ARAI® Progress through Research Update

Towards Safer, Cleaner & Quieter World ...

Design, Development and Testing Services at ARAI

Index Issue 2015-2016

High Frequency NVH Solutions using Statistical Energy Analysis (SEA) based Simulation

Noise and Vibration is often associated as one of the first impression quality criterion while assessing quality of a product. High frequency NVH problems like vehicle in-cab noise, aero-acoustic noise are challenges for today's designers. SEA based simulation is emerging as a promising alternative to address these problems reliably in early design cycle.

Recently, ARAI has developed capability for SEA based high frequency noise simulations aided by conventional CAE tools to provide much needed complete frequency range solutions for automotive and non-automotive applications.

Need for High Frequency NVH Solution

For structures with high frequency excitations, it is not technically or economically feasible to estimate the responses using traditional Finite Element Method (FEM) and Boundary Element Method (BEM). Firstly, computational model size becomes huge demanding excessive computational resources with longer solution times. Secondly, high frequency modes are sensitive to small variations of the system properties and lack of precision in modeling introduces uncertainty and non-reliability.

In SEA approach uncertainty factor is in-built considering statistical behavior of population of systems. SEA model is thousand times smaller (very few degrees of freedom) than its conventional equivalent. It is quick to build and analyze using modest computational resources.

SEA is very effective in new product development cycles where concepts are still evolving and prototypes not available. Many new vehicles are based on previous-generation vehicle with enough NVH similarities. For those problems benchmark vehicle test information incorporated in SEA analytical models helps in quick solutions.

Limitations of Conventional NVH Simulation Tools (For High Frequency Analysis)

- Excessive computational resources
- Longer solution time
- Inability to model uncertainty

Features of SEA

- Quick analysis and solution
- Modest computational resources
- Sensitivity of property variations taken into account
- FEM models created for other analysis can be readily used
- Useful in early vehicle development where prototype is not available

Typical High Frequency NVH Applications

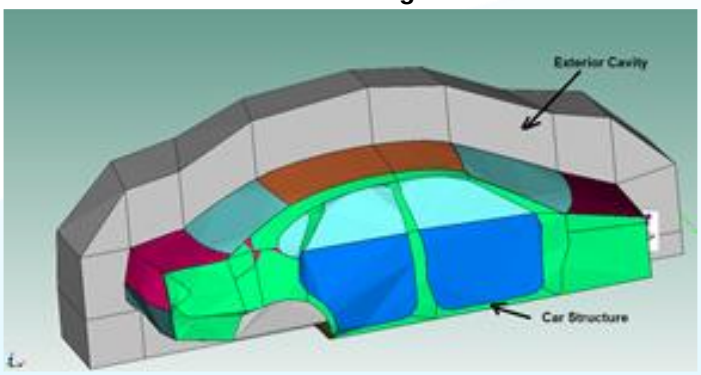
- ***Vehicle Interior Sound Package Design***

The effect of changes to materials, gauge thickness, sound package, or geometry changes on interior noise levels can be predicted with good accuracy. Optimization of sound package helps in reduction of overall vehicle weight and cost. Diverse vehicle body styles and sound package variant concepts can be analyzed effectively.

- ***Acoustic Seal Design***

Door seals and pass-through play vital role in improving sound insulation inside the cabin. These can be effectively analyzed and quick iterations are possible by unique Hybrid FE-SEA approach.

Vehicle Sound Package Simulation



Acoustic Seal Design

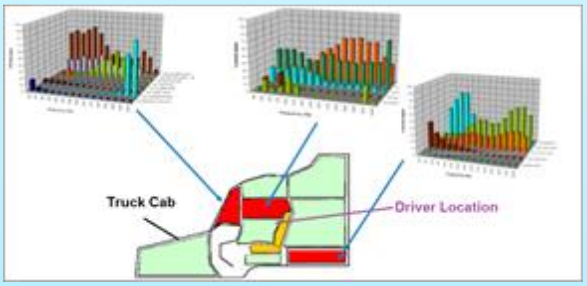
- ***Vehicle Structure Borne Noise Predictions***

Conventional CAE tools can predict structure borne noise up-to 200 Hz. Higher frequency analysis is limited by method inaccuracy. With Hybrid FE-SEA technique, analysis can be extended up to 800 Hz. Here stiff components are modeled in FEM and flexible components by SEA thus capturing total physics.

- ***Noise Path Analysis***

Critical noise paths, through which energy is transmitted from source to the target location, can be predicted by SEA. Relative contribution and rank of each path helps in exploring design solutions.

Vehicle Noise Path Analysis



- ***Fire Wall Panel Acoustic Design***

Vehicle Dash panel or any partition panels in building acoustics can be designed for better insulation of airborne noise sources. Panels are optimized for geometry, damping treatment and type of insulating material.

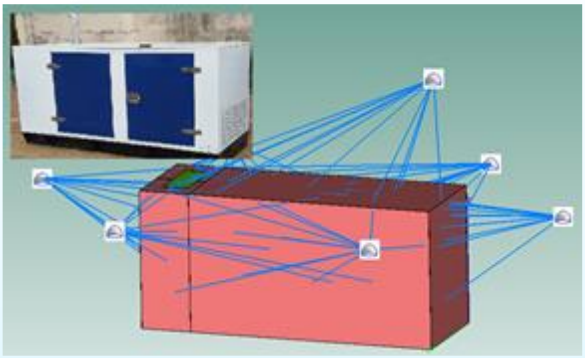
- ***High Frequency Aero-acoustic Solutions***

Aero-acoustic noise sources like wind noise, side mirror noise, turbulent boundary layer noise can be addressed by coupled CFD-SEA solution with good accuracy.

- ***Acoustic Enclosure Design***

Acoustic enclosures for diesel gensets, compressors and engine partial covers can be designed for lower noise emissions with optimum absorbing treatment. Interaction between closed cavity and thin metal panels is modeled by SEA approach.

Acoustic Enclosure Design



- ***Large Duct / Plenum Designs***

HVAC/ industrial ducts can be analyzed above plane wave cut off frequencies capturing diffuse fields. Reliable solutions possible for layout optimization and acoustic lining design.

ARAI NVH Capabilities

- Vehicle Benchmarking and Target Setting
- Noise Source Identification using Transfer Path Analysis (TPA)
- Sound package material characterization
- Combustion Noise Analysis
- Engine Calibration Optimization
- Off-road Vehicle and Construction Equipment Testing
- Tire Noise Analysis
- Experimental Transfer Function Evaluation
- Operational Modal Analysis
- Exhaust System Design

ARAI NVH Major Facilities

- Hemi-anechoic chamber with Engine and Chassis dynamometers
- Reverberation chamber suite with anechoic chamber
- Test Rigs for acoustic material evaluation
- 100 channel data acquisition systems
- Head and torso for sound quality analysis
- Acoustic holography system

Why ARAI

Accuracy of SEA predictions depends largely on precise test inputs like acoustic material properties and noise source characterization. ARAI can generate these test parameters accurately for reliable solutions using state-of-the-art test facilities and material evaluation test rigs.

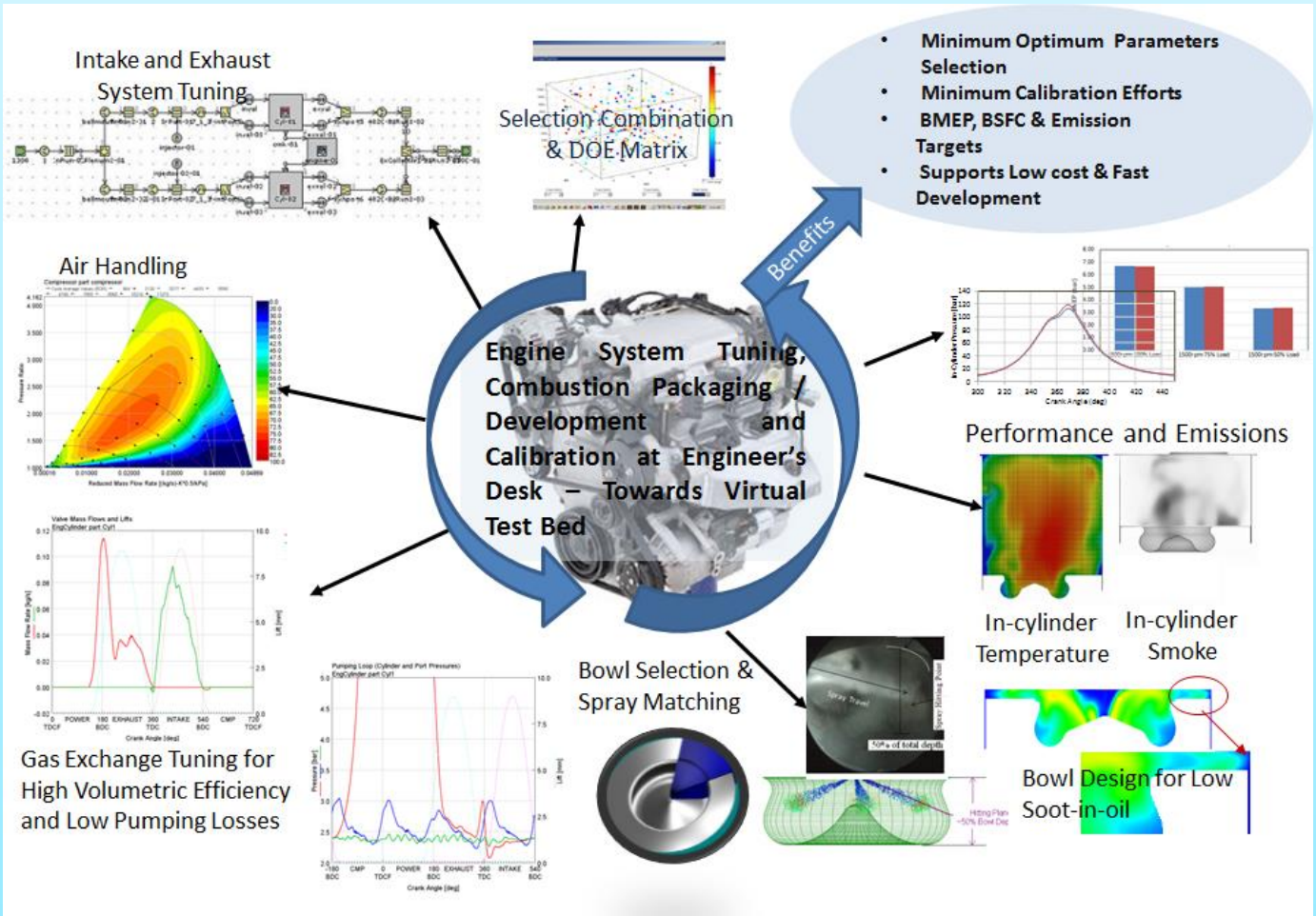
With its profound NVH domain expertise, ARAI can be your preferred solution partner in developing world class, quieter and better products using SEA methodology complimented with conventional CAE tools and test infrastructure.

