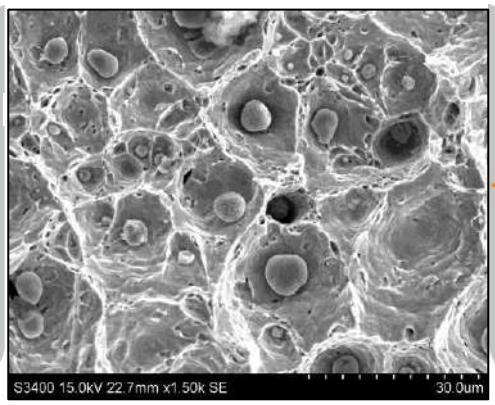
Journal of Materials, Manufacturing & Failure Analysis for Structural Integrity

SFA Mumbai Chapter



PHCET
PILLAI HOC COLLEGE OF ENGINEERING & TECHNOLOGY

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PILLAI HOC COLLEGE OF ENGINEERING & TECHNOLOGY RASAYANI

News at a Glance

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Editor: Prof. R.C. Prasad(rcprasad@mes.ac.in)

From Editor's Desk

WELCOME TO THE LAUNCH OF THE MAIDEN ISSUE OF THE JOURNAL

The failure of structures and their degradation in service is of great concern to the Indian manufacturing industries. It affects all industries and results in loss of equipment's , production loss, environmental pollution and even loss of life that involves costly litigation. The assessment of integrity of components in the presence of defects is becoming increasingly important for the safety as well as economic reasons. The cost of failure estimated by different agencies is around 3-4% of the GDP of a country. Most failures can be prevented if we adopt the available current technology, do R&D and take adequate precautions at the design, manufacturing and operating stages. India is one of the fastest growing economy in the world and needs to identify the root cause of failures in products and take preventive methods to mitigate them. Analysis of failure by industries can expand the knowledge of processing and product development. The purpose of starting this journal is to spread awareness of failure analysis in industries, educational and research organizations through R&D , design thinking and innovation to enhance the product quality and prevent future failures.

Aims & Scope of the Journal :

- **Promote academic research and root cause analysis of industrial failures**
- **Cover failures related to all sectors of industries and all types of loading**
- **Create pool of manpower that is conversant with different analytical tools and techniques of materials characterization and failure modes and effects analysis**
- **Create ecosystem of failure analysis for innovation and entrepreneurship**

The journal is an integral part of the Society for failure analysis Mumbai chapter and the Institute Innovation Council at the Pillai HOC College of Engineering and Technology . The quarterly open access journal intends to cover topics related to materials, manufacturing and failure analysis. We invite authors to contribute manuscripts of their papers. Submission implies that the work has not been published earlier, except in the form of abstracts , lectures, academic theses. It may be a research paper, review paper or a short communication. One of the authors may be designated as the corresponding author with his affiliation and email. Please use spell check and grammar check to avoid errors. The structure of article should consist of Abstract with key words, Introduction, Materials & Methods, Experimental, Results & Discussion followed by references. The style of reference should be as in any standard journal like the Journal of Engineering Failure Analysis published by Elsevier.

LET US LOOK FAILURE ANALYSIS THROUGH THE LENS OF RESEARCH,INNOVATION & ENTERPRENURESHIP

Major Steps in Failure Analysis with Some Case Studies .

Gather Background Information

Catalog Evidence

Non-Destructive Testing | Chemical Analysis | Mechanical Testing | Metallographic Examination

Fractographic Analysis

Analyze Results Come to Conclusion

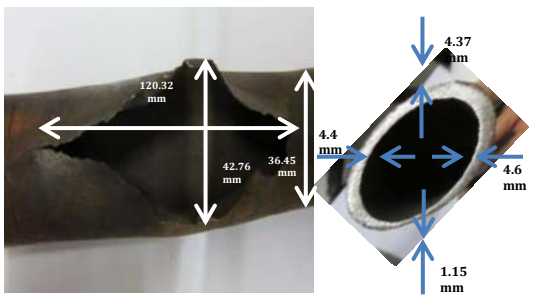
Make Recommendations

Boiler Tube Design
Improper Materials Selection
Defect generated during tube making
Improper Operation (Maintenance)
Inadequate Water Treatment
Root Cause Failure Analysis

Role of root cause failure analysis in failure of boiler tubes

Design
Improper Materials Selection
Defect Generated During Processing
Improper Installation and Maintenance
Inadequate Defect Detection Using NDT
Failure

