



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

Failure Analysis & Prevention

Fundamental Sources of Failure: Deficient material & selection poor assembly

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Improper selection of material

- Deficient material selection can occur due to
 - Inadequacy of tensile data for design purpose
 - Tensile test is good for routine general quality test
 - High tensile strength increase notch sensitivity for fatigue and tensile fracture
 - Over-reliance on tensile data for selection of material and
 - inability to select of metal in light of the expected failure mechanism to develop criteria for the design purpose.



Property deterioration with time

- It makes selection more complicated
 - Resistance to wear
 - Property variation at elevated temperature
 - Resistance to corrosion, stress corrosion cracking and corrosion fatigue

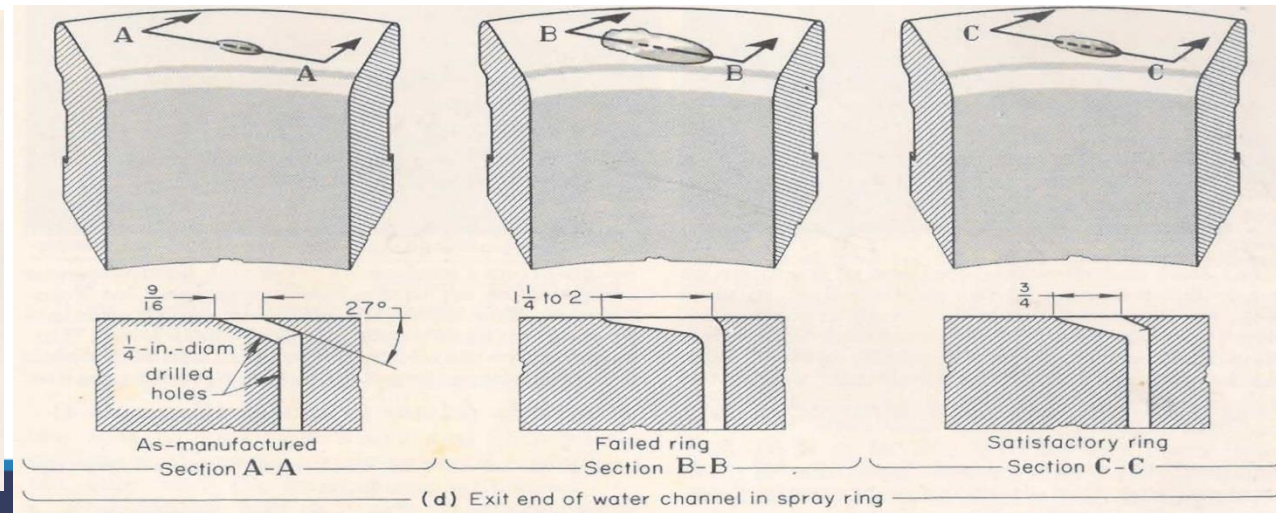
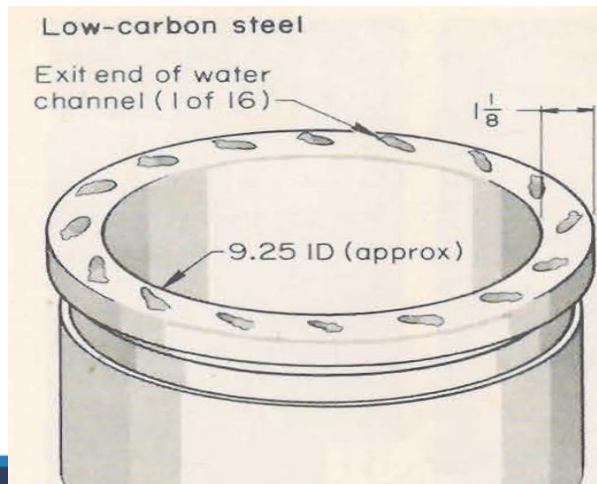


Improper material selection

Failure of carbon steel of spray ring

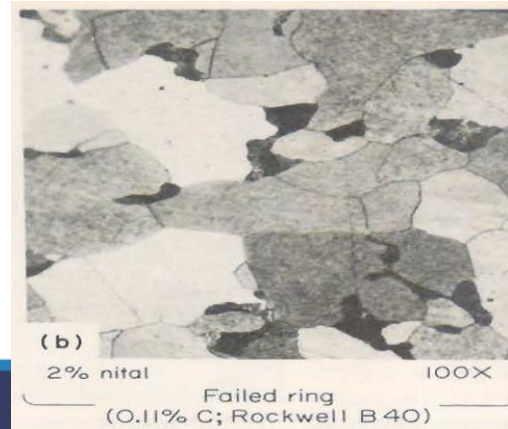
Failed pre-maturely within 4-5 months as compared other doing well for last 4 years.

