FLOW, ENGINE, ACOUSTICS, and TURBOCHARGER RESEARCH LABORATORIES

Providing unique research and educational opportunities for the next generation of automotive engineers

Powertrain Activities

CURRENT RESEARCH - OVERVIEW

For more than three decades, the focus of the Flow, Engine, Acoustics, and Turbocharger Research Laboratories has been on the development and validation of simulation tools to:

- Predict the engine performance by integrating wave dynamics, combustion, and heat transfer;
- Predict the airborne noise generation and attenuation in the breathing system of engines, including the linear and nonlinear acoustic behavior of silencers;
- Understand the noise generated by flow and flow-acoustic coupling, encompassing a wide frequency range, including whoosh, whistle, chirp, hoot, and ring; and
- Investigate the pollutant emissions and their control.

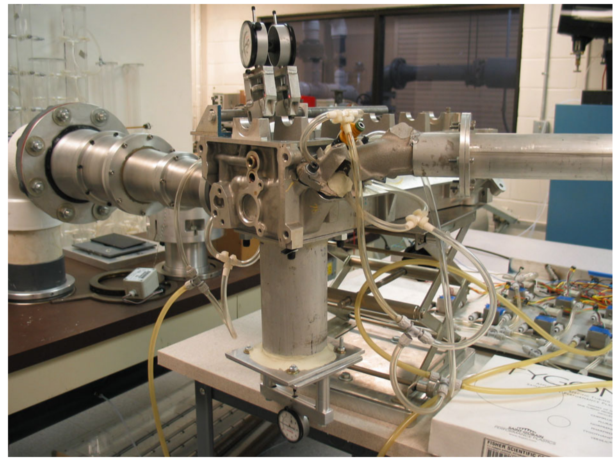
Research also explores innovative concepts to simultaneously (a) improve the engine performance, including fuel efficiency, (b) suppress the flow-generated and/or airborne noise, and (c) minimize the pollutant emissions. While the primary emphasis of research is the development of fundamental understanding and validation of the resulting models, the in-depth knowledge gained in the process is also used to produce design guidelines and novel bench techniques.

The impact of contemporary research in these laboratories has been extraordinary throughout the decades particularly in the following areas: (a) developing reliable models for engine simulations as validated by experiments; (b) identifying and isolating pertinent physics from engines and duplicating these scientific puzzles on a bench-top environment for a more in-depth examination, leading to original knowledge creation and dissemination; (c) promoting a learning environment for engineers that always couples laboratory measurements and computational predictions, while striving to shrink the gap between the two approaches, thereby making the predictions ultimately powerful design tools; (d) building an exemplary collaborative relationship with the automotive industry; and finally, yet perhaps most importantly, (e) successfully educating the young minds to contribute to the future of the mobility and the society.

CURRENT RESEARCH - OBJECTIVES

FLOW RESEARCH

- Measure the steady flow performance of numerous induction and exhaust system elements, including the flow discharge coefficient of ports as a function of valve lift;



- Measure in-cylinder short-circuiting;
- Quantify the charge motion in air flow;
- Measure the narrow band pipetones due to flow/acoustic coupling at the interface of a main duct and connecting sidebranches;
- Measure the wideband turbulent flow noise due to flow separation and flow/wall interaction; and
- Determine the effect of flow on silencers, including perforate/louver interfaces with and without absorbent.

The recent sponsors include Ford Motor Company.

ENGINE RESEARCH

By combining the analytical, computational, and experimental approaches:

- Develop and validate analytical tools to model the coupled induction/in-cylinder/exhaust systems for improving the engine performance with emphasis on fuel efficiency and noise characteristics, and for reducing the pollutant emissions;
- Establish a relationship between flow and engine studies;
- Explore innovative concepts for engine breathing systems; and
- Provide design guidelines.

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ACOUSTICS RESEARCH

Determine the acoustic characteristics of both basic silencers and production components in the:

- Linear frequency domain by implementing the two-microphone technique; and
- Linear/nonlinear time domain by using piezoresistive transducers and a high-speed data acquisition system.

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Contact:
Prof. Ahmet Selamet
930 Kinnear Road, Columbus, Ohio 43212, U.S.A.
Phone: (614) 292-4143 Fax: (614) 688-4111 E-Mail: selamet.1@osu.edu

TURBOCHARGER RESEARCH

- Characterize the performance of both the compressor and turbine of turbochargers by generating detailed, steady-flow operating maps capable of extending beyond the conventional knowledge, including reverse flow;
- Capture the unsteady pressure and velocity fields resulting from flow instabilities (due to surge) in centrifugal compressors at low flow rates both experimentally and computationally;
- Investigate the broadband noise associated with flow separation within compressors and discrete tones due to surge and/or blade passing, hence develop the acoustic maps of compressors;
- Identify the compressor surge line as a function of geometrical changes in the overall compression system;
- Incorporate design changes to attenuate or delay surge;
- Examine the turbine performance as a function of wastegate or variable geometry vane position by use of a computer-controlled linear actuator; and
- Employ a compelling bench-top approach in conjunction with the nonlinear flow simulations within particularly the compression system to better understand the inherent physics, leading to the development of improved predictive tools, including for surge.