Factors Responsible for Failure

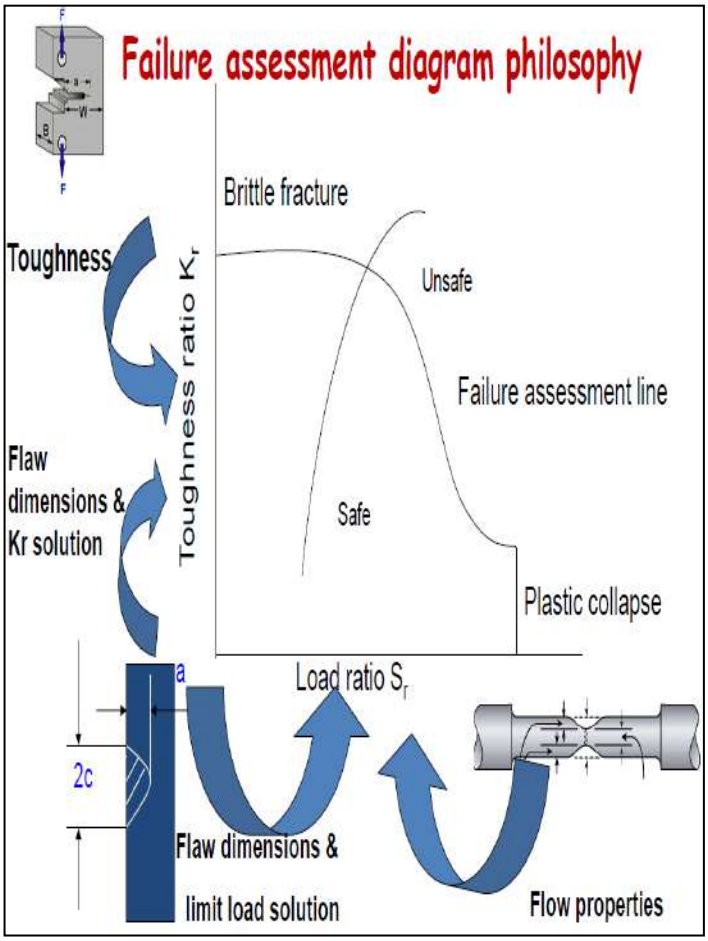


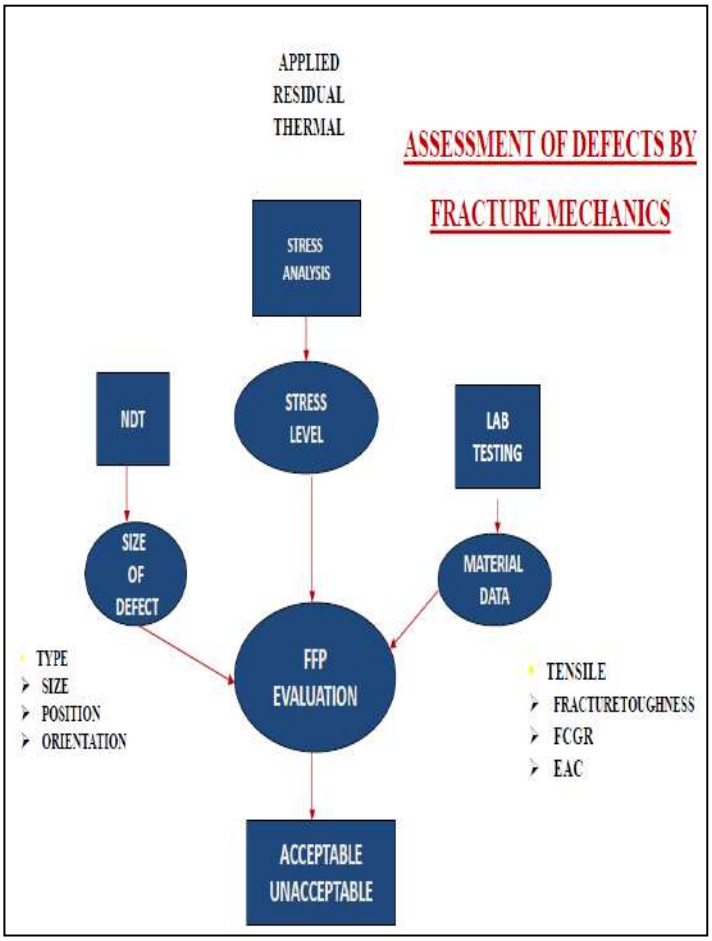
Fish mouth rupture of a tube in Power utility & boiler

Failure of Onshore Naptha Tank due to HE

Failure of a Roller Coaster Axle Rod

Typical burst failures CNG Cylinder.





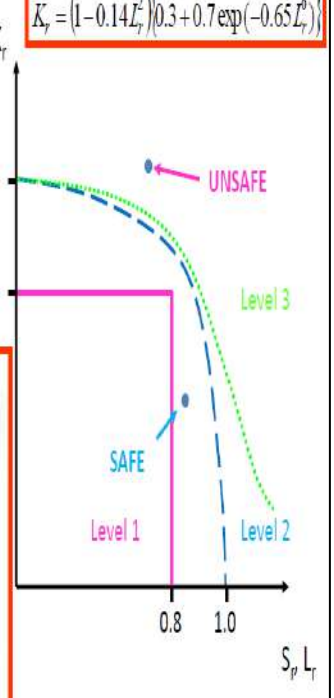
Assessment for Failure

- Level 2:

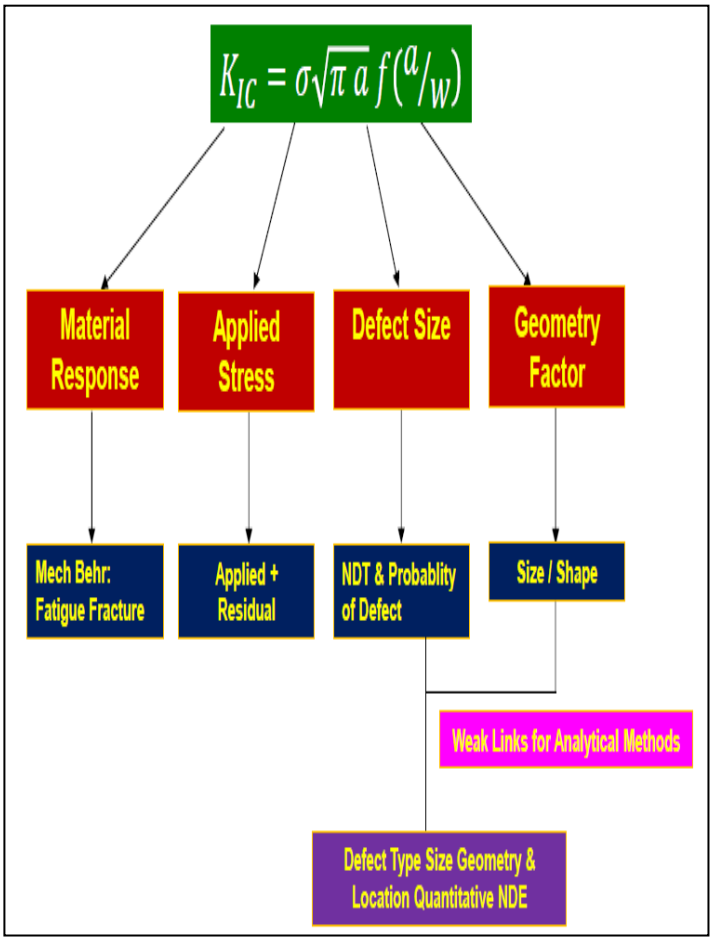
$$K_r < S_r \left[\frac{8}{\pi^2} \ln \sec \left(\frac{\pi}{2} S_r \right) \right]^{-1/2}$$

- Level 3:

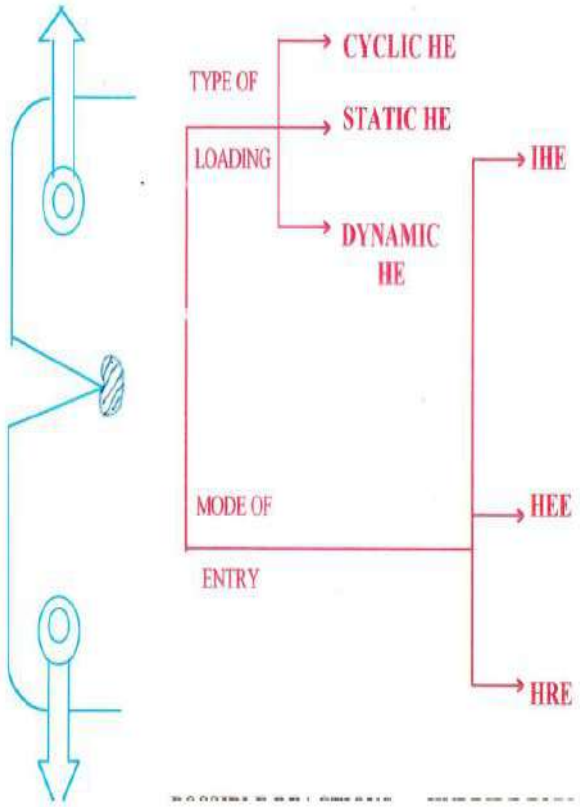
$$K_r = \left(1 - 0.14 L_r^2\right)\left\{0.3 + 0.7 \exp\left(-0.65 L_r^6\right)\right\}$$



	Level 1	Level 2	Level 3
1	Initial Screening level	To assess safety	Greater accuracy
2	σ_y, σ_u and E	σ_y, σ_u and E	Full engineering
3	$S_r = \frac{NetSectionStress}{FlowStress}$	$\frac{\sigma_u}{\sigma_f}$	$L_r = \frac{\sigma_a}{\sigma_y}$

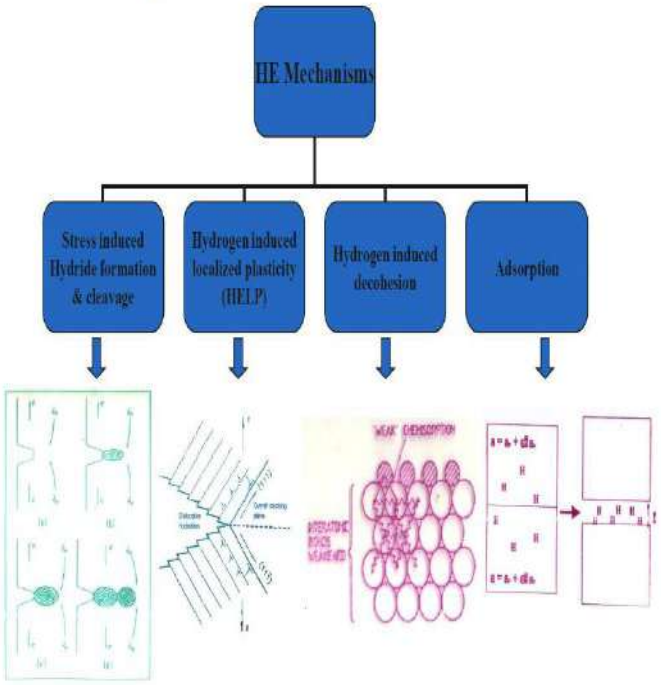


Types of Hydrogen Embrittlement

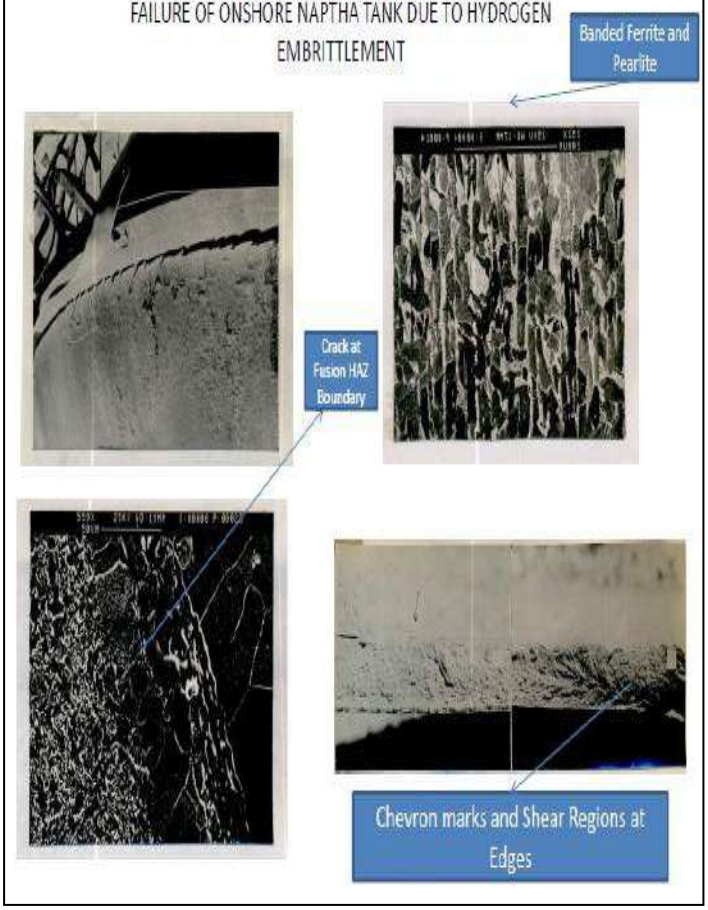


HYDROGEN EMBRITTLEMENT

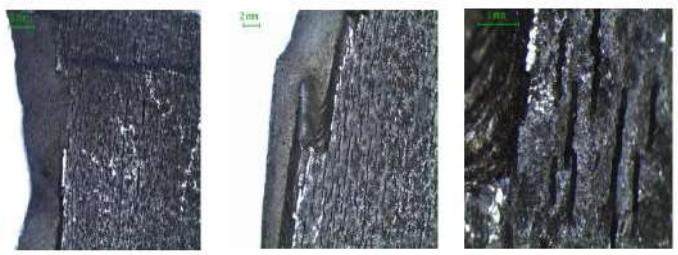
- Failure of metals exposed to Hydrogen are widely reported in industries.
- HE is now considered a phenomena several mechanisms based on experimental evidence and strong personal view.



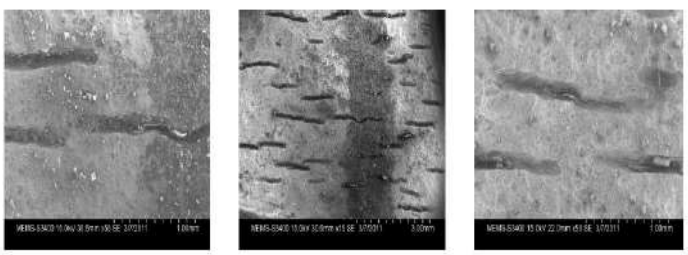
FAILURE OF ONSHORE NAPTHA TANK DUE TO HYDROGEN EMBRITTLEMENT



Hydrogen Embrittlement Failure of CNG Cylinder



Stereo micro photographs of inside surface of the cylinder showing colonies of parallel cracks in rolling directions.



