



2. Retained Austenite and its Measurement

3. Calibration Laboratory at ARAI

4. Failure Analysis and Residual Stress Measurement Facilities at ARAI-Forging Industry Division

5. Symposium on International Automotive Technology (SIAT) 2019

▣ Friction Measurement Facility at ARAI

To understand various frictional power losses of different components of IC engine and overall frictional power of the engine, friction measurement of Internal Combustion (IC) engine is essential.

This activity is quite critical and important, as results of friction analysis are useful in overall engine development activity for improvement of fuel economy and reducing CO₂ emissions.

Power Train Engineering (PTE) department of ARAI, with vast experiences in respective fields of engine development and testing, has established Motoring dyno facility, along with 2 quadrant power control drives with accurate control of speed.

Coolant and oil conditioning systems are installed to ensure various boundary temperature conditions required for friction audit. Oil conditioning system is capable of maintaining temperature control between 40 and 150 °C and coolant conditioning system is capable to maintain temperature control between 30 and 90 °C with ±1 °C accuracy. This ensures accurate measurement of friction power of engine at different desired conditions. Additionally engine data acquisition system provides accurate acquisition of various temperature and pressure parameters.

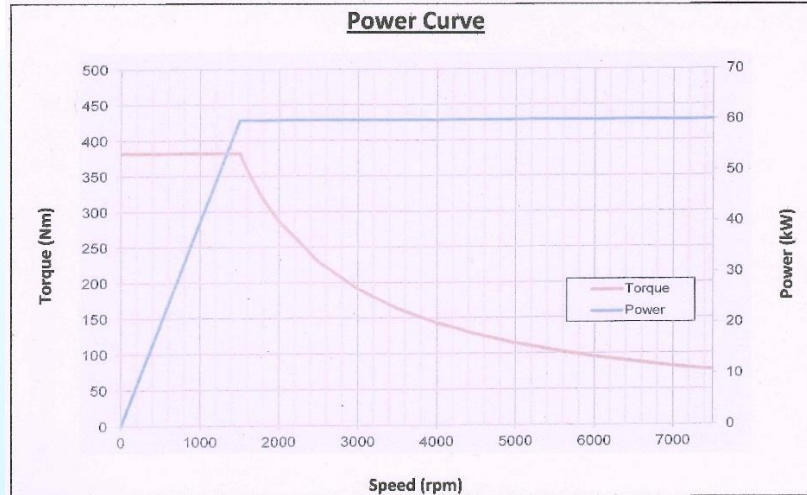
Brief Specification of the Facility

Sr. No.	Equipment /facility	Range	Accuracy
1	Power	60kW @1500 rpm	-
2	Speed	0-7500 rpm	± 1 rpm
3	Torque	Max 382 Nm @1500 RPM	± 0.5 % of reading
4	Temperature Measurement	0 – 200 °C	± 2 °C
5	Pressure Measurement	0 – 10 bar	± 0.02 bar

Salient Benefits of the System

- Highly accurate torque and speed measurement with ultra-precision HBM make T12 torque flange.
- Control of various test boundary conditions with respect to oil and coolant temperature.
- One spot assessment of engine friction and its components.
- High repeatable performance

Characteristic Curve and Photographs



□ Retained Austenite and its Measurement

Introduction of Retained Austenite

Austenite (γ) is a face-centered cubic phase in steels formed at high temperatures. During quenching and other heat treating operations, austenite can be transformed into other phases such as martensite (body-centered tetragonal phase, α). Hardening of steels requires heating to an austenitic phase and quenching to room temperature to produce hard martensitic phase. Austenite is FCC phase that is stable above temperature of 735°C . Due to incomplete transformation, some austenite is retained at room temperature. Austenite that does not transform to martensite upon quenching is called *retained austenite* (RA). Thus, *retained austenite* occurs when steel is not quenched to the M_f , or martensite finish, temperature; that is, low enough form 100% martensite. Because M_f is below room temperature in alloys containing more than 0.30% carbon, significant amounts of untransformed or retained austenite may be present, intermingled with martensite at room temperature.

