

Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Meccanica

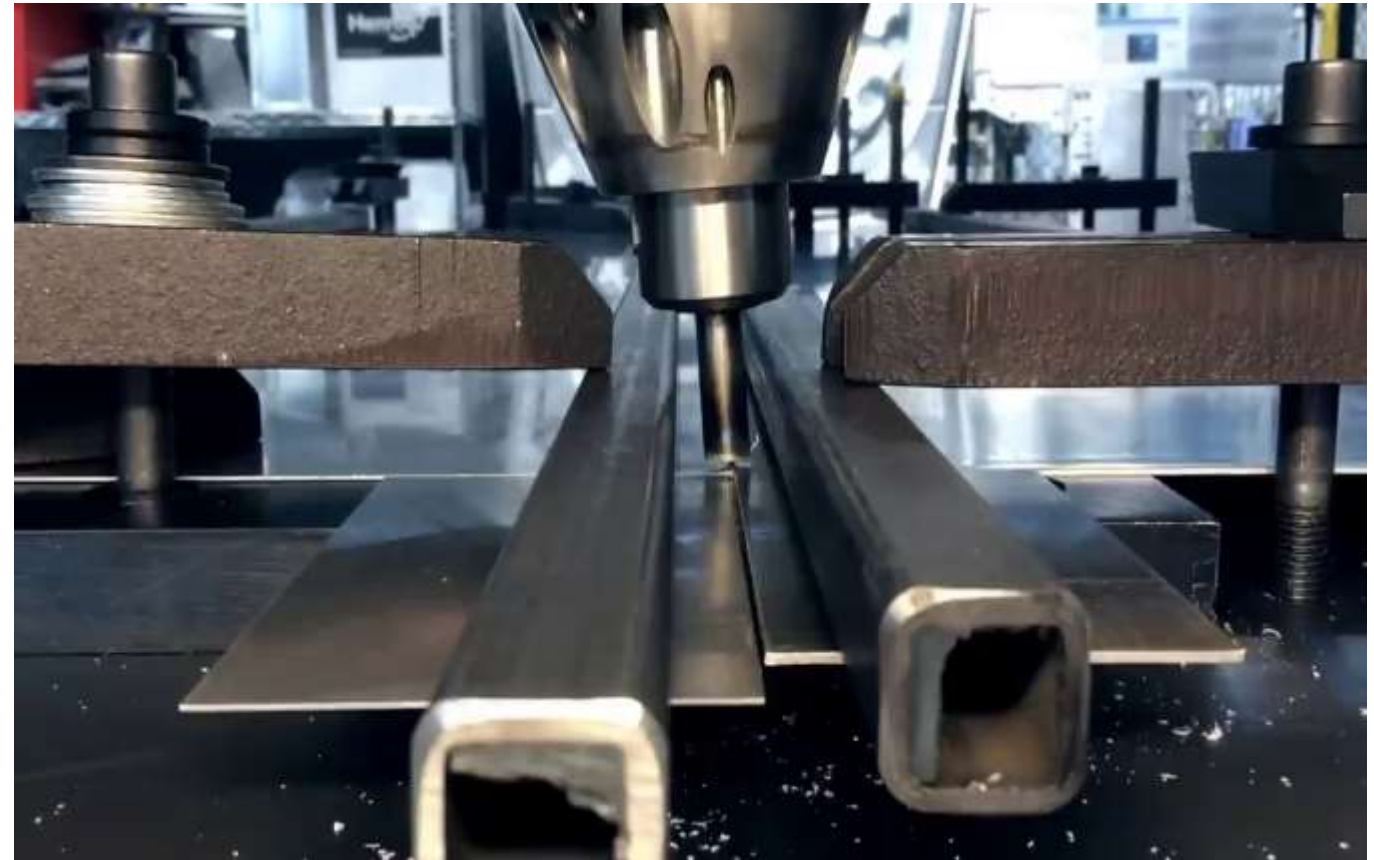
Relazione per la prova finale
RESISTENZA A FATICA DI GIUNZIONI SALDATE OTTENUTE
PER FRICTION STIR WELDING (FSW)

