THE UNIVERSITY of TULSA

Properties of Materials (ME 3034)

Failure Analysis of a Marine Impeller and Wear Ring

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Overview

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  - How it works
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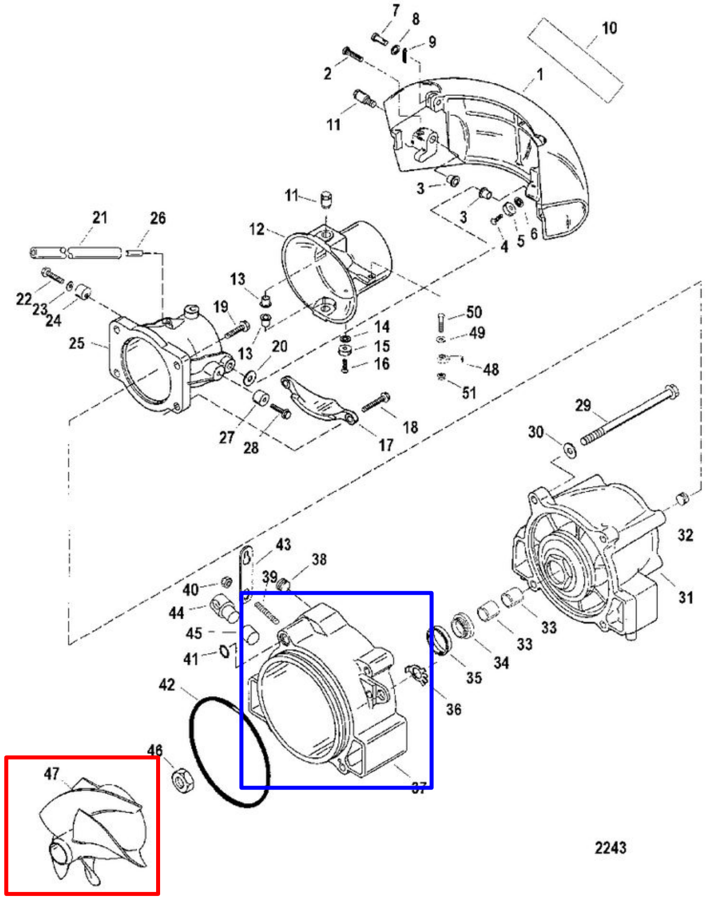
  - SEM pictures
  - Microscope pictures
  - Hardness data
- Reason for Failure
- Recommended Changes
- Work in Progress
- Interview Bio



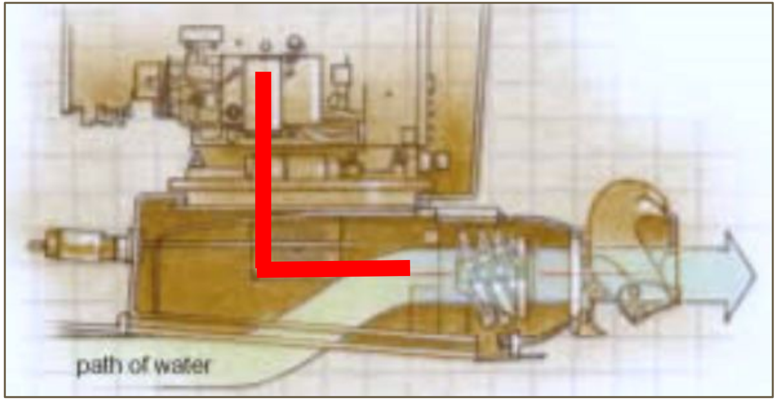
About the part

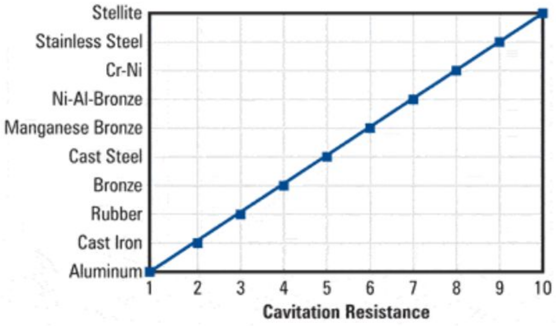
- Two separate parts
  - Wear Ring (aluminum alloy known as XK360)
  - Impeller (stainless steel alloy known as X7)
- 2010 Mercury Marine Sports Jet