Due to different unit cell sizes of austenite than martensite or ferrite and its metastable nature at room temperature, whenever given the opportunity, austenite will transform into martensite and along with dimensional changes it also incorporate great deal of internal stress in a component, often manifesting itself as a crack.

The role of retained austenite in these microstructures is complex, as it can have both positive and adverse effects on properties and performance of these steels. Too much retained austenite can result in lower elastic limits, reduced hardness, lower high cycle fatigue life and dimensional instability. Too little retained austenite, however, can result in poor fracture toughness and reduced low cycle fatigue and rolling contact fatigue life.

Bearing industry, gear industry and tools and die industries are the ones, who look after the percentage of retained austenite, however, applications where dimensional accuracy, hardness of component after heat treatment is involved, also needs to be carefully monitored.

Measurement of Retained Austenite

Retained austenite can be measured by metallography or by x-ray diffraction. Metallography, destructive technique, can be used to determine retained austenite content only if sufficient quantity is present. Metallographic point and linear counting methods were tedious and subject to large errors when the retained austenite content was less than ten per cent. Since austenite is non-magnetic and structural magnetization of ferrite and martensite are similar, it is possible to determine the amount of retained austenite by magnetic techniques. However, reliable measurements by magnetic methods are only possible in complete absence of cementite.



Figure 1: X-Ray Diffractometer at ARAI

X-ray diffraction techniques are commonly non-destructive and can precisely measure retained austenite concentrations as low as 0.5 percent. Obviously, therefore, x-ray diffraction analysis of retained austenite is most often the preferred analysis technique. Austenite, due to its structural difference from other phases in steel, produces diffraction peak at different locations than ferrite and martensite. In simple terms, the amount of retained austenite can be correlated to the ratio of the integrated intensity of the austenite peak to the integrated intensity of peaks associated with other phases. Figure 2 shows difference between XRD plots of samples having different retained austenite. Red plot shows 11-12% RA and blue plot shows less than 1% RA.

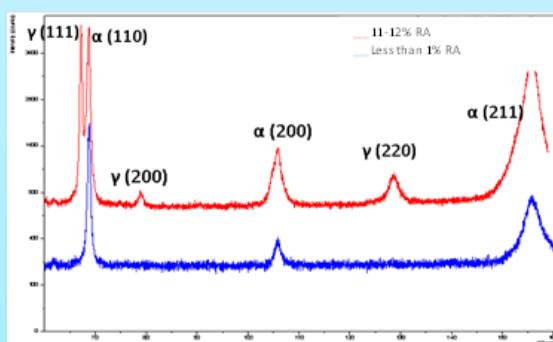


Figure 2: X-Ray Diffraction plots for samples of less than 1% & 11-12 % RA

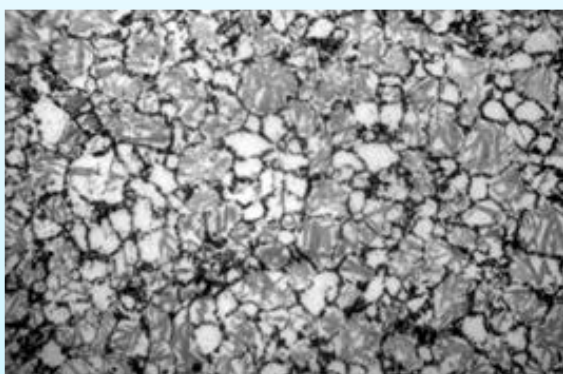
X-ray diffraction patterns depend upon both crystal structures and amounts of phases present in the sample. If crystals are randomly oriented, intensity of diffraction peaks produced by each phase is proportional to the amount of the phase present. Interpretation of x-ray pattern is straightforward and less than 0.5 percent retained austenite can be detected.

