ARAI® Progress through Research Update
Towards Safer, Cleaner & Quieter World ...
Design, Development and Testing Services at ARAI
October - December 2016

ARAI-TIFAC Golden Jubilee Transport Vision Conclave

Theme: Transport Vision for the Future

ARAI has transformed itself from a Test house to globally recognized R&D organization, through its journey of 5 decades. ARAI celebrated its 50th anniversary, the Golden Jubilee of Service to the Nation. As a part of these celebrations, Transport Vision Conclave was organised jointly with TIFAC at ARAI-Pune. TIFAC is the think tank of Department of Science and Technology and works towards developing policies for the future. The theme of the event was vision and roadmap for future transportation in all modes, i.e. land, air, sea and rail. **Transport Vision 2035** roadmap for India was unveiled on the occasion. Distinguished speakers shared their thoughts around the theme of the event, followed by panel discussion, among the panelists representing various modes of transportation. The program was presided over by the eminent scientist, Dr Anil Kakodkar, who is also the Chairman of TIFAC. Poster session was also organized, depicting ARAI's contribution in furthering automotive technology.

In response to the major changes in economic situation, geopolitics and technology domain at global level in the last two decades, TIFAC presented fresh perspective on technology imperatives for India as Technology Vision 2035. **Transportation Vision 2035** roadmap highlights vision for sustainable, clean, safe, inclusive, smart and integrated mobility system. Mobility enhances quality of an individual's life and binds the nation together. By year 2035, technology should enable us to access public transportation within one km from our home. No place will be more than three hours away from district headquarter, five hours from the state capital and eight hours from our national capital. Inter-modal mobility should ensure that no two points in a metropolitan area would be more than an hour away. Every settlement will be connected with an all-weather road and every panchayat will have a helipad for delivery of services such as emergency healthcare. Also, from safe mobility perspective zero pedestrian fatalities should be ensured in all parts of the country. This would require mandatory, technology-assisted driver training. With growing population in urban areas and increasing influx of industrial zones to semi-rural neighborhoods that require 25-50 km of one way travel, providing last mile connectivity through multi-modal means is a huge challenge. Use of ICT to tackle traffic congestion will be essential. Development of vehicles that are twice as fuel efficient but emit half the current emissions will be required.

High quality infrastructure, road transportation technologies and traffic management systems are organically interrelated and should be treated in an integrated manner. In addition, there will be a need for intercity connections through cost-effective modes such as semi-high speed and bullet trains for faster intercity access. Multi-modal mobility for goods and services will need to be enhanced with development of dedicated, high speed freight rail corridors. Last, but not the least, will be the great challenge of developing and producing powertrain for an indigenous transport aircraft. Major need will be implementation of technologies, in such a manner that provides for very affordable, comfortable, clean and punctual transportation for all strata of our citizenry. Special focus on inland waterways and coastal waters for transportation is highlighted. The transport vision document was prepared on a consultative framework and is being placed as a referential document to inspire all the stakeholders and articulates vision for all Indians in 2035.

❑ Test Facility Management / Upgradation / Integration / Automation Services

Central Maintenance Cell (*CMC*) of ARAI has been working in the areas of maintenance, upgradation, automation, integration and overall facility management of Engine / Chassis Test Cells, Environmental Chamber Systems, Vehicle Data Acquisition Systems, etc. **ARAI is now ready to serve the industry in these critical areas of test facility management including process improvement to reduce down time and defects in the service / plants.**

CMC possesses high technical knowledge and multi-skilled Electro-Mechanical team and can bridge the gap of long distance services by OE and criticality of equipment functioning, by providing component level innovation and sort out root causes. CMC also develops calibration method and / or provides calibration verification support for variety of equipment.

