Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Meccanica

Relazione per la prova finale

RESISTENZA STATICA E A FATICA DI COMPONENTI IN MATERIALE METALLICO STAMPATI 3D

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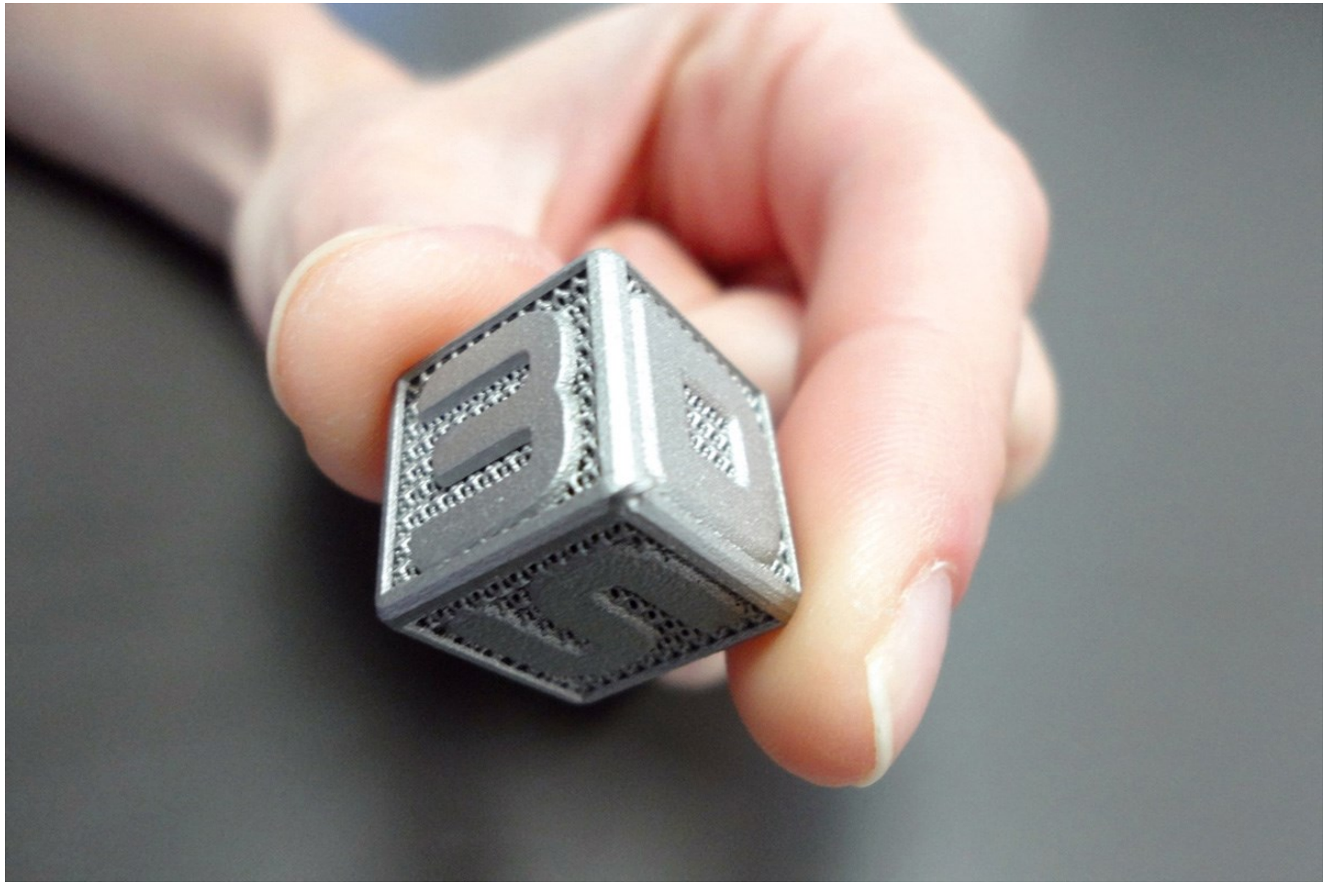
Laureando: *Riccardo Varnerin*

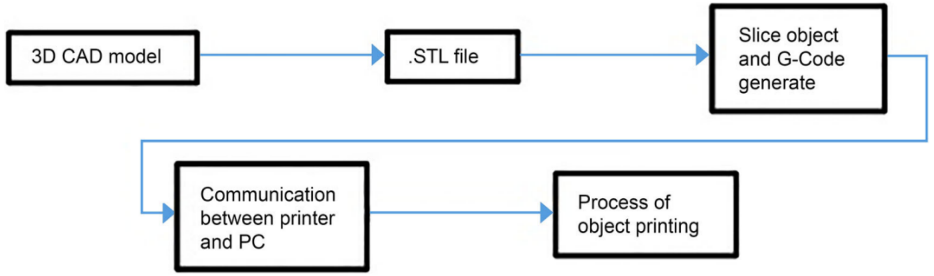
Padova, 18/11/2022

INTRODUZIONE

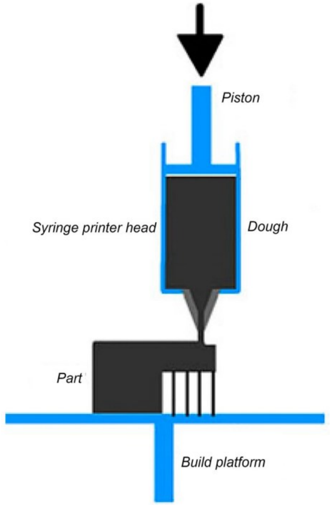
- **Additive manufacturing**
- **Acciai inossidabili**
- **Leghe di alluminio**
- **Leghe di titanio**
- **Difetti**
- **Componente industriale**

