



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

Failure Analysis and Prevention

General Procedure of Failure Analysis: Determination of type of fracture III Chemical Analysis

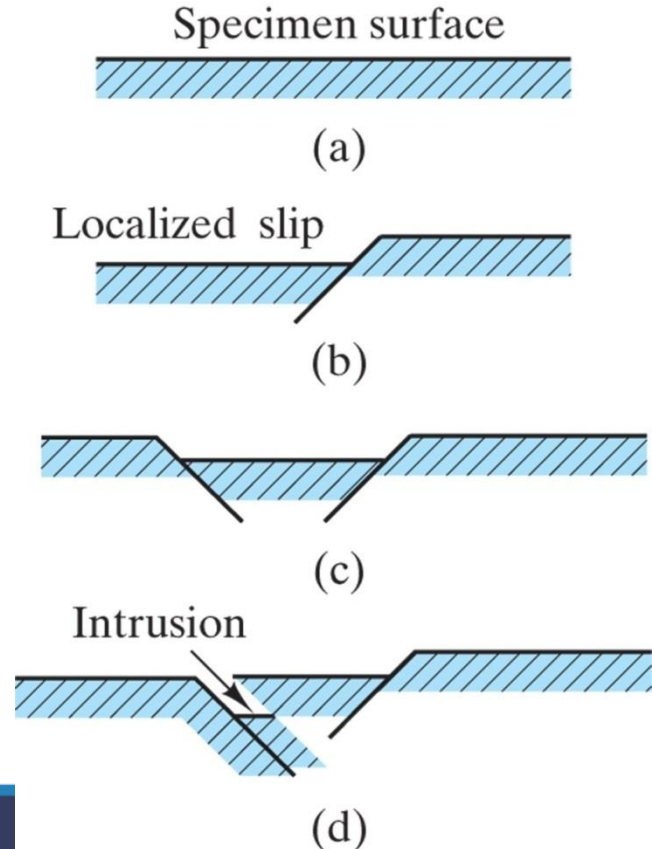
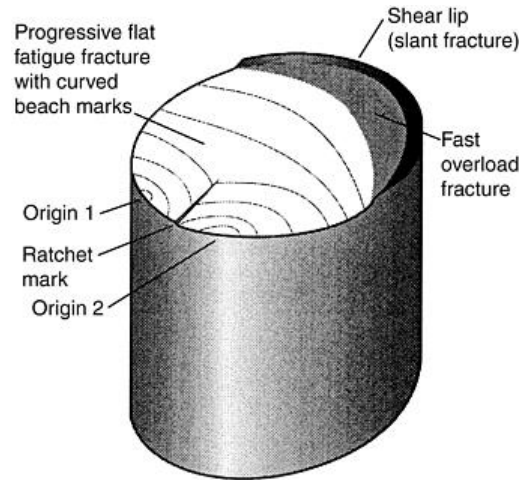
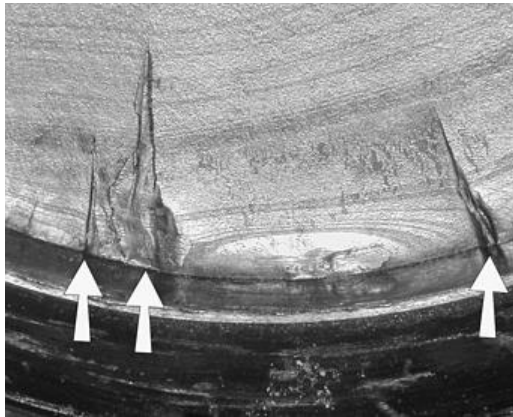
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Fatigue Initiation

- Accumulation of local irreversible plastic deformation
- Creation of microscopic flaws
- Growth and coalescence of flaws to form one or more macroscopic cracks