- https://www.mercurymarine.com/en/us/engines/outboard/jet/200-hp-optimax-sport-jet/

How it Works: Onboard Marine Motor

- Nozzle accelerates fluid through exit
- Reversing Gate swings down to redirect exit for reverse drive
- No NPSH Curve or Head Data Published
- High performance pump, thus cavitational
- Wear Ring: takes damage first

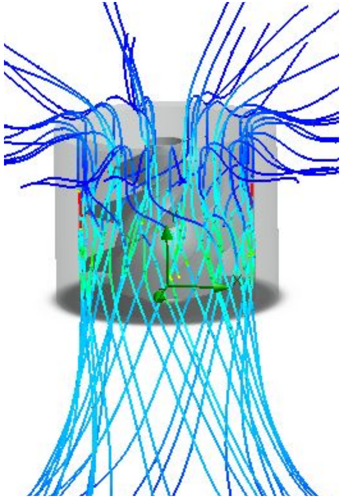


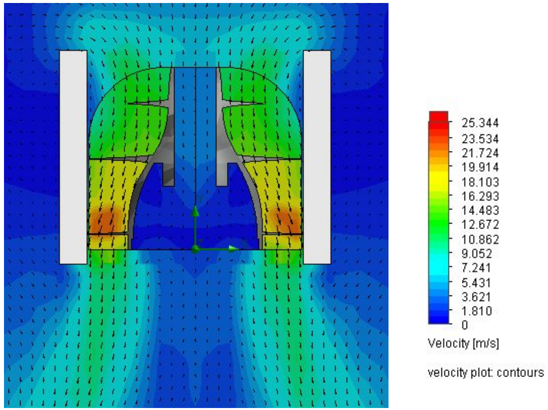


Visual Observations

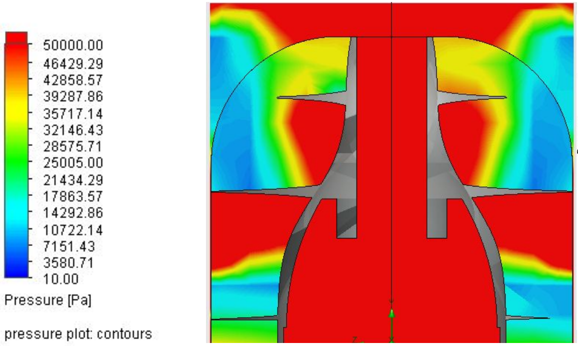
CFD Analysis

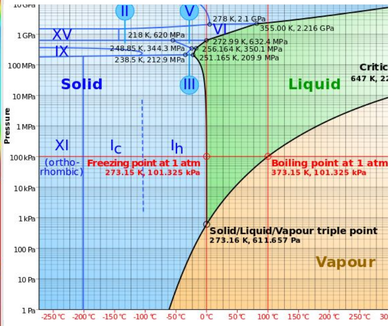
- Velocity plot
  - Shows the movement of fluid
  - 500rad/s (4775rpm)
  - Max of jet boat between
    - (5160-5650)rpm





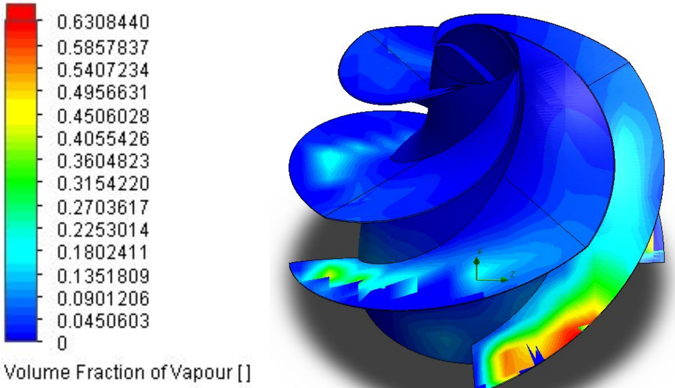
- Pressure Plot
  - Dark blue represents below vapourization point for room temperature
  - Phase diagram plot shows the switch between liquid and vapour
  - normal pressure 101,300Pa