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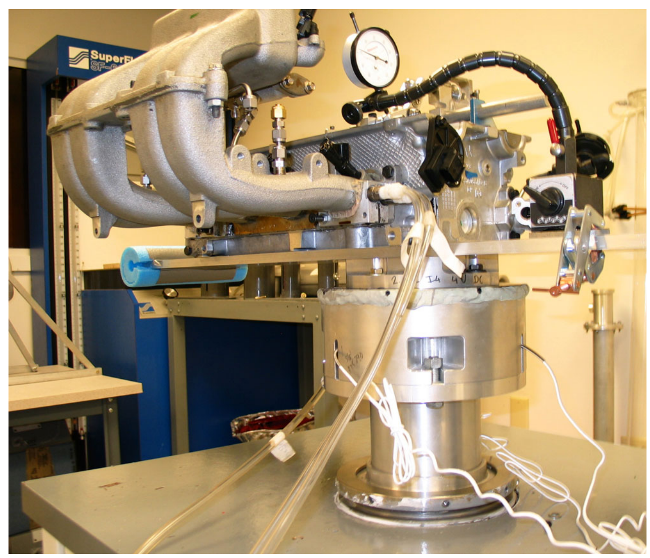
FACILITIES and EQUIPMENT

FLOW RESEARCH LABORATORY



By reducing the background noise levels as much as 40 dB relative to conventional air flowstands, this laboratory has created a desirable setup for numerous studies on in-duct flow/acoustic coupling, flow/wall interaction, and flow/perforate interaction. Thus, this laboratory serves a dual purpose of quantifying flow efficiency of the induction and exhaust system elements and ports, as well as flow noise due to flow/acoustic and flow/structure coupling. The stand which was originally donated by Ford Research Labs, including a 40 HP turbine, calibrated nozzles and instrumentation, has now been computerized.

This facility is equipped with:

- Meriam micromanometers;
- Variety of Validyne differential pressure transducers, PCB piezoelectric pressure transducers; digital and analog barometers;
- Analog Devices A/D converters combined with a PC for the operation of stand and data acquisition;
- B&K sound level meters and HP spectrum analyzers; and
- SuperFlow 600 flow bench.

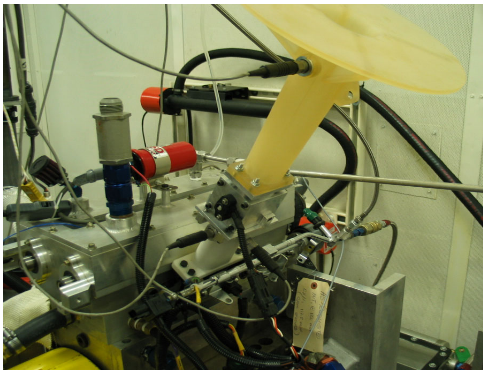
ACOUSTICS RESEARCH LABORATORY

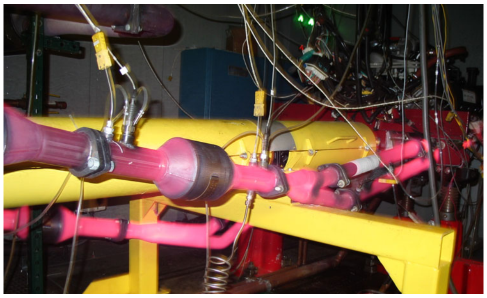
Acoustic characteristics of various configurations are determined in this setup by mounting them between two tubes: an upstream tube that connects the loudspeaker driven by a signal generator module to the silencer and an anechoically terminated downstream tube. For frequency domain measurements, four condenser microphones are used in two pairs mounted upstream and downstream of the silencer flush with the tube surfaces. Microphone signals are then processed by the B&K 3550 system.

This laboratory is equipped with:

- A modular, multichannel analysis system (B&K 3550), which includes a signal analyzer and a multichannel data acquisition unit coupled with a compatible 100kHz-zoom processor, 25kHz-input, and interface modules; and
- Concurrent 5450 high speed data acquisition system combined with Endevco piezoresistive pressure transducers and amplifiers.

ENGINE RESEARCH LABORATORY





This state-of-the-art engine research facility involves two dual-ended dynamometer laboratories, a hemi-anechoic room, and a control room. The fully computerized facility provides a unique capability to conduct combined experimental research on the breathing system of engines in a number of fundamental areas: Engine performance; Wave dynamics, noise generation and attenuation; Combustion; Heat transfer; and Engine-out pollutant emissions.