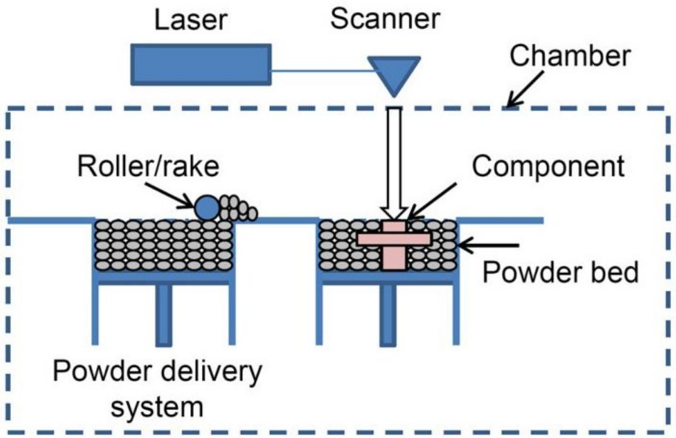


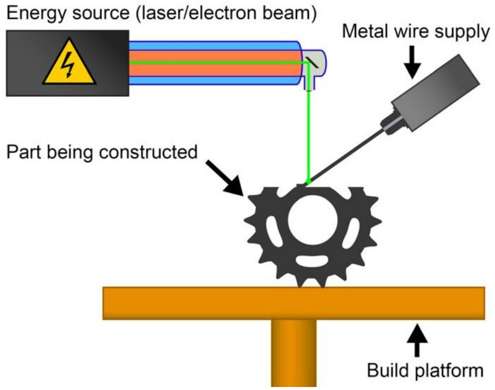
STAMPA 3D → METTERE IL MATERIALE SOLO DOVE SERVE

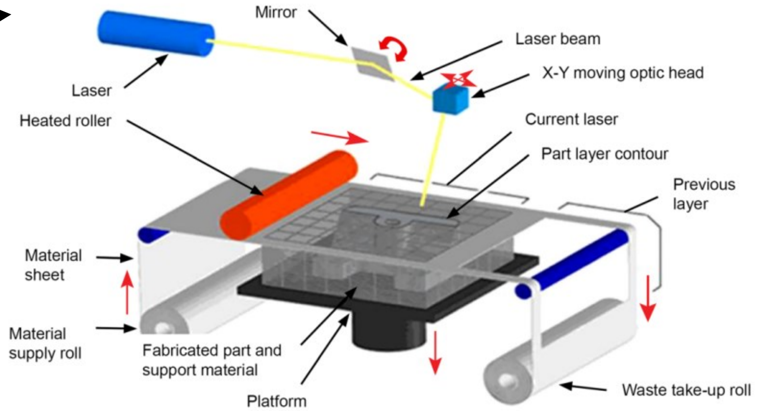


- Vat photopolymerization → fotopolimeri e resine
- Material jetting → fotopolimeri e resine
- Binder jetting → sabbia, vetro e metalli
- Material extrusion → ceramica, siliconi e alimenti
- Powder bed fusion → metalli
- Sheet lamination → polimeri, ceramica e metalli
- Directed energy deposition → polimeri e metalli









- Mercado Rivera, F. J., & Rojas Arciniegas, A. J. (2020). Additive manufacturing methods: Techniques, materials, and closed-loop control applications. The International Journal of Advanced Manufacturing Technology, 109(1-2), 17–31

ACCIAI INOX

PROPRIETA' STATICHE

Provini: 316L, 15-5PH

d = 3mm

SLM con orientamento verticale

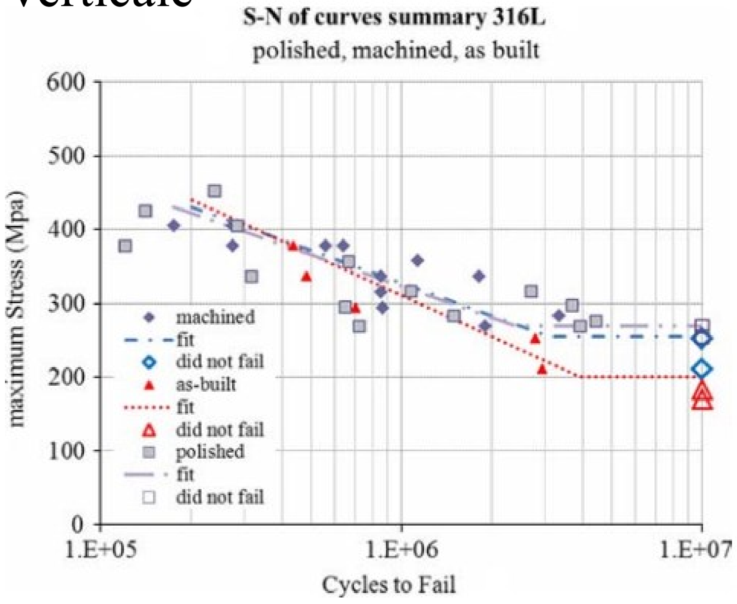
Material	Source	Yield strength (MPa)	Ultimate tensile strength (MPa)	Elongation (%)
316L	Handbook	310	620	30
	SLM (Spierings *et al.*, 2011)	640	760	30
15-5 PH H900	Handbook	1,170	1,310	10
	SLM	1,100	1,470	15

