USING THE OSU TRIGA NRF TO ANALYZE MICROSTRUCTURE IN 3D PRINTED PARTS

Team: B. Boehlecke, C. Jablonski, B. Kyle, S. Moyers
Mentor: Dr. Chen

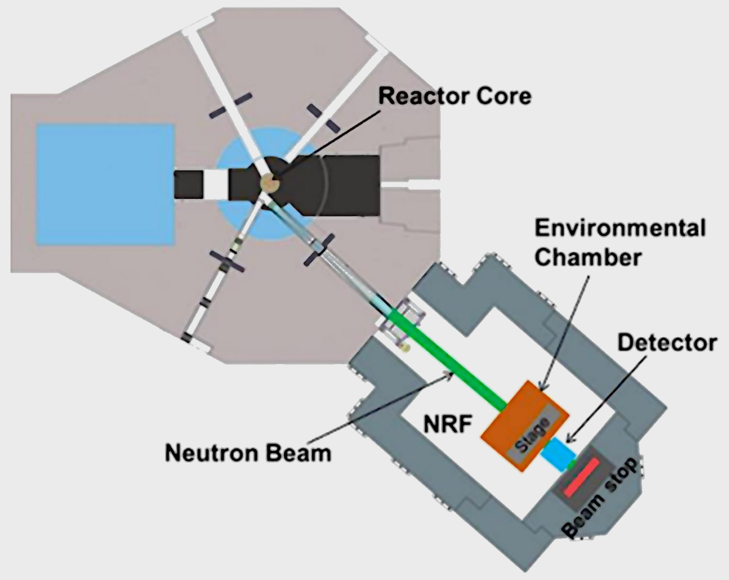
MATERIAL SCIENCE

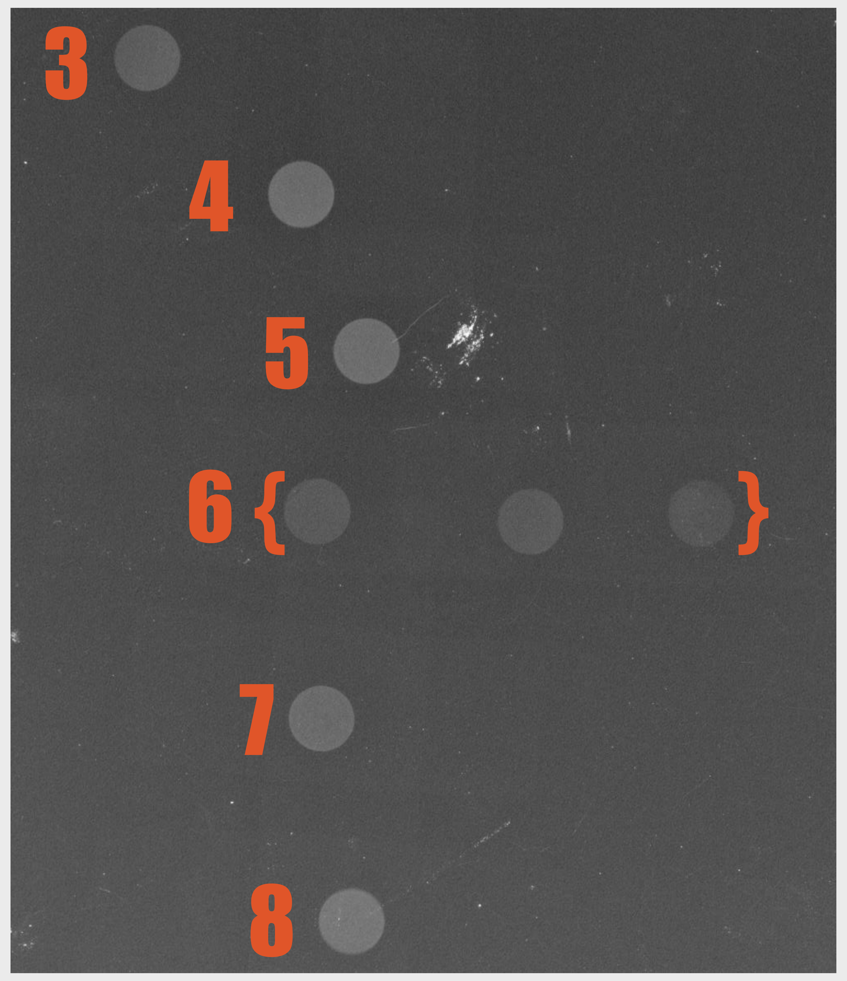
- 3D printing of metal causes microfractures and imperfections within the assemblies.
- Normally, metals form microstructures such as martensite and austenite that can be observed and studied.
- For most metals, laser melted metals included, martensite is the most common microstructure; it forms under most circumstances.
- These microstructures still form within 3D printed parts, but with many added defects and imperfections.
- The main types of imperfections that can form are keyhole pores, spatter defects, and metallurgical pores.
- Keyhole pores occur due to rapid solidification of the metal before the molten metal has had time to completely fill in all the gaps.
- Spatter defects are "high recoil pressure" above the melt pool caused by the high energy density of the laser causes portions of the metal to "jump", leaving solid areas where they should not be.
- Metallurgical pores form when gasses become trapped within the melt pool or in the powder, forming gaps in the material.
- These types of defects are unique to laser 3D printing and can cause issues within the structural integrity or the strength of certain parts.
- These defects are extremely small, approximately 50-100 micrometers in width for the largest ones.