Failure judged from drop in curing temperature (177-182 degree C) being done through hot water sprays at 193 degree C



Carbon steel spray ring failure

- Examination: pits with irregular shaped opening of spray nozzle without corrosion
- Chemical analysis: 0.11 C lower as compared to satisfactory performing ring 0.2C while same other residual elements
- Metallography: satisfactory ring: fine pearlite ferrite with stringer of pearlite and hardness HRB 55 while failed one had coarse ferrite and pearlite with hardness of HRB 40



Carbon steel spray ring failure

- **Conclusions:**
 - Failure of desired curing temperature was due to enlargement of opening of spray ring which in turn increased agitation, reduced velocity that led to lower heat transfer
 - Erosion caused pitting due to cavitation
 - Low carbon, low hardness and coarse grain size reduced erosion resistance
- **Corrective action**
 - Replace the steel with proper composition with sub-critical annealing so that final grain size not more than ASTM 7 and min. HRB 55.
 - Thereafter, no further failure of spray rings was observed.



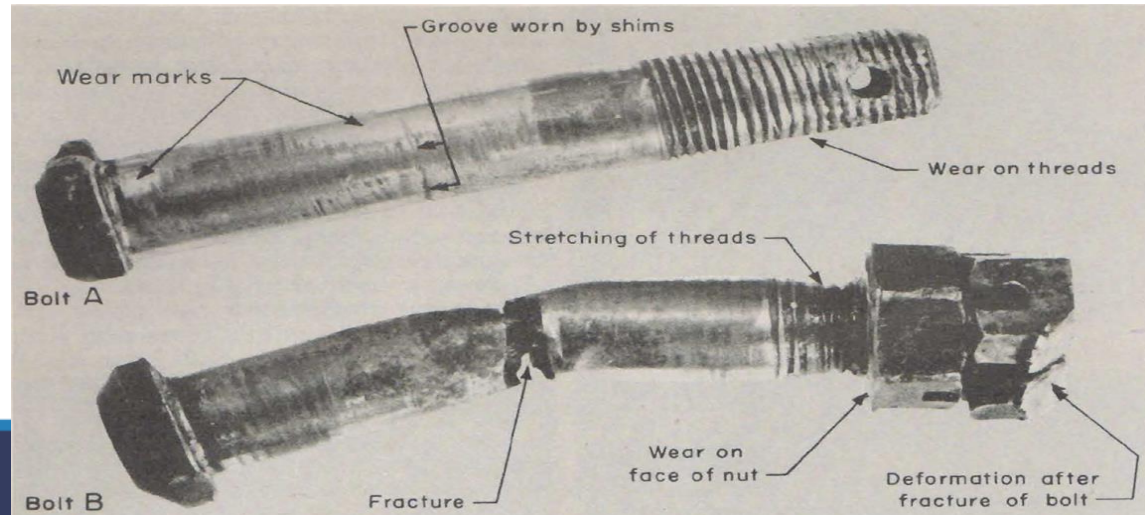
Poor assembling

- Error in assembly can be result from various ways such as:
 - Ambiguity in instruction,
 - insufficient or inappropriate assembly procedure,
 - misalignment,
 - poor workmanship.
- Sometimes failures are also caused by the inadvertent error performed by the workers during the assembly.



Breakdown of air compressor engine

- **Case:** A 4 cylinder engine broke down with fracture of piston, end of connecting rod.
- **Disassembly and examination:** occurred due to failure of two connecting rod bolts used for joining of piston with connecting rod.
- One bolt had no nut showed wear marks



Gear mis-alignment



Failure Analysis & Prevention

Fundamental Sources of Failure: Poor service condition and maintenance

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Poor service conditions

- Failure of an engineering component can occur due to abnormal service condition for which they are not designed.
- These may appear in form of exposure of component to
 - excessive high rate of loading,
 - unfavorable oxidative, corrosive, erosive environment
 - higher or lower temperature conditions for which it has not been designed.



Improper service conditions

- Operation in conditions of abnormally severe conditions of speed, loading, temperature, chemical environment, no-regular maintenance
- Normal inspection and maintenance during service should detect deterioration by expected failure mechanism at regular intervals.