System Integration

Special Test Facility Upgradation

Training on Maintenance Management

Automation Consultancy Services

Key features:

- Consultancy services for automotive test and measuring equipment.
- Elimination of system problem with substitute and JUGAD innovation to make existing equipment work.
- Creative solutions for assured equipment productivity with cost and time saving, to improve machine down time, setup time and operational efficiency.
- Development of calibration method and / or calibration verification.
- Process improvement to reduce defects in service / plants, critical areas of test and manufacturing equipment.
- Training on maintenance management system.
- **Highly knowledgeable, experienced and multi-skilled Mechanical-Electronic support team.**

Customer Meet 2016 – Exploring Possibilities & Promoting Synergy

Based on the strong foundations of trust and loyalty, ARAI strives for harmony with customers. We make every effort to provide quality and timely services to the customers. Customer feedback is considered for improvement that bridge the gaps between our service and customer expectations.

As we continue to build stronger partnership with customers, ARAI organized **"CUSTOMER MEET 2016"** on 25th November 2016 to meet and celebrate success with customers. The aim of this meet was also to commit to customers best of our services regularly.

This programme was organized jointly by ARAI and ACMA, with ocus on western zone component manufacturers to know each other and understand the requirements to serve better and faster. This programme provided a platform to the customers to exchange views with ARAI and ACMA. This will help ARAI to create better infrastructure, facilities, competency, etc. and serve better.

Facilities and services offered by ARAI were also showcased on this occasion. We intended to gather feedback from our business partners, to align our services with their expectations. It was greeted with enthusiastic response and participation of more than 100 personnel from different component manufacturers, viz. lighting, wheel rim, tyre, brake hose, fuel tank, hinges and latches, safety glass, etc. from different parts of western zone.

The meet was presided over by Mrs. Rashmi Urdhwareshe, Director – ARAI and inaugurated by Mr. V Madhavan, President - Group Business Development, Anand Automotive (P) Ltd. in the presence of Mr. Piyush Munot, Co-Chairman – ACMA Western Region & Director KCTR Varsha Automotive Pvt. Ltd. Mr. A. V. Mannikar, Sr. Deputy Director and Head of Automotive Safety Lab and Mr. Nitin B. Dhande, Senior Deputy Director and Head Business Development & Corporate Planning, ARAI.

Dignitaries at the Inauguration
Mrs. Rashmi Urdhwareshe, Mr. V Madhavan, Mr. Piyush Munot, Mr. A. V. Mannikar and Mr. N. B. Dhande

ARAI Experts made following presentations in the Meet, sharing information about ARAI facilities, capabilities and services, new and forthcoming Govt. notifications, updation of Type approval & COP procedures, applicability of EMI and EMC on components, etc.

Topics	Speakers
ARAI Corporate Presentation	Nitin B. Dhande, Senior Dy. Director & Head - BDCP
Active Safety Component testing and AIS:037	B. V. Shamsundara, General Manager, SHL
Passive Safety Component testing	P. P. Chitnis, General Manager, PSL
New and expected CMVR Notifications	Vikram Tandon, Dy. General Manager, HMR
EMI & EMC testing	A. B. Mulay, Dy. General Manager, AED
Customer Feedback Session	• Nitin B. Dhande, Senior Dy. Director & Head BDCP • U. A. Kulkarni, Deputy Director, SHL

Customer feedback was much sought-after technical session of the event. Many customers shared their experience and expressed further expectations from ARAI with respect to new facilities, better service, readiness of forthcoming regulations, etc.

Discussion on customer feedback started with address by Mr. Nitin B. Dhande and Mr. U. A. Kulkarni, Deputy Director.

Customer feedback session

Participants at the Meet

Simulation-Based Development of SCR System for Automotive Application

1. Introduction

The upcoming BS VI emission legislation demands combination of advanced combustion technologies and highly effective after-treatment system. Requirement of reduction in NOx emission by 90% in BS VI compared to BS IV arises difficulty in selection and matching of compact, but efficient SCR system. Therefore, well adapted designs are essential to fulfil system targets concerning emissions, durability and cost effectiveness.

