Fatigue Behavior of Cold Spray Coating

Atieh Moridi

Postdoctoral Researcher

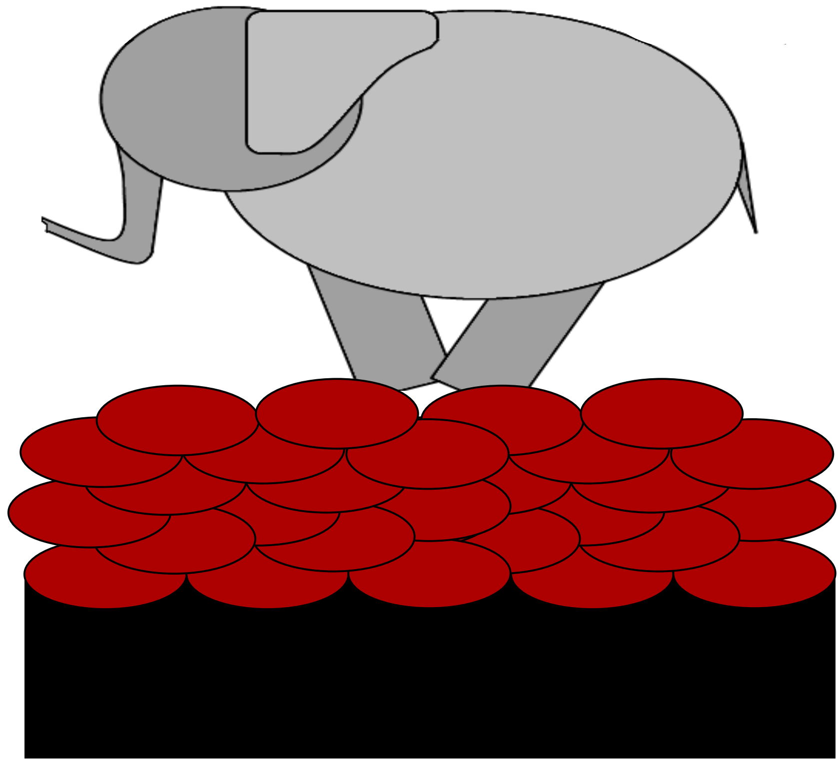
Department of Materials Science and Engineering

amoridi@mit.edu

Repair

Cosmetic repair

Structural repair



Repair

- Procedure

- Nature of the damage
  - Low (local loss of material e.g. pore, crack, scratch, gas holes, pit, etc)
  - Medium (structural integrity is partially damaged, e.g. corrosion, wear)

Motivation

- Controversial results are available in literature.

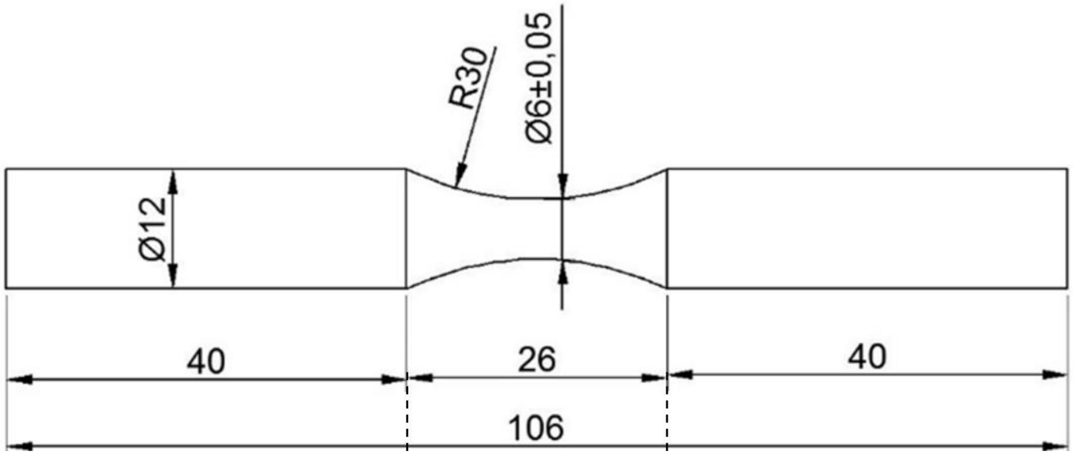
Reference	Material	Gas Type	Pressure (bar)	T(K)	Coating thickness (µm)	Specimen type	Surface roughness Ra(µm)	Increase/ Decrease in fatigue life
T.S. Price, et al. *J Therm Spray Technol*. **15** 507-512 (2006).	Ti on Ti6Al4V	He	30	300	120	Hourglass	[illegible]	Decrease-Delamination
J. Cizek, et. Al., *Surf Coat Technol*, **217**, 23-33(2013).	Ti on Ti6Al4V	He	16	533	700	[illegible]	11.28	Decrease-Delamination
E. Sansoucy, et. al. J Therm Spray Technol, 16 (2007) 651-660.	Al-Co-Ce on AA2024-T3	He	40	473	[illegible]	Flat	-	Increase-No delamination
A Moridi et. al. On fatigue behavior of cold spray coating, MRS Proceedings 1650, mrsf13-1650-jj05-03	Al on Al 5052	N2	[illegible]	[illegible]	100	Flat	9.5	Slight increase-Delamination
	Al7075 on Al 5052	N2	[illegible]	773	100	Flat	5.5	Increase-No delamination
	Al 6082 on Al 6082	[illegible]	30	623	100	Hourglass	12.41	Increase-No delamination
Yandouzi, et. al. J Therm Spray Technol, 23 (2014)1281-90.	Al on Al2024	N2	17	500	500-600	Flat		Equal to the substrate