Virtual Engine Simulation – Low cost Powertrain Development

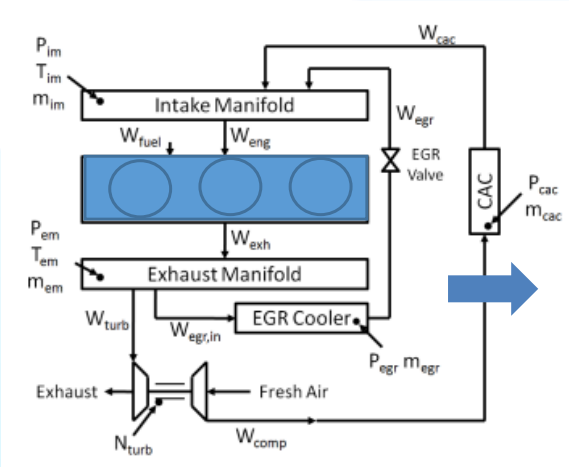
Evolution of Internal Combustion Engines (ICE) is guided by lowering of fuel consumption and polluting emission limits. **Engine control system is becoming increasingly complex and refined**, capable of managing all possible engine operating conditions. Engine system is also more and more complex due to addition of thermodynamic, hydraulic and electro-mechanical sub-systems. Engine simulation by means of more or less detailed models is a crucial aid in design of control system and sub-systems: on one hand, it avoids greater part of experimentation and thus reduces design cost and time, on the other hand, it makes it possible to perform detailed analysis and characterize the phenomena taking place inside the engine.

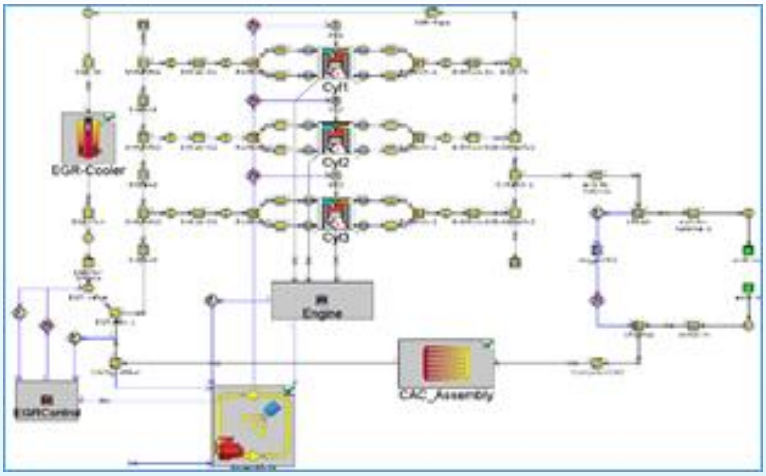
In this endeavour, Powertrain Engineering (PTE) Division of ARAI has developed in-house following specific competency:

- 0D and 1D modeling of engines in stationary and transitory mode for engine control.
- 1D predictive modeling of engine performance and emissions
- Multi-dimensional CFD analysis of gas exchange processes in engines, under real life operation conditions
- CFD 3-D analysis of processes with both open valves and closed valves (Spray, Combustion) in diesel engine
- Optimization/matching of combustion chamber - injector (injection pattern and spray pattern) for direct injection engines.
- Development of injection strategies (split and multiple) for performance and emissions formation control
- Use of DoE with virtual tools to predict performance and emissions for entire hardware combinations and range of operation.
- Optimum selection of nozzle configuration, swirl, valve timings and profile, turbocharging system, EGR system, intake and exhaust system through 1-D and 3-D CFD analysis.
- Prediction of Soot-in-Oil and reduce soot-in-Oil through optimum selection of injector and combustion chamber

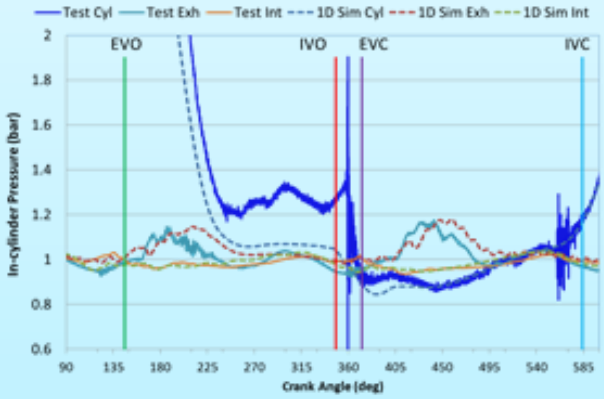


Air Handling System: Engine air handling system is very complex and important for any engine application to meet desired performance and emissions. Selection of every part of both Intake and exhaust system, including pipe length and diameter plays an important role in engine breathing system. Experienced and skilled PTE-ARAI simulation group offers services to optimise complete air handling system - Intake and Exhaust system, EGR system, manifold tuning, valve timings and valve profiles, turbocharger, inter cooler, EGR cooler requirements, etc. to achieve maximum desired volumetric efficiency with minimum pumping work.

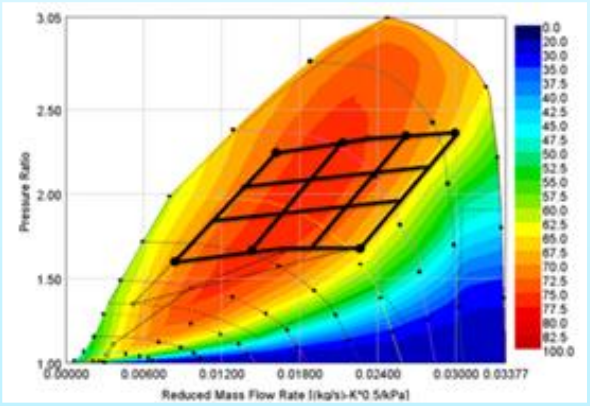




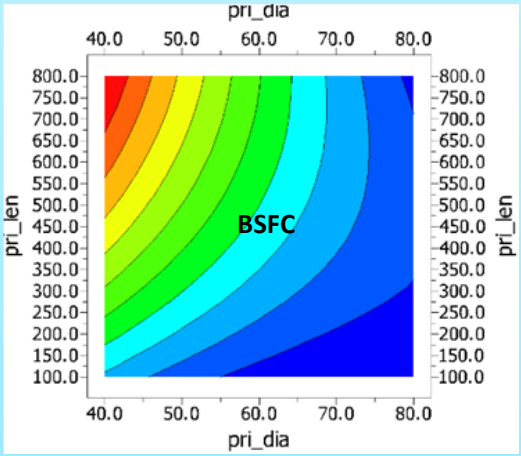
Mathematical and Thermodynamic Model of a Typical Diesel Engine



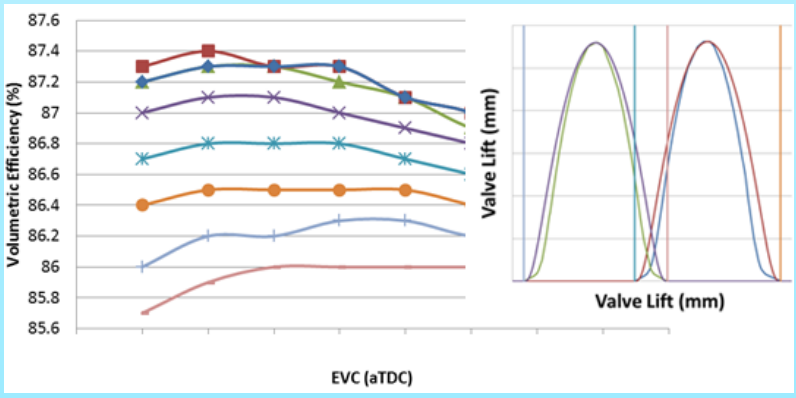
Gas Exchange and Valve Timing Study Comparison with Experiments



Turbocharger Mapping for Engine Operating zone and High Altitudes

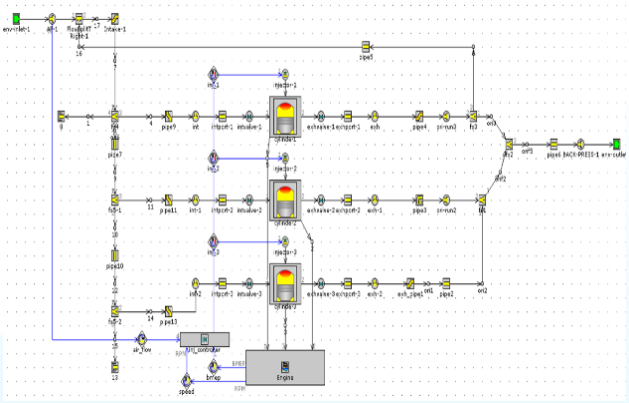


Intake Pipe Length and Diameter Tuning Selection for Best BSFC

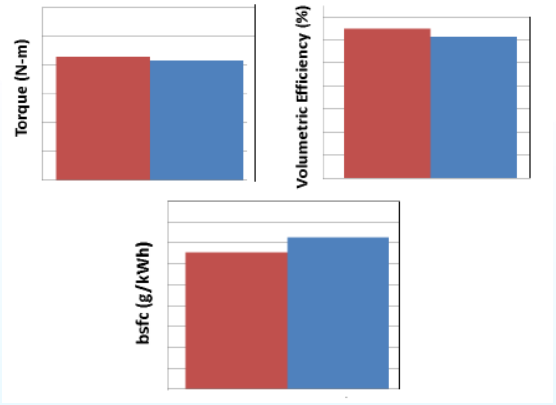


Valve Timing and Profile Optimization for Desired Volumetric Efficiency

ARAI Experience: ARAI has carried out optimization of diesel engine Air Handling System (AHS) using virtual tool and optimum configuration selected for testing. Error band of simulation results with experimentally observed volumetric efficiency and Torques is 3 to 5% and BSFC is 4%.

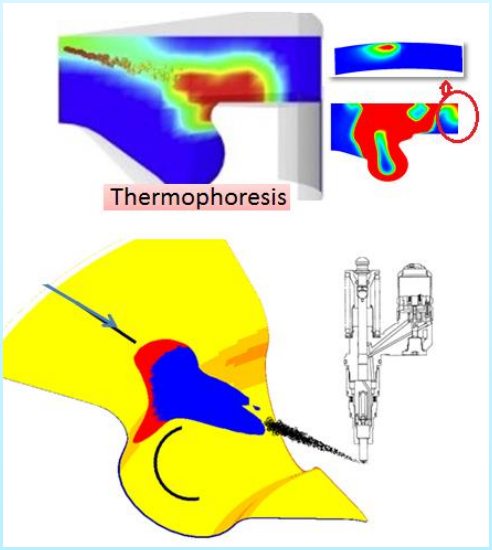


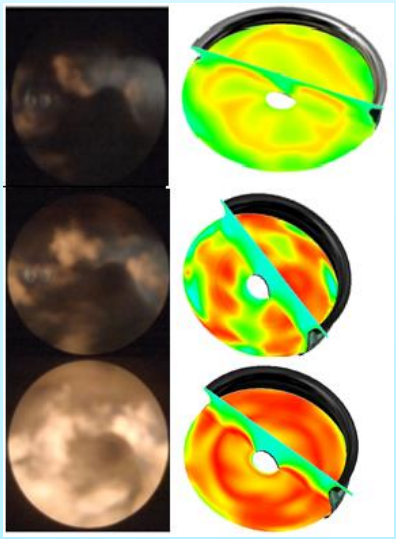
Virtual Model for Tuning of Air Handling System



Comparison of Virtual and Experimental Results

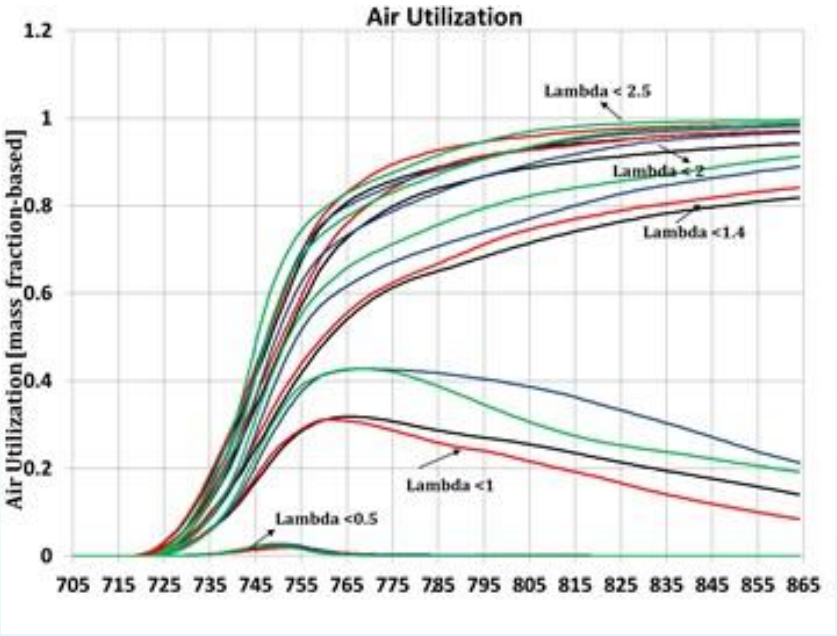
In-Cylinder Combustion Analysis: Increased competition demands least time to market with great customer acceptance. Virtual testing plays an important role in selection of right combustion package to meet desired performance and emission target. PTE-ARAI offer services in this direction with ample experience on automotive, off-road, HEV/CEV and Genset applications.

