Failure Analysis: The Role of Surface Roughness

Chosen Module:
Fatigue and Failure
Group - H

Ragul Visag R - AE23B105
Sankaranarayanan B - AE23B057
Nithyashree Prabhu - AE23B053
Banoth Bhanuprakash - AE23B101
Mutad Farhaana - AE23B109

Aim

To show the effect of roughness of material on its properties such as ductility, ultimate tensile strength.

Theory

Effects of Surface Roughness

- Stress Concentration- Surface roughness, characterized by micro-scale irregularities, creates geometric discontinuities. When a material is stressed, these discontinuities cause the lines of force to concentrate at the peaks and valleys of the roughness profile, resulting in higher stresses in those areas.
- Crack initiation- Surface roughness can significantly reduce crack initiation life in materials subjected to cyclic loading because it increases stress concentrations and creates localized stress fields that can facilitate crack initiation. A rougher surface tends to shorten the fatigue life compared to a smoother surface.
- Wear and Tear- Surface roughness Increases Friction especially in contact loading causing Wear and tear
- Measurement Inaccuracy- Surface roughness can introduce measurement inaccuracies in various applications

Maximum and Minimum effects

Maximum Effects

Surface roughness Exert Maximum Effects

- If the thickness of specimen is low
- The surface roughness parameters are high
- Surface Roughness effects are more pronounced when fatigue failure is involved

Minimal Effects

Surface roughness Exert Minimum Effects

- If the thickness of specimen is high the effects will be minimum in the interior regions
- The surface roughness parameters are not high enough the effects will be negligible
- Slight roughening (light sanding or machining) may induce residual compressive stresses or strain-harden the surface which minimize surface roughness effects and sometimes even inverting the effects

Surface Roughness Parameters

Ra – Roughness Average It Measures the deviation of a surface from a mean height It's a crucial parameter in manufacturing because it directly reflects the surface's overall condition, influencing factors like friction, adhesion, and wear. A lower Ra value indicates a smoother surface, while a higher value signifies a rougher

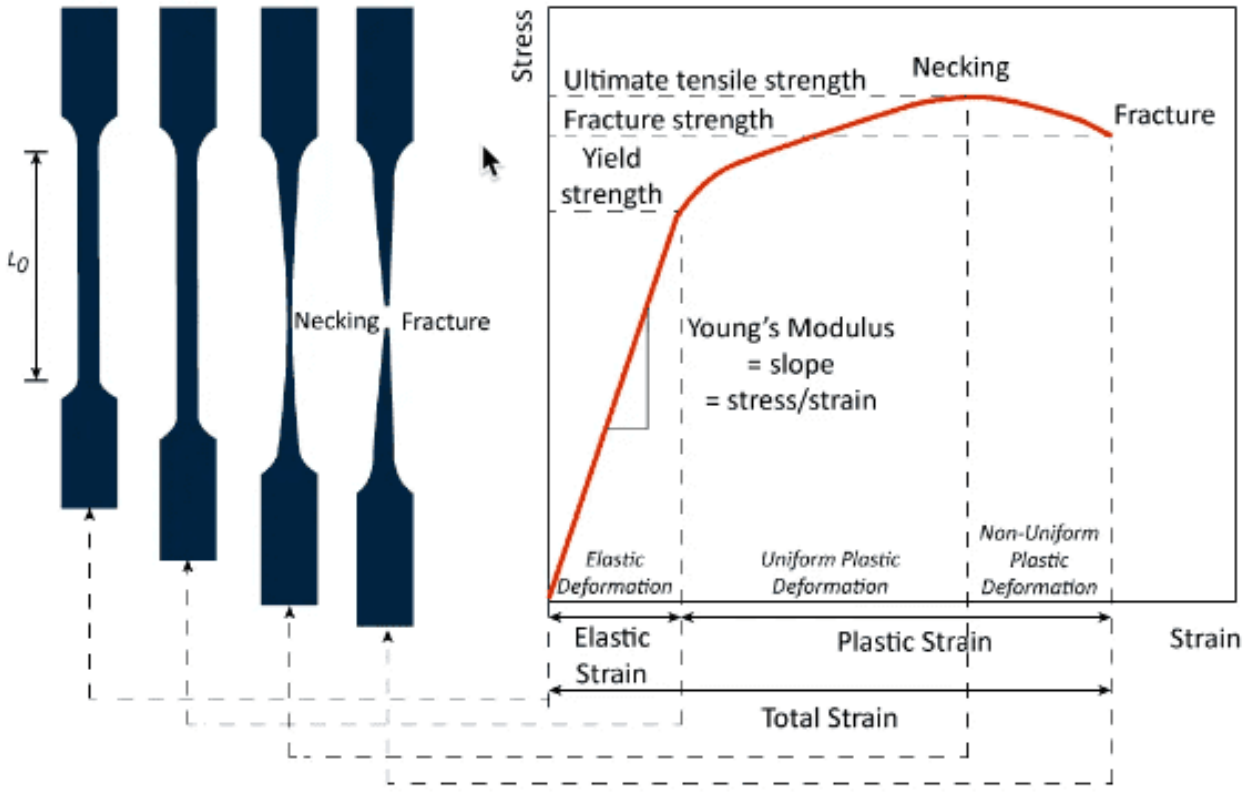
surface.