Increase=No delamination

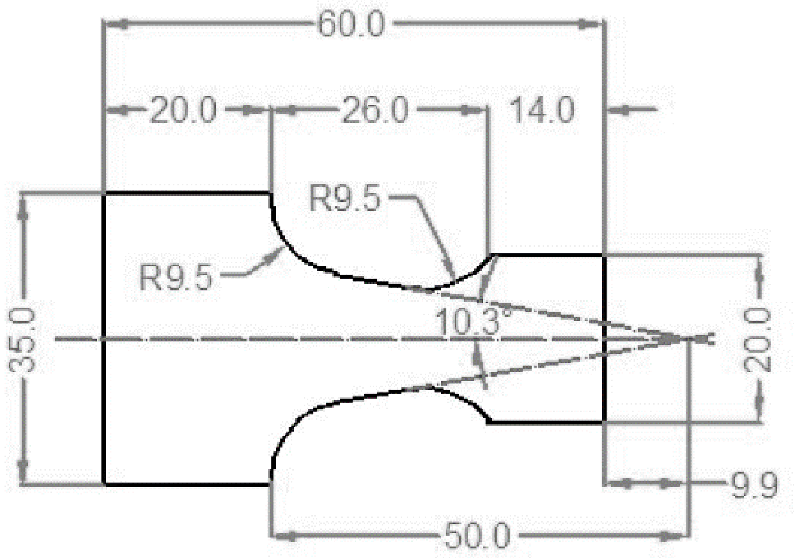
Fatigue Specimen

- Stress gradient effect

Rotating bending



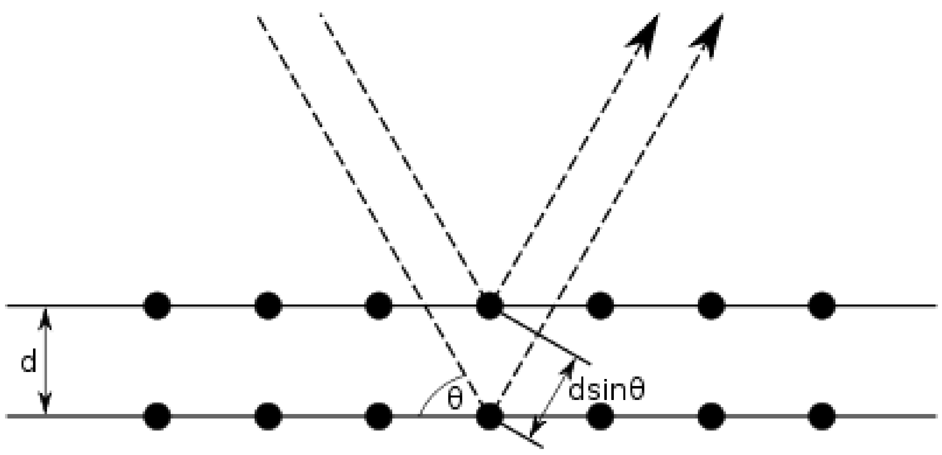
Cantilever Flat Sheet

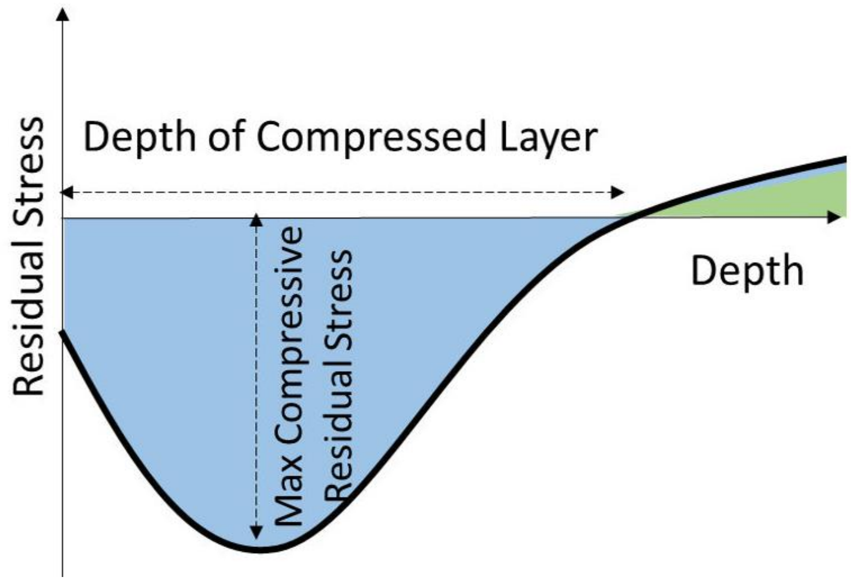


Residual Stress

- X-ray diffraction
  - Expensive, delicate apparatus generally limited to a laboratory
  - Sample must be polycrystalline
  - Only shallow (<0.025 mm) surface layer is measured