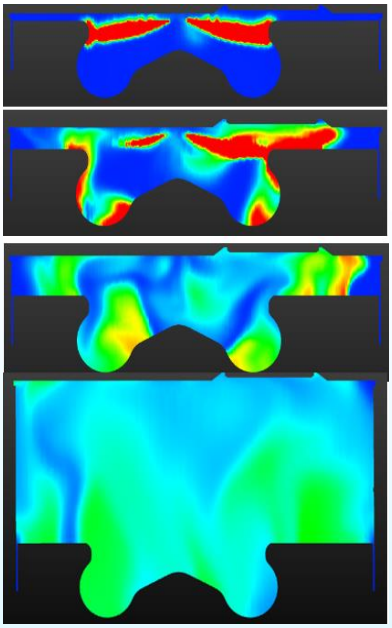




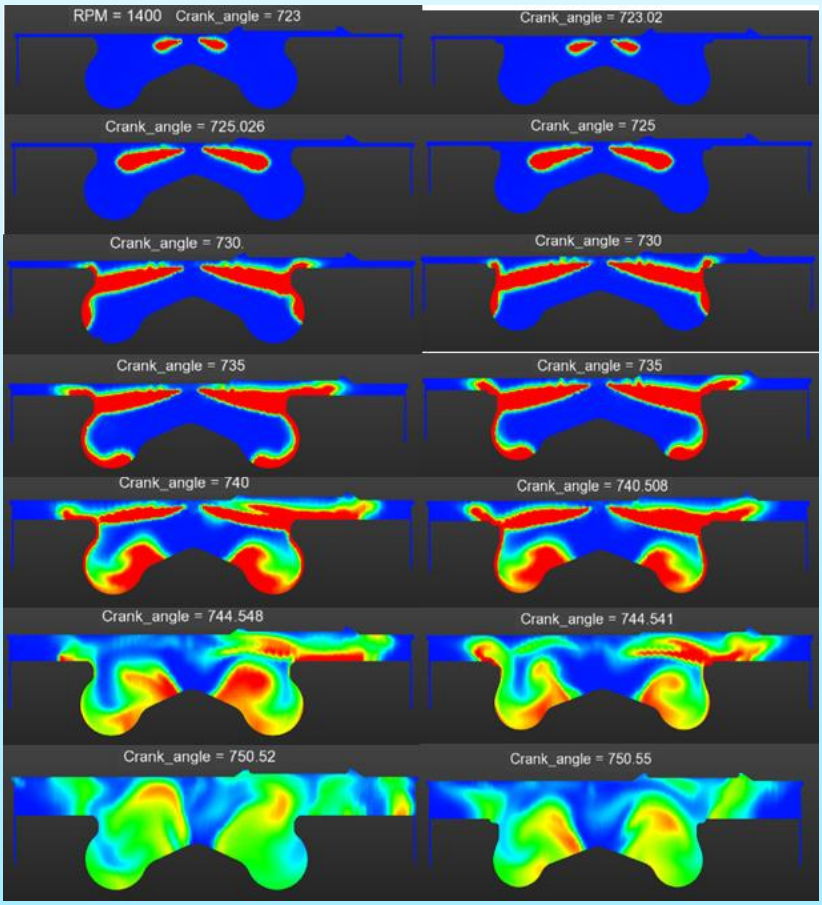
- Soot-in-Oil is never ending problem and it is very critical to meet stringent emission regulations and fuel efficiency.
- Optimum combustion chamber suitable for advanced combustion strategies and higher injection pressures so as to minimize Soot-in-Oil as much as possible.
- Soot cloud is extending to outer regions of combustion chamber where particles may escape to lubrication system through narrow clearance in e liner region.
- Some fraction of particles will be transported with blow-by.

- To achieve best fuel efficiency and lower emissions, bowl design and injection matching is very important.
- ARAI detailed analysis of virtual techniques well validated with experiments.
- ARAI has compared virtual in-cylinder flame temperature with actual in-cylinder flame (as shown above).

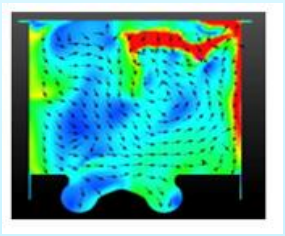




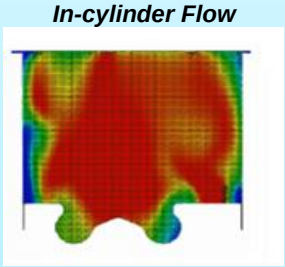
In-cylinder Air Utilization Analysis



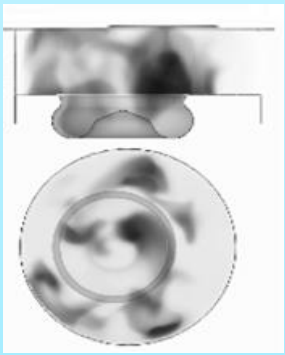
In-cylinder fuel-air interaction study of different bowls



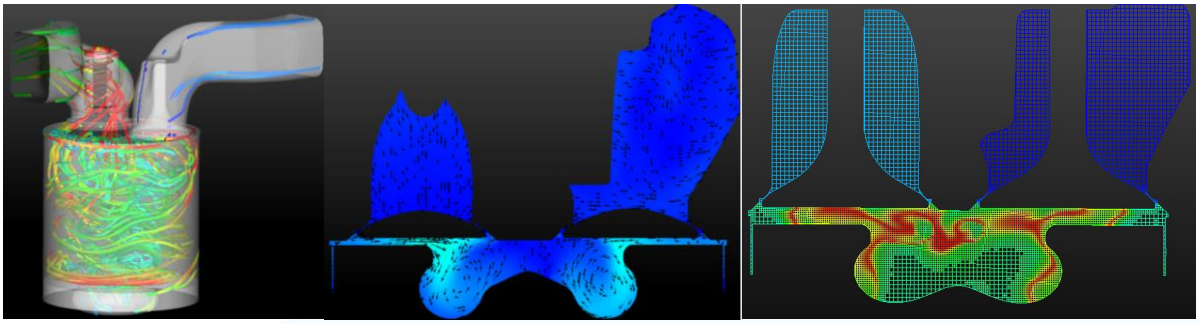
In-cylinder Flow



In-cylinder Temperature



In-cylinder Soot Analysis



Open cycle In-cylinder combustion analysis – Influence of port geometry, swirl on in-cylinder combustion

Strategic scientific approach **(Statistical-Virtual → Optimum Engine Package for Testing)** followed by ARAI allow selection of minimum and optimum engine sub-systems and combustion package during design and concept phase of engine development cycle to achieve target performance and emissions.

ARAI Inaugurates its New Pedestrian Safety Test Facility at ARAI Chakan Centre

The newly set up Pedestrian Safety Test Facility was inaugurated by Dr. Rajan Katoch, Secretary, Ministry of Heavy Industries and Public Enterprise, Government of India, on 13th July 2015 at ARAI, Chakan, in the presence of industry stalwarts and Government officials.

Facility Details:

A world class Pedestrian Safety Test facility has been set up in Passive Safety Laboratory at ARAI, Chakan. The facility is useful for Pedestrian as well as Occupant Safety Impact simulation testing. The facility mainly comprises of the Universal Launcher having various inter-changeable impact modules, as described below, to simulate different impact test condition as per national as well as international standards viz. AIS-100, ECE-R-127, GTR-9, ECE-21, ECE-12, EMVSS-201 & 201(U), FMVSS-203, FMVSS-222, Euro- NCAP & other NCAP requirements as well.

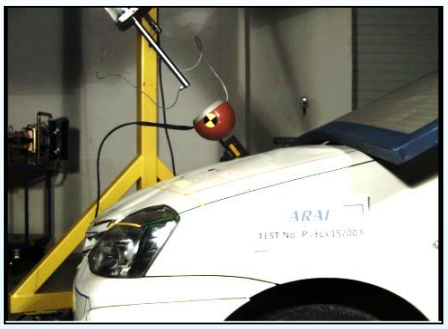
Inter-changeable Impact Modules

- Child Head Impactor-3.5 kg
- Adult Head Impactor-4.5 kg
- Upper Leg Impactor (TRL)
- Lower Leg Impactor (TRL)
- Pendulum Head Impactor
- Linear Guided Head Impactor
- Body Block Impactor
- Free Motion Head Impactor (FMH)
- Knee Impactor

The test facility works on servo hydraulic principle with close loop speed control and allows perfect impact speed control. Speed accuracy of launcher is ± 0.5%. The max speed achievable is 60 kmph. Target point accuracy is ± 5 mm. It has got 16 channels data acquisition system with 8 digital channels, which can acquire additional channels apart from regulatory requirements. Also, it has 2 cameras with High Resolution Colour CMOS technology to capture high speed videography at 2,000 FPS by using 2 HMI Lighting systems with UV filter glass.

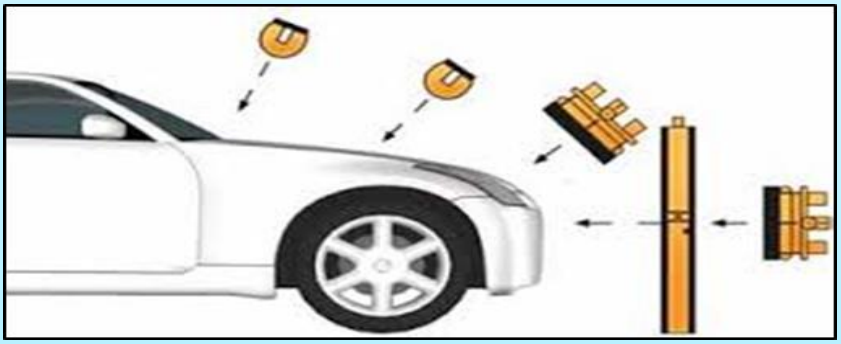
Various Types of Modules & Impactors

Pedestrian Safety Test Facility



Adult / Child Head Impact

Upper Leg Impact



Pedestrian Safety Test Simulation

Lower Leg Impact

Head Form

Upper Leg

Lower Leg

FMH

Body Block

HMI Lights

Speed Trap

Cutting Edge: ARAI is working as a Technical Partner for the Auto Industry for development of a Pedestrian friendly vehicle by using World Class Pedestrian Safety Test facility along with CAE analysis and its co-relation. Pedestrian Safety Laboratory is well equipped to prepare three vehicles simultaneously for the testing and save overall testing time.