Powertrain Engineering (PTE) has established competency for selection of efficient SCR system by evaluating appropriate catalyst material, coating and brick size using virtual simulation tools. Packaging layout of SCR system can also be optimized for different urea doser-mixer integration in reactor tube and its interaction with engine performance. This approach helps to achieve highest SCR conversion efficiency under the set of constraints, which significantly reduces time and efforts required during experimentations.

2. Challenges and Complexities in Design Selection of SCR System

Selection and matching of SCR system involves challenges and complexity due to

- Space constraints on vehicle
- Additional weight of after-treatment system on vehicle
- Increase in system backpressure on engine and its adverse impact on fuel economy
- Cost of ownership of after-treatment systems
- Ammonia slip due to space velocity, ANR, higher temperature, etc.
- Complete conversion of urea to ammonia in achieving required uniformity index of NH_3 and velocity
- Avoidance of urea deposition, urea crystallization, low temperature deposit
- Good conversion efficiencies only at narrow temperature window

Simulation can help to develop thorough understanding of complete process in identifying root causes and helps in design selection of highest efficiency SCR system.

3. SCR System Design Selection by Simulation Technique

PTE has developed cost effective approach for complete replacement of experimentation for design and selection of SCR system in concept and layout phase. In first stage, designing packaging layout, which includes decomposition tube length, mixer-doser integration and mixer-doser orientation using 3-D CFD tools, can be optimized for prediction of uniformity index (NH_3 + HNCO and velocity) at upstream of catalyst. In second stage, results obtained from 3-D CFD tools are used as input data for 1-D thermodynamic simulation to calibrate storage modelling, reaction rate parameter, impact of variation in NO_2, space velocity, coating and catalyst type on NOx conversion efficiency to satisfy comprehensive set of performance criteria. In third stage, characteristic parameters of second stage are used for 3-D CFD simulation to evaluate overall performance, including fine tuning of after-treatment system.

PTE has performed case-study for BS-VI development with an objective to simulate, calibrate and optimize after-treatment system for BS-IV compliant commercial vehicle. The after-treatment system includes DOC, DPF and SCR system. This case study was performed to achieve required NOx conversion efficiency of SCR system for BS-VI emission norms.

State-of-the-art approach for selection and matching of SCR system begins with optimizing packaging layout of SCR sub-system by 3-D CFD simulation. In this task, design of packaging layout from 3-D CFD simulations is performed considering interaction of following parameters:

- Flow conditions (velocities, temperatures, pressure drop)
- Spray preparation (NH_3 distribution, wall film formation, risk of deposits, effect of mixing devices)
- Substrate flow conditions (flow uniformity, pressure gradients)
- Appropriate NOx sensor location

3-D CFD tool is used to meet above design criteria by implementing all relevant physical and chemical phenomena such as -

- Momentum interaction between gas phase and droplets
- Evaporation and Thermolysis of droplets
- Hydrolysis of isocyanic acid in gas phase
- Heat transfer between wall and droplets
- Spray / wall interaction
- Two-component wall film, including interaction with gas phase and reactor tube.

NOx conversion in SCR system is simulated for two selected operating points, i.e. high flow high temperature and low flow low temperature of an emission test cycle, with after-treatment module of CFD tool. Urea injection is considered in a transient manner with 1Hz pulse frequency.

3.1. CFD Analysis

CFD model used for case study is a sub-system of an after-treatment system, consisting of decomposition tube with an injector housing, static mixer and SCR catalyst. CFD fluid volume of this system is shown in Fig.1. Outlet assembly of SCR is not included in this study for simplification. Mesh is created in 3-D CFD with a mesh count of about 2 million elements, including two prism layer around wall zones to resolve near wall conditions. Fig.2 shows computational mesh created for this model.