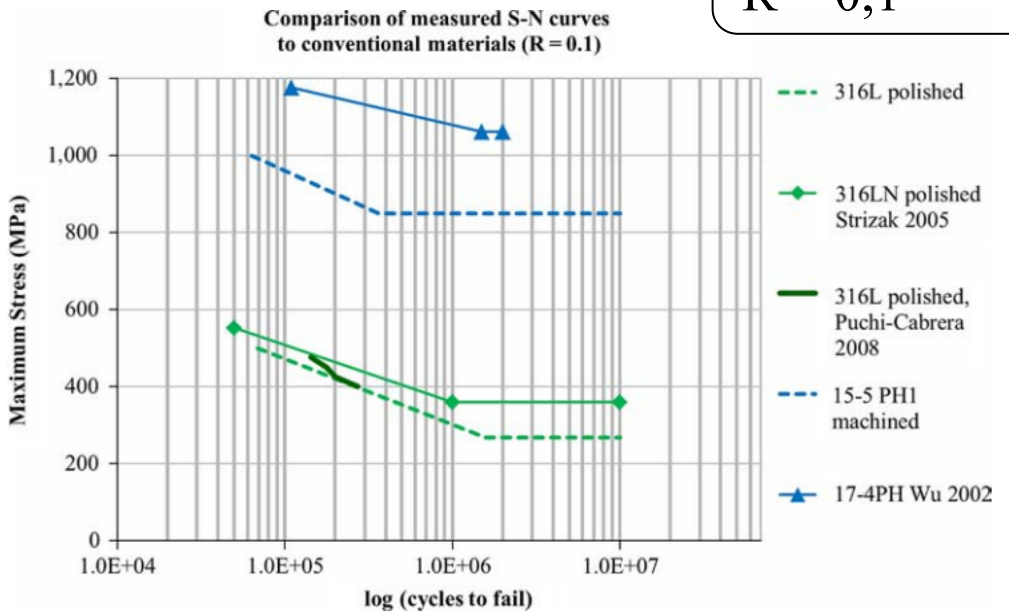
CURVE DI FATICA

carico assiale
R = 0,1

316L (NO TT)
- As-buit
- Lavorato
- Lucidato

15-5PH (H900)
- lavorato



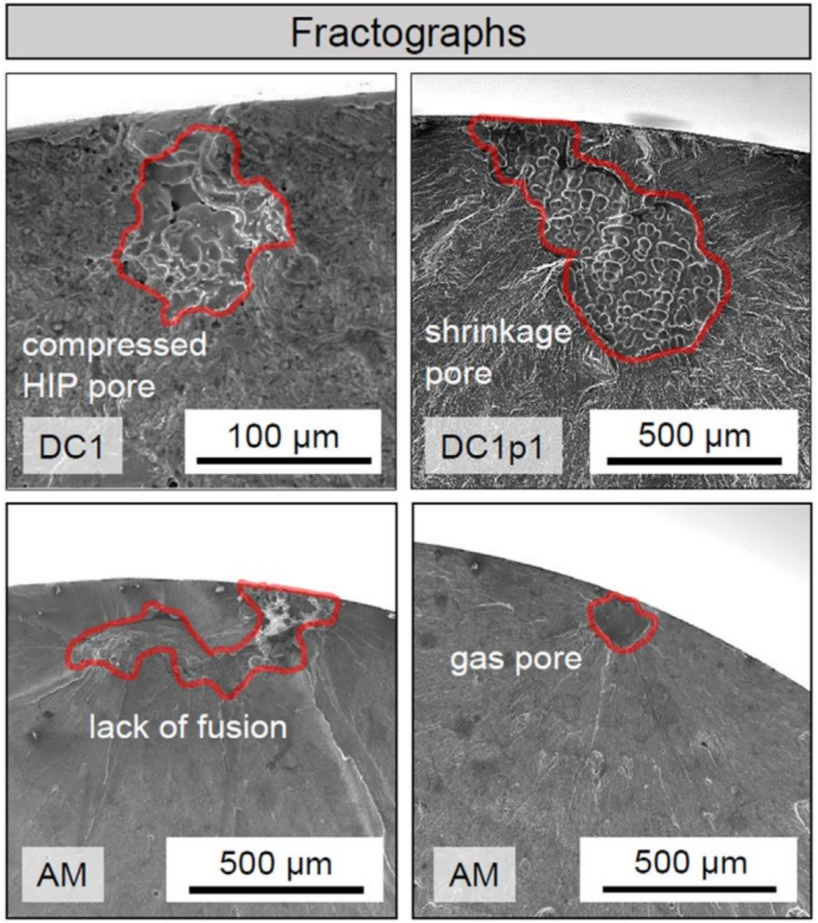


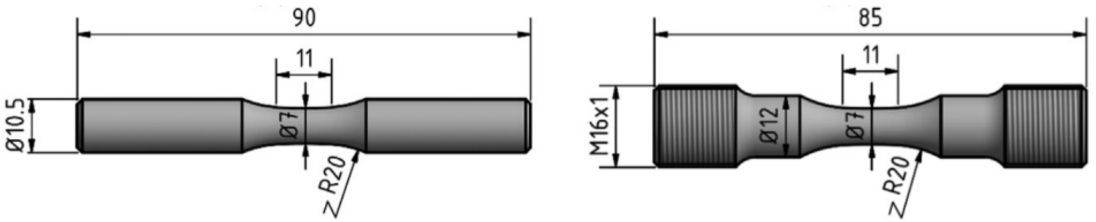
- Spierings, A. B., Starr, T. L., & Wegener, K. (2013). Fatigue performance of additive manufactured metallic parts. Rapid Prototyping Journal, 19(2), 88–94.

LEGHE DI ALLUMINIO

Provini: AlSi7Mg, ALSi10Mg → Laser PBF con orientamento verticale (NO TT)
→ Pressofusione (DC) e colata in sabbia (SC) (T6)