Two-peak method is the quickest method of analysis, however, unfortunately, many variables, such as preferred orientation, grain size, etc. can significantly affect the results and hence make two-peak measurement erroneous. Method of Averbach and Cohen in accordance with ASTM is also widely used. Integrated intensities of austenite (200) and (220), and ferrite (200) and (211) diffraction peaks are measured on automated diffractometers, providing four austenite / ferrite peak intensity ratios. Use of multiple diffraction peaks minimizes effects of preferred orientation and allows interference from carbides to be detected.

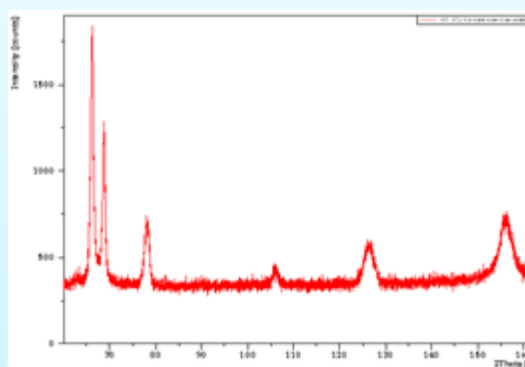
Facility at ARAI for retained austenite measurement

ARAI has Multipurpose X-Ray Diffractometer of PANalytical make X'PERT Pro model. This is vertical goniometer powder XRD with scanning range of 5 to 162° 2 θ . With X-ray source of Cobalt, Copper and Chromium, variety of materials can be tested for phase identification, phase quantification, residual stress analysis, microscopic texture analysis, etc. This equipment is equipped with ICDD database for phase identification. Figure 1 shows the facility at ARAI.

Figure 3 shows difference between metallographic method and XRD method. Metallographic method results in retained austenite as 27-28%, which is calculated with image analysis software, however, human intervention is needed for threshold limit definition. XRD plot of same sample reveals Retained austenite % as 42.6%.



Optical microscope image at 1000X magnification.
Etchant: Nital 4% (RA % 27-28%)



By X-Ray Diffraction method, % of Retained Austenite = 42.6%

Figure 3 : Results of Metallographic Technique and XRD Technique for Retained Austenite Measurement

□ Calibration Laboratory at ARAI

Calibration Laboratory at ARAI is well equipped to serve calibration needs of internal as well as external customer. The laboratory is accredited as per ISO IEC 17025 by NABL. It also undertakes turnkey calibration assignments and onsite calibration services covered under NABL Accreditation. The calibration facilities have traceability to National / International level.