High magnification SEM fractographs reveal that cracks initiate, grow and coalesce.

Failure Analysis of Car Crankshaft

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***Abstract*—The root cause analysis of a prematurely failed crankshaft of a car engine is reported. The micro, macro & fractography of failed surface was conducted using SEM. Assuming that transition from journal to web is properly designed, it is suspected that crack initiation might be due to improper material or poor machining (chatter marks) in the oil drilled hole that may cause stress concentration where cracks may initiate and propagate to fracture by fatigue. The steps to mitigate such failures in SG iron is suggested**

Keywords— Crankshaft, SG Iron, Microstructure, Fractography, Failure Analysis.

PREAMBLE

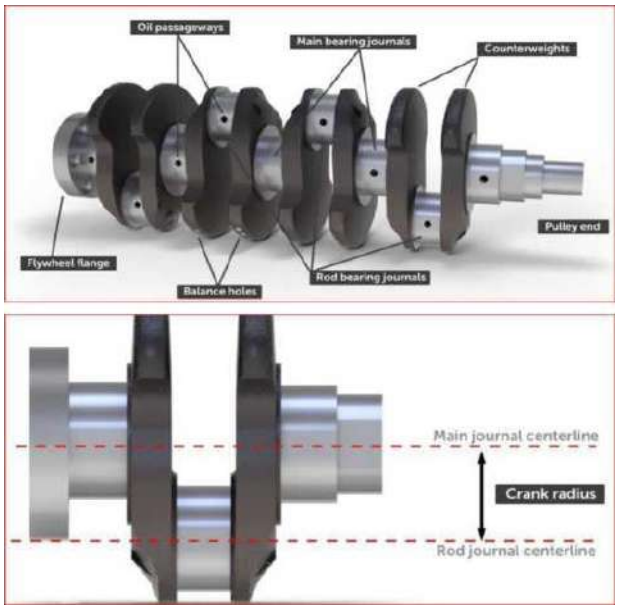


Fig. Crankshaft with nomenclutre of different parts

https://www.howacarworks.com/crankshaft

Crankshaft is a central part of a car engine that consists of a series of cranks and crankpins as shown in Figure above. Connecting rod of the engine is attached to this. It transfers power of firing cylinder by burning fuel into mechanical motion that helps the wheels to run.

Oil holes are chamfered to improve lubrication and avoid metal to metal contact. Crankshafts are subjected to strong rotational forces. Mass of connecting rod and piston moving up and down exert various types of forces. Counter weights are provided to balance out these forces and allow smooth running at high RPM. Crankshafts are made of Cast iron for lower loads. After casting journals are machined smooth, oil passageways are drilled. Webs are left with rough casting. High performance crankshafts are made by forging or machined from a block of solid billet. After casting journals are machined smooth, oil passageways are drilled. Webs are left with rough casting. Since engine components are the origin of most of the failures a number of researchers have studied the modes and mechanisms of failures of car engine crankshafts (1,2).

I. Introduction

The crankshaft of a car engine block that gives drive from engine to camshaft through connecting rod failed after a run of 10681 Kms. During service the Crankshaft is subjected to reciprocating fatigue motion. The load comprises of rotating cum bending that is cyclic in nature. In order to avoid stress concentration that is normal common causes for failure, fillet radii are provided at the junction of the journal with the web. Fillet rolling is done on the journal to improve fatigue life after machining.

Material:

The crankshaft part of car that failed during service was made of cast SG iron grade B. Most of the carbon is present as spheroid graphite corresponding to form VI. The required microstructure is expected to contain predominantly pearlitic matrix with less than 10% ferrite and spheroidal graphite (type VI) greater than 90%. During casting suppliers may add alloying elements other than specified to achieve required hardness of 240-290 HB. The specified and analyzed composition of the alloy is given in Table 1.

Table 1: Specified and analyzed composition of SG iron Grade B.

	INDICATIVE %					MANDATORY %				
	C	Si	Mn	Ni	Mo	Mg	S	P	Cu	Sn
Specified	3.70	2.65	0.04			*JL* !r> p p	<=.015	<=.05	0.5 - 1.2	<=.04
Analysed	3.39	2.47	0.23	0.096	0.014	0.043	.002	011	0.45	.009

Microstructure:

The required microstructure is expected to contain predominantly pearlitic matrix with less than 10% ferrite and spheroidal graphite (type VI) greater than 90%. For

metallographic investigation, micro sections were taken from the crankshaft and examined under scanning electron microscope. The microstructure was found to consist of nodules, some of which are surrounded by ferrite that look like bull's eye Fig.1 (a&b). The matrix predominantly consists of pearlite Fig. 1(c). The orientation of pearlite is found to change at the grain boundary. In addition of nodule, ferrite and Pearlite, a number of inclusions and crack like defects are seen. .