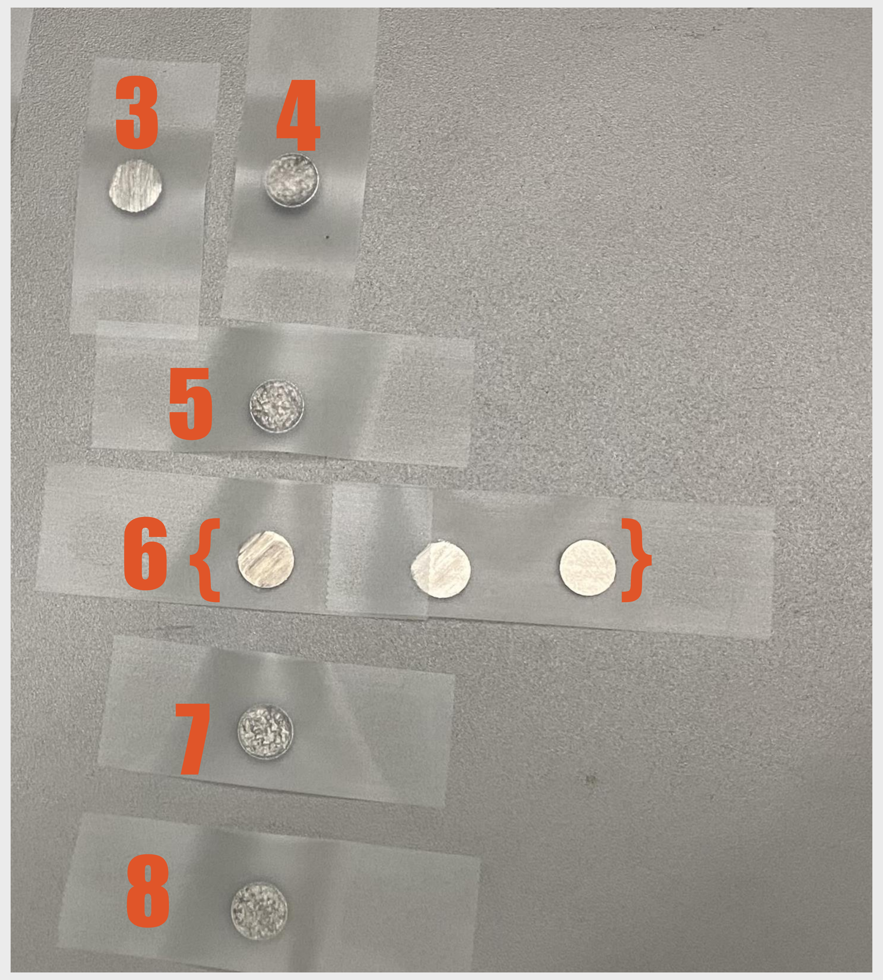
Oregon State University

NEUTRON RADIOGRAPHY FACILITY (NRF)

- Attached to OSTR 1 MW_{th} Research Reactor
  - Tangential Beam Port #3
  - Consists of collimator, beam stop, sample chamber, reactor, neutron beam
- Neutron radiography likes thermal neutrons ~0.25eV
  - Thermal Flux: 4.41E06 ± 2.9E03 cm^{-2} s^{-1}
  - Epithermal Flux: 6.77E04 ± 3.6E02 cm^{-2} s^{-1}







3D PRINTED PELLETS

The metallic pellets are SAE 304 stainless steal with a partial weight percent of yttrium. These pellets were additively manufactured(AM), a practice of 3D printing metal parts from a metallic powder bed by fusion with a high-powered laser.

When looking at the samples on the left, there is some variation in the shade because of their thickness. This was the plan, to observe how the samples microstructure varied with thickness and printing speed. The initial experiment was to examine the samples before and after polishing.

The left image is the result from neutron imaging, not quite the quality needed for observing the microstructure, which also led to polishing being unnecessary.

IMAGE RESOLUTION

To get useful images out the NRF we need to be able to resolve fine details of the samples. The resolution can be thought as "how much information does this image contain?" In neutron radiography this resolution comes from the number of neutrons hitting the plate over the time of the exposure. The rule of thumb is a longer exposure results in more neutrons granting higher resolution. The image above was taken with a 30 second exposure but two longer exposures were also taken, one at 1 minute and the other at 2 minutes. Unfortunately, both of these images failed due to being massively over exposed. Too many neutrons hit the plate and any information to be gained was lost.

NEUTRON RADIOGRAPHY

- Non-destructive imaging known as neutron radiography (NR) has been used since the 1950s.
- NR is a similar practice to X-ray imaging; neutrons interact with the nucleus of atoms and X-rays interact with electrons.
- Neutrons can pass through dense materials such as titanium, steel, tungsten, lead, concrete, etc.
- Neutrons have difficulty passing through less dense materials such as water and polymers.
- Easily passing through dense materials allows for advanced imaging inside metallic parts, such as the ones used in cars, planes, and turbines.
- Two main methods of NR; Neutron Imaging Plates (NIP) and Neutron Scintillators Imaging (NSI).
- Neutron Imaging plates use a gadolinium film with a high thermal neutron cross section and require extended exposure to thermal neutrons. It makes high resolution images.
- Neutron scintillator imaging uses a neutron scintillator with a crystal that emits a photon from neutron interactions. It can take dynamic imaging and requires very little thermal neutron exposure but sacrifices resolution.