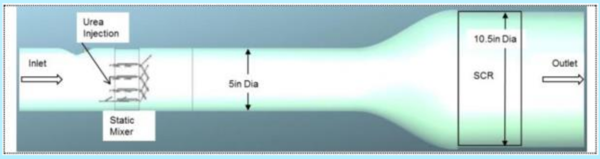


Fig 1: CFD Model

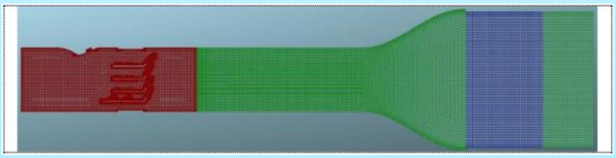


Fig 2: CFD Mesh

3.2. CFD Results

The aim of the case study was to optimize position of two-stage mixer for maximizing UI (NH_3+HNCO, Velocity) for more than 95% NOx conversion efficiency. Prior to optimization of packaging layout, urea injection on mixer is evaluated for effectiveness of collision. Fig. 3 and 4 show that spray plum is hitting on right blade to enhance mixing performance by fast evaporation.

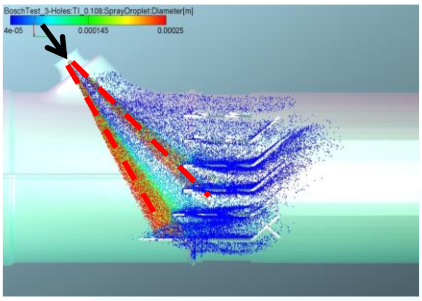


Fig 3: Spray hitting on mixer

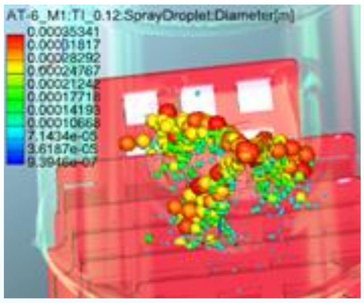


Fig 4: Droplet collision

In next step, cone mixer and two-stage mixer, along with orientation of two-stage mixer, were evaluated in the same reactor tube to achieve more than 95% conversion efficiency within acceptable pressure drop.

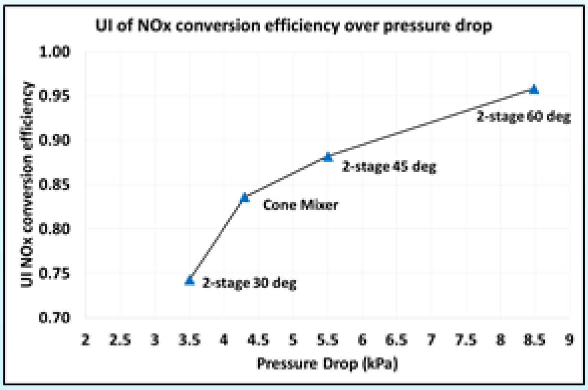


Fig 5: UI of NOx conversion efficiency

Given the trade-off between back pressure and mixing performance, mixers with good performance often have high back pressure to the system. Especially attack angle of urea spray interacts with exhaust gas velocity, resulting in spectrum of performance, as shown in Fig.5. Mixing performance of two-stage mixer increases with higher pressure drop and higher degree of orientation of mixer with respective to axial because of active evaporation and thermal decomposition caused by wide response area of urea sprayed into exhaust gas.

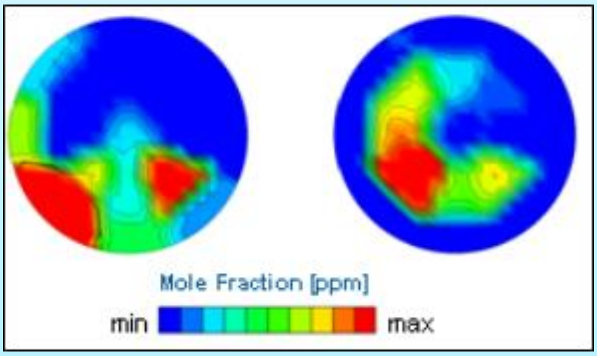


Fig 6: NH_3+HNCO distribution upstream of SCR

Fig. 6. shows distribution of NOx reduction efficiency of two-stage mixers with 60 deg orientation at high flow high temperature and low flow low temperature operating condition. This allows fastest SCR reaction and is reflected in high NOx reduction efficiency. The uniformity indices reflect very good distribution of reductant over whole area of SCR catalyst with medium pressure drop.