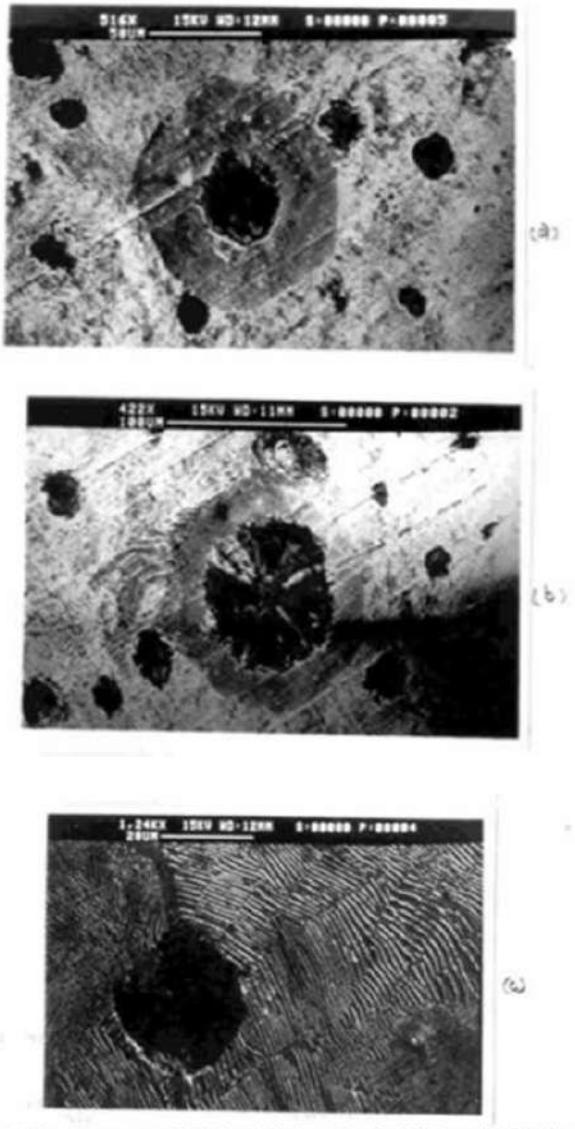


Fig. 1. The microstructure of failed crankshaft consists of nodules in predominantly pearlitic matrix. Some of the nodules are surrounded by ferrite (a & b). At high magnification pearlite is found to consist of alternate layer of ferrite and cementite (c).

Tensile strength:

SG iron possesses higher tensile strength and ductility compared to grey cast iron. It also exhibits high modulus of elasticity and almost a linear stress strain relationship below proof stress region. Tensile property requirements meet product qualification for the Crankshaft as listed in Table 2 along with the determined value from a sample cut from the failed component.

Remarks	Iron Grade	Condition	Cut specimen			Separately cast specimen		
			TS MPa	YS MPa	RA	TS	YS	RA
Required	SG iron Grade B	Cast	735	441	5	735	470	
Determined			740	553	4			

Tensile fractography:

The fractured features of tensile failed cast SG iron are shown in Fig 2 (a - f).

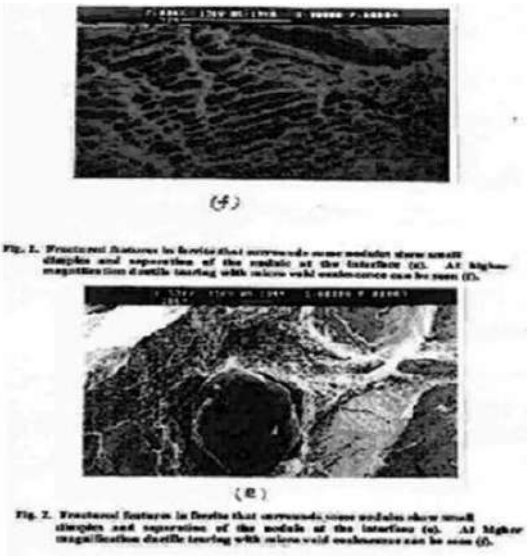
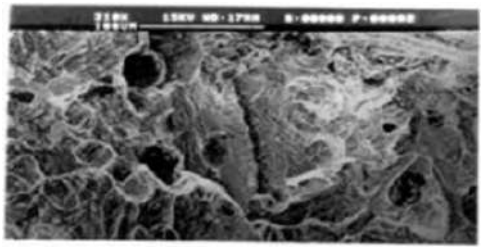


Fig. 2. Fractured features in ferrite that surrounds some nodules show small dimples and separation of the nodule at the interface (e). At higher magnification ductile tearing with micro void coalescence can be seen (f).



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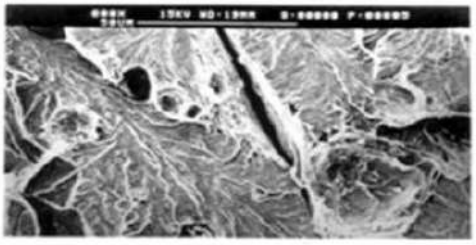


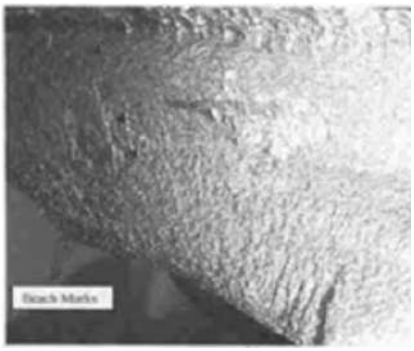
Fig. 2(d) At higher magnification riverlines are clearly visible.

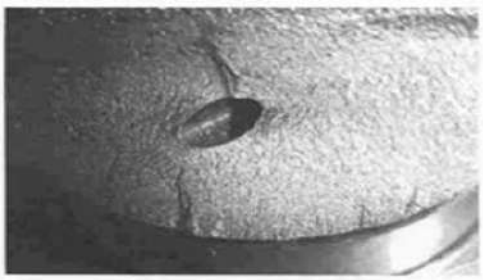
Fracture features are predominantly brittle and consist of river lines in the pearlitic area. The cracks nucleating at graphite nodule matrix interface face severe constraint due to surrounding brittle pearlitic matrix. This gives rise to brittle fracture of the pearlitic matrix. Cleavage facets (river lines) extend to next nodule. The brittle cracks get blunted at the nodule /matrix interface Fig 2. Agglomeration of nodules facilitates crack joining Fig 2. The growth and separation of nodules absorb a lot of energy giving rise to crack growth resistance. The uniformly distributed nodules surrounded with ferrite will therefore give rise better fatigue crack growth resistance. However, the strength and toughness need to be optimized by controlling the number, size and shape of nodules and their distribution. Fractured features in the ferritic region that surrounds the nodules show dimples (ductile feature) Fig 2. The same area when magnified clearly shows ductile tearing with micro void coalescence

Macro Examination:

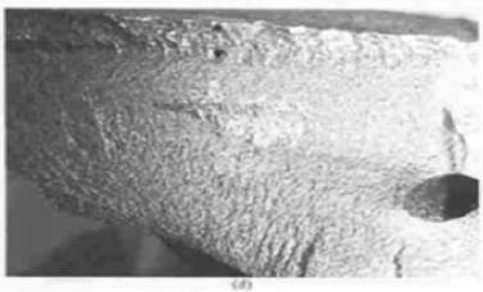
1) The fracture surface of the failed crankshaft is shown in Fig 3(a-d). The arrows in the figures show the points from which the failure appears to have originated.
2) These points are located at the journal fillets at different levels. When this crack merge they create a cliff wall that appears like chevron marks that point towards the origin (transition region of fillet).
3) The fracture that started from fillet has typical; appearance of beach (shell) marks. The beach marks are produced by cyclic loading and periods of rest normally experienced by crankshaft in service.
4) These beach marks travel through rifle drilled oil hole and are intercepted by chevron marks. These holes are produced by gun drilling and were found to contain surface defects.
5) When fatigue cracks grow to considerable length, the area remaining intact becomes small, leading to overload fracture as shown in Fig 3(d).
6) Since the transition from journal to web is properly designed and tooled, it is suspected that initiation might be either due to improper material with low fracture toughness are due to poor machining which initiates crack that propagate to failure by fatigue.
7) The chemical analysis revealed that mandatory required composition was met. The alloying has been done in a manner to achieve the required hardness and the tensile properties. However, the ratio of the yield stress to tensile stress was higher (Table 2). This is expected to provide small amount of stable crack growth. The tensile fractographs therefore predominantly showed cleavage fracture.