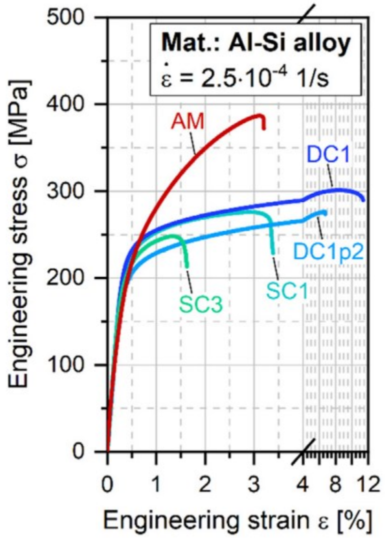
Campioni lucidati e rettificati



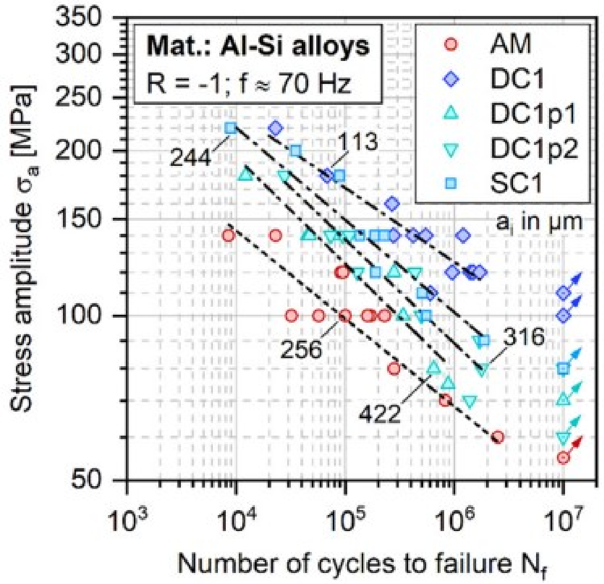


d = 7mm

PROVA DI TRAZIONE



CURVE DI FATICA

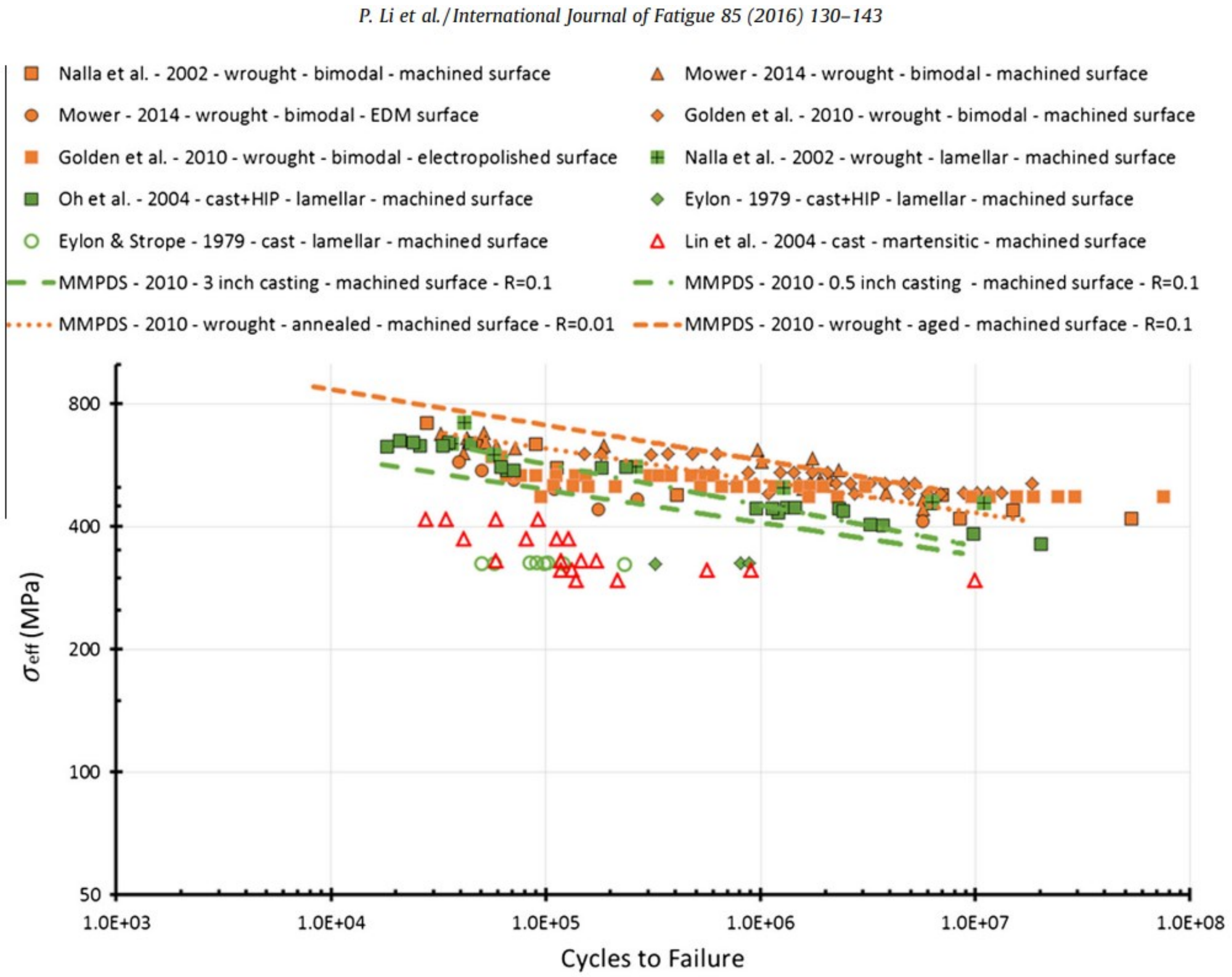


carico assiale
R = -1

- Tenkamp, J., Stern, F., & Walther, F. (2022). Uniform fatigue damage tolerance assessment for additively manufactured and cast Al-Si Alloys: An elastic-plastic fracture mechanical approach. Additive Manufacturing Letters, 3, 100054.