Design, Simulation and Validation of Security Bollard

Protection against explosive threats and vehicular impact threats has steadily increased post various attacks at various places in the world. Building security has become priority and is defined by an exterior perimeter to provide safe distance from Vehicle Borne Improvised Explosive Device (VBIED). This exterior perimeter is accomplished by designing vehicle barrier system (VBS) capable of stopping design malevolent vehicle load within the building site protection perimeter.

There are many potential barrier options to consider while designing VBS. One of them is bollard, which is a vertical pole protruding from the ground to very less but visible height. It is commonly used as vehicle barrier for regulating traffic and can also be used for stopping suspicious vehicle from entering in the restricted area. The security bollards are rated with regard to their energy absorption capacity during such vehicular impact. Rating is dependent on the bollard performance and its effectiveness towards stopping the vehicle of certain weight moving at certain speed. Bollard testing and subsequent security rating is assigned as per ISO-IWA 14-1:2013 which is used globally.

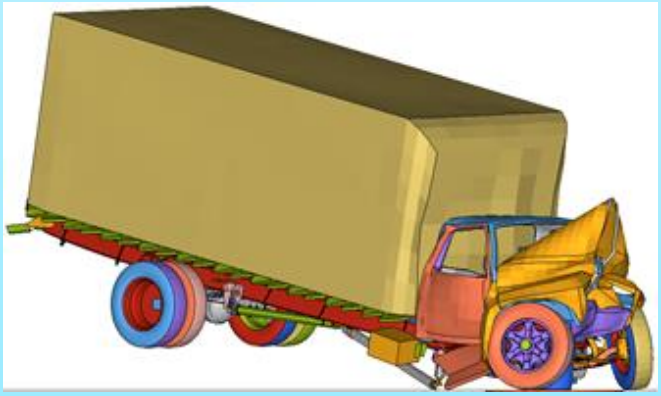
CAE Section of ARAI has been working in the area of automotive crash simulations for a long time. It has developed robust methodologies up to the level of certification of vehicles based on CAE results. Identifying this demand for vehicle barriers, CAE has extended its services to design and evaluate vehicle security barriers and other such non-automotive applications.

Such a security bollard was jointly designed by ARAI and a bollard manufacturing company, for stopping the vehicle of 7200 kg weight at 83 km/h (energy equivalent = 1900 kJ).

Design of experiments (DoE) techniques were used for shortlisting the critical design parameters of bollard tube. The designed bollard was validated successfully at Horiba-MIRA, UK. Deformation pattern of bollard FE simulation was well correlated with physical the tests.

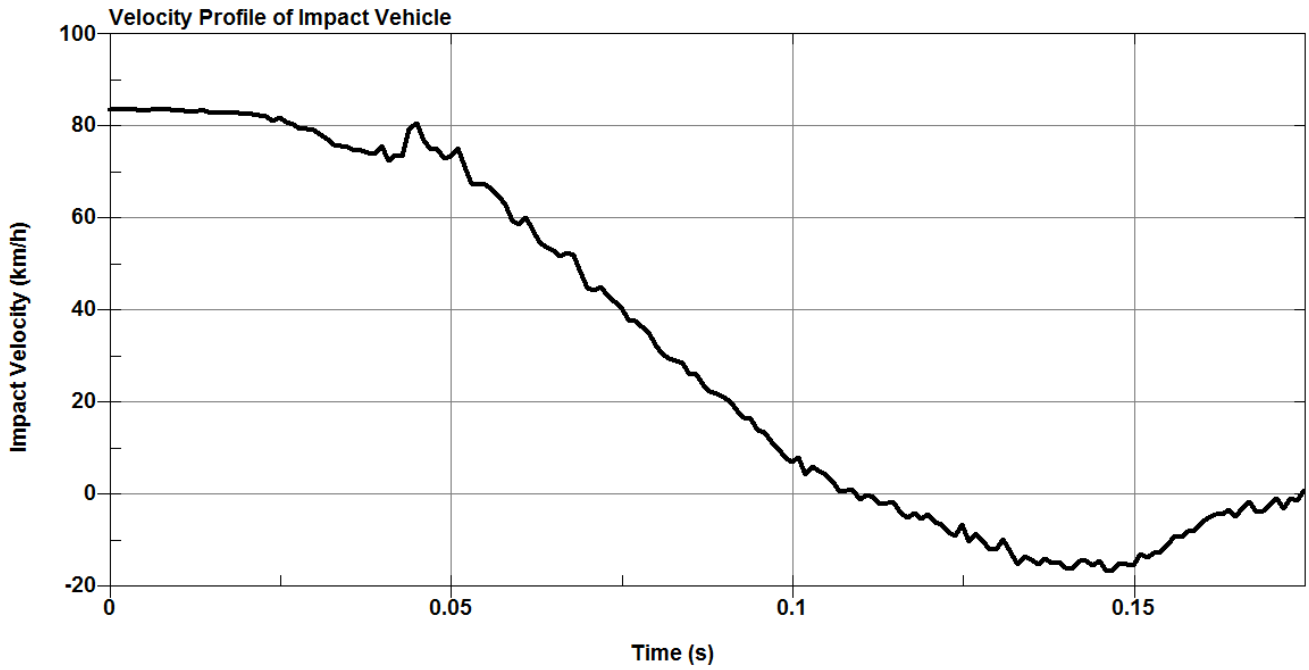
FE Simulation (Before Impact)

Physical Test (Courtesy Swaraj Secutech Pvt. Ltd.)



FE Simulation (After Impact)

Physical Test (Courtesy Swaraj Secutech Pvt. Ltd.)



ARAI Expands its EMC Test Facility

Establishment of 2nd EMC Chamber

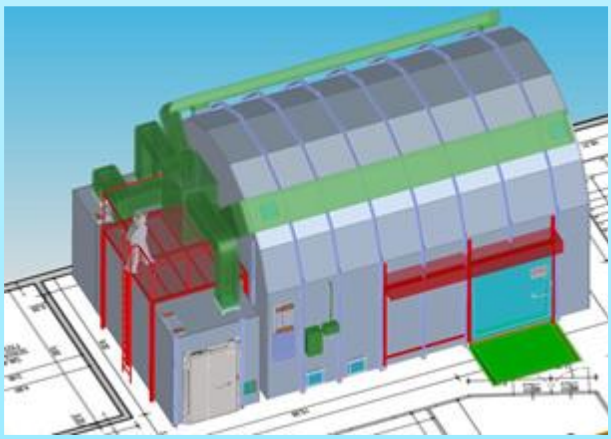
Capable of Testing

- Automotive Electronics Components
- 2-wheelers / 3-wheeler
- Industrial Electronics
- Defence Electronics
- Wireless Technologies
- Medical Devices

Accredited to ISO/IEC 17025

- Dimensions (L X W X H): 8.8m X 6.5m X 6.2m
- Turn Table: 1.5m diameter
- Antenna Mast: 1 to 4m Antenna height scans
- Optical converters for CAN, LIN, RS-232, RS-485, USB
- Audio / Video monitoring of Device Under Test

Shortened Lead Time



ARAI has "Under One Roof" facility for evaluation testing of automotive electronics. ARAI can assist industry by providing services at various stages of product development cycle.

1. **Capturing Customer Requirement**
    - Consultancy for applicability and Design Verification Plan
    - Customized Load-Box

2. **Design Validation EMC**

    With Automotive domain knowledge and experience of 1000 man-months, ARAI can offer consultancy for
    - Design Improvements
    - Identification of potential Failures
    - EMC Audit of PCB layout

3. **Design Validation Environmental**
    - Design Improvements
    - Identification of potential Failures
    - Thermal Audit of PCB layout

4. **Failure Analysis**

    Detailed failure analysis can be done using tools such as EMI Scan Tool, Thermography, Stereo Microscope, Material Analysis, etc.

Thermal Imaging Camera 	**Application:** Thermal imaging or thermography, detects heat patterns or temperature change in objects / assemblies. This helps to identify hot spot / defective components or heat generating sources from the entire assembly. Example Printed Circuit Board, Enclosure, Exhaust System, etc.
Digital Stereo Microscope 	Digital stereo microscope is used to perform high magnification Inspection of various parts and assemblies with microscope and Digital camera integrated. Non-destructive inspection essential in failure analysis (cracks, breaks, discontinuities, etc.) can be accomplished by means of varied zoom level. Zoom Range: 10x-80x using 1x objective and up to 160x using 2x objective.
EMI Scan Tool 	**Application:** Near field measurements for printed circuit boards, other electronic parts and wirings thus taking care of EMI problems at design stage itself. ❑ Frequency Range : 150 kHz – 3000 MHz ❑ Scanning Area : 300 x 350 mm ❑ Scanning Resolution : 1mm x 1mm

5. Design Modification

Based on failure analysis, recommendation for design modification such as PCB re-layout, enclosure modification, component selection for EMI suppression / filters, etc.

6. Validation Trials

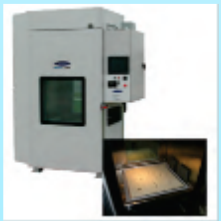
ARAI can offer its state-of-the-art testing facility on utilization basis to customers for perform Validation trials.

7. Product Validation and Compliance Testing

- All facilities are under-one-roof
- Automotive Domain Knowledge
- MOU with International Authorities for certification support
- Accreditation as per ISO/IEC 17025
- State-of-the-art test facility
- Trained engineers

EMC Test Facility	
Radiated Emission (RE) Test	Radiated Immunity (RI)-Antenna Method
Radiated Immunity (RI)-TEM cell method	Radiated Immunity (RI)-BCI method
Radiated Immunity (RI)-Strip line method	Immunity against Handheld Radio Transmitters
Magnetic field Immunity	Copper shielded room for Conducted Emission
Conducted Transient Immunity	Conducted Transient Emission
EMI/EMC testing on industrial Electronics	Electrostatic Discharge (ESD)
Electrical Safety Analyser	EMI Scan Tool
Environmental Test Facility	
HALT/HASS Facility	Combined Temperature & Vibration
Universal Oven	Thermal Shock
Sine/Shock/ Random Vibration	Thermal Imaging Camera






Seminar on Tyres – Technology and Regulations

Seminar on Tyres – Technology and Regulations on 7th August 2015 was greeted with enthusiastic response and participation from practicing engineers, scholars and students in engineering discipline.

The event, presided over by the Mrs. Rashmi Urdhwareshe, Director – ARAI, was inaugurated by Mr. S. S. Mugali, Director, BIS – Pune, witnessed presence of renowned speakers from tyre and allied industries.

- Mr. Vinay Vijayvargia, Secretary, ITTAC, India
- Dr.Thomas Becherer, Continental Reifen Deutschland GmbH, Germany
- Dr. Stephan Koehne, Testing Services, Germany
- Mr. Mario Calvitti, APTC – Bridgestone, Thailand
- Mr. Ashutosh Jha, Michelin, India
- Mr. Steve Sattler, MTS, USA
- Mr.J. H. Kim, China Certificates Technology, South Korea

Inauguration: **(From left) Shri. Vinay Vijayvargia, Shri. A. V. Mannikar, Shri. S. S. Mugali, Mrs. Rashmi Urdhwareshe**

The technical sessions started with the inaugural address by Shri. S. S. Mugali, Director – BIS Pune, which focused on role of BIS in standardization and certification of tyres in India. The talk titled – "Role & Functioning of ITTAC in Tyre Standards and related Aspects" by Mr. Vinay Vijayvargia, Secretary, ITTAC, was an account of Indian tyre industry and the responsibilities of Indian Tyre Technical Advisory Committee in tyre standardization. He also spoke about the publications and tyre safety campaigns introduced by ITTAC for the benefit of consumers.