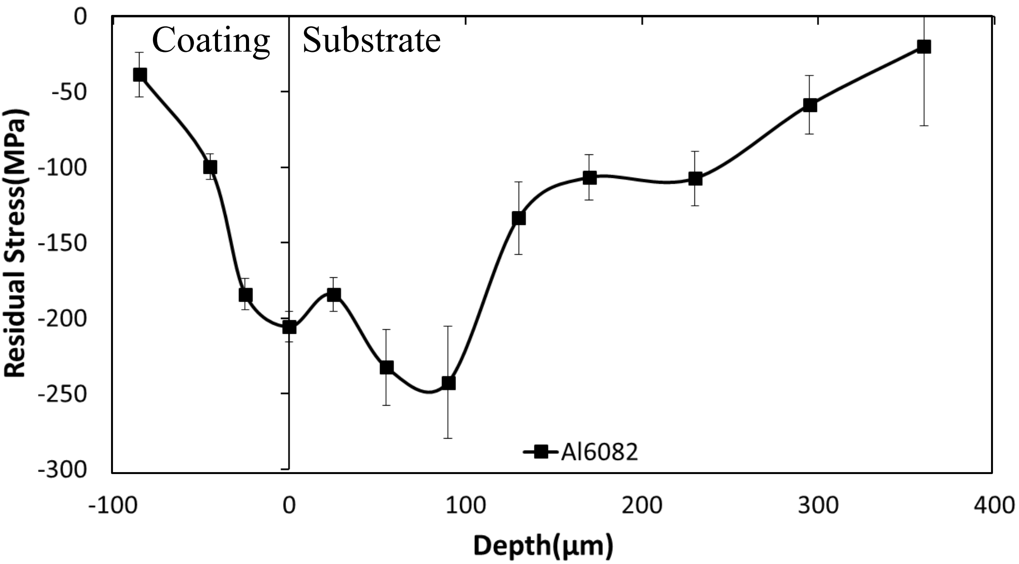
$$n\lambda = 2d\sin\theta$$

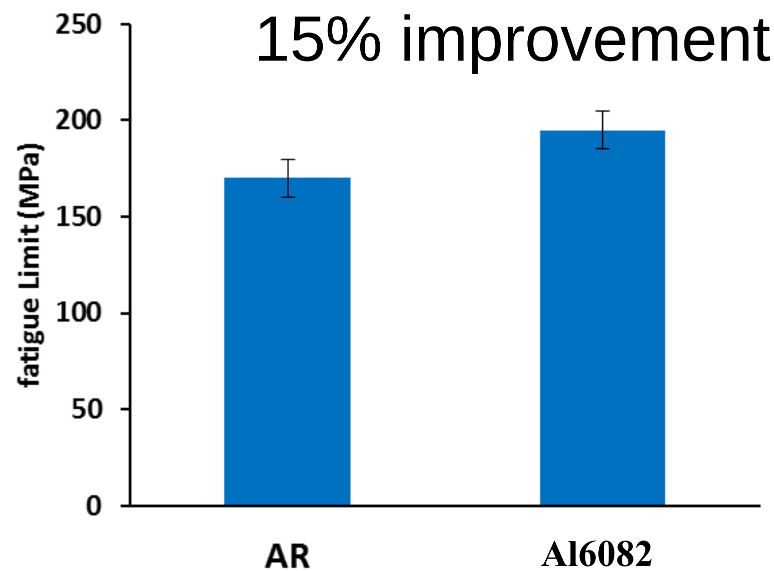




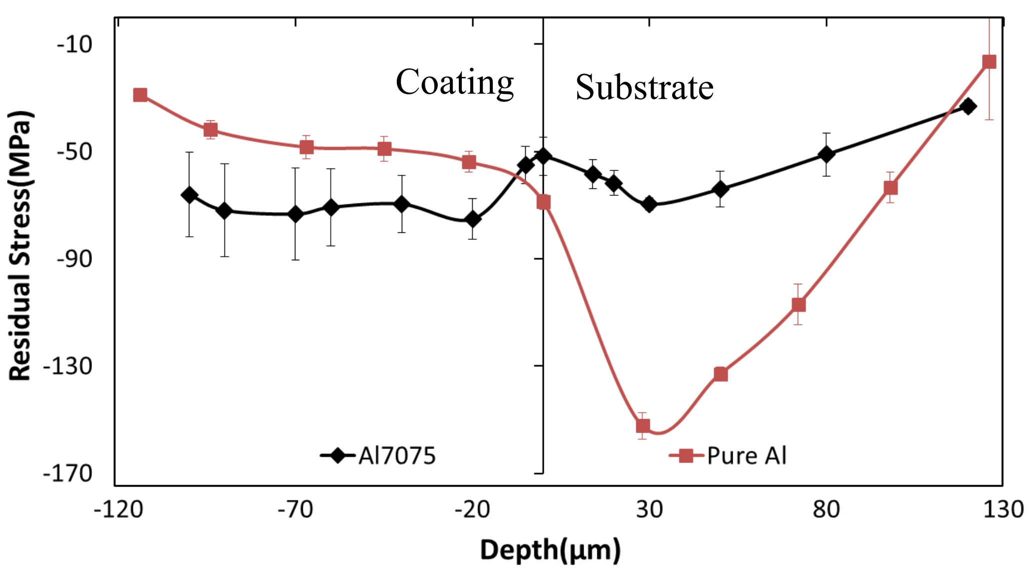
Fatigue Behavior of Coated Specimens

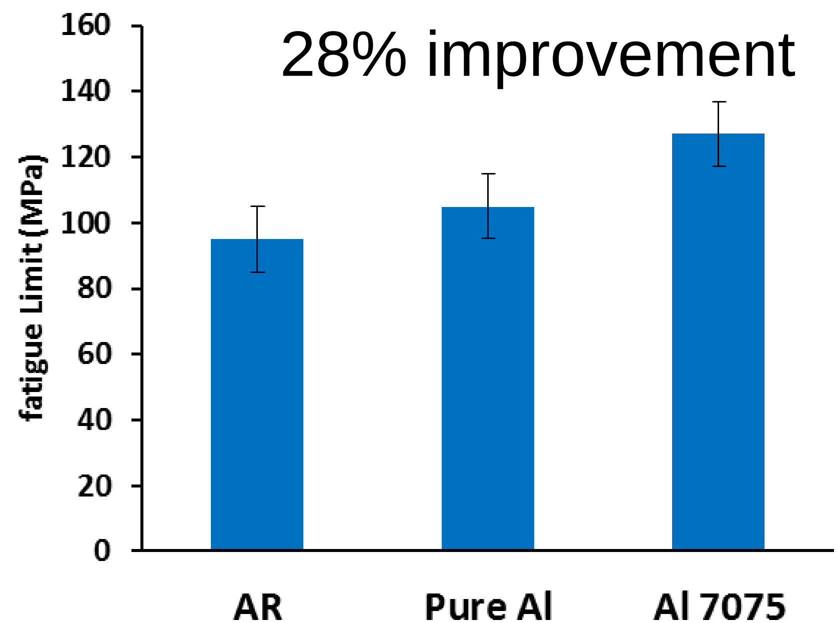
- Similar materials Al 6082 on Al 6082



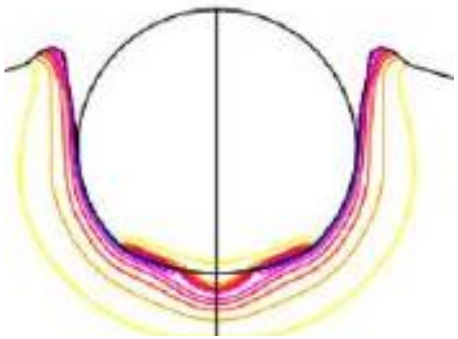


- Dissimilar material

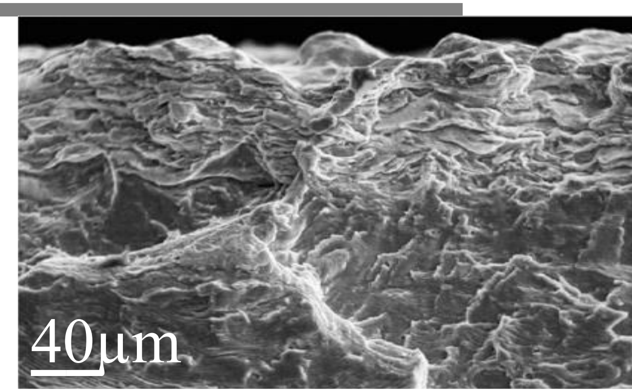