Other Parameters

- Rq – Root Mean Square Roughness
- Rz – Average Maximum Height of the Profile
- Rt – Total Height of the Profile
- Rv – Maximum Valley Depth

Stress Strain Curve Parameters

- Proportional Limit-Material behaves elastically, meaning it returns to its original shape when the load is removed. The slope of this region represents the material's Young's modulus.
- Elastic Limit-Maximum stress it can withstand without undergoing permanent deformation
- Yield Point-This point marks the transition from elastic to plastic behavior. It's where the material begins to deform permanently under load
- Ultimate Stress Point-This is the highest point on the stress-strain curve, indicating the maximum stress the material can withstand before it starts to fracture.
- Fracture or Breaking Point- This is the point where the material breaks or fails.



Apparatus

- Profilometer
- Universal Testing Machine (UTM)
- Six Aluminium dogbone specimens
- Sandpaper of different grades

Experimental Procedure

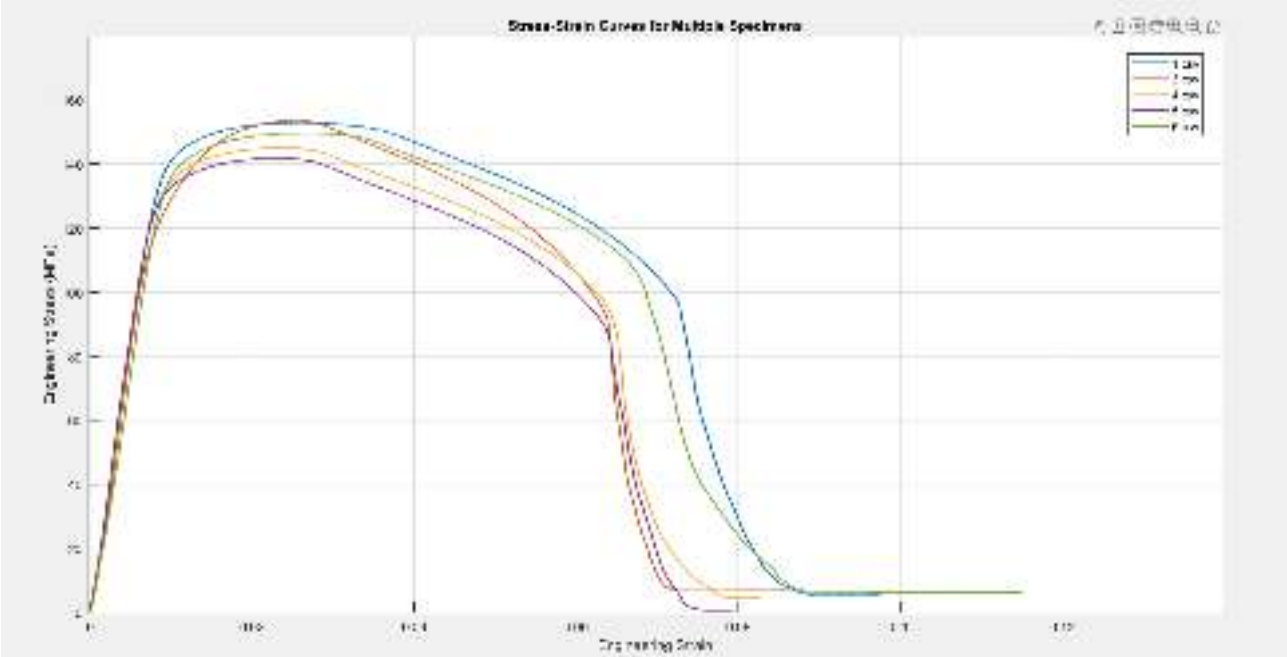
- First, we got the raw materials - 2mm Aluminium plate and sandpaper of five different grades. In our case, we got sandpapers of grade 100, 150, 180, 320 and 400.
- We used water jet cutting to get 6 dog-bone specimens from the Al plate.
- We sanded the Specimen 1 with grade 100, Specimen 2 with grade 100, 150 Specimen 3 with grade 100, 150, 180 Specimen 4 with grade 100, 150, 180, 320 Specimen 5 with grade 100, 150, 180, 320, 400 Specimen 6 is not sanded.
- And then we took the specimens to measure their surface roughness using profilometer.
- After that we did tensile stress for each specimen in the UTM.
- With the help of Force and Stroke data from the UTM and initial dimensions of the specimens ,we plotted the stress-strain plot for each specimen.

Sources of Errors

- The measurement of roughness using profilometer wasn't done properly.