This facility is equipped with:

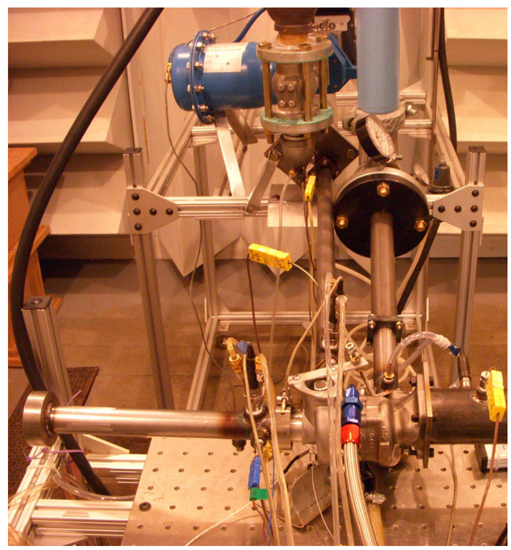
- Ford 3.5L V6 GTDI EcoBoost Twin Turbo, Ford 5.4L V8 Triton, Ford single cylinder, Chrysler 2.4L I4, Chrysler single cylinder, and Jaguar 3.0L V6 engines;
- A 300 HP absorbing/225 HP motoring double-ended GE Electric Dynamometer; A 190 HP absorbing/180 HP motoring double-ended GE Electric Dynamometer;
- Two Horiba 2000 EDTCS engine/dyno control and data acquisition systems;
- Horiba 7100 emission analyzer bench;
- A new data acquisition system equipped with a National Instruments cDAQ-9178 chassis providing 32 channels of thermocouple measurements, 8 channels of 0-20 mA input, and 8 channels of 0-20 mA output. Also, a NI PXIe-1073 chassis allowing for 16 channels of variable input voltage at a 1.25 MHz simultaneous sampling rate and 8 channels of input 0-5 V at a 250 kHz simultaneous sampling rate;
- Two Dyne System Digital Throttle Controllers and Dyne Lock IV dyno controllers coupled with control unit and transformer;
- Stanley-Carter engine oil/water cooling stand;
- Two Pierburg FT22-34 fuel flow meters;
- Numerous PCB/Kistler/Endevco transducers and digital amplifiers; and
- Tektronix digital scopes and other instrumentation.

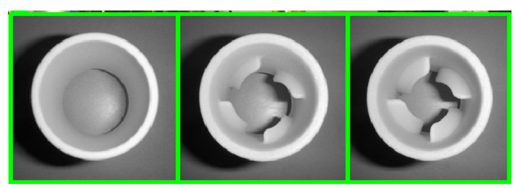
TURBOCHARGER RESEARCH LABORATORY

This novel laboratory was designed to accommodate a range of turbochargers, while combining numerous steady and unsteady measurement capabilities. The turbocharger bench is located within a hemi-anechoic chamber to reduce the impact of reflected sound waves on external acoustic measurements. A Quincy QSI-750 screw compressor supplies mass flow rates in excess of 0.5 kg/s at pressure ratios of up to 6:1 to drive the turbine. Pressure fluctuations from the screw compressor are suppressed by a large, in-line accumulator tank, providing steady flow to the turbine. A 15 kW electric heater is incorporated to warm up the flow upstream of the turbine in order to increase the power delivered to the compressor and extend its operating range. The turbine and compressor loops are isolated from one another to decouple the mass flow rates, allowing maximum flexibility. Precise compressor and turbine operating points are obtained through computer-controlled pneumatic valves, installed upstream of the turbine and downstream of the compressor.

This laboratory is equipped with:

- Variety of Kistler/PCB/Validyne in-duct pressure transducers and digital amplifiers;
- External PCB free-field microphone array;
- PicoTurn eddy current speed sensor with 200 rpm to 400 krpm range;
- Custom-built fast-response type T and standard 1/16" type K thermocouples;
- Oil system, including a pump, regulator, heater, and cooler to provide lubrication to the bearing housing at a controlled temperature and pressure;
- Calibrated orifice flow meters on both the turbine and compressor loops; and
- A data acquisition system equipped with a National Instruments cDAQ-9178 chassis providing 32 channels of thermocouple measurements, 8 channels of 0-20 mA input, and 8 channels of 0-20 mA output. Acoustic measurements are acquired with 12 channels, simultaneously sampled at 50 kHz. A NI PXIe-1073 chassis also allowing for 16 channels of variable input voltage at a 1.25 MHz simultaneous sampling rate and 8 channels of input 0-5 V at a 250 kHz simultaneous sampling rate.
- A LaVision time-resolved, stereo Particle Image Velocimetry (PIV) system to measure the velocity field within the compression system of a turbocharger. The primary components of this system include: dual-cavity Nd:YLF high repetition rate laser with adjustable light sheet optics, pair of high-speed cameras, sub-micron flow seeder, high speed controller, and workstation PC with DaVis software package. Neutrally buoyant oil particles are introduced to the flow field, where they are illuminated by a laser sheet. By simultaneously capturing successive images with a small (typically a few microseconds) time separation, the movement of oil particles is statistically tracked, and all three velocity components can be spatially resolved on the laser sheet.





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