Dr. Stephan Koehne, Founder – Testing Services GmbH educated the audience about tyre testing requirements as per ECE R 117. He also elucidated tyre labelling requirements established in Europe. Dr. Thomas Becherer, Manager (Standards & Regulations EMEA) enlightened the listeners on the requirements, relevance and consequences of ECE R 117. In his presentation he covered the need for laboratory alignment in rolling resistance measurement and analyzed various aspects of wet grip braking test.

Mr. Ashutosh Jha, Product Category Manager for Africa India and Middle East, Michelin, deliberated the relevance and contribution of rolling resistance in the fuel consumption of road vehicles. He described the efforts and studies initiated by Michelin towards progress in this regard. Mr. Mario Calvitti, Asia Pacific Technical Centre – Bridgestone, Thailand presented Next Generation Ecology Tire Technology developed by Bridgestone. The objectives credited to this initiative are – low CO_2 emissions, Ultra low rolling resistance coefficient and aero drag reduction.

Mr. Steve Sattler, MTS – USA, gripped the participants with testing capabilities of various machines and equipment developed by MTS. Videos depicting fascinating world of tyre testing aided Mr. Steve Sattler to reach out the audience. Mr. J. H. Kim, President, China Certificates Technology, Korea elaborated global certification requirements for tyres with glimpses of certification process in China, Taiwan, Brazil, Indonesia, Vietnam, Mexico, South Africa and Philippines as he progressed through the presentation.

Presentations by various ARAI Executives, addressed the variety of activities carried out in the field of tyres – Technology and Regulations in nutshell. Mr. N. B. Dhande, Sr. Deputy Director, (Business Development and Corporate Planning), ARAI, introduced the activities of ARAI to the audience. This was followed by presentation by Mr. N. V. Karanth, Sr. Deputy Director, NVH - ARAI on the activities of NVH lab in tyre testing. The Presentation by Mr. P. R. Pawar, Dy. General Manager, Structural Dynamics Lab, described the activities and capabilities of Structural Dynamics Laboratory at ARAI in the field of tyre and vehicle dynamics.

Mr. Abdullah Jamal, Deputy Manager, Vehicle Evaluation Lab (VEL), ARAI, presented on-field test possibilities offered by VEL and Mr. Thomas Cherian, Deputy Manager, Safety & Homologation Lab (SHL), ARAI, encompassed in his presentation, tyre homologation services offered by ARAI.

Panel Discussion on “Significance of Rolling Resistance, Wet Grip Adhesion, Tyre Noise Regulations and Tyre Labelling in India” was a much sought-after session of the event. The Panel members:

Mr. A. Akbar Badusha, Deputy Director, VEL-ARAI-Moderator
Dr. P. Chattaraj, NATRAX
Dr. Thomas Becherer, Continental
Mr. Ashutosh Jha, Michelin
Mr. Mario Calvitti, Bridgestone
Mr. Manoj Jacob John, MRF Tyres

Panel Discussion: (From left)- Manoj Jacob John, Dr. Thomas Becherer, A Akbar Badusha, Dr. P Chattaraj, Mario Calvitti, Ashutosh Jha

Panel discussion started with the address by the moderator, Mr. Akbar Badusha, who introduced the topic and set the tone for discussion. Panel Members presented their views on the topic and responded to the queries from the moderator and the audience, resulting in an interactive session. Panel highlighted the requirements and benefit of rolling resistance of tyres. Tyre labelling, comprising of rolling resistance, wet grip and noise is a mandatory requirement in many countries. Panel debated on the readiness of Indian tyre manufacturers for tyre labeling. Eying export market, very few manufacturers have started this activity. Presently no test facilities related to tyre labelling are available in India and test outside India is expensive and time consuming. The topic of rolling resistance requirements is under discussion in one of the BIS committees, viz. TED 6. Panel highlighted that - before making these requirements mandatory, focused assessment of road quality is necessary because rolling resistance mainly depends on the road quality.

The gathering of over 120 participants at the seminar constituted practicing engineers of tyre manufacturing companies, regulatory agencies, researchers and students. The participants visited Tyre Testing Lab of ARAI.

Tyre Testing Facilities

The event concluded with the Valedictory Function and Vote of Thanks by Mr. B. V. Shamsundara, General Manager, SHL - ARAI. Inspired by the overwhelming response, tentative date of the seminar for next year was announced 18 – 19 August 2016.

❑ ARAI offers Indigenously Developed Downsized 3 Cylinder High Power Density CRDI Diesel Engine Design

ARAI has indigenously designed and developed **state-of-the-art 3 Cylinder, CRDI, downsized high power density diesel engine** with specific power capability of **75kW/lit and 26 bar BMEP level**. Mechanical and thermal design of the engine is prepared for maximum operating combustion pressure of 200 bar, making the design best suitable for medium sized passenger cars, LCV, SUV and hybrid electric vehicle applications. Engine development was programmed in two phases with Phase-I target as 75 kW@4000 rpm delivering max Torque 235 Nm@2000rpm and in Phase-II, performance target is 115 kW@4200 rpm delivering max torque 310 Nm@2000rpm.

Newly designed 3-cylinder engine prototype has successfully delivered its Phase-I power and max torque target of **75 kW** (50 kW/l) **and 235 Nm** with minimum BSFC of **210 g/kWh** and peak pressure reaching **168 bar.** The prototype engine has successfully **completed 500 hours of durability testing, stabilizing base mechanical design of systems.** Engine components are examined for their quality after the durability and found in acceptable condition as per the standard criteria. Three more engines are being built, which will be used for combustion optimization and assessing vehicle performance parameters.

Combustion refinement is further scheduled targeting **112 kW** (75 kW/l) with lower levels of BSFC and emissions meeting Euro-VI.

Engine design offers box dimension of 634x670x669 mm (LxWxH) and weight-to-power ratio of **1.9 kg/kW (@75kW/lit),** compared to benchmark engines varying from 1.6~2.0 kg/kW for similar type of applications.

Fig 1 : ARAI 3 CYL High Power Density Diesel Engine

Salient Features of the ARAI 3-Cylinder Engine

- ✓ Design Capability for 200 bar peak combustion pressure (26 bar Max BMEP).
- ✓ Compacted Graphite Iron (CGI) Material for cylinder head and engine block for higher ratings.
- ✓ Ladder frame structure housed mass balancing system - primary and secondary mass balancing system for complete engine inertia balancing.
- ✓ High alloyed steel crankshaft with fracture split connecting rod.
- ✓ Dry cylinder liner machined with torque plate approach for cylinder bore honing to get controlled bore deformations.
- ✓ Multi-layer cylinder head gasket with 6 bolts per cylinder.
- ✓ 4 valve per cylinder layout with double overhead camshafts.
- ✓ Hydraulic Lash Adjusters (HLA) for controlled valve train dynamics and serviceability point of view.
- ✓ Timing chain drive on the rear side for improved NVH and durability of drive system.
- ✓ Aluminum alloy gallery cooled piston capable of withstanding high mechanical and thermal loads @ 200 bar.
- ✓ Third generation 2000 bar CRDI systems with Piezo-electric injectors.
- ✓ Glow-plugs for instant engine start during cold conditions.
- ✓ Cooled progressive high pressure EGR.
- ✓ Start / Stop Featured PMSM Starter Motor.

<u>Achieved Phase-I Performance:</u>

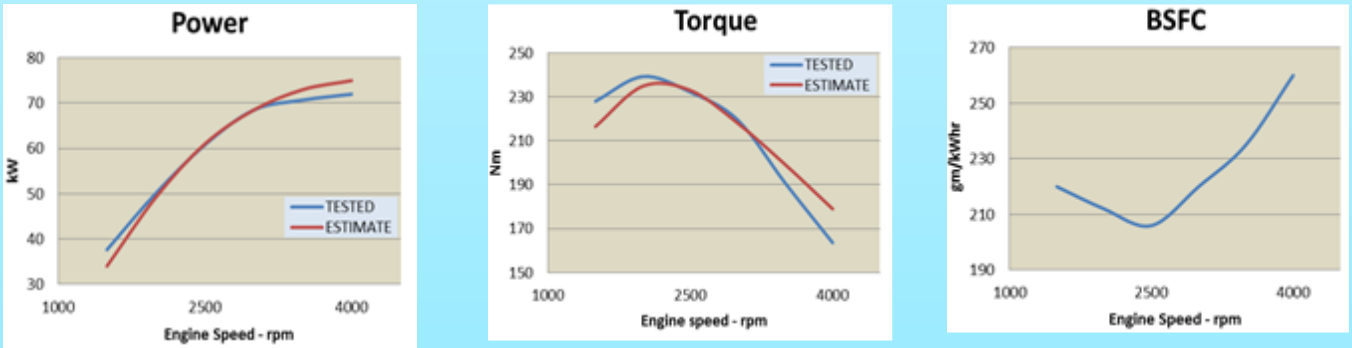
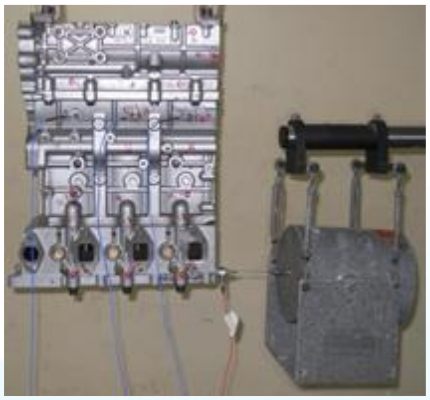


Fig 2 : Phase-I Engine Performance

Engine build has been validated for its NVH behavior with good correlations observed between simulation predicted and experimental modal behavior.



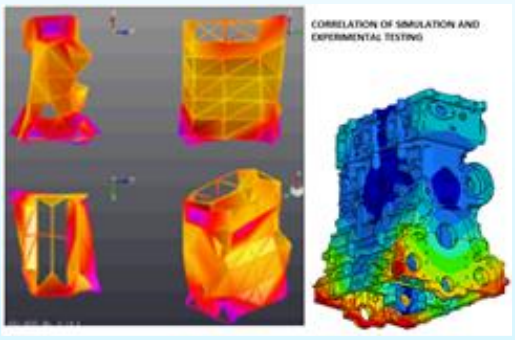


Fig 3: Engine Block Assembly Modal Testing

Fig 4: Connecting Rod Fatigue Testing

Fig 5: Crankshaft Fatigue Testing

Component level fatigue testing has been carried out for critical components such as cylinder block, cylinder head, crankshaft and connecting rod withstanding engine loads generated due to 200 bar combustion pressure. Components have passed tests with satisfactory results as per industry standards.

Fig 6: Off-Shoot Design 1 lit 2-CYL Diesel Engine

Based on the base three cylinder engine configuration, design-on-paper is available at ARAI for 2 cylinder (1 liter) and 4 cylinder (2 liter) design versions. 2, 3 and 4 cylinder engines can be used in variety of applications, including off-road and stationary.

2-cylinder diesel engine, in its compact form, would suit specially for small passenger and goods transport vehicles needing power capability ranging from 40-60 kW. This engine size is also suitable as range extender engine and hybrid systems.

This R&D project is aimed at developing advanced diesel engine technology at ARAI to be offered to engine and vehicle manufacturers globally for passenger car / light motor / SUV / hybrid electric vehicle applications. The engine, in its present form or with necessary peripheral changes, can be adapted for specific application layout.

De-featured versions of engine is also suitable for high performance off-road applications in Tractor, CEV and stationary applications.

ARAI has also developed suitable transmission system for this three-cylinder engine, thus offering complete powertrain solution to interested vehicle manufacturers.