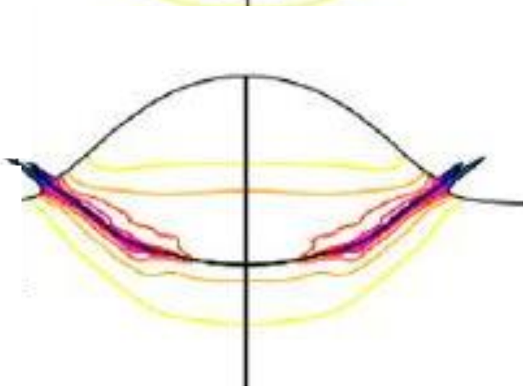


Fracture Analysis

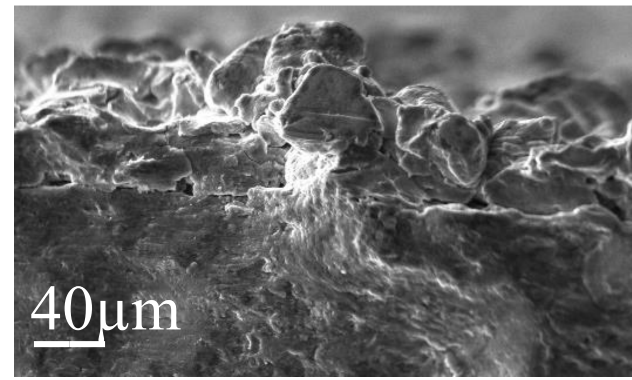


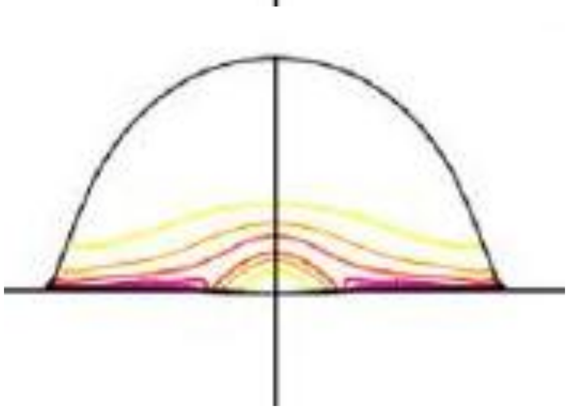
Hard on soft



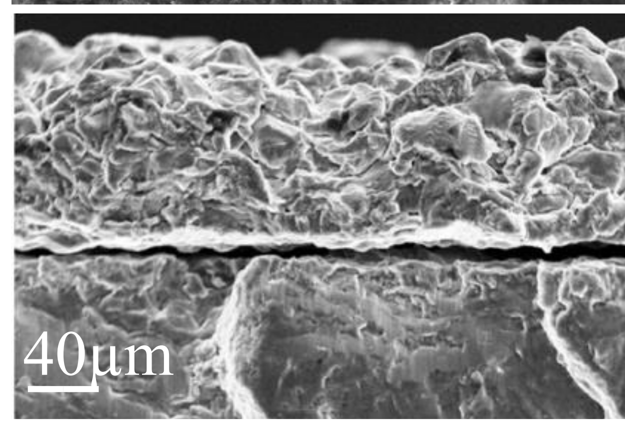


Similar





Soft on hard



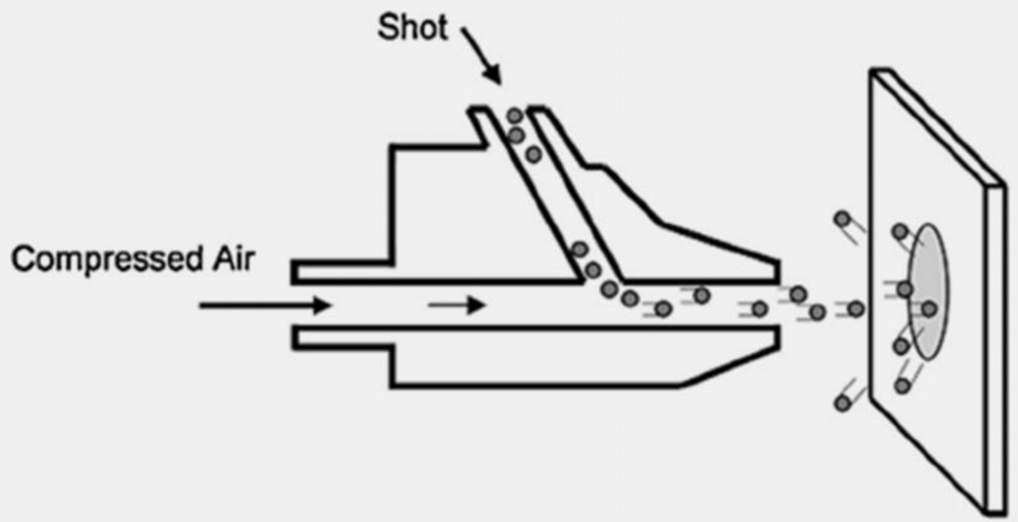
Fatigue Limit

- Precondition
  - No delamination
- Degree of Improvement
  - Residual stress
    - Pressure
    - Temperature