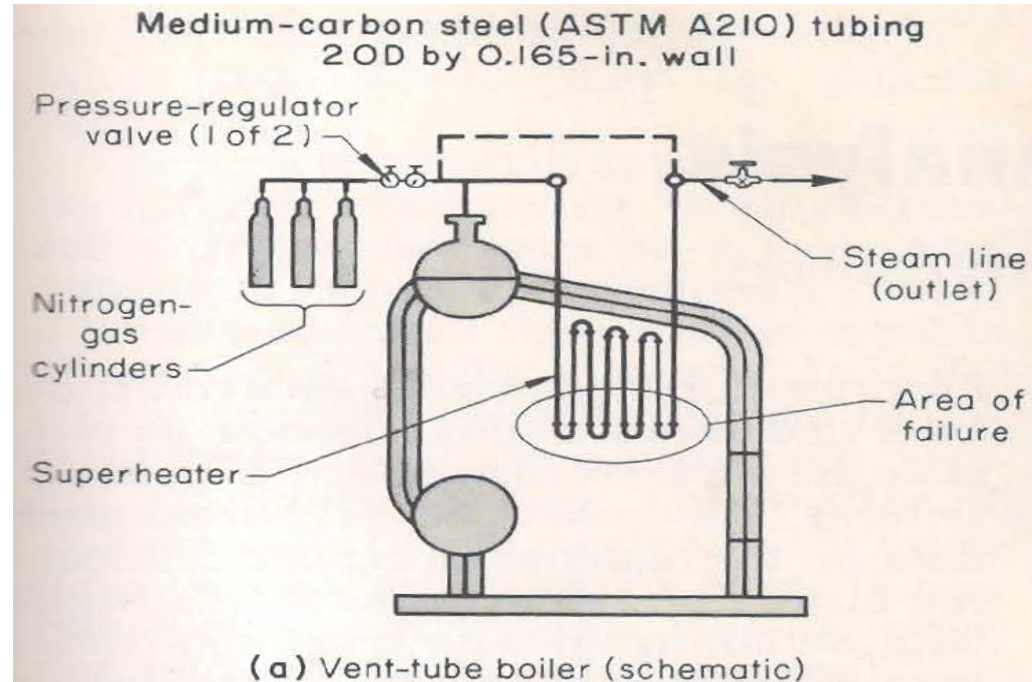
Case study: Boiler tube

- Start ups: is critical for complex equipment, after maintenance, intermittent operations to deal with extreme temperature gradient and stress and other abnormal conditions
- Service
- Shut down: proper procedure should be mentioned.
- Pitting corrosion in super heater tubes of boiler during several annually shot down



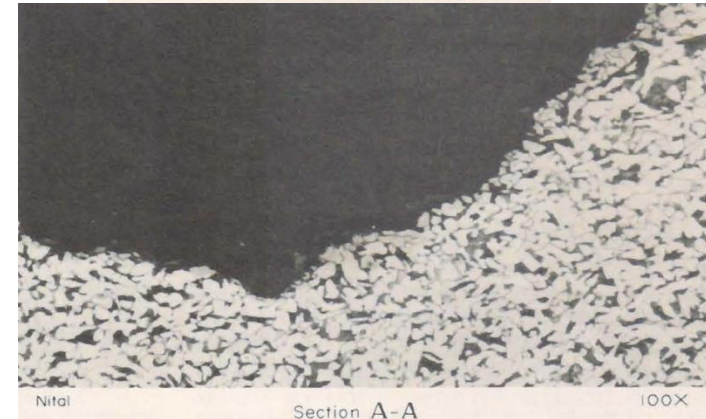
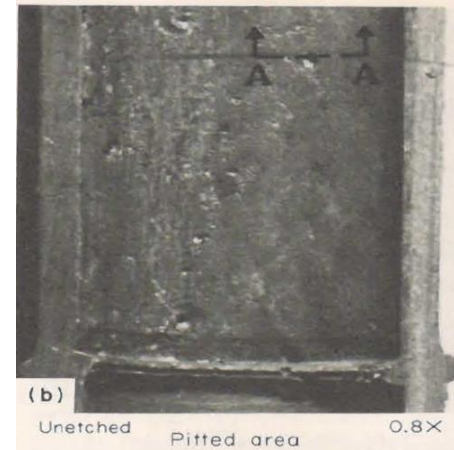
Failure of boiler tubes

- During hydrostatic testing of 15 year old of boiler showed leakage in super-heater tubes at 400°C and 700 psi.
- Tubes of 50 mm size and 4.12 mm thickness had been in service for nine year at 650 psi at 400°C



Investigation

- **Visual:** black adherent magnetic scale with localised presence of powdery, loose, none-magnetic black scale showed pits on removal
- **Analysis of deposit:** XRD showed Fe_3O_4 (black iron oxides), Fe_2O_3 (red dust), FeO without chlorides
- **Metallography:** Normal medium carbo steel structure, no segregation and heterogeneity



Discussion

- Absence of chloride showed no HCL effect used for cleaning of tubes
- Fe_3O_4 formation suggest presence of little oxygen for pitting
- Fe_2O_3 from loose, powdery none-magnetic brown deposit suggests pitting caused by presence of excess oxygen. Observed in normal moist corrosion.
- History revealed that during shot down of 15 days annual overhaul for requisite repairs.
- Oxygen rich condensate caused pitting in low points of bend regions during overhaul; period.