Down Sized Power Plant for Hybrid Electric Vehicle Technology

Developed engine and its offshoot designs are perfect candidates as downsized power plants along with suitable electric drive technology to make full parallel Hybrid Electric Vehicle configuration. For example, Phase-I engine (75 kW) can be coupled with electric motor having power range as 25-60 kW. This combination will result in mild and full parallel hybrid electric vehicle architecture. Use of this downsized engine (75 kW) along with suitable electric motor rating to get degree of hybridization in the range of 20-45% will be an optimum solution towards meeting futuristic CO_2 emission norms and fossil fuel economy improvements in the range of 15-30%. Rear timing drivetrain offers advantage of reduced torsional vibrations as an input to complex Hybrid Electric Vehicle Transmission, which is an inbuilt advantage of the developed engine.

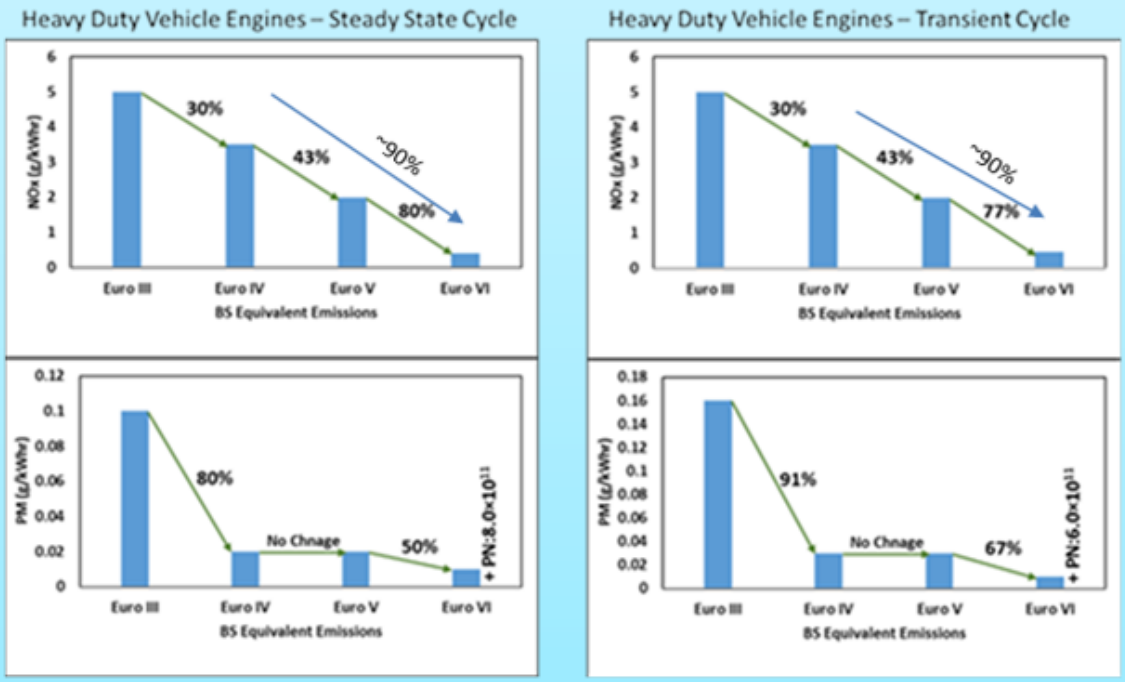
ARAI invites interested OEMs with an intention to share the "Indigenously Developed Engine Technology with Off-shoot Design Versions in their Product Portfolios".

ARAI offers to perform full package of development work from suitable engine layout modifications around the developed architecture, combustion and emission development, association in prototyping and production phases, etc.

❑ Advanced Diesel Combustion Concept: PCCI – A Step Towards Meeting BS VI Emission Regulations

Background of the Work

- Roadmap for BS VI emissions is under execution and Graph 1 given below show reduction requirement in NOx and PM emissions with respect to the previous stages for heavy duty engines (reference – European emissions) and similar reductions are required for other sectors also.
- NOx-PM and NOx-Fuel consumption trade-off would be great challenge for diesel engines to meet these upcoming stringent emission norms, which require expensive and complex after-treatment solutions. Moreover, diesel engines are facing strong competition from gasoline and other alternative fueled engines. After-treatment solution increases overall Cost of Ownership (COO)

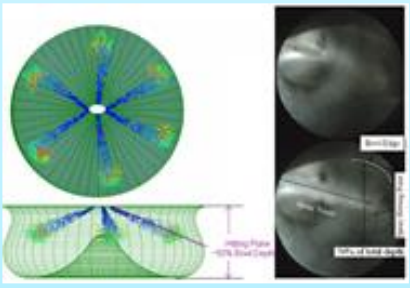


Graph 1: Emission Reduction Required

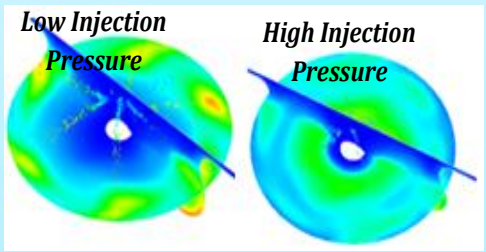
Observations and Results:

- In PCCI combustion, total heat energy is released in few crank angle duration leading to very high in-cylinder pressure, which is a critical aspect to control. Extensive 1-D/3-D simulation carried out to determine optimum operating control parameters, e.g. compression ratio (CR), bowl, injection pressures, nozzle configuration, EGR ratio and temperature, EGR mixture, boosting system, etc. This approach helps to run engine on PCCI mode without any damage to engine.
- EGR mixer designed to minimize cylinder-to-cylinder variations to minimum level so as to control engine instability.
- Fuel injection pressure, pilot quantity, pilot separation, EGR ratio and temperature, etc. tuned to operate engine in PCCI mode and expand operating zone.
- Fundamental understanding of PCCI and Conventional DI combustion, injection start, injection end, spray travel, start of combustion, combustion flame travel and flame intensity, NOx and Soot traces at various operating points analyzed using high speed photography.
- In initial stage, PCCI mode optimized from 10 to 50% load region and conventional combustion mode used for higher load regions with this configuration.
- With 2valves/cyl, WGTC and DOC loading of 15 g/cft, BS IV emissions achieved with 3% improvement in fuel efficiency.
- Same concept used for constant speed genset application and meet stage-2 emissions with margin and good fuel efficiency.
- Below given graphs (Graph 2 to Graph 8) show the approach and analysis performed in this study.

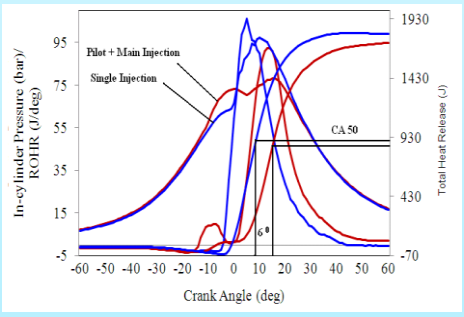
Air-fuel Interaction Study with Injection Pressure



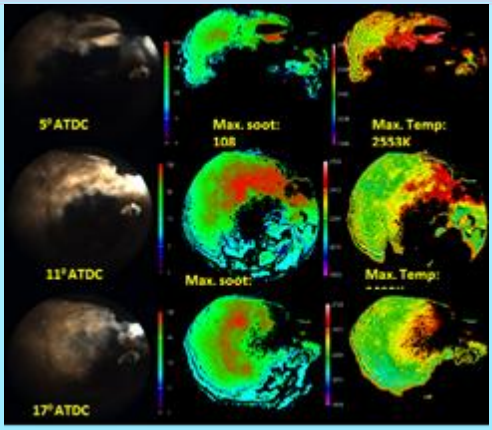
Graph 2: Bowl design & Spray Bowl Matching



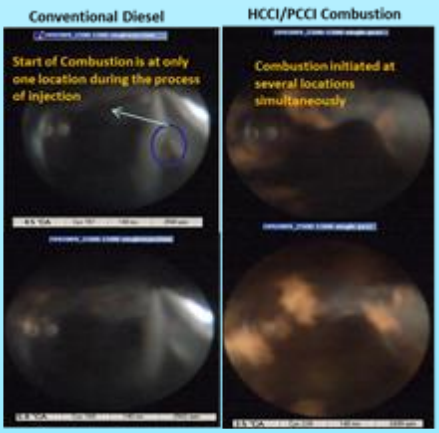
Graph 3: Mixture homogeneity study



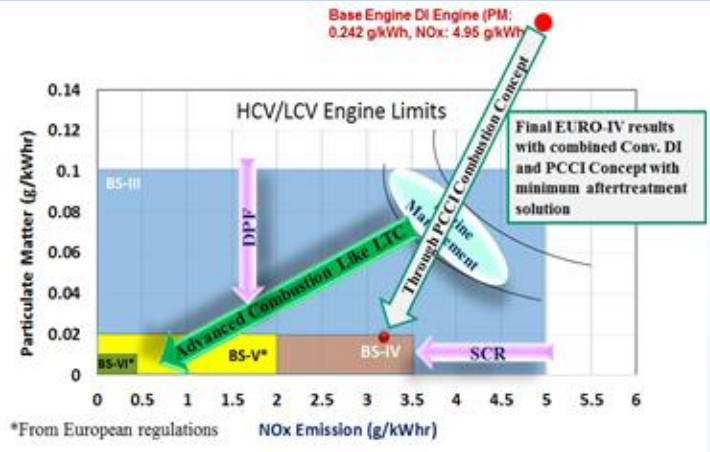
Graph 4: In-cylinder Analysis



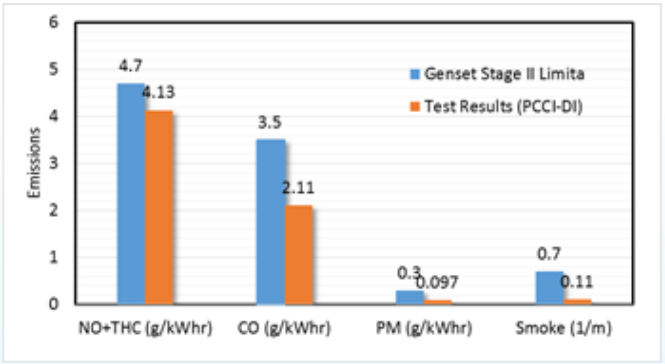
Graph 5: In-cylinder Soot/NOx/Temperature Analysis in PCCI Mode



Graph 6: Conventional DI and PCCI Combustion



Graph 7: Advanced combustion techniques with very low DOC loading, 2valve/cyl, WGT TC and it shows the potential of technology to meet future emissions



Graph 8: shows meeting Genset Stage-2 Emissions without exhaust after-treatment system

Further Work

With this base work on PCCI combustion technology, ARAI has commenced working on "Low Temperature Combustion (LTC)" concept with an objective to develop technology solution to meet-

- BS-VI emissions with low cost / low complexity after-treatment solution
- Up to 5% fuel efficiency improvement over base engine configuration

❑ Launch of ARAI Golden Jubilee Celebrations

ARAI, established way back in 1966, has been playing commendable role over the years in assisting the Automotive and Allied Industry in development and testing of their products so as to manufacture safe, fuel efficient and eco-friendly mobility. ARAI, in its 50 year of existence, is celebrating Golden Jubilee this year.

While serving the Automotive Industry and the nation over the period of 50 years, ARAI has become the backbone of Indian Automotive Industry. ARAI is a leading homologation, testing and research centre in India and recognized world over. Looking back, it has been a momentous journey, from being as a testing agency to emerging as a renowned global R&D Institute.