  - Coating and substrate material properties
- Fatigue limit

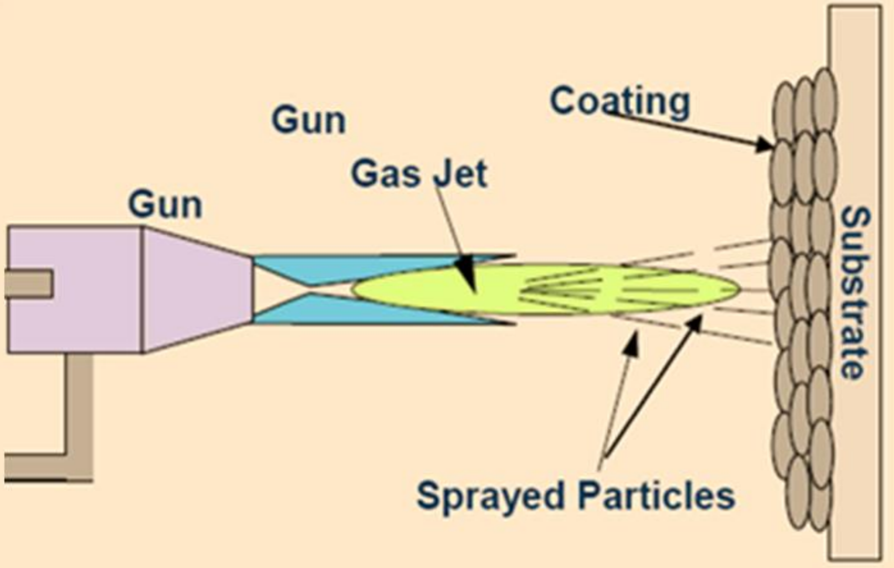
$$\begin{cases} \sigma = \sigma_{-1}\left(1 - \alpha \dfrac{\sigma_{rs(s)}}{\sigma_{u(s)}}\right)\left(1 + \sqrt{\dfrac{1600}{HV_c^{\,2}} X^{*}}\right)_s & \text{if } \mathrm{HV_c} > HV_s \\ \sigma = \sigma_{-1}\left(1 - \alpha \dfrac{\sigma_{rs(s)}}{\sigma_{u(s)}}\right) & \text{if } \mathrm{HV_c} = HV_s \end{cases}$$