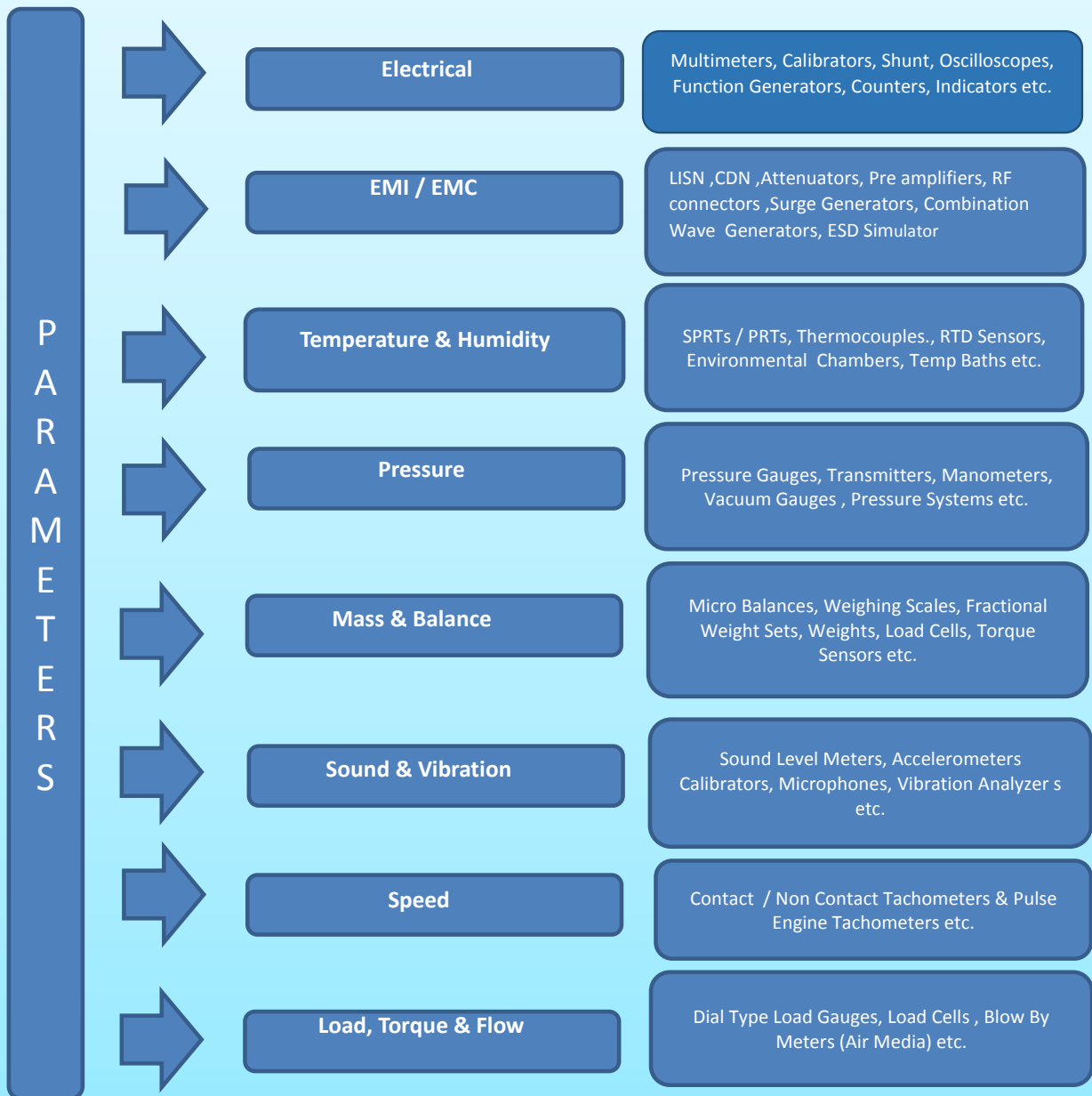
❖ Addition of New Facility

To meet customer requirements, new facility for EMC calibration is recently established, which caters to calibration of -

- Line impedance Stabilization Network (LISN), Attenuators, Pre-amplifiers, CDN, Connectors
- Electrostatic Discharge Generators (ESD)
- Combination Wave Generators, EFT generators required for Conducted Immunity Test.

➤ **Capabilities of ARAI Calibration Lab**

- One of the leading laboratories in India
- Qualified and experienced technical staff
- NABL Accredited (ISO/IEC17025) since 2000
- Wide Range of calibration facilities under One roof
- Onsite calibration facility for various parameters
- Undertake turn-key calibration assignments
- Customer centric approach
- Customer retention for more than 7 to 10 years shows quality services



➤ **Various Facilities at Calibration Lab**

❑ **THERMAL CALIBRATION**



CMC: Calibration Measurement Capability

A) Primary Calibration



Primary Calibration (Fixed Point Cell)	Range	CMC (±)
Boiling Point of Ln2	-196°C	0.015°C
Mercury	-38.8344°C	0.0049°C
TPW	0.01°C	0.004°C
Gallium	29.7646°C	0.005°C
Indium	156.5985°C	0.0007°C
Tin	231.928°C	0.0058°C
Zinc	419.527°C	0.008°C
Aluminium	660.323°C	0.016°C

B) Secondary Calibration



Secondary Calibration	
Range	CMC (±)
-50 to -40°C	0.1°C
-40 to 25°C	0.06°C
25 to 650°C	0.1°C
650 to 1200°C	1.30°C to 1.32°C
20 to 90% RH at 25°C to 40°C	1.50 %RH

