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| Course Title | Internal Combustion Engine Fundamentals | | | | |
| Course Code | ME431 | | | | |
| Course Type | Compulsory | | | | |
| Level | BSc (Level 1) | | | | |
| Year / Semester | 4th/Fall | | | | |
| Teacher's Name | Dr. Charalambos Chasos | | | | |
| ECTS | 6 | Lectures / week | 3 | Laboratories/week | 1 |
| Course Purpose | The course purpose is to educate students in the structure and analysis of the operation of various types of internal combustion engines (ICE) and their main components. Furthermore, the course aims to teach the students how to estimate the performance factors of ICE, to assess the effects on performance of various operating parameters, including engine load, speed, fuel type and operating conditions. In addition, the course prepares the students in order to select state-of-the-art experimental and analysis methods for the assessment of ICE and their components, and to characterize the ICE operation, fuel consumption and the exhaust gas emissions. The present course belongs in the BSc. in Mechanical Engineering programme and provides fundamental and specialized knowledge of ICE which is required for mechanical engineers. | | | | |
| Learning Outcomes | By the completion of the course, the students should be able to:<br>1. Describe the geometry/structure and operation of four-stroke and two-stroke internal combustion engines (ICE). Explain the differences in geometry, components and operation of spark-ignition (SI) and compression ignition (CI) engines, both naturally aspirated and supercharged.<br>2. Describe the four-stroke ICE valve timing mechanism, draw the valve timing diagram and summarise the flow processes through the inlet and exhaust valves.<br>3. Compare the ICE real cycles with the ideal thermodynamic cycles and name the losses and differences in thermal efficiency.<br>4. List the engine performance parameters and apply equations for the calculation of the engine performance data.<br>5. Explain the factors that influence engine performance and use engine performance graphs to define the engine operating points.<br>6. Assess the volumetric efficiency of ICE and identify how it is affected by technical and operation parameters.<br>7. Solve the energy balance in ICE and discuss the relevant losses due to friction, cooling and flow processes. | | | | |

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| | 8. Define the combustion initiation for SI ICE and CI ICE Compression Ignition (CI), as well as characterise combustion according to mixture composition (premixed, homogeneous or stratified).<br>9. Use chemical formulas of fuels and combustion equations and estimate the stoichiometric air-fuel composition and air-fuel ratio for various hydrocarbon fuels.<br>10. Draw the various types of fuel injection systems including indirect injectors for port-fuel injection (PFI), and direct gasoline injector (GDI) systems for SI engines.<br>11. List supercharging technologies and compare turbochargers and mechanical compressors. Describe developments in internal combustion engines and explain alternative types of internal combustion engines.<br>12. Name the classic and modern experimental and modelling techniques for the characterisation of engine performance, and select experimental methods for the estimation of ICE performance data. Design and carry out engine measurements, analyse the measurements and compare experimental data with theory. | | |
| Prerequisites | ME200, ME202 | Corequisites | None |
| Course Content | **ICE thermodynamics principles:** isentropic compression, isentropic expansion, heating, cooling, the ideal air-standard Otto cycle and the ideal air-standard Diesel cycle, flow processes, pressure-volume (p-v) diagrams and thermal efficiency equations.<br><br>**Four-stroke cycle**: SI engines and CI engines parts, strokes, flow processes and operation, valve timing diagrams, real cycle p-v diagrams, naturally-aspirated and supercharged engines, full-load and part-load p-v diagrams.<br><br>**Two-stroke cycle**: engines parts, strokes, flow processes and operation, applications.<br><br>**ICE output and efficiency**: load, torque, brake power, friction power, indicated power, mechanical efficiency.<br><br>**Performance characteristics**: engine load and speed, fuel consumption, specific fuel consumption (sfc), volumetric efficiency, thermal efficiency, exhaust emissions, brake power, performance maps for SI and CI engines.<br><br>**Factors influencing performance**: size of cylinder, speed, load, ignition timing, compression ratio, air-fuel ratio, fuel injection, engine cooling, supercharging.<br><br>**Real engine cycles**: air standard cycles, fuel-air cycles, actual cycles and their losses. Engine cylinder pressure history, advance and retard spark timing effects, unfavorable engine operation, knock and pre-ignition for SI engines, combustion delay in CI engines. | | |

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| | **Properties of fuels, the combustion process and emissions**: fuels for SI engines, knock rating of SI engines, Octane number requirement, Diesel fuels, Cetane number requirement, combustion process and flame development, exhaust gas emissions and exhaust after-treatment systems.<br><br>**Alternative forms of ICE:** the Wankel rotary combustion engine, the variable compression ratio engine.<br><br>**Developments in ICE**: fuel injection systems, supercharging systems, dual-fuel engines, gas-engines, engine management system layout (sensors and actuators), exhaust gas recirculation (EGR) system, and emissions abatement systems. Presentation of research results of modelling and simulations of ICE injection and combustion processes.<br><br>**Laboratory Work**: Small group experiments performed with the use of common vehicle engines and/or single cylinder engines under certain loading conditions. The experimental results will be analysed and compared with engines manufacturer specifications and/or theoretical performance data. The following experiments are performed during the course:<br><br>- Emissions measurements of a SI ICE.<br>- Emissions measurements of a Diesel ICE.<br>- Emissions measurements of a vehicle spark-ignition engine and use of on-board diagnostics (OBD) system.<br><br>**Assignment:** individual problem solving small exercises for ICE engine operation and performance, or individual problem for real engine performance data calculations, analysis and comparisons from a real ICE test case with engine specifications. |
| Teaching Methodology | The course is delivered to the students by means of lectures, exercises solution on the whiteboard, conducted with the help of computer presentations, as well as demonstrations of various ICE and ICE section models and components in the ICE Laboratory. Lecture notes and presentations are available through the E-learn site of the course for students to use in combination with the textbooks and references. |
| Bibliography | **(a) Textbooks:**<br><br>1. John B. Heywood. “Internal Combustion Engine Fundamentals”. McGraw Hill Education, 1989.<br><br>**(b) References:**<br><br>1. Colin Ferguson, Allan Kirkpatrick. “Internal Combustion Engines”. John Wiley and Sons, 2000.<br>2. Richard Stone. “Introduction to Internal Combustion Engines”. Palgrave Macmillan, 1999.<br>3. John L. Lumley, W. C. Reynolds. “Engines: An Introduction”. Cambridge University Press, 1999. |

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| | 4. Willard W. Pulkrabek. “Engineering Fundamentals of the Internal Combustion Engine”. Prentice Hall, 1997.<br>5. Eastop T. D. and McConkey A. “Applied thermodynamics for engineering technologists”. 5th Edition, Prentice Hall, 1993. |
| Assessment | **(a) Methods:**<br>• Assignment 10%<br>• Laboratory reports 10%<br>• Mid-term examination 20%<br>• Final Exam 60%<br><br>**(b) Criteria:**<br>• The assessment criteria are included in the edited documents of the laboratory exercises and the edited document of the assignment. In particular, the clarity of the content and writing, the structure, the quality of graphs, tables and data analysis illustration, the discussion and conclusions are assessed.<br>• The mid-term exam is done during the seventh week of the semester, which assesses the students’ performance on the subject matter taught during the first six weeks of the semester. Two questions ask for diagrams, graphs and calculations which are assessed on the correctness, clarity, results and units used.<br>• The final exam includes four questions (theoretical and analytical) and assesses students on the subject matter of the course and their ability to describe ICE, to draw diagrams and graphs, carry out calculations and compare and discuss the results. |
| Language | English |