Hybrid Treatment

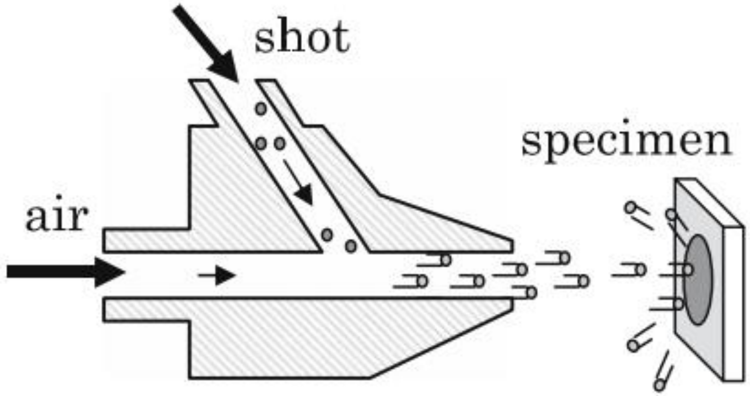
Shot peening



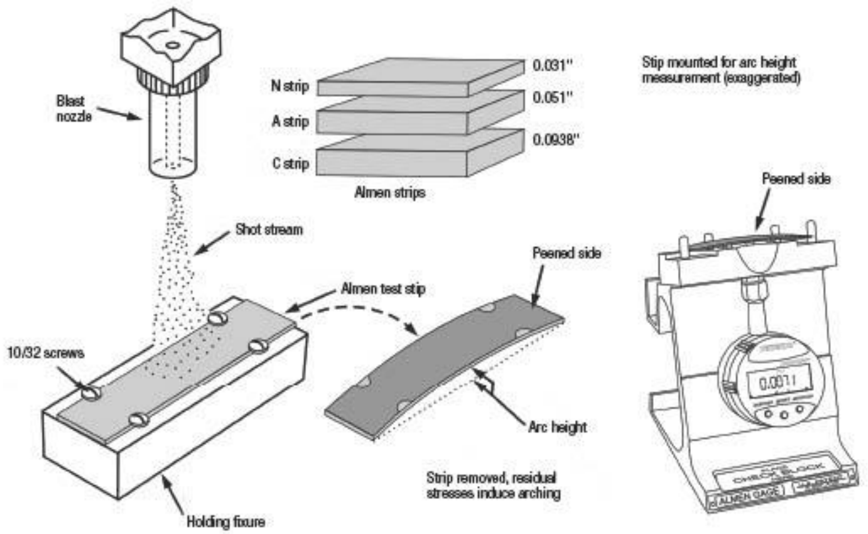
Cold spray



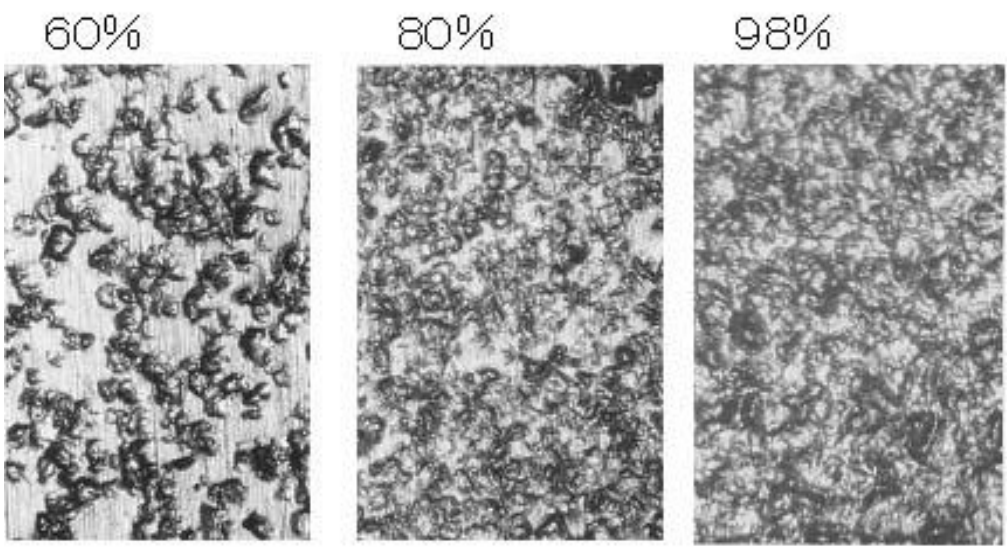
Shot Peening



Intensity



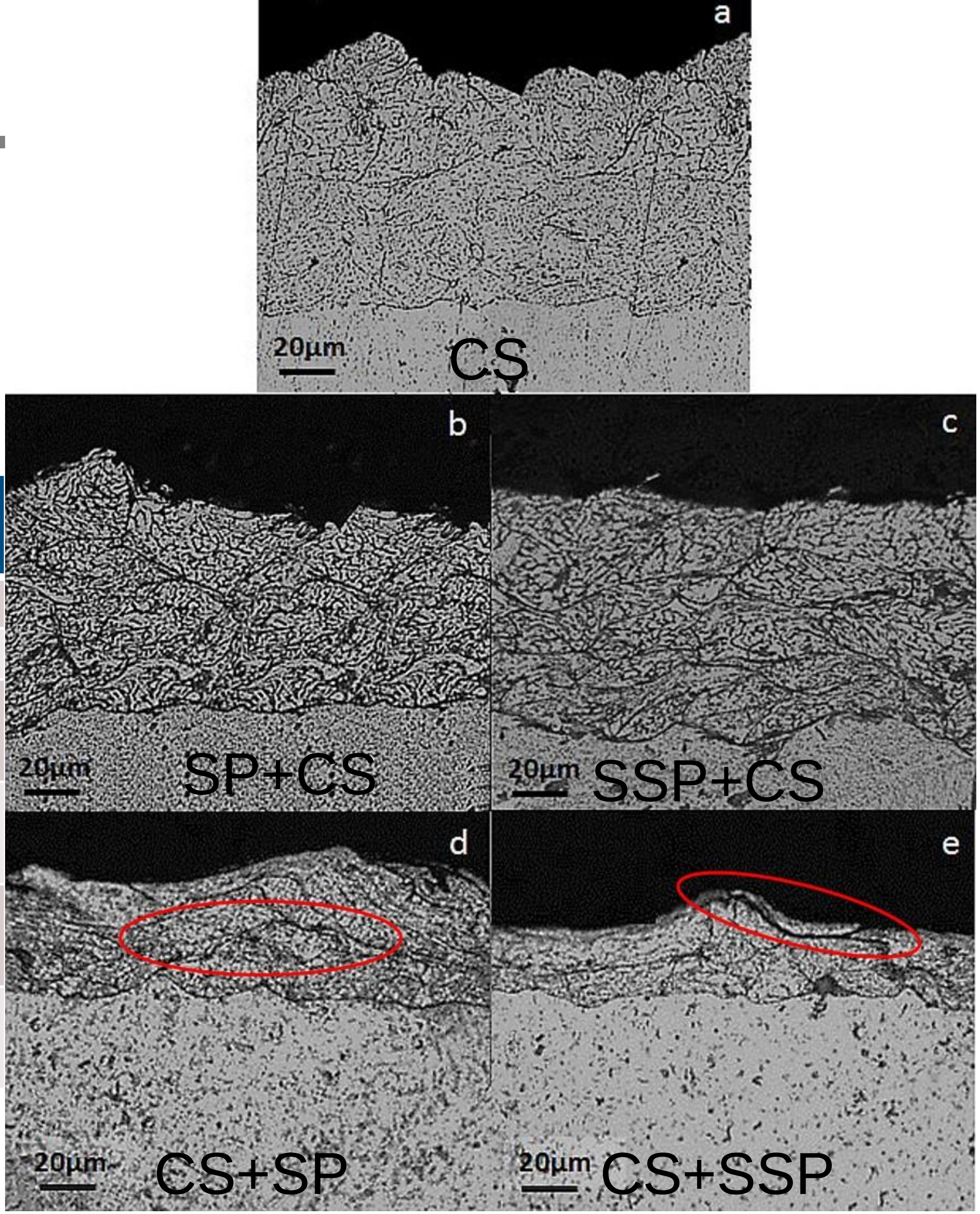
Coverage



Hybrid Treatment

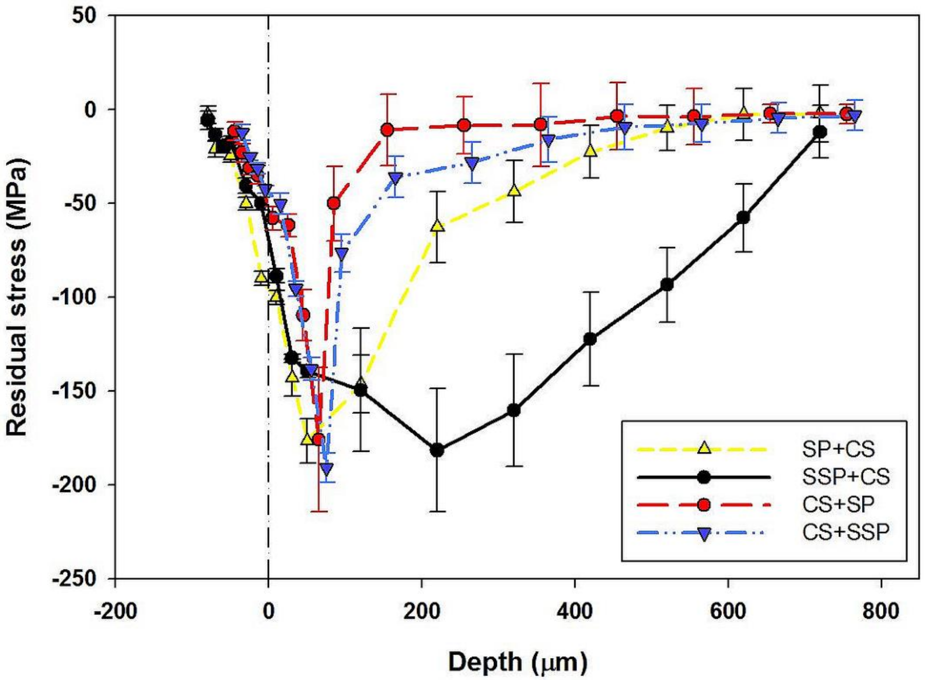
- Intensity and Coverage
  - SP
  - SSP