❑ **MECHANICAL CALIBRATION**

A) Comparator Balance



Comparator Balance	
Range	CMC (±)
Up to 22 g	0.006 mg to 0.012 mg
Up to 220 g	0.07 mg
Up to 610 g	0.28 mg
Up to 5100 g	10 mg
Up to 12 Kg	300 mg
Up to 150 Kg	3 g

B) Mass



Mass	
Range	CMC (±)
1 mg to 500 g	0.0021 mg to 0.3 mg
1 Kg to 5 Kg	2 mg to 5 mg
10 Kg to 100 Kg	200 mg to 1 g
1 mg to 500 g (E2 Class) Weight Set Calibration Facility newly added	

C) Pressure



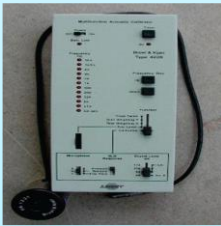
Pressure (at Lab and Onsite)	
Range	CMC (±)
0 to 1000 bar g	0.016% rdg
0 -250 mbar g	0.1 mbar
0 – 25 bar g	0.014% rdg
0 – 2.5 bar A	0.013% rdg
-250 mbar to 0 mbar	0.1 mbar
-0.1 to -1 bar g	0.016% rdg

D) Acceleration



Accelerometer @ Lab (Piezoelectric, Piezo Resistive, Capacitive, etc.)	
Range	CMC (±)
Accelerometers (0.1 to 10 g)	(3 Hz to 10 kHz) 0.8% to 1.8%
Vibration Shakers, Exciters (0.5 g to 10 g)	(10 Hz to 10 kHz) 1.28% to 1.44%
Vibration Meters for Acceleration (0.5 g to 10 g) for Displacement (0.01 mm to 5 mm)	(10 Hz to 5 kHz) 2.06%

E) Sound Level



Sound Level	
Range	CMC (±)
31.5Hz to 16 kHz At 94 dB	0.3dB to 0.6 dB

F) Speed



Speed Calibration	
Range	CMC (±)
Non- Contact Mode 100 to 10000 rpm	2 rpm
Contact Mode 100 to 5000 rpm	2 rpm



□ **ELECTRO TECHNICAL CALIBRATION**



DC & AC Voltage	100 μ V to 1000 V & 1 mV to 1000 V (10 Hz to 300 kHz)
DC & AC Current	10 μ A to 20 A & 10 μ A to 20 A (10 Hz to 5 kHz)
Resistance	1 Ω to 1G Ω
Discrete Standard	25 Ω , 100 Ω , 300 Ω & 400 Ω
Thermometer	-250 to 1768 $^{\circ}$ C
RTD	-200 TO 850 $^{\circ}$ C
Capacitance	3 nf to 30 mf

□ **FLUID FLOW CALIBRATION**

A) Blow By Meter



Blow by Meter (Air Media)	
Range	CMC (\pm)
10 to \leq 30LPM	1.5%
> 30 to \leq 100LPM	1.05%
> 10 to \leq 200 LPM	1.02%

B) PLU Calibration (Non NABL Facility)



Fuel Flow Meter Calibration (DFL & PLU)	
Range	CMC (\pm)
1 Lph to 50 Lph	0.3% rdg