(a)





(c)



(d)

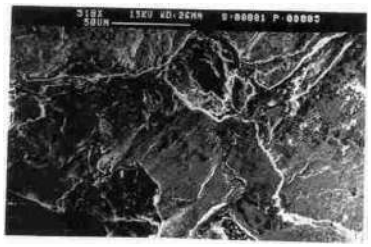
Fig. 3(c & d): Fracture surface of failed crankshaft. Beach Marks travel through rifle drilled oil hole and are intercepted by chevron marks (c). Final overload fracture as indicated by arrow can be seen in (d).

Fractography and failure analysis:

In order to investigate the cause of the failure the failed crankshaft was examined under SEM. The failure initiated at transition region from groove that contained surface discontinuities Fig 4 (a - e) and progressed in the web region. The nodular structure here is not a defect, still the nodule separated region resulting from machining can act as a potential stress raiser site Fig 4(b). A number of secondary cracks and porosities are also seen Fig 4 (f - g). in addition to secondary cracks, porosities, nodule separation at the matrix interface can be seen in fig 4 (h & i). For material like SG iron having lower toughness these sites can very well act as stress raiser from where cracks can originate. Fig 4 (h & i) show separation of nodule at the matrix interface along with secondary cracks and porosities. The micro fractography of the failed web region show striations (feather marks) in addition to nodule separation (j & k).

A comparison of fatigue and monotonic fracture faces of the ductile iron indicates that tensile fracture consists of brittle river lines and separation along nodules, whereas features of fracture of failed parts consist of beach marks (macroscopic) Fig 3 and striations in micro fractography Fig 4 (j & k).

A closure examination of the oil hole by SEM reveals that smooth zones are followed by chatter marks (stress concentration sites). deep grooves at nodules and at interfaces are clearly visible Fig 4 (i - l).



4¹ I'nK'togn.ph of the failed crankshaft shows that failure initiated from transition region front grooves that contained surface discontinuities (a-e) and progresses in the web region

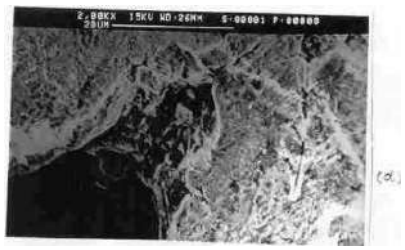


Fig. 4. Fractograph of the failed crankshaft shows that fuilurc initiated from transition region from grooves that contained surface discontinuities (a-e) and progresses in the web region.

The sequence of fracture, however, appears to be crack initiation at transition region from groove that contained surface discontinuities, propagation of crack in the web region through the oil hole and final fracture bv overload.

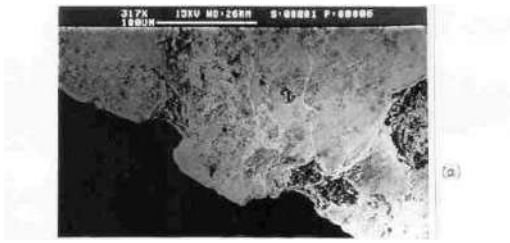


Fig. 4. Fractograph of the failed crankshaft shows that failure initiated from transition region from grooves that contained surface discontinuities (a-c) and progresses in the web region.

Fig. 4. Fractograph of the Tailed crankshaft shows that failure initiated from contained transition region from grooves that and surface discontinuities (a-e) progresses in the web region.

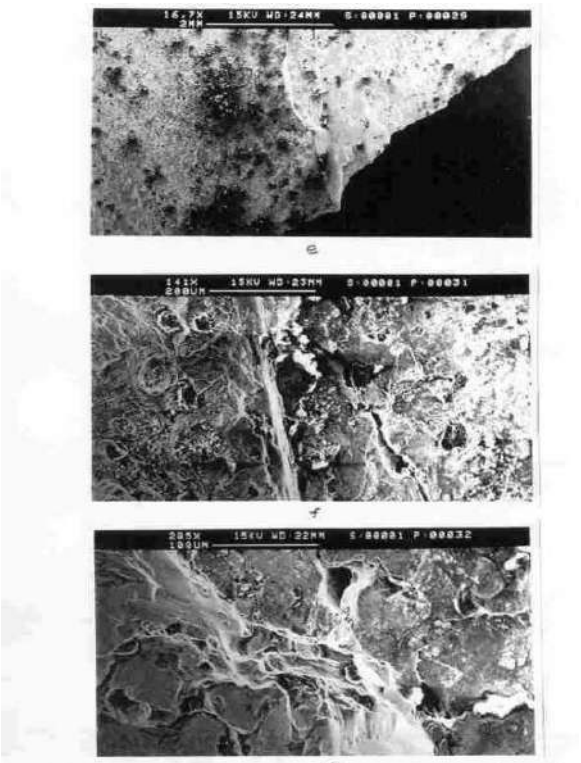
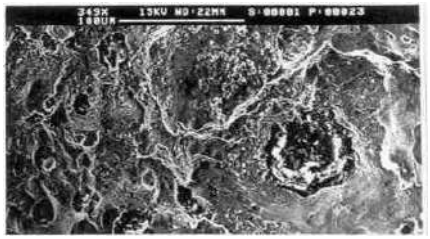


Fig. 4. Fractograph of the failed crankshaft shows a number of secondary cracks and porosities (f-g).



rig- 4. I'ractograph of failed crankshaft show number of secondary cracks porosities and nodule separation at the matrix interface (h & i).

Fractograpli of failed crankshaft shows a number of secondary cracks, porosities and nodule separation at the matrix interface (li & i).