- Order of treatments

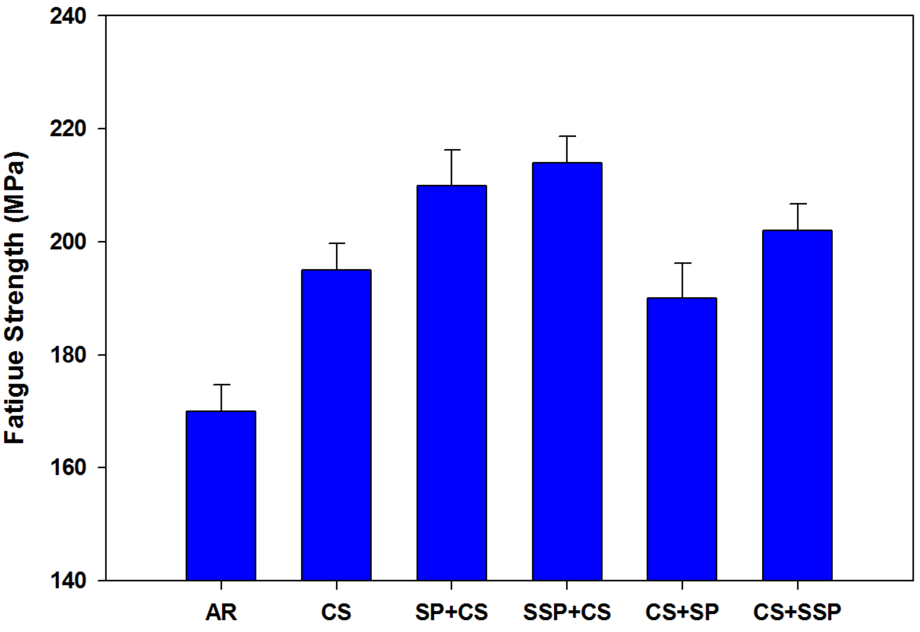
Group name	Description
AR	As received
CS	Cold sprayed
CS+SP	Cold spray followed by shot peening
CS+SSP	Cold spray followed by severe shot peening
SP+CS	Shot peening followed by cold spray
SSP+CS	Severe shot peening followed by cold spray



A Moridi, et al, Surf and coating technology, 2015.