□ **LOAD CELL CALIBRATION**

Range 0 to 100kN : Compression and Tension Mode

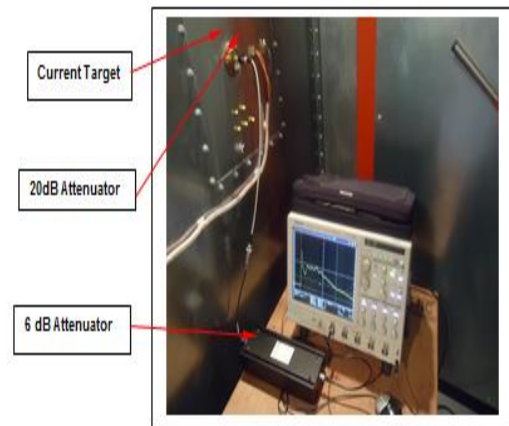
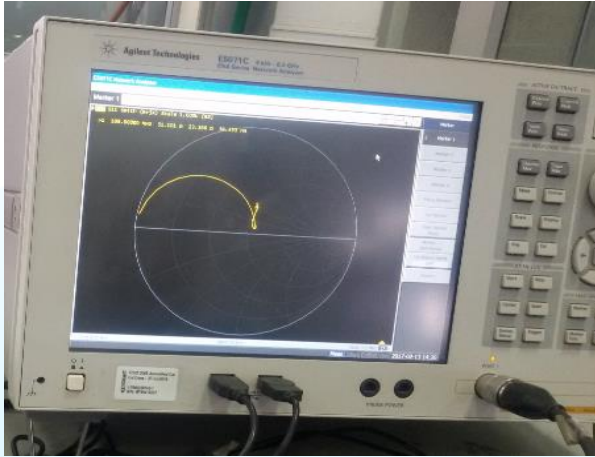
□ **UTM MACHINE CALIBRATION**

Range 0 to 100kN : Compression and Tension Mode

□ **STEERING TORQUE CALIBRATION**

Range 100 Nm to 1000 Nm

NEW Facility Calibration of EMC instrument



Line
Stabilisation
network
(LISN) Impedance
Preamplifier
CDN
Attenuator



ESD
Simulators
for Voltage
Ipk, Ipkat t1 &
rise/Fall Time



Combination
Wave
Generators

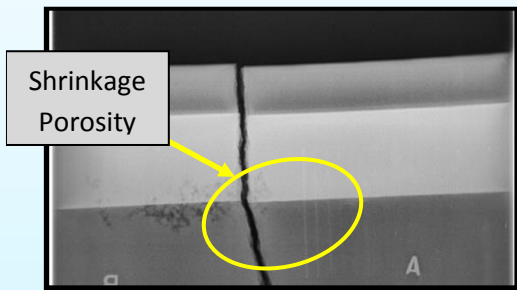
- Different types of Generators
Voltage, Rise,
Fall time and
Time duration

Failure Analysis and Residual Stress Measurement Facilities at ARAI – Forging Industry Division

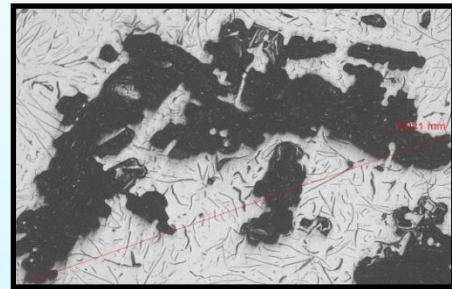
ARAI – Forging Industry Division specializes in carrying out failure analysis and residual stress measurement of various automotive / non-automotive components by available state-of-the-art in-house facilities and equipment. Systematic approach of failure analysis has provided root causes of failures and remedial solutions to be adopted in process to avoid such incidents in future.

Case 1: Failure Analysis of Wheel Drum

In typical failure analysis of wheel drum casting multiple discrepancies such as presence of shrinkage porosity, lower Hardness and tensile strength and deviations in dimensions at failure locations lead to failure. It was recommended to improve casting process at various stages to avoid failure of component.