Provini: Ti6Al4V

METODI TRADIZIONALI



Sono stati esaminati provini realizzati con metodo tradizionale e AM con diversi:

- Trattamenti termici / HIP
- Finitura superficiale
- Microstruttura

I provini avevano sezione circolare ma il diametro non era specificato

Carico assiale

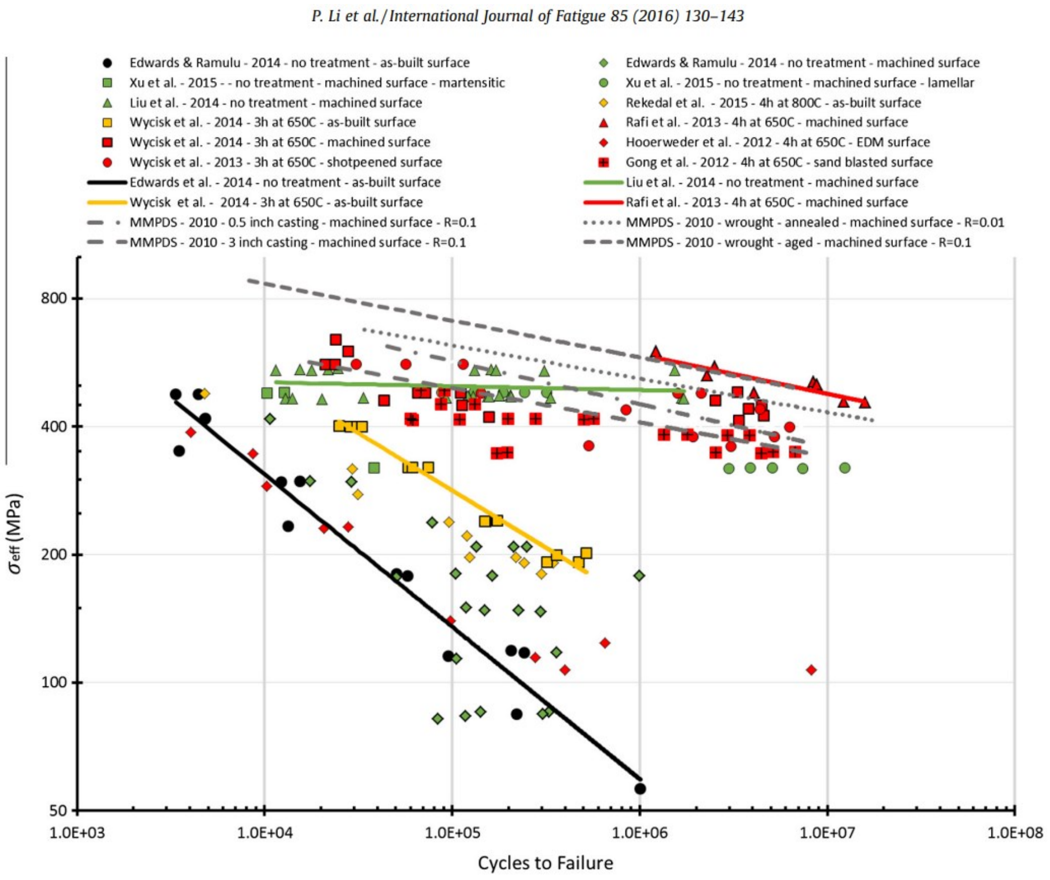
Le prove sono state effettuate a diversi rapporti di fatica

