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Peak stress dependence for tantalum spall when shocked near the spall strength

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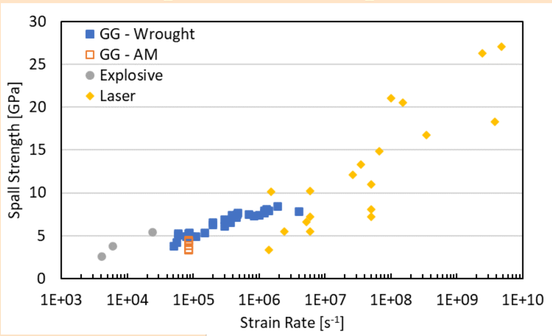
Motivation: The spall strength of tantalum has been extensively studied under dynamic loading across a wide range of grain sizes, strain rates, and compression techniques. Gas gun experiments have typically imparted peak stresses >2x the spall strength. Evidence of incipient spall has been identified in tantalum samples shocked to stresses believed to be slightly below the published spall strength. Experiments were desired to identify whether the spall strength is suppressed when peak stresses are similar to spall strengths.

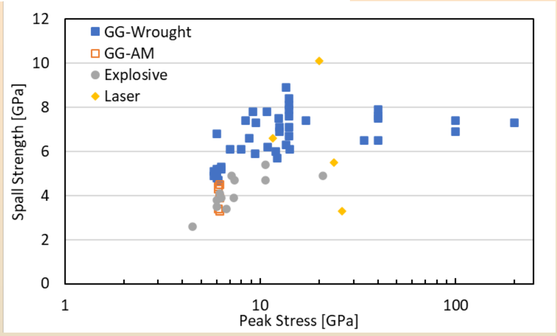
Existing data:

- Strong dependence on strain rate[1-9]
- Weak dependence on peak stress >6 GPa[1-6,10-17]



A strong dependence of spall strength on strain rate was identified for samples tested using explosive, plate impact, and laser drive.

A dependence of the spall strength with respect to peak stress has been identified for peak stresses from 6-10 GPa.

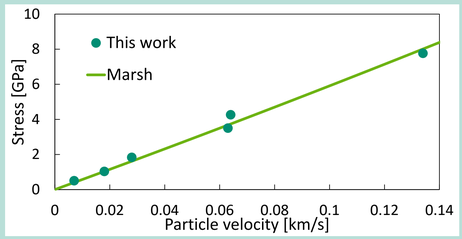


Methods:

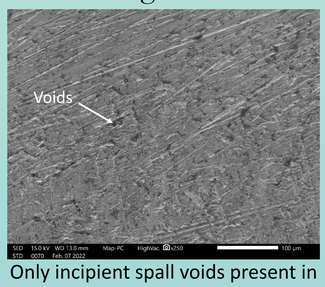
- Measure Hugoniot to confirm extrapolation to low pressure is valid
  - Reverse ballistic impact experiments into PMMA, LiF, Sapphire
- Measure spall strength in annealed and as-received Ta at marginal peak stress
  - Sapphire impactor with free-surface VISAR/PDV measurement
  - SEM imaging of cross-sectioned surface to examine spall plane

Results:

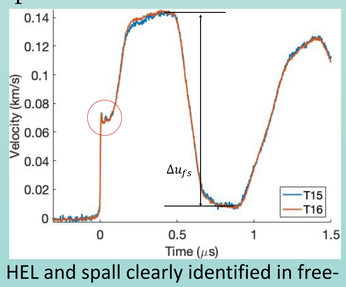
- Hugoniot agrees with LASL Shock Hugoniot Data[18]



- Clear signature of spall present in free surface velocity profile
  - SEM imaging indicates that only incipient spall occurred – no growth of damage sites present



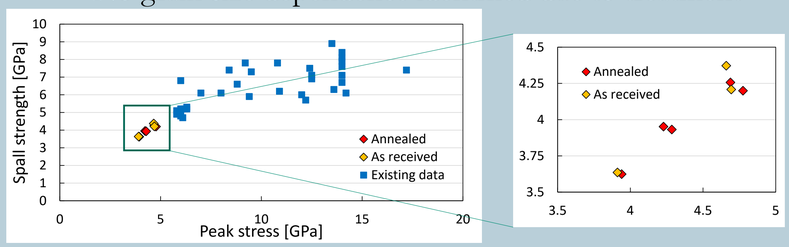
Only incipient spall voids present in SEM micrograph



HEL and spall clearly identified in free-surface measurement of annealed material

Discussion/Conclusion:

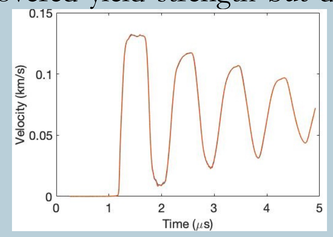
- A correlation between the spall strength and peak compressive stress was identified for both the as-received and annealed material
  - No grain size dependence identified due to treatment



- No signature of HEL and dynamic yielding identified in as-received material
  - Annealing of Ta sheet recovered yield strength but did not impact spall strength

Condition	Impact velocity	HEL stress
Annealed	166 m/s	2.4 GPa
Annealed	183 m/s	2.3 GPa
Annealed	200 m/s	2.3 GPa
As received	166 m/s	N/A
As received	200 m/s	N/A

HEL stresses for annealed and as-received samples



No HEL identified for as-received material

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