Removal by Grit or by UHP Waterjetting

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In Mid-May 2008, I got two separate inquiries about "How much metal will UHP waterjetting remove compared to dry blasting?

In each case, the owner was looking at corroded areas and didn't have a protocol or specification for UHP waterjetting for corrosion removal.

The question of material removal of metals has been studied for several years. This subject has been looked at in depth by the companies like Thiokol who use UHP waterjetting to remove corrosion, and the aircraft engine manufacturers (Delta, Lufthansa, KLM, United, General Electric) who use UHP waterjetting to remove hard coatings where they previously used chemical stripping or very fine grit. These companies have very intricate parts and cannot stand loss of metal.

1991 Metallurgy Report on Surface Stress of Steel after Cleaning with 36,000 psi waterjet.
There is a metallurgy report dated 1991 from Materials Evaluation Lab who looked at this for Jet Edge who was doing some work for a Global Oil Production Company. The oil company engineers wanted and analysis of stress on steel after cleaning with 36-40,000 psi waterjetting. The UHP WJ equipment was an intensifier system- this means it had low flow volume.
These are the engineer's conclusions:
1. Pressurized water effectively removed rust and other corrosion products from metal surfaces. This was done with minimal disturbance of microstructural features.
2. Methods using abrasive particles were necessary for the removal of adherent mill scale. Those techniques cause severe distortion of the metal surface.
3. The pressurized water method was considered the best preparatory cleaning for non-destructive inspection. It offered a more "authentic" representation of the surface than the other methods evaluated.

1999 Thiokol Paper on Erosion of Steel Substrate Exposed to Ultra-High Pressure Waterjet
The 1999 WJTA paper by Swenson and Miller of Thiokol "EROSION OF STEEL SUBSTRATES WHEN EXPOSED TO ULTRAPRESSURE WATERJET CLEANING SYSTEMS "is a good summary of the substrate change.

The first pass of a UHP WJ removes some material. I have always thought, as I have looked at micro-photographs, this first-pass removal would be the hackles and/or any embedded abrasive material from the original profile. Then the second or third pass doesn't remove any additional material. Thiokol has a very minimal tolerance for removal.

Let me summarize what the table shows:

One pass, 36,000 psi, 0.015 mil (0.000015 inch) maximum erosion
Two passes, 40,000 psi, 0.021 mil (0.000021 inch) maximum erosion
Three passes, 40,000 psi, 0.021 mil (0.000021 inch) maximum erosion
Six passes, 40,000 psi, 0.021 mil (0.000022 inch) maximum erosion
One refurbishment, zirconium silicate grit, 0.70 mil (0.0007 inch), erosion

The abrasive blast removal is 0.7 mils; the UHP WJ removal is <0.02 mils.

Their findings are:
The level of material erosion is decreased by approximately 98% when UHP WJ is used compared to abrasive blasting.

All the papers and studies will say: Do not let the UHP WJ nozzle sit on the surface at a single spot; particularly when it is not spinning.

That is reflected as a 0 inch per minute transverse rate. If the focused nozzle is at rest and pointed at one spot, you can get material loss although still at a lower rate than abrasive blasting.

Cleaning of Sewer Pipe with Pressurized Water Systems.
D. Wright, J. Wolgamott, G. Zink, WJTA American Waterjet Conference, Houston, paper 2B-1, (2005); D. Wright, J. Wolgamott, G. Zink, 2005 WJTA American Waterjet Conference, Houston, paper 2B-2, (2005)

This erosion of material if the nozzle is at rest is also true for interior pipe cleaning. Zink and Wolgamott of Stoneage have published a series of WJTA papers showing the effects of bad nozzles and nozzles at rest on the erosion of the interior of pipe.

Calculation of Erosion in terms of energy per square area per minute per hydraulic horsepower
One of the major UHP pump manufacturers has studied this erosion and energy concentration at length as they sell both cleaning and cutting equipment.
A typical surface cleaning application is 0.8 liters/minute (3 gallons per minute) at 280 MPa (40,000 psi) at a rate of 22 square meters (200 square feet) per hour. To erode MILD steel, you would need about 150 times more energy in terms of square area per minute per hydraulic horsepower. In other words, you would need to slow down to about 0.15 sq meter per hour at the same parameters in order to get erosion.

Removal of Surface Radiation from Steel- Dry Blasting compared to Ultra-High Pressure Water
UHP WJ is routinely used to remove surface radiation from steel in nuclear plants.
John S. Oechsle Jr., who is now retired, worked with S.G. Pinney & Assoc. in Florida and prior to that in the 1950's worked with Metalweld and DuPont in the nuclear industry. IN 1999, he talked to me about what happened to the surface, removal of Corrosion, and surface radiation. The exterior surface of any metal starts to change as soon as it comes out of the mill. The change is at the outer boundary and as you go into the material, you reach the bulk property region.

Metalweld and DuPont in the 1950's showed that corrosion invades the surface by about 2.5 mils at the grain boundary. To remove all contamination by dry blasting, it required 5 consecutive blasts consuming 47.5 lb. of abrasive/ft.^{2} to remove enough steel to eliminate the surface corrosion contamination. NACE No. 1/ SSPC-SP 5 was the standard.

Ultrahigh-pressure water at 36000 to 55000 psi removed the surface contamination in one full pass. On a project in Japan, 28 tons of structural steel had been in immersion in a nuclear plant for 19 years. The steel was corroded and radioactive. The customer wanted to clean the steel to less than detectable radiation for removal from the site. All steel was ultrahigh-pressure blasted at 55000 psi. 27.5 tons were moved off site at less than detectable radiation so only one-half ton of steel was removed in total.