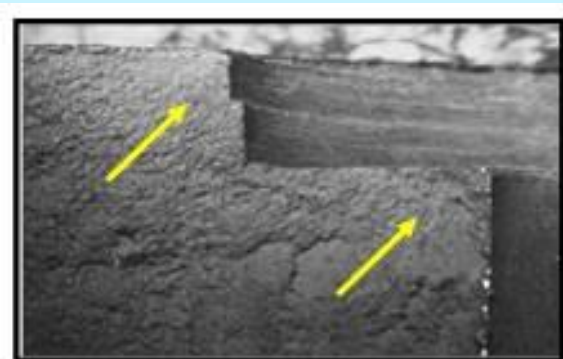
Shrinkage Porosity seen in X-ray Radiography



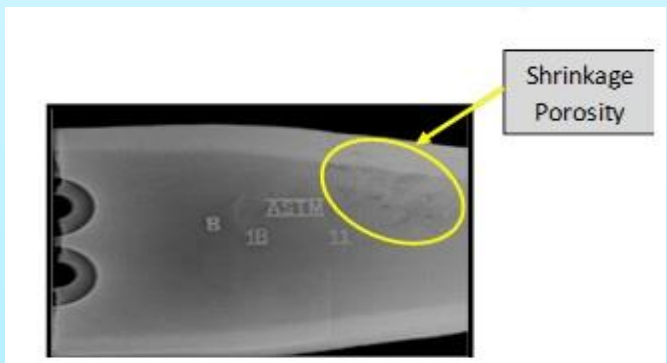
Porosity seen in Microstructure

Case 2: Failure analysis of Support Bracket

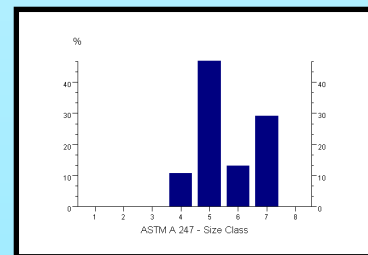
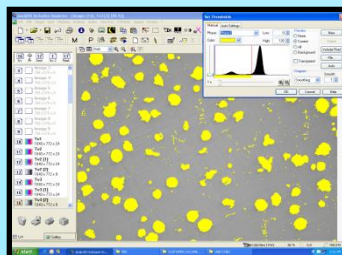
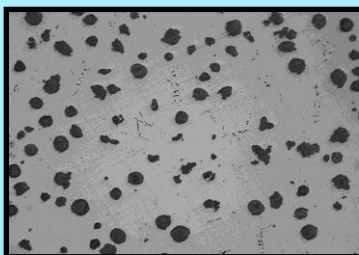
Failure analysis of support bracket showed presence of shrinkage porosity at multiple locations near and at mounting holes from where fracture initiated. Deviation in dimensions and lower Tensile & Yield strength also observed. Microstructure showed lower nodularity which decreased strength of component.



Fracture starting from mounting hole



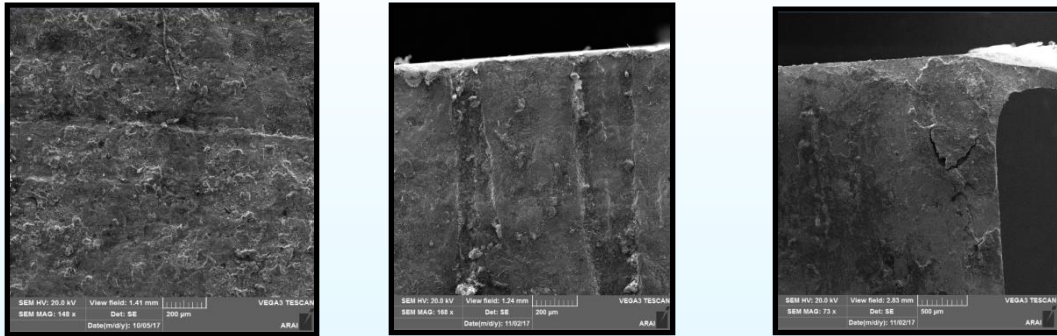
Shrinkage porosity seen in X-ray radiography



Quantification of nodularity by image analysis showing less nodularity of bracket

Case 3: Failure Analysis of Leaf Spring

Another case of failure analysis on leaf spring, showed prominent presence of surface imperfections (in the form of parallel lines/rolling marks) on surface along with presence of tensile and lower magnitude of compressive residual stresses, which lead to failure of leaf spring by fatigue. It was recommended to improve surface finish of final component and improve shot peening process parameters to induce higher magnitude of compressive residual stresses.