Fatigue Mechanism

- Cracks in Material grows *incrementally*

$$\frac{da}{dN} = (\Delta K)^m$$

typ. 1 to 6

$$\sim (\Delta\sigma)\sqrt{a}$$

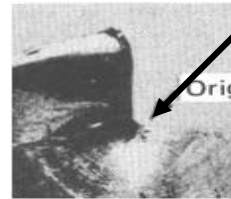
increase in crack length per loading cycle

- To avoid failure

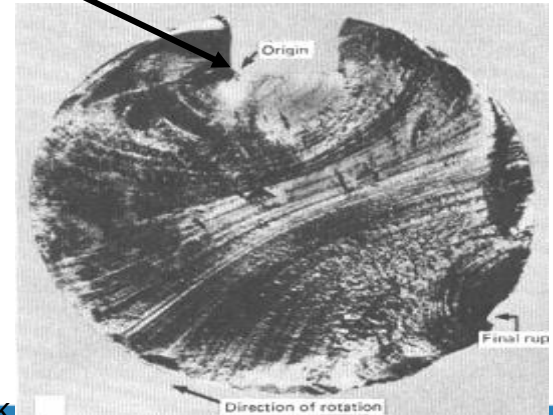
$$K_{max} < K_C$$

Crack growth rate increases with

- $\Delta\sigma$ increases
- crack gets longer
- loading freq. increases.



crack origin



Adapted from
from D.J. Wulpi,
*Understanding How
Components Fail*,
American Society for
Metals, Materials Park,
OH, 1985.



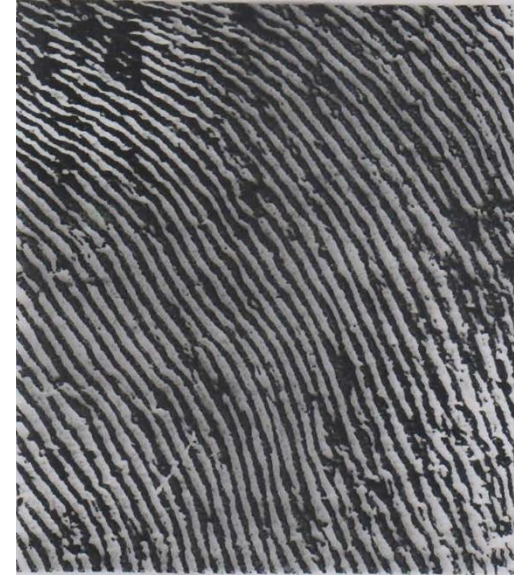
Striated ridges fracture: fatigue : constant / variable amplitude as per spacing



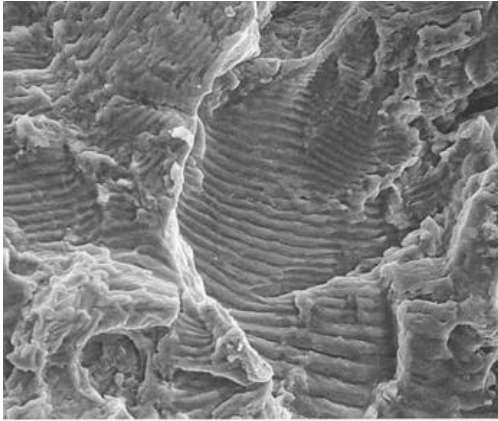
(a)



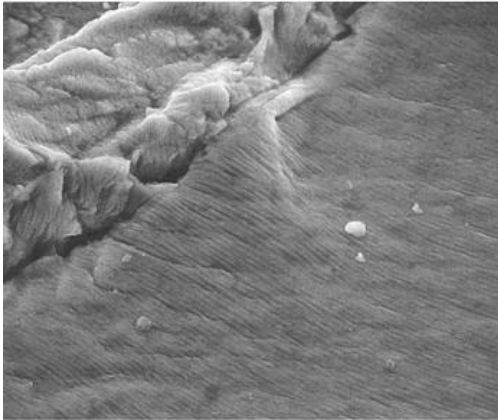
(b)



