ALL ARE WELCOME
Ph.D. SEMINAR TALK - 2

Title of the seminar: Design and Development of a Small-Bore Gasoline Direct-Injection Optical Engine, and Investigation of In-Cylinder Flow Within It

Speaker: Velugula Ravi, ME19D407,

Biography of the Speaker:
Ph.D. Research Scholar, Dept. of Mechanical Engineering

Date and time: 01-May-2025 (Thursday) and 3:00 p.m.
Venue: Hybrid Mode (Diesel Hall, First Floor, IC Engine Laboratory)

Link For Hybrid mode: https://meet.google.com/dko-uadt-uqp

Affiliation of the Speaker:
Guide(s) name: Prof. Mayank Mittal and Prof. A Ramesh

DC Member: Dr. Venkatarathnam G (Chairperson),
Dr. Amit Kumar (External),
Dr. Manivannan P V (Internal),
Dr. Shyama Prasad Das (Internal).

ABSTRACT:

Small-bore engines are experiencing strong global demand, particularly in two- and three-wheeler vehicles, due to their compact size and suitability for urban mobility. Recent studies on direct-injection (DI) spark-ignition engines (moderate- to large-sized engines) have shown their significant promise in terms of fuel economy and performance when compared to traditional engines. Although DI offers numerous advantages such as precise fuel delivery, enhanced fuel economy, and lower engine-out emissions, it also introduces several significant challenges. One of the most critical issues is the formation of inhomogeneous fuel-air mixtures, along with fuel impingement on cylinder walls and piston surfaces, which is more prominent in small-bore engines. These issues can lead to incomplete combustion, increased emissions, and reduced thermal efficiency. These challenges become particularly pronounced at low engine speeds and lower throttle openings. Since fuel-air mixing is governed by fluid motion, a thorough investigation of in-cylinder flow processes is essential to effectively address these limitations and fully leverage the advantages of DI in small-bore engines. A key aspect of this analysis involves studying the cycle-to-cycle variations (CCV) of the flow fields, as these variations can significantly influence combustion stability, fuel economy, and emission characteristics.

A small-bore GDI optical engine was developed (as part of Seminar 1 contents) and is currently being utilized for flow measurements using particle image velocimetry (PIV) (as part of the Seminar-2), focusing on throttle openings of 25% and 100% and engine speeds of 600 and 1200 rpm. This comprehensive setup involved several critical stages, including the seeding of flow with tracer particles, formation of a laser sheet for illuminating the measurement plane, precise synchronization between the laser and the camera, and acquisition of high-quality images during engine operation. Subsequently, calibration procedures were performed, and the captured PIV raw images were post-processed using PIVlab to obtain the corresponding velocity fields. Various flow field parameters such as ensemble-averaged flow fields, vorticity, kinetic energy, and fluctuating kinetic energy were

evaluated for the analysis. In addition, the relevance index and quadruple proper orthogonal decomposition techniques were employed to assess cycle-to-cycle variations.

Temporal evolution of the in-cylinder flow fields is examined using ensemble-averaged velocity fields. The results indicated that the flow fields exhibited similar structures at different speeds, however, varied with changes in throttle openings. The distributions of vorticity, representing local angular rotation of the flow; kinetic energy, indicating the energy content within the flow fields; and fluctuating kinetic energy, used for analyzing free shear zones, were analyzed along with their respective cycle averaged values. CCV in the flow fields were quantified using both relevance index and proper orthogonal decomposition-based mean energy share metrics. The CCV obtained from these two metrics showed comparable trends, with a complex dependence on throttle opening and engine speed. It was observed that the CCV was higher during the early intake stroke under part-throttle conditions compared to full-throttle. However, from the late intake to mid-compression stroke, the CCV was lower under part-throttle conditions, which was attributed to the increased intensity of the flow fields. For different engine speeds, the CCV was found to be similar during the intake stroke, but significant differences emerged starting from the early compression stroke onwards. These findings provide valuable insights into the complex nature of in-cylinder flow behavior in small-bore direct-injection engines under varying operating conditions.