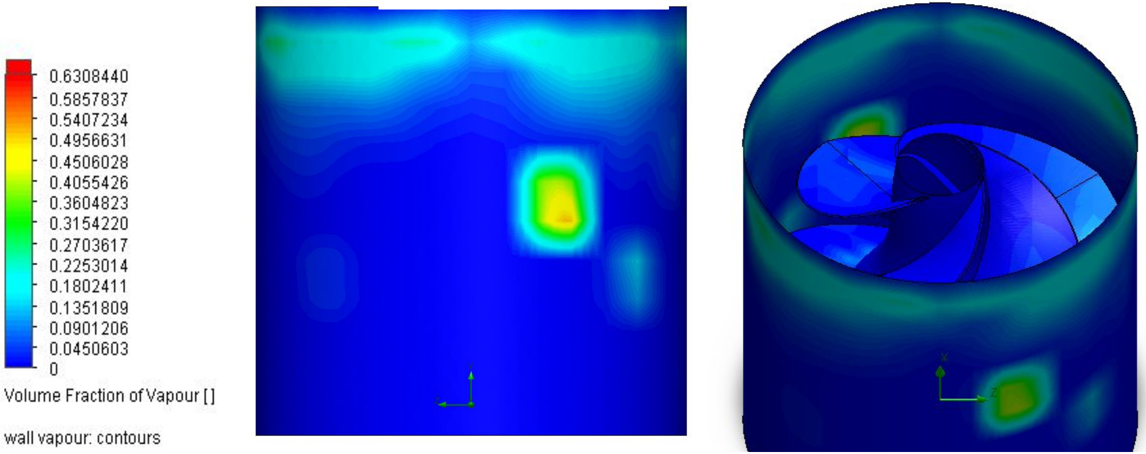
CFD Analysis

- Percent Fluid Vapourization on impeller
  - red represents about 60% vapour
  - vapour points are where it cavitated on real object.



impeller vapour: contours

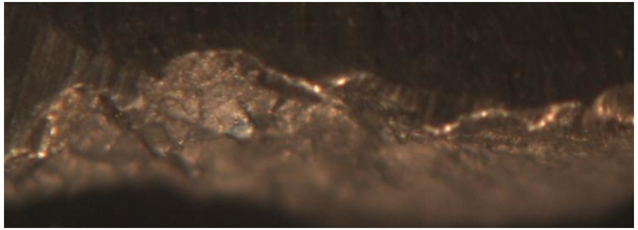
- Percent fluid vapourization on wear ring
  - ~45% vapourization
  - The localized point circles the entire wear ring (because solidworks models it as rotating fluid with a stationary part)
  - correlates with cavitation on real wear ring.



