. NOx traps, SCR (Selective Reduction Catalyst). Particles filtration.

WEEK 4

3.50 d

Materials - Mechanical strength (1.5 days)
Metallurgist basic tools: iron/carbon diagram, TTT, CCT. Characteristics of the alloy steels used in the automotive industry: cast irons, steels, alumina. Rough casting manufacturing processes. Surface treatment. Parts mechanical properties: Young’s modulus, minimum yield, shear rating. Analysis of the engine major parts whose material and manufacturing process have to be chosen.
Part damage modes (1 day)
Thermal, mechanical and tribologic damages. Goodmann diagram. Stribeck curve.
Vibro-acoustics/NVH (1 day)
Waves and sound: magnitudes defining a wave, propagation mode (air, solids). NVH vocabulary: dB, dBA, harmonics, resonance …
Signal creation and lock-on, analysis and interpretation (sonogram, tracking).
Powertrain noises and vibrations. Attenuation, isolation. Vibration impact on the surrounding parts. Line shafting vibration.