Coarse and fine

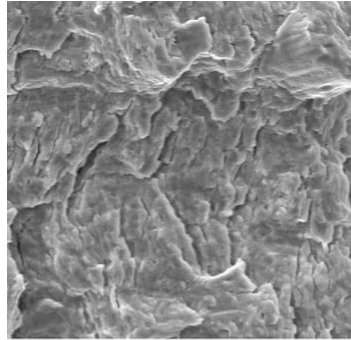


(a)

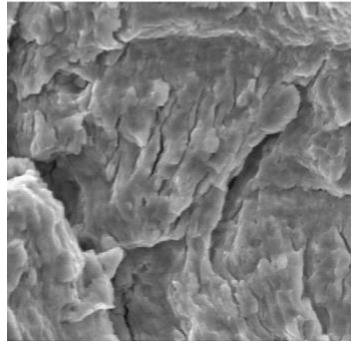


(b)

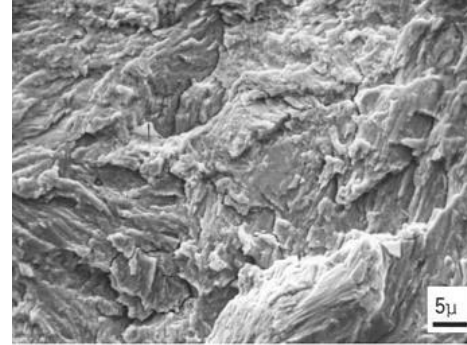
Poorly defined/ no striation



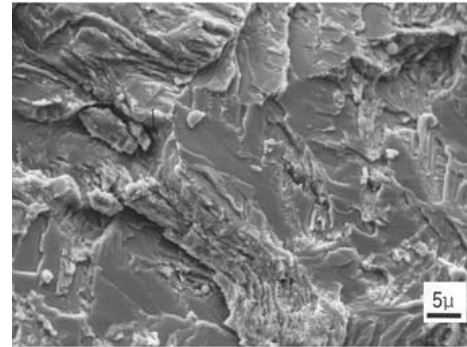
(a)



(b)



(a)



(b)

Chemical Analysis

- Confirmation of chemical composition with standard/specification
- Determination of effect of service: carburising, or decarburising, loss of alloying elements
- Investigate the segregation and depletion of alloying elements
- Study of bulk material, films/coatings, surface deposits oxides, rusts and corrosion products
- Distribution of elements is more important than amount (within limits)
- Analysis of gases oxygen, hydrogen, nitrogen etc. as these affect mechanical properties and cracking and embrittlement



Chemical Analysis & FA

- It affects
 - Microstructure
 - Mechanical properties
 - Response to the heat treatment
 - Corrosion behaviour
 - Hardenability and cracking sensitivity



Methods of analysis

- Optical emission spectrometer: dissolved elements in metal
- Atomic absorption spectrometer: C, S, O₂, N₂, H₂
- Wet chemical analysis: high concentration alloying elements with greater accuracy and concentration of anions Cl⁻, NO₃⁻, S⁻⁻



Methods of spectroscopy

- X ray diffraction based methods for crystalline compounds
- X ray fluorescence spectroscopy for both crystalline and amorphous metals: solid, liquid and gases
- Infrared/UV spectroscopy: organic compound such as oil, grease, rubber and plastics

Micro Probe Analyzer

- EPMA: surface area of about 1 microns in diameter up to 0.1 % content up to atomic No. 3 elements
- Ion Micro Probe Analyzer: same as EPMA with element as low as 100 ppm