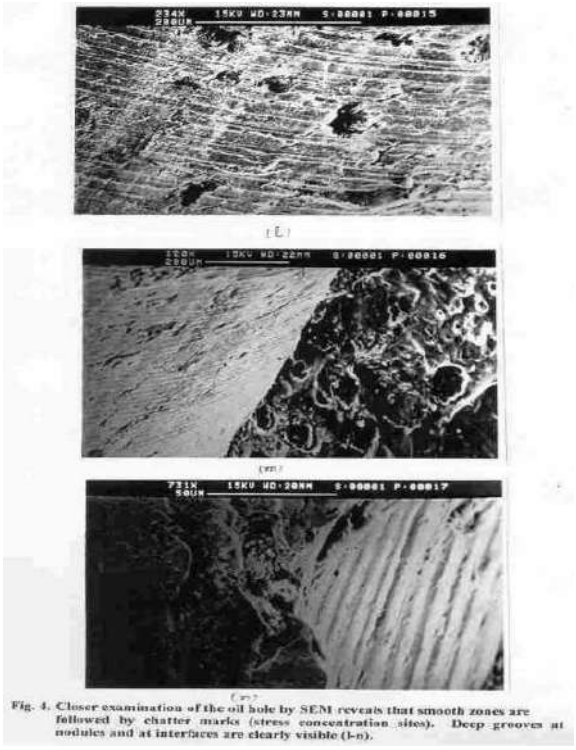


Fig. 4. Closer examination of the oil hole by SEM reveals that smooth zones are followed by chatter marks (stress concentration sites). Deep grooves at nodules and at interfaces are clearly visible (l-n).

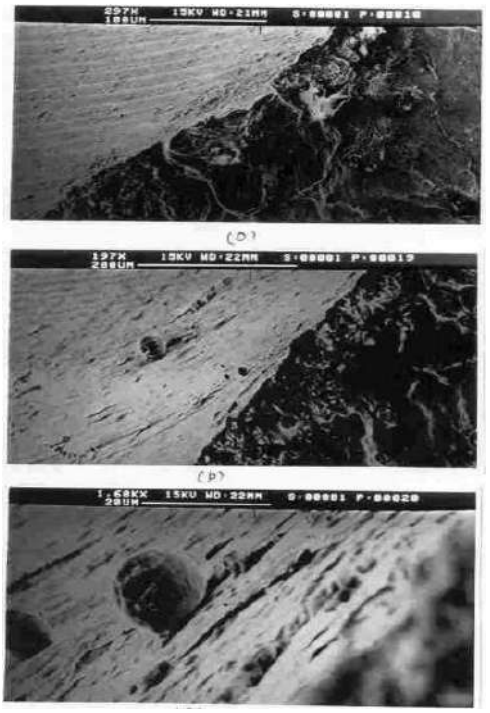


Fig. 4. Closer cvuminaliun of Ihc oil hole by SEM reveals thul smooth zones arc followed by chatter marks (stress concentration sites). Deep grooves nodules and at interfaces are clearly visible (o-tj).

RECOMMENDATIONS:

Steps may be taken to avoid surface discontinuity during machining that may cause stress concentration sites from which cracks initiate and propagate to failure by fatigue.

Austempered ductile iron which has high strength and fracture toughness as well as fatigue crack growth resistance may be considered as a substitute material.

Fatigue strength may further be imparted by providing residual compressive stress at the surface.

REFERNCES:

1.Heyes A." Automotive component failures", Engineering Failure Analysis 2(1998),129-41

2. Wang C. et.al, " Analysis of an unusual crankshaft failure", Engineering Failure Analysis 12(2005),465-73

PHCET Signs MoU With IRMRA

The Pillai HOC College of Engineering & Technology signed an MoU with the Indian Rubber Manufacturer's Association on 13 July 2021.

Through this they entered into an alliance to make use of their respective strengths and interests for adopting best practices to establish strong academia-industry interface to improve the education system in India by creating quality culture by exposing students and working professionals for adopting a disciplined and systemic approach to problem solving which is missing today in professionals in most cases.

Under this collaboration joint conferences/seminars . training. CEP for skill development , certificate programs shall be conducted to mentor UG/PG students to enhance their employability potential. It will also inspire them to do internships and research in the cutting edge technology of polymers, rubber technology and composites.

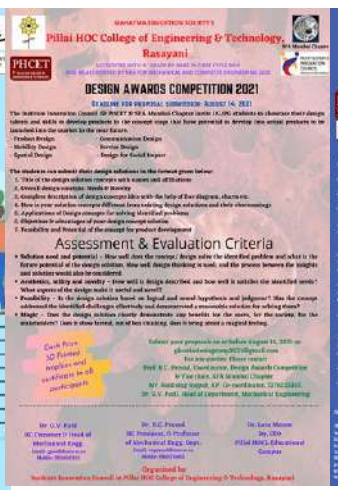
An Alliance Steering Council (ASC) comprising of the special interest group on Materials, Manufacturing, Modelling and Failure Analysis at PHCET and two nominees from IRMRA shall monitor and set operating plans for alliance, identify opportunities for joint collaborative research. It is proposed that the ASC meets every three months virtually or face to face to review progress. Professor R.C.Prasad would be the alliance champion from Pillai HOC College of Engineering & Technology and IRMRA would be represented by Director, Dr. Rajkumar Kasilingam.

Events Organised/ Forthcoming

QForm Olympiad 2021

- The International Students Olympiad in Hot Bulk forging and Extrusion Technologies is an annual event since 2016. Hundreds of students of mechanical engineering departments of many universities from different countries take part in these events. This year 2021, about 200 students from 53 universities and 19 countries took part in the Olympiad along with a new group of participants from France. The logos of participating institutes are given below
- QForm Group is the traditional coordinator of this event. The Olympiad has proved its effectiveness in achieving its goals. Particularly students who participate in the Olympiad are very motivated and most likely will become highly qualified engineers and professionals. Writing the Olympiad report on the technology development case requires abilities to present the results and arguments most convincingly.
- The Council for Innovation, Incubation, Entrepreneurship and start-ups at the PHCET conducted an online half day training Webinar on Advanced Forming Process Simulation on April 10,2021 to encourage, inspire & nurture students to promote innovation and create an ecosystem for entrepreneurship and start-ups. More than 110 students of Mechanical & Automobile Engineering Departments of PHCET Rasayani participated in this program.
- Subsequent to that the Innovation & start-up Council at the PHCET has arranged a Hands-on training session for students selected for participating in the Qform International Olympiad 2021