- The test specimens may have internal material defects like voids, which may vary from material to material and influence its behaviour.
- Inconsistent preparation of specimens, insufficient number of specimens could lead to errors in results.

Plot

Figure 1: Stress-strain curves of Five specimens



Results and conclusions

- The Ultimate tensile strength(UTS) values increase in the order 5 , 4 , 6 , 3 , 1 .
- That is, the UTS value increases with an increase in roughness.

- Fracture strain values increase in the order of 3,5,4,6,1
- Although we do not see a monotonic relation, the specimen with the highest roughness shows more ductility and the specimen with lowest roughness show almost lowest ductility(that is ,fractures early).
- The yield point is highest for the specimen with the highest roughness.
- These relations are opposite of what we expected . (UTS ,yield point and Fracture strain decrease with increase in roughness)
- It might be due to the direction of sanding. Instead of sanding it perpendicular to loading, we did the sanding parallel to loading.
- If the sanding is done perpendicular to the loading, UTS, ductility, yield point decrease with increasing roughness.
- When sanding is done parallel to loading, scratches and grooves run along the length of the specimen, cracks are aligned with tensile axis, reducing the stress concentration effects and thus reducing the chances of early crack initiation.
- This results in relatively higher UTS value for a given roughness level.

Individual Contributions

Ragul Visag R (AE23B105)-
→ Raw Material, Experiments, Presentation
Sankaranarayanan B (AE23B057)-
→Raw Material, Experiments, Presentation
Nithyashree Prabhu (AE23B053)-
→ Water jet ,Presentation, Report
Banoth Bhanuprakash(AE23B101)-
→ Presentation, Report
Mutad Farhaana (AE23B109)-
→ Water jet, Presentation, Report

Acknowledgment

We would like to thank TA Priyanka ma'am, Water jet technician Manoj sir for helping us with the project and Prof. Nidish Narayan Balaji for giving us a new experience.