Surface deposits

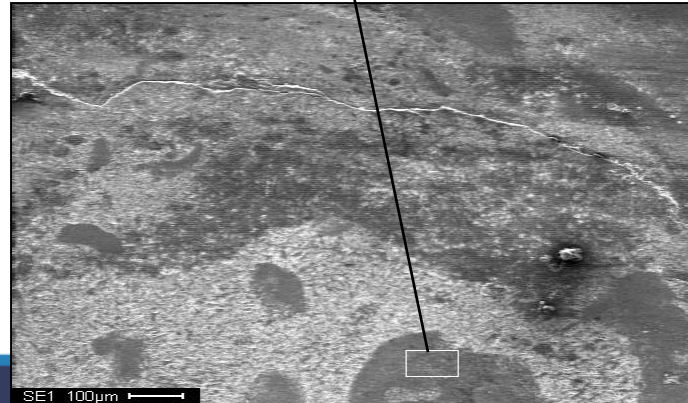
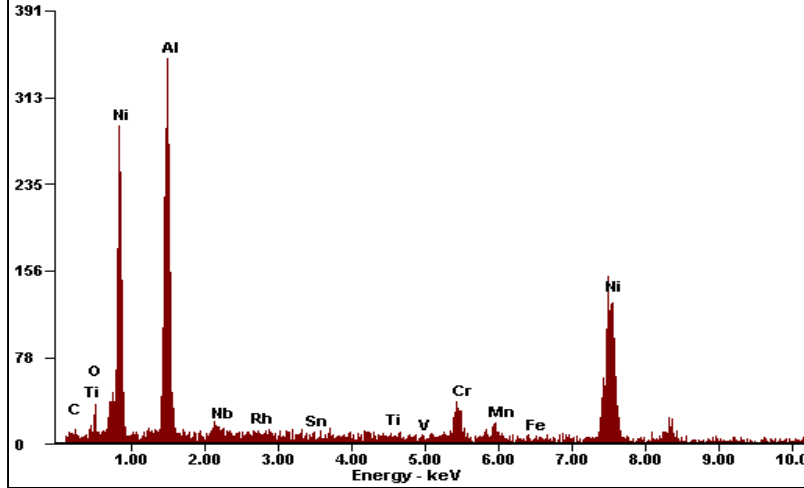
- Few microns deposits: Auger electron spectroscopy, Mossbauer spectrometer
- Auger electron spectroscopy: element with atomic No. down to 3 over area of 1-50 microns
- Mossbauer spectrometer: analysis of compounds such as oxides, sulphides, carbides in ferrous alloy of depth from 3000 Å to 0.00005 inch

Techniques

- Point analysis
- Area analysis
- Line analysis
- Elemental mapping



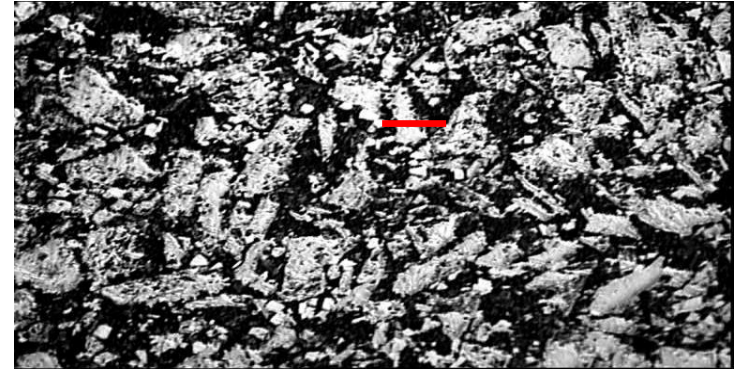
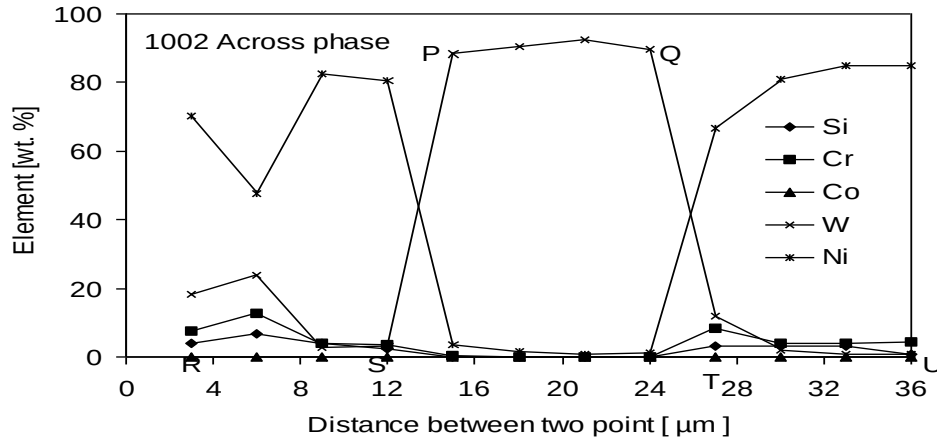
c:\edax32\genesis\genmaps.spc 11-May-2007 10:54:16
LSecs : 7