Surface imperfections (in the form of parallel lines/rolling marks)

Along with various metallurgical testing, residual stress measurement is gaining significance and is very useful to anticipate multiple functional parameters, for improving product quality, safety and reduce catastrophic failures in components. Characterization of residual stresses, along with routine quality check, is gaining importance with increased demand from OEMs and Tier 1 and 2 suppliers to assure component quality, durability and avoiding premature failures in service.

ARAI-FID is equipped with portable residual stress analyzer of Proto (Canada) make, which works on principle of X ray diffraction and Bragg's Law. Multiple automotive and non-automotive components can be analyzed to know change in residual stress pattern w.r.t. various processing and critical areas, which may attribute to failure. In the hydro-formed steel shell shown below, residual stress pattern is analyzed to stresses near and away from failure locations.



RSA on steel shell for defence application

ARAI-FID has residual stress analyzer of make, iXRD, which is in continuous usage for analyzing various components such as Gears, Crankshafts, Connecting rods, Axle shafts, Brackets, Compressor Valves, Leaf Springs, Heavy Engine Blocks, etc. and more than 3000 measurements are taken per year by serving around 50 different customers.

**Symposium on International
Automotive Technology, 2019
16-18 January 2019
Pune (India)**



COUNTDOWN BEGINS FOR SIAT 2019

Symposium on International Automotive Technology (SIAT), widely acclaimed by global automotive fraternity, is a benchmark biennial international event, organized by ARAI that serves as a forum for exchange of ideas and brainstorming for the automotive industry, with participation of eminent experts, professionals, engineers and academicians world over, in various automobile arenas.

The last symposium, held in January 2017, was a thumping success in terms of delegate participation, presentation of technical papers and keynotes, poster presentations, etc. The concurrent SIAT Expo had witnessed participation of over 100 organizations from India and abroad, showcasing their products through over 200 exhibition stalls.

The forthcoming edition of SIAT, viz. SIAT 2019, the 16th in the series, is being organized by ARAI, in association with SAEINDIA, NATRiP and SAE International (USA), at Pune (India), from 16-18 January 2019.

Theme of SIAT 2019 is “**Empowering Mobility – The Safe & Intelligent Way**”.

SIAT 2019 will focus on recent advances in various automotive areas, such as Safety, Emissions, Engines, Noise, Electric Mobility, Electronics, Intelligent Transport, Vehicle Dynamics, Materials, Alternate Fuels and Simulation & Modelling. It will also bring to fore innovative ideas and solutions in automotive technologies to meet future challenges. During this Symposium, over 200 technical papers, including 40 keynotes, on various subjects will be presented by renowned experts from India and abroad. Papers presented in SIAT are treated as SAE papers and will find place in SAE database. First announcement of SIAT 2019 is hosted on ARAI Website <www.araiindia.com>, which can be browsed using the link: <http://siat.araiindia.com>.

SIAT EXPO 2019, being organized concurrently, would offer appropriate platform for spectrum of worldwide companies to showcase their products / technologies / innovations / services through various stalls.

Contact for registration:

Mr. A. A. Badusha
Convenor, SIAT 2019 and
Senior Deputy Director, ARAI
Email: siat2019@araiindia.com
Tel.:+91-20-30231150 / 1370 Mobile:+91-99755 81060

Contact for booking of stalls in SIAT EXPO 2019:

Mr. R. S. Mahajan
Coordinator, SIAT EXPO 2019 and
General Manager, ARAI
Email: siatexpo2019@araiindia.com
Tel.: +91-20-30231491 Mobile: +91-86050 17906

ARAI would appeal automotive fraternity for proactive participation in the Symposium and sharing of research work by way of presentation of technical papers / keynotes as well as showcasing their products, technologies, equipment, etc. by booking of booths at SIAT Expo.

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



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