$$\sigma_{eff} = \sigma_{max}\left(\frac{1-R}{2}\right)^{0,28}$$

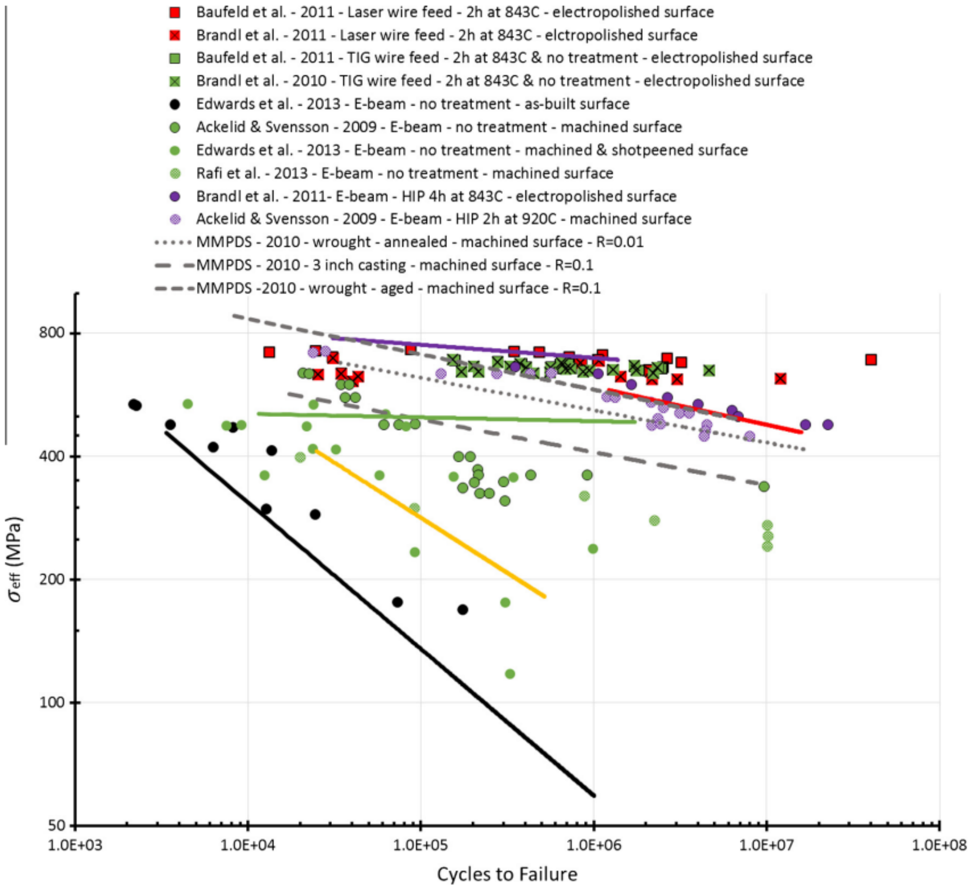
- Li, P., Warner, D. H., Fatemi, A., & Phan, N. (2016). Critical assessment of the fatigue performance of additively manufactured ti–6al–4v and perspective for future research. International Journal of Fatigue, 85, 130–143.

ADDITIVE MANUFACTURING

LASER PBF



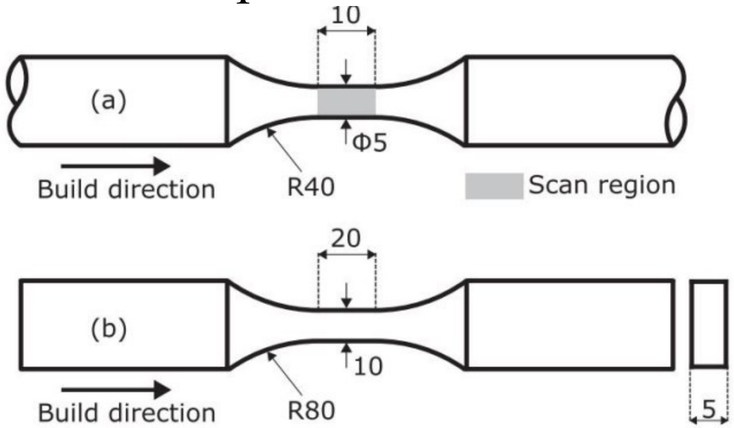
E-BEAM PBF
LASER WIRE-FEED DED
TIG WIRE-FEED DED



- Li, P., Warner, D. H., Fatemi, A., & Phan, N. (2016). Critical assessment of the fatigue performance of additively manufactured ti–6al–4v and perspective for future research. International Journal of Fatigue, 85, 130–143.