wall vapour: contours

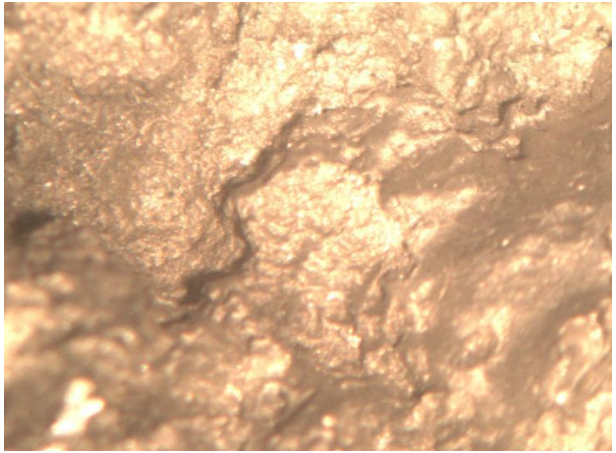
Microscope Pictures of damage

Stainless steel impeller

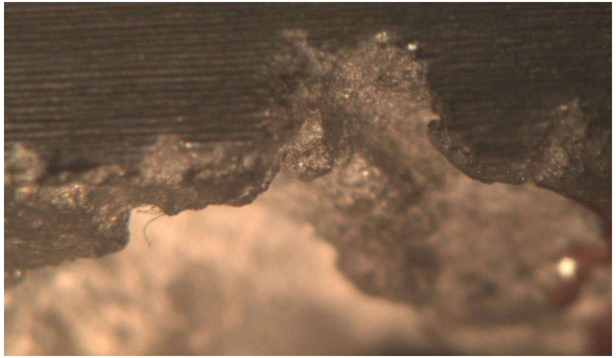


<- top view ->

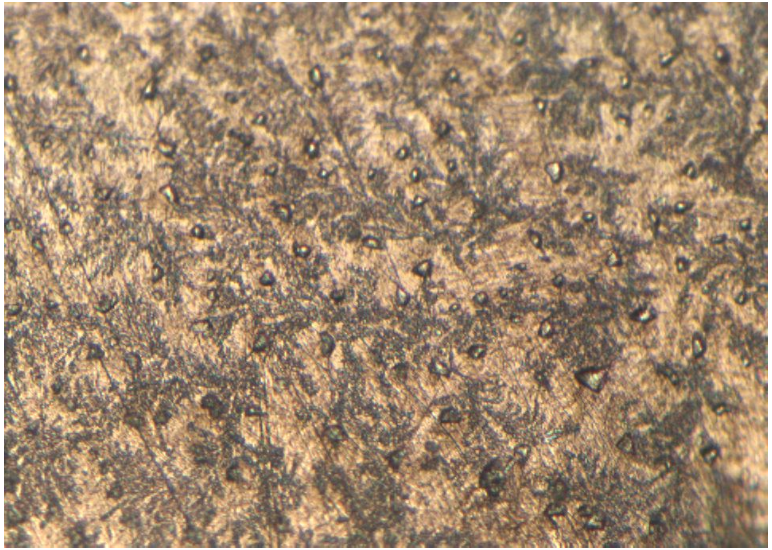
<- side view ->



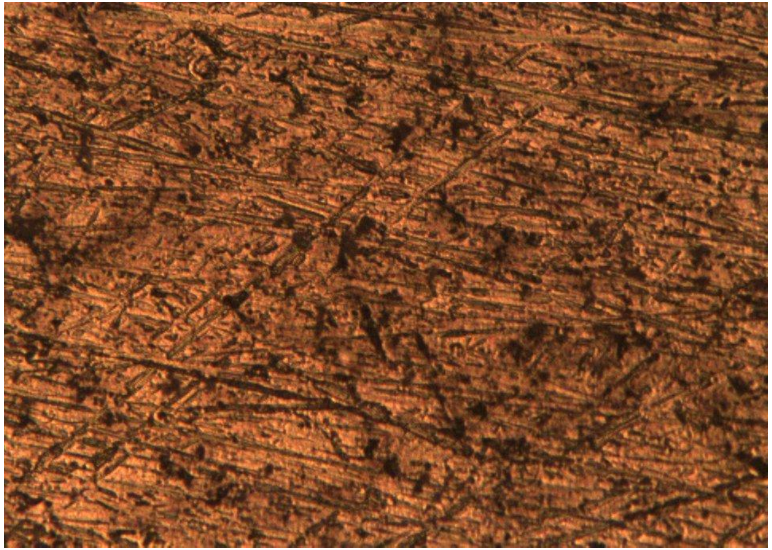
Aluminum wear ring



Grain Structure Microscope pictures



Stainless steel impeller

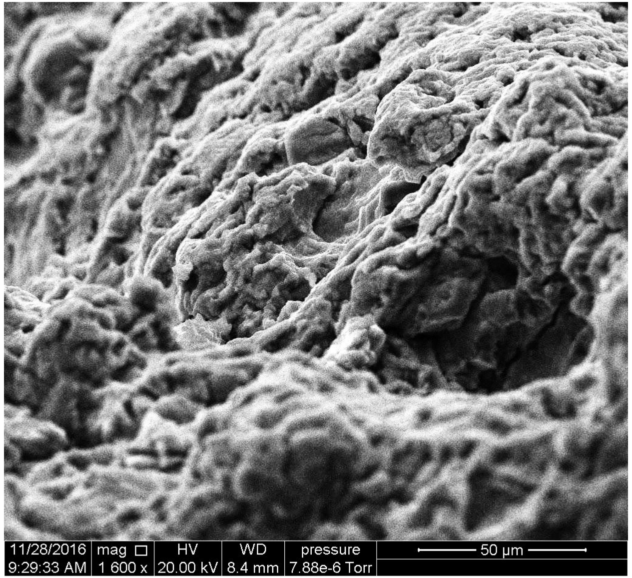