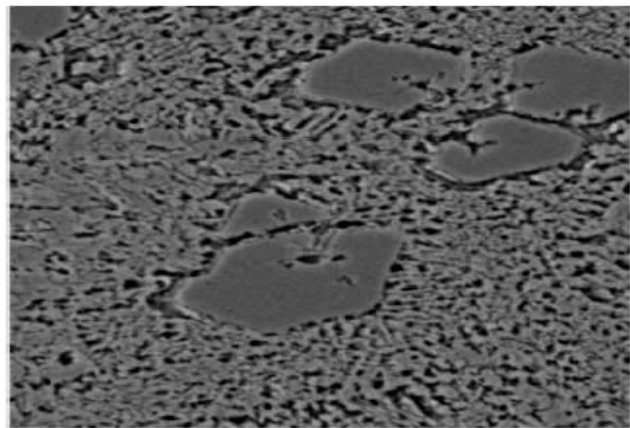
EDAX Analysis

Element	Wt%	At%
C	07.86	22.33
O	03.28	06.99
Al	28.38	35.87
Nb	01.74	00.64
Rh	01.04	00.34
Sn	01.15	00.33
Ti	00.89	00.63
V	00.60	00.40
Cr	05.12	03.36
Mn	01.81	01.12
Fe	00.69	00.42
Ni	47.45	27.56
Matrix	Correction	ZAF

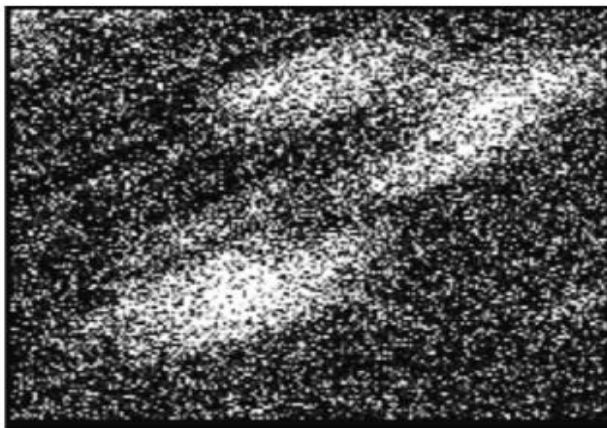
Chemical analysis (EPMA)