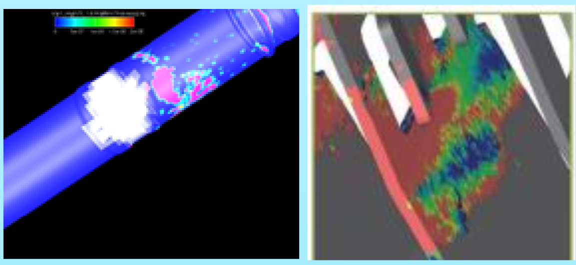


Fig 7: Urea deposition on reactor & mixer

Wall film formation and propagation within the SCR system were simulated for low flow and low temperature operating condition. As shown in Fig. 7, temperature decrease of mixer due to spray impingement was observed. Also some regions of reactor tube with low temperature were seen as deposits for first 3 pulse of urea injection. However, these deposits might not appear after few cycles, which is computationally expensive to predict in CFD.

3.3. 1-D Simulation Analysis

Although detailed chemistry is available within 3-D CFD software package to compute NOx conversion efficiency, it requires relatively longer period of computation. PTE has developed competency using 1-D thermodynamic simulation tool to solve adsorption / desorption reaction, SCR reaction, including surface chemistry, etc. that can be used in lieu of detailed chemistry, resulting in dramatically reduced computational time. This approach helps to predict NOx conversion efficiency of SCR catalyst and ammonia slip.

PTE has studied all relevant catalytic reactions in 1-D thermodynamic simulation tool to determine -

- Layout of exhaust after-treatment system
- Determination of necessary brick volume
- Selection of catalytic coating from available types
- Prediction of NOx conversion efficiency over entire engine operating zone
- Prediction of drive cycle emission

In this task, 1-D thermodynamic simulations are performed first to predict elementary reaction (NH_3 adsorption-desorption reaction) prior to SCR reaction. The amount of reducing agent (NH_3 in urea SCR) storage on the substrate is very important parameter for catalytic converter model calibration. Model can only predict precise catalytic conversion reactions if the catalyst storage model is well calibrated. Validity of storage modelling is confirmed as shown in Fig. 8. From this simulation at each temperature, 1 and 2 active site densities of both weak and strong NH_3-adsorption site for the reaction model were determined. After that, reaction-kinetic parameters for NH_3 adsorption / desorption reactions (i.e. frequency factor, activation energy, active site density) were identified by the transient simulation as shown in Fig. 9.