Aluminum wear ring

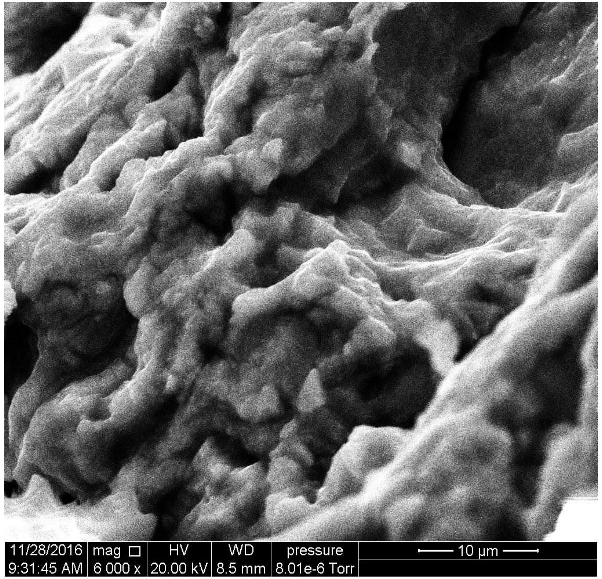
Scanning Electron Microscopy:

220x - 6000x @ 20.00 kV

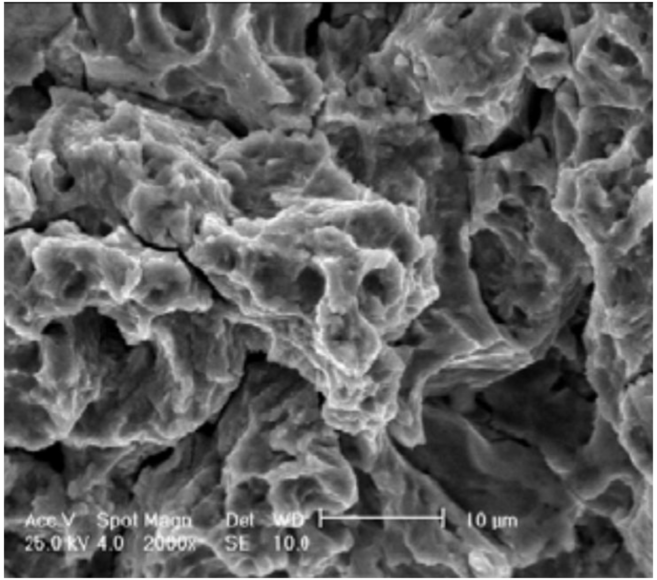
Direct evidence of cavitation damage on wear ring



1600X



6000X



Reference Comparison (same scale)

Hardness data

- Near cavitation (Rockwell F): 48.9
- Far from cavitation (Rockwell F): 80.3
- Impeller steel (Rockwell A): 59.8