The certificates of participation and three best performers from PHCET Rasayani, Mumbai University is given below:



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INSTITUTIONS CONDUCTED

SCHOOLS

(S.S.C. PROGRAMME)

- **Chembur English Pre-Primary & Primary School** - *Chembur*
- **Chembur English High School** - *Chembur*
- **Chembur Marathi Madhyamik Shala** - *Chembur*
- **Powai Marathi Madhyamik Shala** - *Powai*
- **Mahatma School of Academics and Sports** - *Khanda Colony, New Panvel* (Pre-Primary, Primary & Secondary, English & Marathi Media)
- **HOC International School** - *Rasayani* **(English & Marathi Media)**

(CBSE PROGRAMME)

- **Mahatma International School** *Khanda Colony, New Panvel*
- **HOC International School** - *Rasayani*

JUNIOR COLLEGES

- **Chembur English Junior College** - *Chembur*
- **Mahatma Night Junior College** - *Chembur*
- **Mahatma School of Academics & Sports, Junior College of Arts, Science & Commerce** *Khanda Colony, New Panvel*
- **HOC Junior College** - *Rasayani* (Junior College of Arts, Commerce, Science with Vocational)

TEACHERS' TRAINING INSTITUTIONS

D.T.Ed. B.Ed. B.P.Ed. M.Ed. Ph.D.

Approved by National Council for Teacher Education (NCTE) (Affiliated to the University of Mumbai & Recognised by Govt. of Maharashtra.)

- **Mahatma Junior College of Education (D.T.Ed.)- *Chembur*** (English & Marathi Media)
- **Pillai College of Education & Research (B.Ed.),** Chembur Re-Accredited 'A' Grade by NAAC
- **Pillai College of Education & Research (B.Ed.),** Accredited 'A' Grade by NAAC *Khanda Colony, New Panvel*
- **Pillai HOC College of Education & Research (B. Ed), *Rasayani***
- **Vidyadhiraja College of Physical Education & Research (B.P.Ed),** *Khanda Colony, New Panvel*
- **Pillai College of Education & Research (M.Ed.),** Chembur
- **Pillai College of Education & Research (M.Ed.),** Accredited 'A' Grade by NAAC *Khanda Colony, New Panvel*
- **Pillai College of Education & Research (Ph.D Centre),** *Khanda Colony, New Panvel*

INTERNATIONAL SCHOOLS & INTERNATIONAL JUNIOR COLLEGES

(CIPP / IGCSE/ICSE/IB SCHOOLS) — 'AS' / 'A' level and 'IB' Programme

- **DR. PILLAI GLOBAL ACADEMY**
- **Gorai**
- **New Panvel**

POLYTECHNIC (3-Year Diploma Programme)

AICTE Approved, Recognized by Govt. of Maharashtra & Affiliated to MSBTE

- **Pillai HOC Polytechnic** - *Rasayani*

Diploma in Computer Engineering
Diploma in Electronics & Tele- communication Engineering
Diploma in Mechanical Engineering
Diploma in Civil Engineering

DEGREE COLLEGES

Bachelor and Master

(Affiliated to the University of Mumbai & Recognised by Govt. of Maharashtra.)

- **Mahatma Night Degree College of Arts & Commerce-** Chembur
- **Pillai College of Arts, Commerce & Science** - New Panvel **Re-Accredited 'A' Grade by NAAC**

B.Com.
B.Com. (Accounting & Finance)
B.Com. (Financial Markets)
B.M.S.
B.M.M.
B. Sc. (I. T.)
B. Sc. (Computer Science)
B.Sc. (Biotechnology)
M.Sc. (I.T.)
M.Sc. (Biotechnology)
M.Com.(Business Management)
M.Com. (Accounting & Finance)

- **Pillai HOC College of Arts, Science & Commerce - *Rasayani***

B.Com.
B.M.S.
B.Sc. (I.T.)
B.Sc. (Computer Science)
B. Com. (Accounting & Finance)
B.M.M.
B.Sc. (Maths, Chemistry, Biology & Physics)
B.A. (English Ancillary, History & Economics)

ARCHITECTURE

Bachelor and Master

(Approved by the Council of Architecture and AICTE) (Affiliated to the University of Mumbai & Recognised by Govt. of Maharashtra.)

- **Pillai College of Architecture** - New Panvel
- **Pillai HOC College of Architecture-** Rasayani (B.Arch. 5-year degree course)
- ***M.ARCH.* (Urban Design)**
- **Pillai College of Architecture** - New Panvel
- ***Ph.D.***

MANAGEMENT COURSE

MMS

(Approved by AICTE) (Affiliated to the University of Mumbai & Recognised by Govt. of Maharashtra.) *NBA Accredited* *'A' Grade by DTE, Govt. of Maharashtra*

- **Pillai Institute Of Management Studies & Research - *New Panvel*** (MMS: 2-year Post-Graduate Course) **Executive MBA**
- **Pillai HOC Institute Of Management Studies & Research - *Rasayani*** (MMS: 2-year Post-Graduate Course)

ENGINEERING COURSE

Bachelor, Master & PhD

(Approved by AICTE) (Affiliated to the University of Mumbai & Recognised by Govt. of Maharashtra.) *NBA Accredited*

- **Pillai College of Engineering- New Panvel**

B. E. in Information Technology
B. E. in Computer Engineering
B. E. in Electronics Engineering
B. E. in Mechanical Engineering
B. E. in Electronics & Tele- communication Engineering
B. E. in Automobile Engineering
M. E. in Information Technology
M. E. in Computer Engineering
M. E. in Electronics Engineering
M. E. in Mechanical Engineering (CAD/CAM, Robotics)
M. E. in Mechanical Engineering (Thermal)

PhD (Technology)
Computer Engineering
Mechanical Engineering
Information Technology

- **Pillai HOC College of Engineering & Technology, *Rasayani*** Accredited 'A' Grade by NAAC

B.E. in Mechanical Engineering
B.E. in Electronics & Telecommunication Engineering
B.E. in Automobile Engineering
B.E. in Information Technology
B.E. in Computer Engineering
B.E. in Civil Engineering
B.E. in Electrical Engineering
M.E. in Mechanical Engineering (Machine Design)
M.E. in Electronics & Telecommunication Engineering
M.E. in Computer Engineering
M.E. in Civil Engineering (Construction & Management)

PhD (Technology)
Civil Engineering
Computer Engineering

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