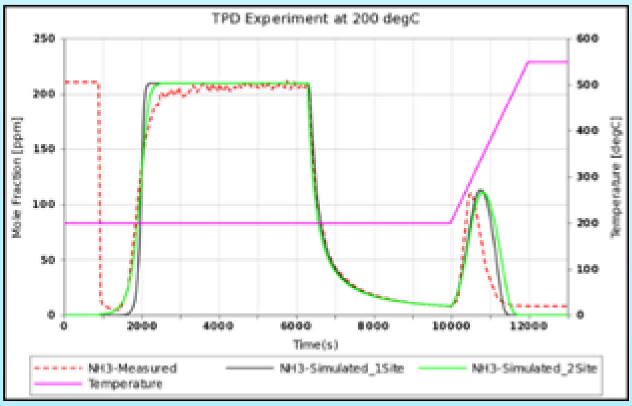


Fig 8: Storage Modelling

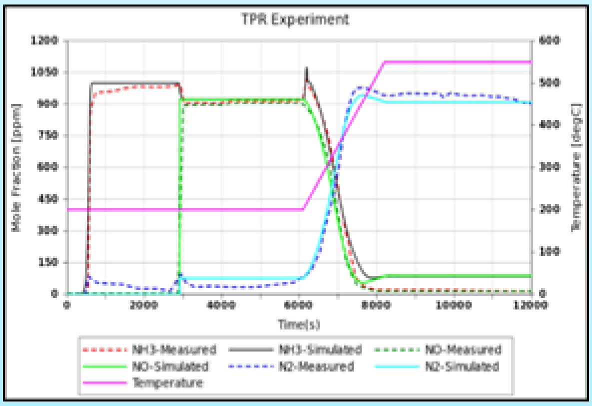


Fig 9: Catalytic Reaction Modelling

By using these calibrated parameters, catalytic reactions are simulated for Cu-Z & Fe-Z catalyst. Catalyst selection is very critical phase in catalytic converter system design. As shown in Fig. 10, copper exchanged zeolites offer better low temperature conversion whereas Iron exchanged Zeolites offer better high temperature conversion. Vanadium based catalysts offer economical solution and better Sulphur tolerance.

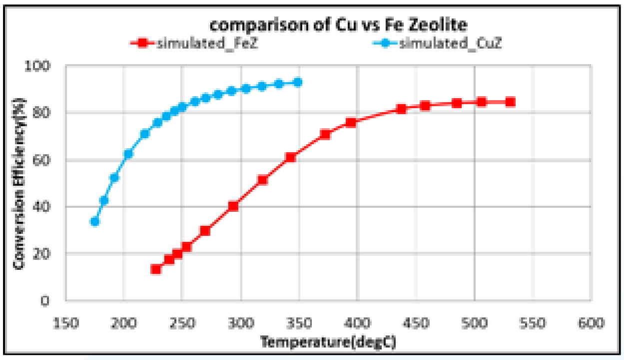


Fig 10: Simulated Results of Fe-Catalyst and Cu-Catalyst for NOx reduction

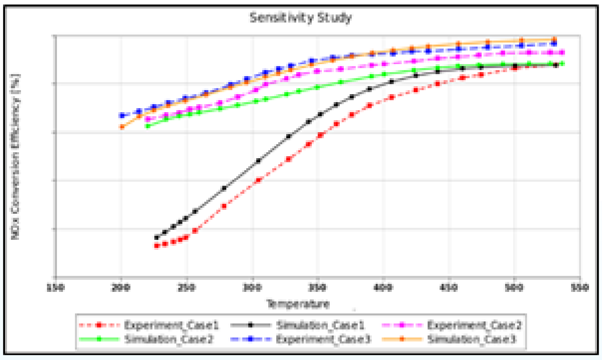


Fig 11: NOx Reduction of Fe-Catalyst for Space Velocity Variation

Once model with reaction rates is calibrated for both storage and catalytic reactions, it is further simulated with variation in parameters such as temperature, space velocity, exhaust feed composition variation to achieve 90% NOx conversion efficiency as shown in Fig. 11.

Finally, to achieve 90% NOx conversion efficiency, low temperature conversion efficiency improves with increase in the inlet feed NO_2 fraction due to slow and fast SCR reactions occurring at the same time. As shown in Fig. 12, at NO_2 fraction beyond 0.75, drop in conversion efficiency is observed due to dominant slow SCR reaction. Some catalysts show more sensitivity to inlet NO_2 feed than others and NO_2 feed of 0.5 is considered ideal for all the catalysts.