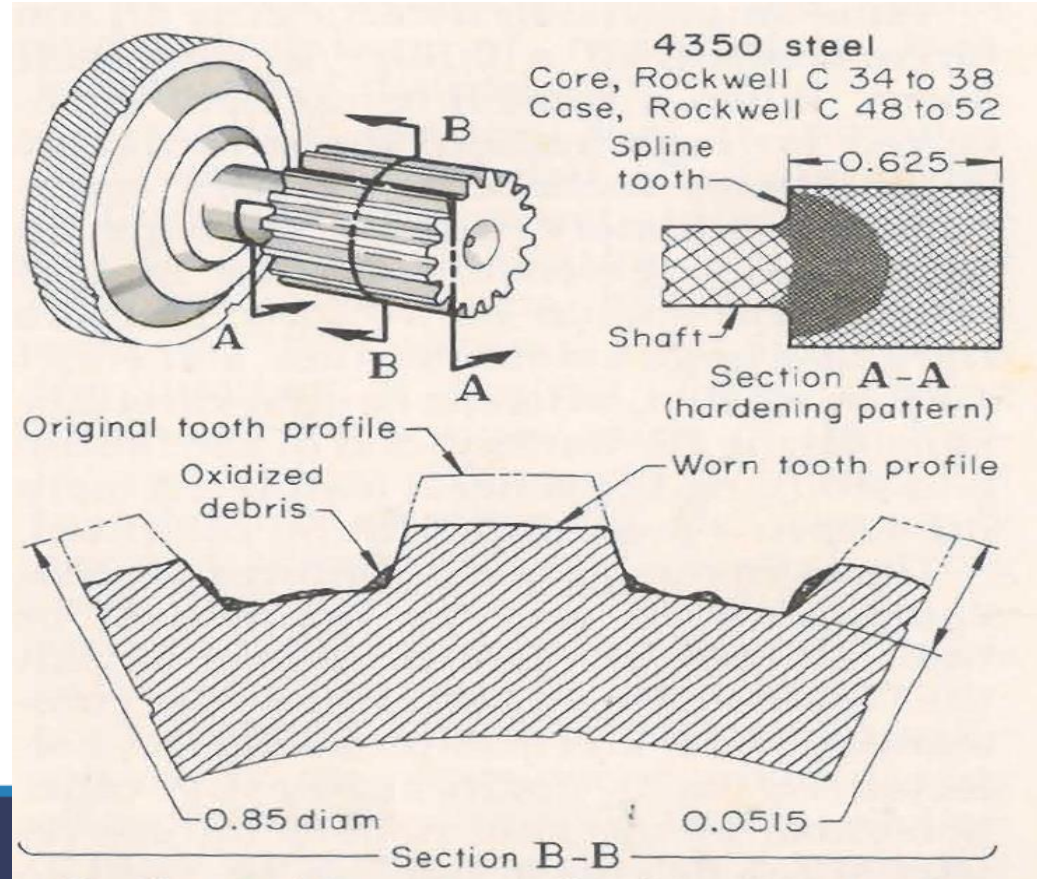
Poor maintenance strategy

- A well developed and clear maintenance plan with steps for maintenance including what, when, where, who and how, is specified explicitly.
- Lack of information on proper schedule of maintenance, procedure of the maintenance frequently causes premature failure of moving components.



Splined end of 4350 steel drive shaft

- Failed after 700-900 hrs
- Shaft of 4350 hardness HRC 34-38
- Case hardened to HRC 48-52 min depth 780 micron
- Counter surface C58-62 with MoS₂ coating



Observation

- Oxidized debris at the root area
- No residual lubricant on splined shaft
- MPT showed no surface defects
- Chemistry and metallography as expected
- Conclusion:
 - failed due to excessive wear due to breaking down of lubricating film

Recommendation: lubrication after each 300 hrs and hardness increased from 48-53 to 58-63 RC