Hardness closer to the exhaust port is significantly lower than the hardness further away on the wear ring

Reasons for Failure

- Main Reason: Heat from engine and exhaust port softened the aluminum, allowing for a large section of cavitation
- Other Possible Reasons:
    - Chemical erosion on wear ring
        - Rejected: Orientation does not support
    - Normal cavitation on the impeller and wear ring
        - <10% BEP leads to cavitation
        - Not enough information for a BEP calculation or a NPSH curve
        - Rejected: Damage is localized as opposed to diffuse

Recommended Changes: How to Improve it

- Similar Impeller - Wear Ring Designs, such as those by Seadoo, use a removable plastic wear ring cover that can be easily replaced for ~$14.99
- Regular Maintenance/Repair: Multiple online forums suggest that using JB weld to fill in cavitated areas is an effective way to repair the part and restore factory performance
- The cavitation damage seen on the impeller appeared to be standard cavitation damage over time (not a failure) thus replacement of the impeller is still a necessity at some point. Switching to a more cavitation-resistant material (such as stellite) would improve this lifetime.

Conclusion:

While these improvements/treatments are possible and may improve parts' lifetimes, **we do not suggest design changes to the parts studied**.

The failure was likely caused by heightened exhaust temperatures from the **engine**, possibly due to improper WoT use or poor maintenance. Extended tests to determine repeatable failure would be necessary to determine if the engine exhaust temperatures were **anomalously high** in this case. A survey of literature and forum discussions did not reveal any comparable failures, suggesting the engine exhaust temperature is not normally harmful.

There was no evidence of any casting flaws or material defects in our parts.

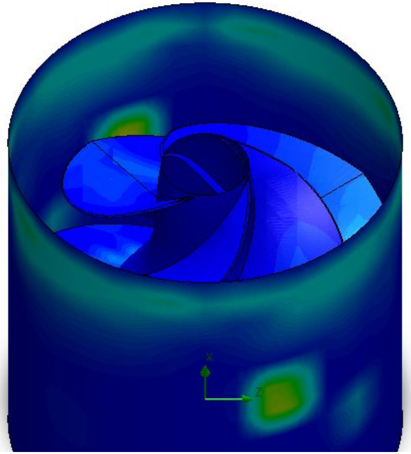
Work in Progress

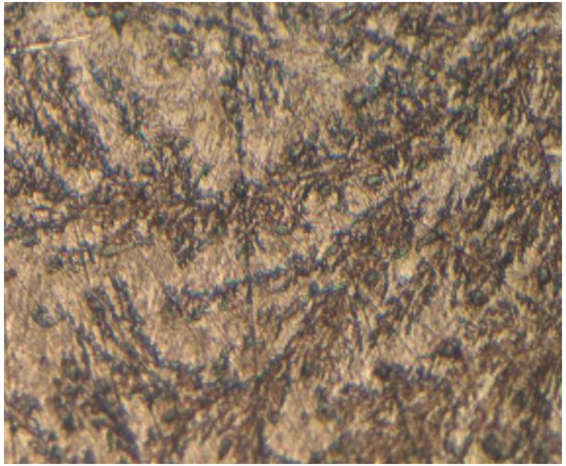
- Finish hardness testing
- Finish writing report