DIFETTI INTERNI

Provini: Ti6Al4V – laser PBF
orientamento verticale
TT 800°C per 2h - microstruttura α + β

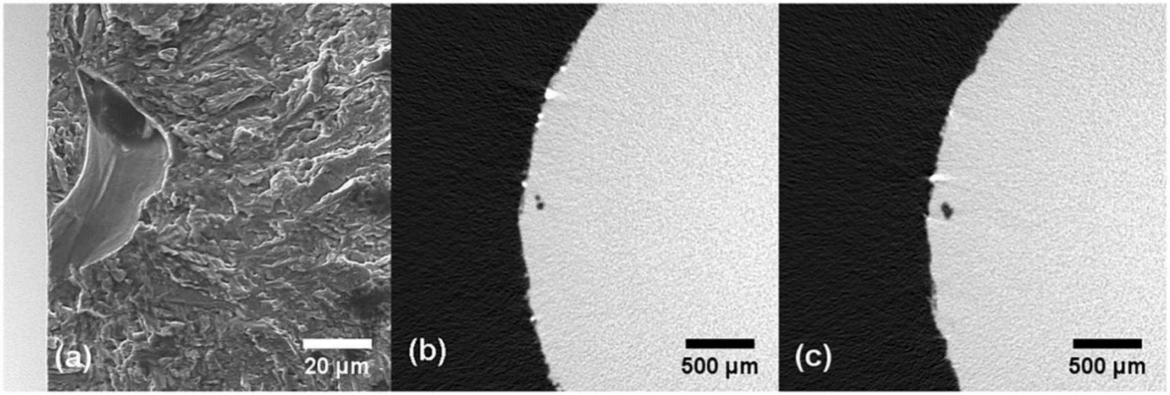


d = 5mm

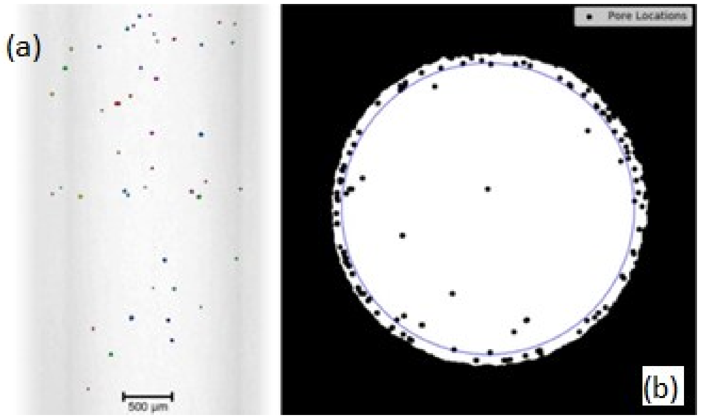
5mm x 10mm

carico assiale
R = 0,1

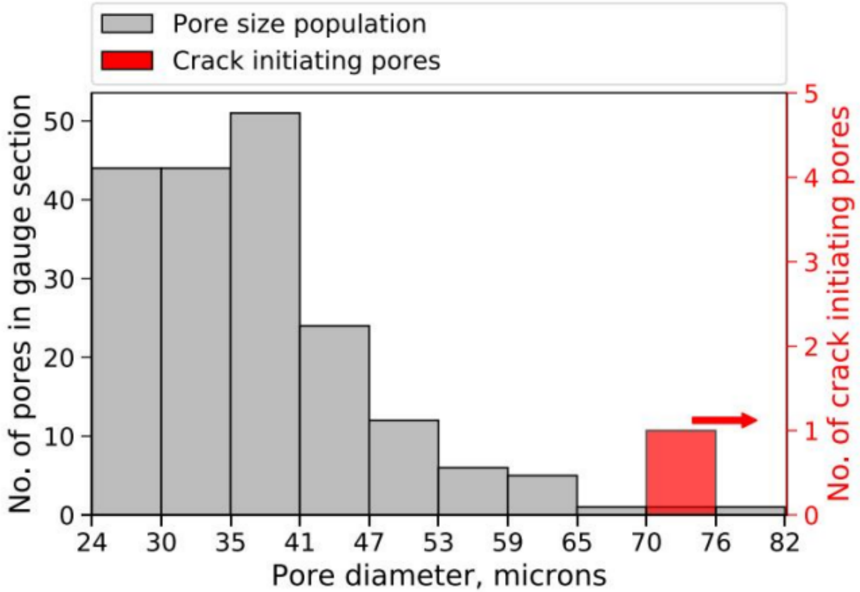
SUPERFICIE DI FRATTURA



DISTRIBUZIONE DIFETTI



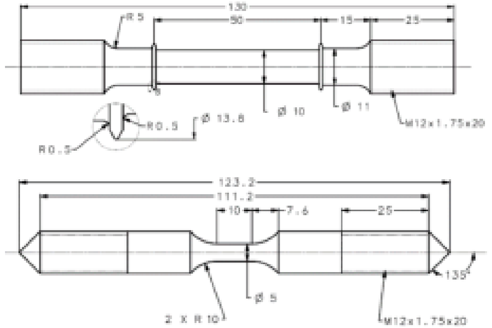
POPOLAZIONE E DIMENSIONE PORI

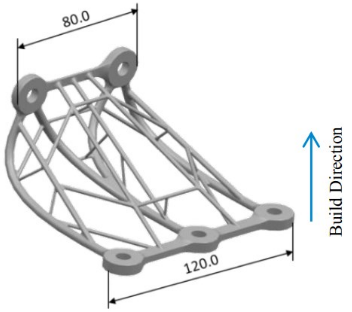


- Akgun, E., Zhang, X., Lowe, T., Zhang, Y., & Doré, M. (2022). Fatigue of laser powder-bed fusion additive manufactured TI-6AL-4V in presence of process-induced porosity defects. Engineering Fracture Mechanics, 259, 108140.