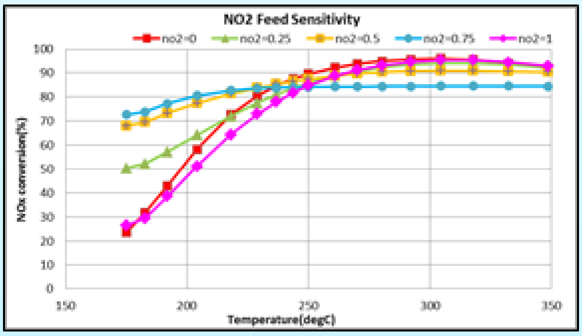
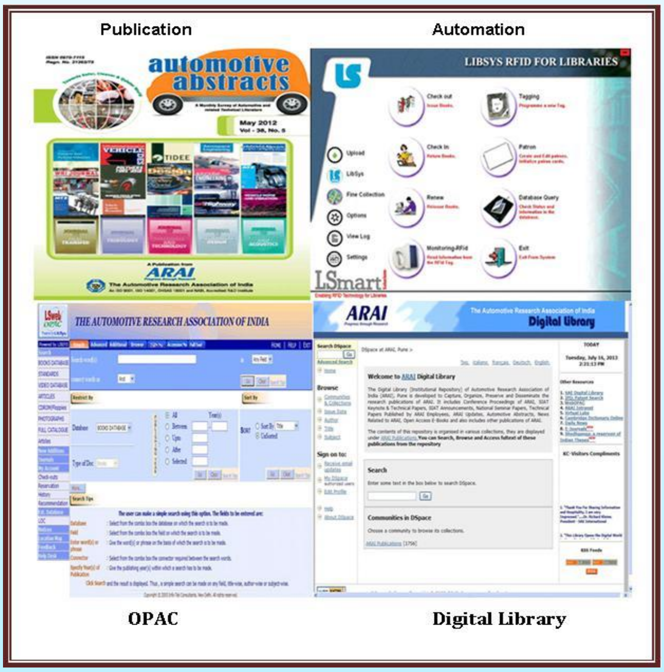


Fig 12: NOx reduction of Fe-Z catalyst for NO_2 variation

ARAI Knowledge Centre Services

ARAI's well-equipped and fully computerized Knowledge Centre provides information support to satisfy the information needs of in-house researchers, faculty members and Academy students. It also serves professionals, faculty, students and various government organizations to gather knowledge in automotive engineering domain.

Knowledge Centre has collection of around 23000 books and standards, 75000 SAE Technical papers, 500 SAE Special publications and Academy Project Reports on various topics like powertrain, electric & hybrid vehicles, emissions, NVH, brakes, fatigue, vehicle dynamics, safety, automotive electronics, automotive materials, management, soft skills, etc. and technical reports, seminar/conference proceedings such as SAE, IMechE, SIAT, FISITA, etc. Every year, more than 100 books are added to Knowledge Centre. It also has rich collection of National and International standards like IS, SAE, JASO, ISO, DIN, ASTM, BS, EEC/ECE, ADR, AIS, etc. It also has a good collection of national and international journals with back volumes. Collection of SAE Technical papers is another valuable addition to the Knowledge Centre. Library Web OPAC is available on website www.araiindia.com



Digital Services at ARAI Knowledge Centre

Sections in ARAI Knowledge Centre

Collection-at-a-Glance	
Book, Conference Proceedings & CDs	8000
Standards	15000
SAE Technical Papers from 1974 onwards	75000
SAE SP/PT/P Publications	500
Subscription of Periodicals	35
Periodicals on Gratis & Exchange	12
Student Project Reports	650

Knowledge Centre offers **Annual Membership** to educational and research institutes, companies and professionals from automotive field with two options. It also offers daily, weekly and monthly membership for reference purpose.

Membership for Reference: (OPTION 1)

Membership with Book Borrowing Facility: (OPTION 2)

This membership facility helps students, faculty and professionals to keep updated in automotive domain.

Automotive Abstracts: Monthly Publication of ARAI

Automotive Abstracts (ISSN No. 0970-7115) offers most comprehensive service to the automotive industry in India. Abstracts of articles published in most of the leading Journals / Periodicals on Automotive Technology and International Symposium such as IMechE, FISITA, ISATA, SIAT, etc. are included in our publication. It includes Autonews, Technoscan, IPR scan, Forthcoming events, etc.

Annual subscription period is fixed from April to March (11 print issues, e-version+December Index issue in CD).

Mrs. Rashmi Urdhwareshe, Director, ARAI
director@araiindia.com

ARAI®
Progress through Research

The Automotive Research Association of India
Survey No. 102, Vetal Hill, Off Paud Road, Kothrud, Pune 411 038 (India)
Tel.: +91-20-3023 1101, 3023 1111 Fax: +91-20-3023 1104