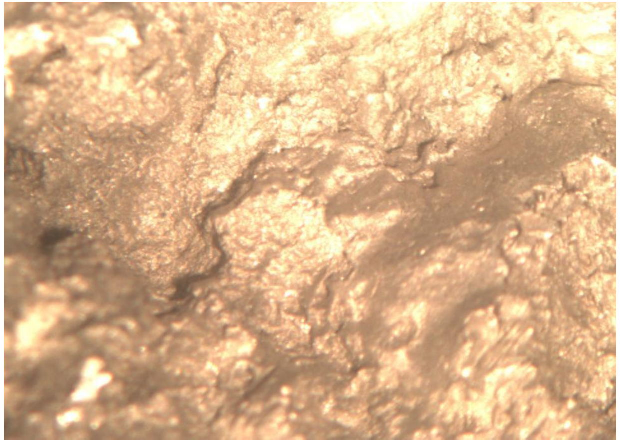
Interview Bio: Jason Fishell

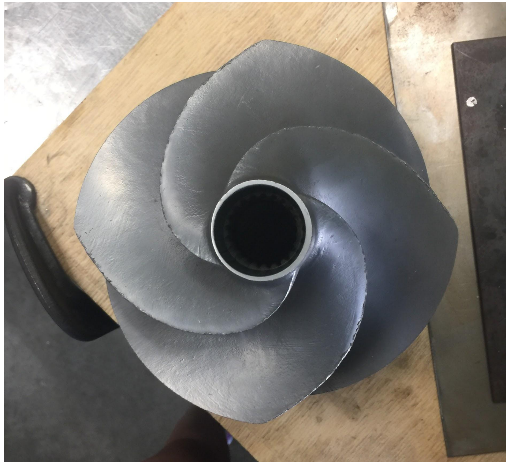
- Experienced Program Director within the construction industry
- University of Maryland
- Previous employers: Bechtel, Areva, Day & Zimmermann, and Mitsubishi Nuclear Energy
- Maintenance within various domestic nuclear power facilities
- Construction of the new Walter Reed Military Hospital

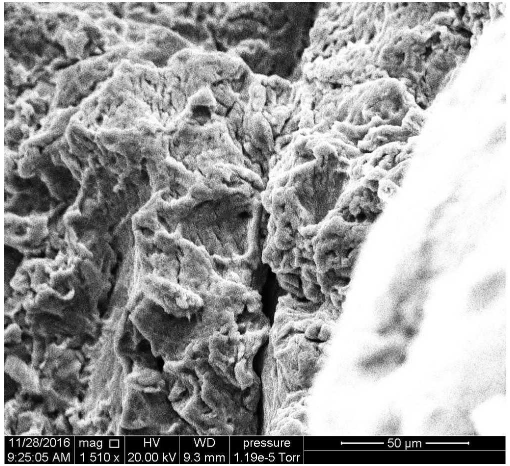
Questions?







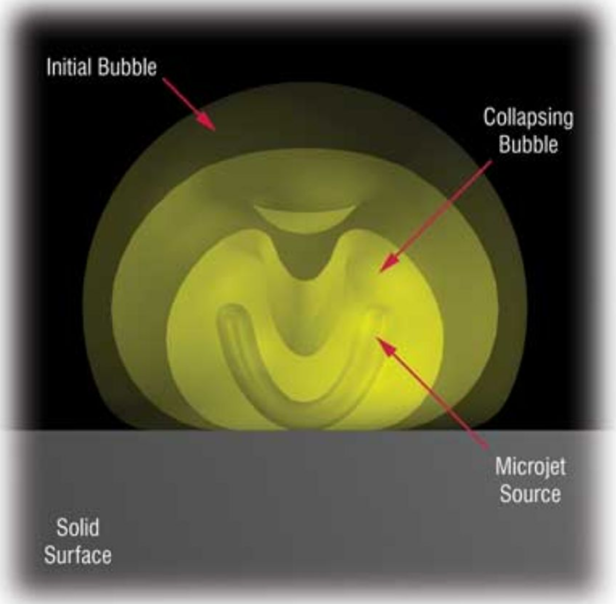



11/28/2016 mag HV WD pressure
9:25:05 AM 1 510 x 20.00 kV 9.3 mm 1.19e-5 Torr
50 µm

What about..? (Cavitation and Stellite)

Cavitation is the formation of vapor cavities in the liquid. In our case, the formation is caused by pressure differences that cause localized pressures to drop below the vapor pressure of the fluid.

The bubble quickly collapses as the local pressure normalizes; a destructive “microjet” driven by the collapsing bubble impacts the solid surface, causing cavitational damage.



Stellite alloy is a range of cobalt-chromium alloys designed for wear resistance. It may also contain tungsten or molybdenum and a small but important amount of carbon.