Golden Jubilee of ARAI commenced with the Launch of Jubilee Celebrations on 3rd January 2016 at the auspicious hands of Hon'ble Chief Minister of Maharashtra, Shri Devendra Fadnavis and in the august presence of Dr. K. Sivan, Director, Vikram Sarabhai Space Centre, Thiruvananthapuram; Dr. Abhay Firodia, Chairman and Managing Director, Force Motors Ltd; Shri Ravi Chopra, Piaggio Vehicles India Pvt. Ltd. Dignitaries from Automotive and Allied Industry and Government of India graced the occasion with their esteemed presence. This event was an amalgamation of past and future as it acknowledged the history and at the same time envisaged the future.

Hon'ble Chief Minister unveiled ARAI's Golden Jubilee Logo in the presence of a large gathering. While commending the role played by ARAI in the past, he appreciated ARAI's vision and the technology roadmap prepared by ARAI for the future. He further mentioned that the whole world is looking at India and the institutes like ARAI, should necessarily evolve new techniques and develop new technologies and lead the way in taking Indian Automobile Industry ahead. Shri Ravi Chopra, in his welcome address, touched upon ARAI's rich history of achievements and glories. Dr. Abhay Firodia, Chairman Force Motors, addressed the gathering on evolution of India from a market place to a manufacturing hub of automobiles.

Dr. K. Sivan, Director, Vikram Sarabhai Space Centre (ISRO-VSSC), in his address, announced that ARAI and VSSC are working for development of energy storage devices for Electric Vehicle (EVs) & Hybrid Electric Vehicle (HEV) applications. He further mentioned that space technologies are being increasingly used in day-to-day life, like digital camera, which uses technology invented for spacecraft. He also informed about development of 'super hydrophobic material that is fire resistant' by our scientists.

As a prelude to the documentary on Automotive Industry in India, ARAI showcased a small montage of this great Indian automobile story. ARAI's plans of setting up of an automotive industry museum, displaying journey of India's automobile industry over the years, was also presented. Mrs. Rashmi Urdhwareshe, Director – ARAI, expressed that the "blueprint for the automotive museum project is ready and ARAI is in discussions with various stakeholders to finalize the plan".

Over the years, ARAI has metamorphosed from setting up tools, testing and validation, building expertise, then to research and IP generation phase. ARAI showcased its capabilities and achievements in ARAI Pavilion titled "**Building Automotive Excellence**" during the launch of Golden Jubilee Celebrations. The pavilion highlighted ARAI efforts in areas of –

- Driving Green Mobility
- Striving for Safety
- ARAI's role in "Make In India" initiative

In Green Mobility zone, a small public transport electric commercial vehicle, developed by ARAI was displayed. It also showcased ARAI's efforts in promoting e–mobility through technology developments to skill development, as well as its role in FAME-India. ARAI also showcased its capabilities in alternate and environment-friendly fuels such as use of ethanol or technology for dual fuel, i.e. Diesel and CNG (two fuels simultaneous). It also showcased its capability in engine development for various on-road and off-road applications.

In Safer Mobility zone, it showcased its studies in vehicle-road interaction, technologies such as Integrated Safety System, which includes ABS-ESP; Adaptive Front Lighting System for enhanced visibility; work on Steering system for improving driving comfort as well as reducing turning radius; which are very useful for commercial vehicles. Concepts like emergency call: E-call was also demonstrated.

Pavilion also highlighted ARAI's efforts for Cleaner and Safer Environment, which showcased efforts and achievements in the areas of fuel efficiency improvements and climate change; Air Quality Management as well as setting up Inspection and Certification regime across India.

ARAI
YEARS OF BUILDING AUTOMOTIVE EXCELLENCE
1966 - 2016

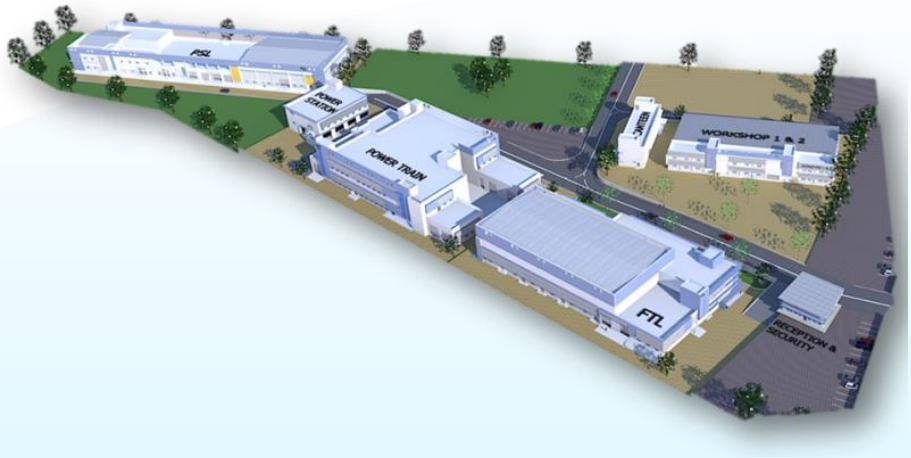
During the event, ARAI's support for "Make in India" was highlighted through "Design in India", "Innovate for India", "Validate in India".

❑ Inauguration of ARAI Homologation and Technology Centre (HTC), Chakan on 4 Jan 2016

Shri Anant Geete, Hon'ble Minister of Heavy Industries & Public Enterprises, Government of India, inaugurated "ARAI Homologation and Technology Centre" in the industrial / automobile hub at Chakan (near Pune), in the august presence of Shri Shivajirao Adhalrao Patil, Hon'ble Member of Parliament; Shri R K Singh, Joint Secretary (DHI); Shri Abhay Damle, Joint Secretary, Ministry of Road Transport & Highways; Shri Sanjay Bandopadhyaya, CEO and Project Director (NATRIP); Shri Nitin Gokarn, Former CEO and Project Director (NATRIP); Shri Rajan Wadhera, President – ARAI and Shri Vikram Kirloskar, Vice President – ARAI. A large gathering of dignitaries from the Government of India and Automotive and Allied Industry were present on this momentous occasion.

Hon'ble Minister, in his address, highlighted the need of creation of this Centre and appreciated the efforts taken by ARAI and NATRIP in setting up this Centre and the support extended by Ministry of Heavy Industries & Public Enterprises in all respect.

ARAI Homologation and Technology Centre has been set-up under Government of India's National Automotive Testing and R&D Infrastructure Project (NATRiP). This project is for creating core global competencies in automotive sector in India. This centre is situated in Phase-III of MIDC, Chakan near Pune, which is an industrial hub, and hence, has close proximity to end-users, i.e. automotive and component manufacturers. The main aim of creation of this Centre is to cater to the growing development and testing needs of the auto and allied industry.



Following laboratories established at this centre are now operational:

- Passive Safety Laboratory
- Powertrain Laboratory
- Fatigue & Materials Laboratory
- Automotive Electronics Laboratory

The facilities established in Powertrain and Fatigue & Materials labs are for creating ***Centres of Excellence in Powertrain, Fatigue and Materials.*** Powertrain laboratory is for testing of vehicles, engines & powertrains and other accessories for their performances with respect to power, efficiency, exhaust emissions, etc. Fatigue & Materials laboratory is for prediction of structural failures and evaluation of vehicular structural components, systems & sub systems, and chassis / full vehicle subjected to real life dynamic loading conditions. The facilities in Passive Safety laboratory are for providing homologation support for upcoming crash regulations and upcoming Bharat New Vehicles Safety Assessment Programme (BNVSAP), a safety star rating system for India.

Also, state-of-the-art testing infrastructure for testing of electric and hybrid electric vehicles is being developed at this Centre under Government of India's FAME-India Scheme.

Powertrain Laboratory – *Centre of Excellence*

This laboratory will be used for testing of vehicles, engines & powertrains and other accessories to assess performance with respect to power, efficiency, exhaust emissions, etc. It consists of different types of engines / chassis dynamometers, controlling and measuring equipment, and instrumentation. The laboratory and test cells will be climatically controlled and fitted with advanced systems for fire protection, telecommunications and data transfer for ensuring confidentially.

Facilities at Powertrain Laboratory

The laboratory is treated acoustically for controlling noise pollution. The major facilities in this laboratory include:

- Vehicle Test Cell (CVTC) to test vehicles up to Light Commercial Vehicle (LCV) category using 4 x 4 Chassis Dynamometer for performance and emission tests
- Climatic Soak Room (-30° C to 50° C)
- Vehicle Test Cell (VTC) to test up to Light Commercial Vehicle (LCV) category using 4 x 4 Chassis Dynamometer with controlled climate with temperature of 25° C ± 3° C associated with humidity control for emission tests
- Soak Room for above test cell with temperature of 25° C ± 3° C
- Mileage accumulation test cell with 4 x 4 Chassis Dynamometer for endurance testing
- Test Cell for Transmission / Gear box performance testing
- Variable Volume / Variable Temperature (VV / VT), Sealed Housing for Evaporative Determination (SHED) Area

Fatigue Testing Laboratory – *Centre of Excellence*

This laboratory can predict structural failures and evaluate vehicular structural components, systems and sub-systems and chassis / full vehicle subjected to real life dynamic loading conditions. It provides seismic foundations, super strong floor areas to sustain reaction loads of very high magnitude and a high-pressure, high-volume centralized hydraulic power system with its distribution through an underground piping network. The major facilities in this laboratory include:

- Climatic MAST facility for components
- Climatic 4 Poster for LCV
- X Poster
- Universal Test Benches with maximum capacity of 500 kN
- HPS of 2600 LPM (expandable to 4000 LPM), 210 bar with piping network through subsurface trenches and a pump house as plant room
- Electro-dynamic Shaker with climatic chamber
- Instrumentation and vehicle preparation area

Facilities at Fatigue Laboratory

Passive Safety Laboratory
This laboratory provides homologation support for upcoming crash regulations and Bharat New Vehicles Safety Assessment Programme (BNVSAP), a safety star rating system for India. This facility will help in building safer, crash-worthy and pedestrian-friendly vehicles.

Facilities at the Passive Safety Laboratory

The major facilities include:

- Main crash hall
- Climatically controlled vehicle preparation area
- 500 HP drive system to propel test vehicle
- Underground Photo Pits
- Climatically controlled instrumented dummy room
- Climatically controlled calibration laboratory
- High speed videography setup with image analysis software
- Movable high intensity lighting system at truss level
- Pedestrian Safety Laboratory
- Sled facility with programmable stopping device

Automotive Electronics Laboratory

One of the key elements of successful implementation of the National Mission for Electric Mobility (NMEM) is establishment of facilities for testing of electric and hybrid electric vehicles. ARAI is assisting the Government in formulation and development of electric and hybrid vehicle regulations, norms, policies, etc. State-of-the-art testing infrastructure for testing electric and hybrid electric vehicles is being developed at this centre under FAME-India Scheme of Government of India. The major facilities in this laboratory include:

- 100kW Motor Test Bed
- 250kW Motor Test Bed
- HCV Chassis Dynamometer with Emission Measurement System
- Battery Performance Test System
- 100kW DC Power Supply, 450V/200A
- 250kW DC Power Supply, 800V/600A

Embedded Software Testing and Validation

With the increase of Embedded Control Software content within vehicles, the concerns related to functional safety aspects due to software are also increasing. Due to involvement of high volume, it is utmost important to control cost of automotive embedded systems. Finding software bugs before a product is released is the key to avoid damage to product brand and direct costs associated with product recalls. With the emergence of standards like ISO 26262, which act as guideline for embedded system development, software testing has become important aspect in product development cycle. This makes software testing and validation necessity for the Automotive Industry.