COMPONENTE INDUSTRIALE

Staffa di un motore aeronautico in Ti6Al4V prodotta tramite SLM
Granulometria 15-45µm, sabbiata e TT a 650°C per 3h in atmosfera di argon e raffreddata in forno a Tamb





dimensioni in mm

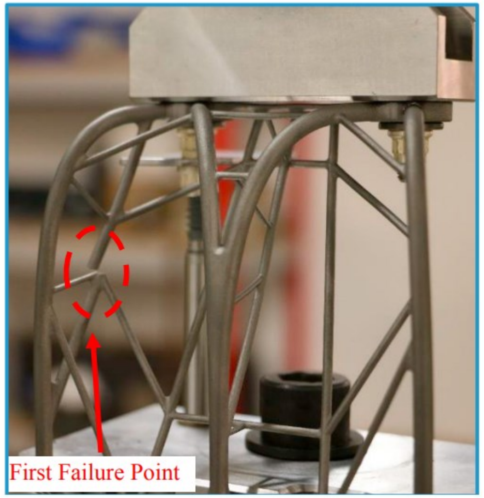
PRESTAZIONI A TRAZIONE

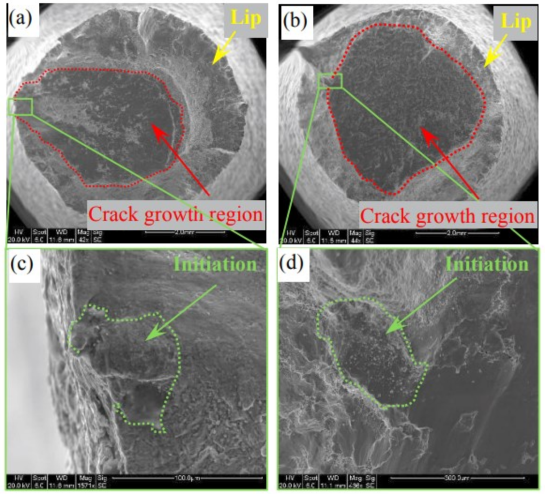
Test Identification Number (#)	Temperature (°C)	SR (s^{-1})	Young's Modulus (MPa)	0.2% PS (MPa)	UTS (MPa)	Ductility (%)	RTS
TT1	20	0.0002	116000	1020	1114	6.4	1.09
TT2	20	0.0265	121816	1125	1171	8.7	1.04
Annealed Ti-6Al-4V Bar [MMPDS-15, 2020]	20			861	930	10	

PROVA DI FATICA LCF UNIASSIALE

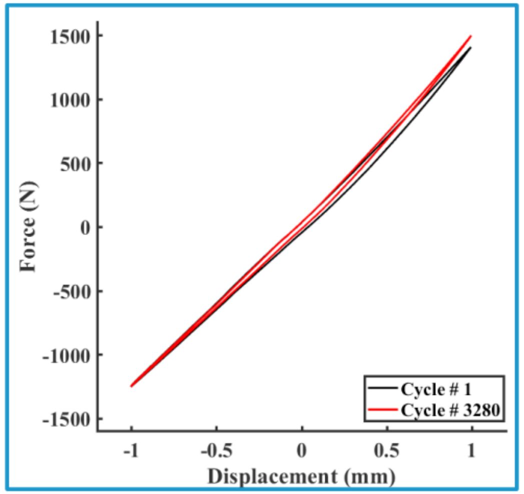
Carico assiale
R = -1

CICLI DI ISTERESI STAFFA

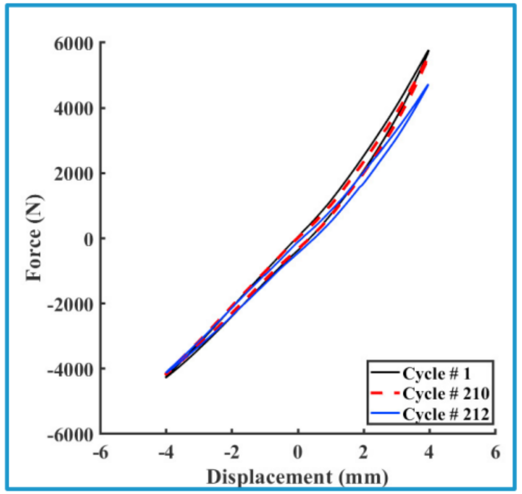




s = ±1mm



s = ±4mm



- Gupta, A., Bennett, C. J., & Sun, W. (2022). Fatigue property-performance relationship of additively manufactured ti-6al-4v bracket for aero-engine application: An experimental study. Procedia Structural Integrity, 38, 40–49

CONCLUSIONI

PROVE STATICHE → Migliore resistenza a trazione (UTS anche fino a +25%)

PROVE STATICHE → Allungamento simile o minore (fino a 30% in meno)

FATICA

- Rugosità → LAVORAZIONI SUPERFICIALI
- Difetti (pori o vuoti di fusione) → LAVORAZIONI SUPERFICIALI, TRATTAMENTO DI HIP
- Stress residui → TRATTAMENTO TERMICO
- Microstruttura → TRATTAMENTO TERMICO

⇒ Resistenza a fatica comparabile con i metodi tradizionali

IMPORTANTE MIGLIORARE I PARAMTRI DI PROCESSO DI COSTRUZIONE
potenza della fonte di energia, percorso e strategie di scanning, spessore dello strato di polvere, ecc. (variano dal processo e dalla macchina utilizzata)