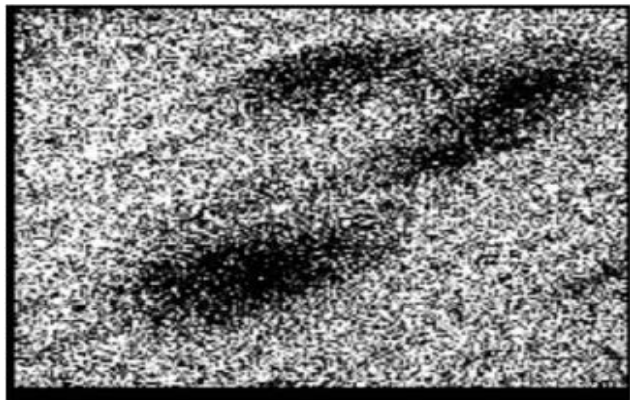
Elemental maps



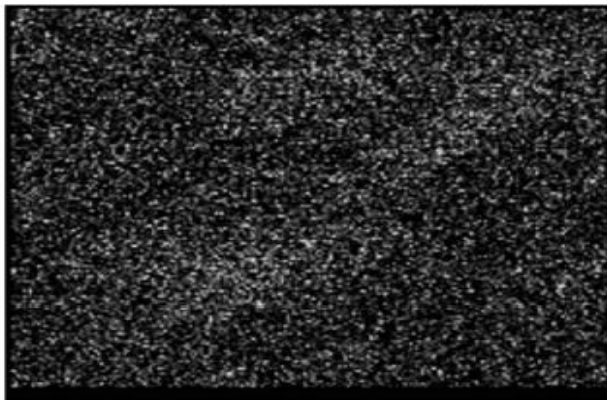
30 μm Electron Image 1



Cr Ka1

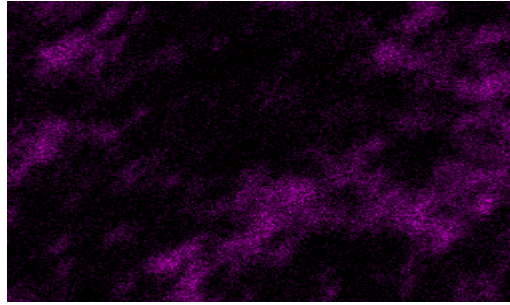
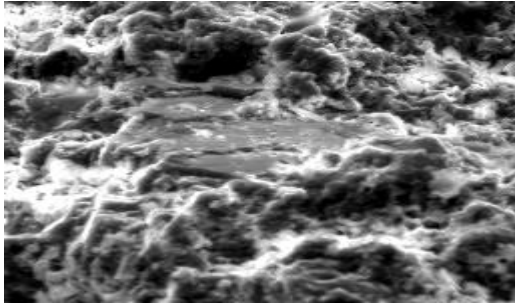


Fe Ka1

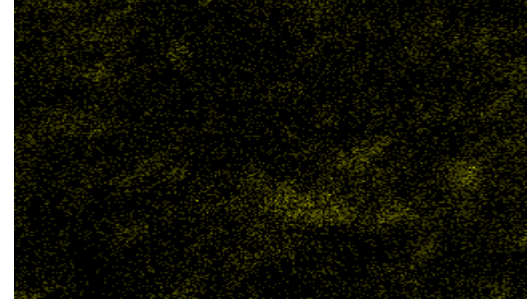


Mn Ka1

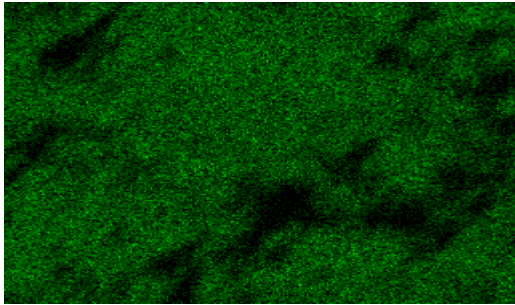
Elemental mapping



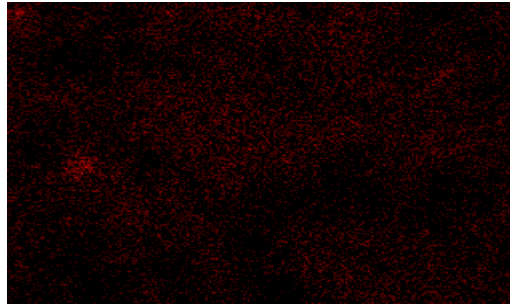
Si



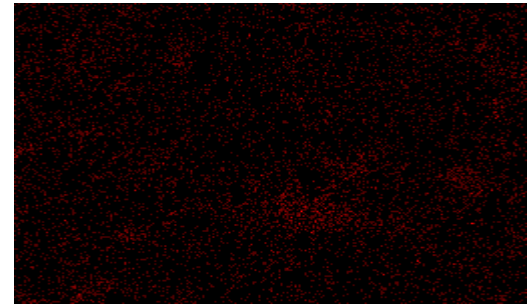
Al



Ca



C



K