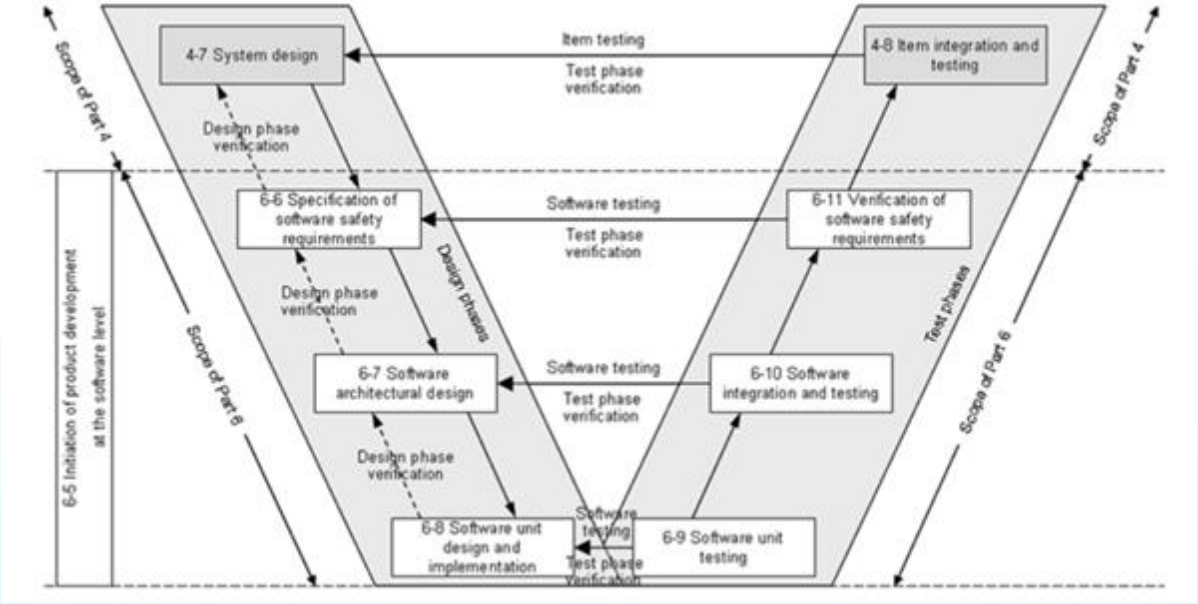
ARAI is now ready with advanced Tool Chain to assist automotive industry in “Software Testing and Validation”.

Main services offered in this area are -

- Software Testing for Coding Standard compliance as per MISRA / any customized standard
- Software black box and white box testing
- Verification of Requirements Traceability
- Dynamic Testing on EUC hardware level
- Software verification as per ISO 26262 guidelines

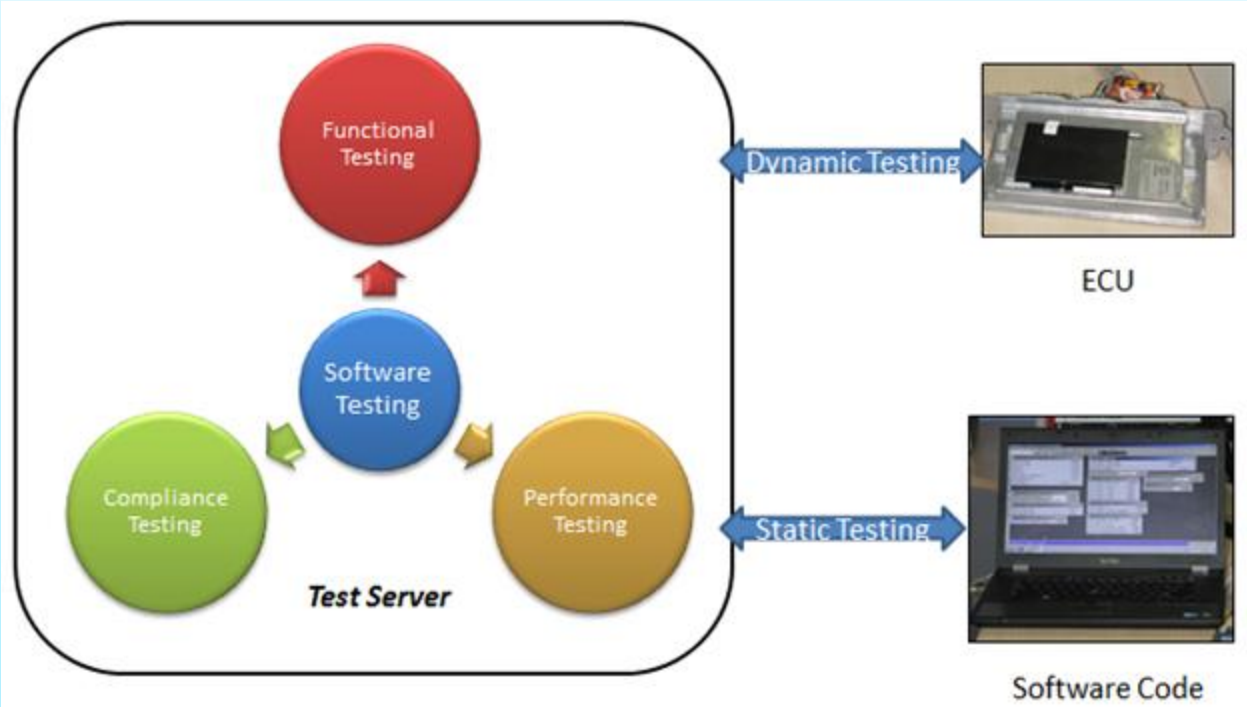
Tool chain is based on Industry renowned Tool Suite, which is certified for safety-critical development in the automotive industry, under ISO 26262-8:2011.

This tool chain will aid developers throughout software development process outlined by ISO 26262 as per following V-Model diagram



To safeguard IP of customer software code, we have established server based tool chain, wherein customer can log onto ARAI server and use license to test their software without disclosing any confidential data. Software will be tested and reports will be automatically generated on the server.

The block diagram of the setup is given below.



For further details, please contact -

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ARAI Participation in Auto Expo 2016 at New Delhi and Motor Show at Greater Noida - 4-9 February 2016

ARAI participated in Auto Expo 2016 (Components & Vehicle) at Pragati Maidan, New Delhi & Motor Show at Greater Noida, during 4 - 9 February 2016.

In this Expo, ARAI displayed its capacity and capabilities in the areas of Vehicles, Components and Sub-system, Research & Development, Certification and Testing, mainly in line with **Make in India** theme that includes ARAI Journey towards Make in India, Design in India, Innovate for India, Validate in India and Skill Development. Along with above initiatives, we have displayed ARAI developed products like Clutch Test Rig, Engines for various applications, ECUs, etc.

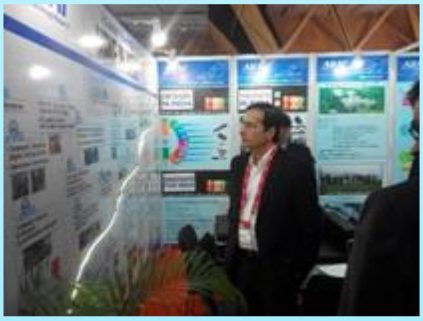
Also published 1st announcement of Symposium on International Automotive Technology, 2017 (SIAT 2017). This is a biennial and highly appreciated technical event in the area of automotive technologies hosted by ARAI.

As a Brand building initiative for ARAI, participation in this major exposition provided unique opportunity to reach out to its wide customer range & update them on various R&D and certification capabilities & expansion plans.

ARAI received overwhelming response in this Expo from auto industry with many important and key executives visited ARAI stall that includes Mr. Rajan Wadhera, Mr. Anant Talaulicar, Mr. Kirti Rathod, Chairman – ACMA Western Region and visitors from domestic and overseas delegations, viz. Nigeria Govt. Delegation, Korea Auto Component Industry, Srilanka ACMA, etc.

Photographs of ARAI Stall at Pragati Maidan, New Delhi and Motor Show at Greater Noida






CALL FOR REGISTRATION

❑ PROGRAMME

		SIAT 2017	SIAT EXPO 2017
18 Jan 2017	Wed	Inaugural Session & Technical Sessions	Inaugural Session & Exhibition
19 Jan 2017	Thu	Technical Sessions	Exhibition
20 Jan 2017	Fri	Technical Sessions	Exhibition
21 Jan 2017	Sat	Technical Sessions & Valedictory Session	Exhibition

❑ REFERENCE TECHNICAL BULLETIN

Reference Technical Bulletin comprising of technical articles, advertisements, etc. will be published to commemorate SIAT 2017. It will provide an opportunity for sharing various technical advancements in automotive technology. Technical notes, case studies, product information, etc. are invited for inclusion in this Reference Technical Bulletin. For more details, please contact: Mr R. S Mahajan, GM, CAE, Email: mahajan.nvh@araiindia.com

❑ CALL FOR REGISTRATION

Invitation for online registration of delegates, delegate fee is payable Online/Cash or through Demand Draft made in favour of ”The Automotive Research Association of India”, payable at Pune, India. Log on to http://siat.araiindia.com for online enrolment. Registered delegates will be entitled to participate in the Symposium, Exhibition, Luncheons, and Cultural Programmes. They will also receive Symposium Proceedings and Delegate Kit.

❑ CALL FOR STUDENT POSTERS

Poster competition for students under the categories of 1) Emission, 2) Safety and 3) Noise, Vibration and Harshness (NVH). For more details, please contact Mr S. S Ramdasi, GM, PTE Email: ramdasi.edl@araiindia.com

❑ SIAT EXPO 2017

A grand exposition of automotive technology, products and equipment pertaining to Auto Industry, is being organized concurrent to SIAT 2017. The exposition will attract automotive OEMs, TIER-I, TIER-II and TIER-III suppliers, equipment providers. CAD/CAM/CAE tool providers and other to showcase their products and service capabilities. This time over 180 exhibition stalls are available for booking. This exposition is open to all automotive personnel and interested individuals and will be an excellent opportunity for promotion of business and dissemination of information.

❑ IMPORTANT DATES

Description	Last Date
Receipt of Abstracts	30 April, 2016
Acceptance of Abstracts	30 June, 2016
Receipt of Draft Manuscripts	31 August, 2016
Receipt of Final Papers	15 November, 2016

❑ DELGATE FEES *

Category	Upto 1st October 2016	After 1st October 2016
Indian Author (first author only)	Rs. 9,000/-	Rs. 10,000/-
Indian Delegate(s)	Rs. 18,000/-	Rs. 20,000/-
Indian Delegates (Group discount for 5 or more delegates from same company)	Rs. 16,000/-	Rs. 18,000/-
Foreign Author (first author only)	US$ 350	US$ 400
Foreign Delegate(s)	US$ 700	US$ 800
Foreign Delegates (Group discount for 3 or more delegates from same company)	US$ 650	US$ 700

- Service Tax extra as applicable.
- Delegate fee is payable in cash or through demand draft drawn in favour of "The Automotive Research Association of India", payable at Pune, India.
- Registered delegates will be entitled to participate in the Symposium Exposition, Luncheon and Cultural Programmes. They will also receive Symposium Proceedings and Delegate Kit.

❑ AWARDS

Technical Papers (Specified Category)	Technical Papers (Open Category)	Exhibition Stalls (Best Display)	Student Poster Presentation Competition Awards
• Best International Paper • Best Oral Presentation • Best Paper on Safety • Best Paper on Simulation & Modelling • Best Indian Paper on Environmental Pollution • Innovation Award on Vehicle Electrification • Mahesh Modi Environmental Technology Award	First Prize Second Prize Third Prize	First Prize Second Prize Third Prize	First Prize Second Prize Third Prize

❑ ***For Registration, Correspondence, please contact:***

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❑ ***For booking of stalls in SIAT EXPO 2017, please contact :***

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