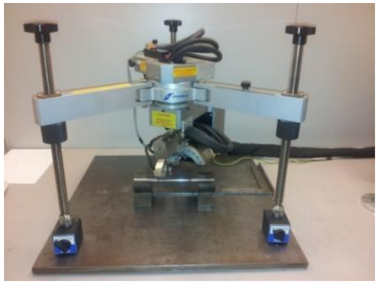
Residual Stress and Fatigue Limit





Depth of compressed layer correspond to fatigue limit

SSP+CS : 10% and 26% with respect to CS and AR



Fractography

AR

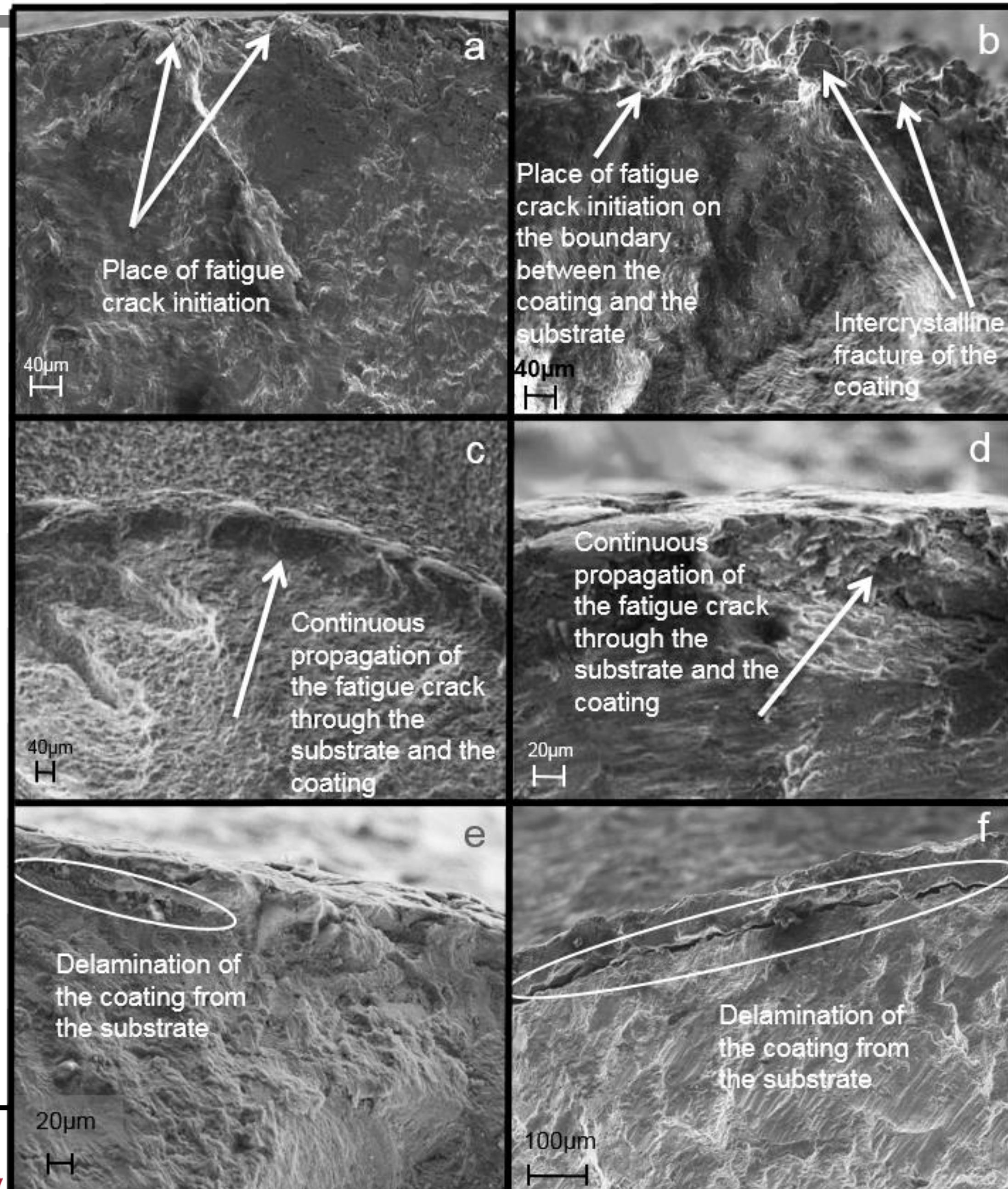
CS

SP+CS

SSP+CS

CS+SP

CS+SSP



Acknowledgment

- Mario Guagliano, Polimi, Italy
- Ming Dao, MIT
- Mostafa Hassani-Gangaraj, MIT
- Simone Vezzu, Veneto nanaotech, Italy