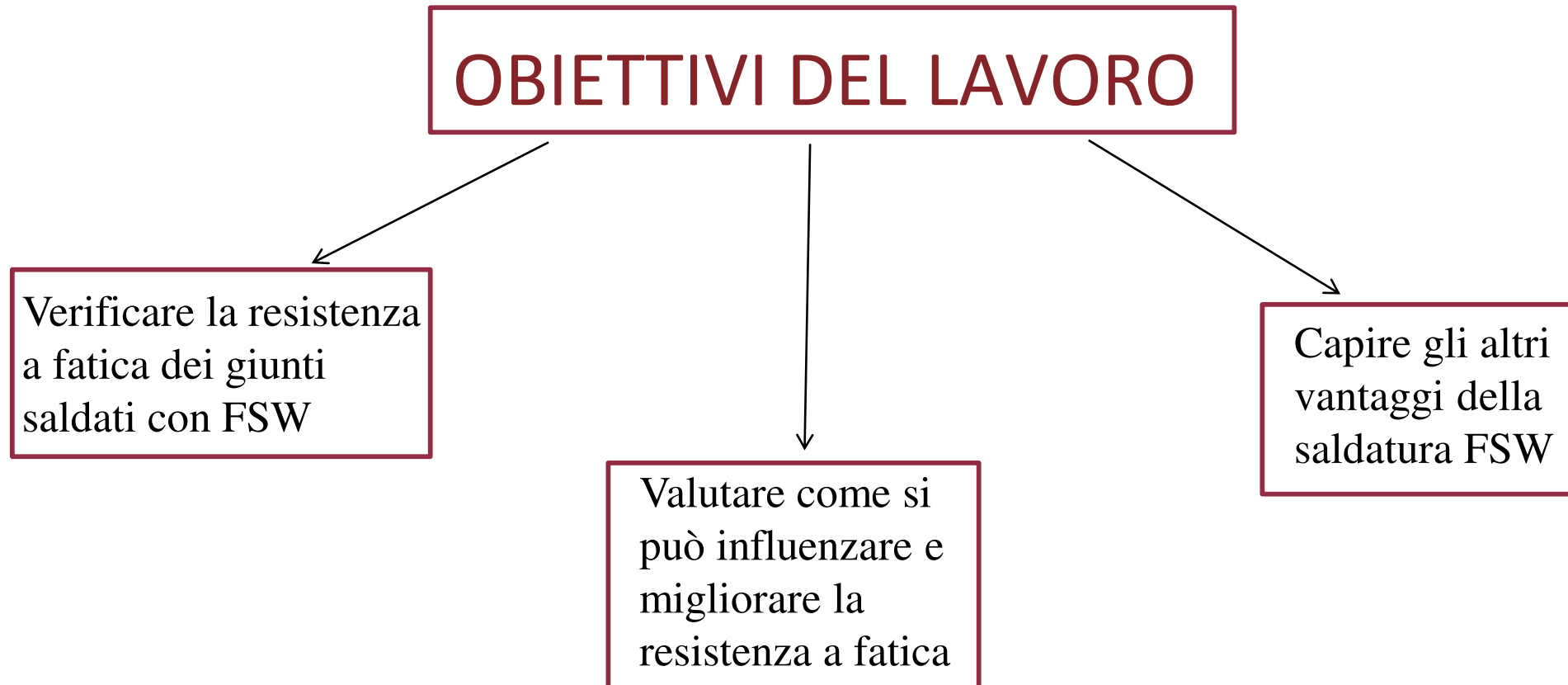
Tutor universitario: Prof. Alberto Campagnolo

Laureando: *Lorenzo Lodici*

Padova, 15/09/2023

- Inventata nel 1991
- Si basa sul calore d'attrito generato
- Non porta il materiale a fusione





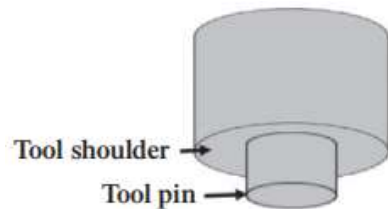
CARATTERISTICHE

Weld tool shoulder

1. Tool shoulder diameter
2. Tool shoulder surface morphology
3. Tool shoulder design
 - Flat/Concave/Convex

Weld tool pin

1. Tool pin design
 - Cylindrical/triangular//hexagonal, etc.
2. Tool pin height/width/diameter
3. Tool pin surface morphology



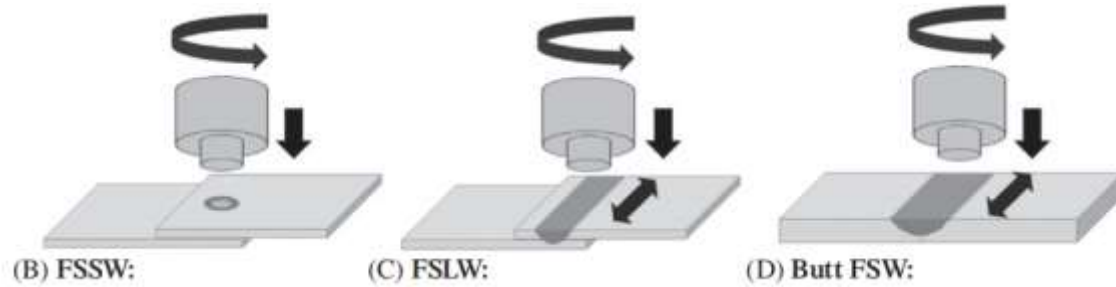
(A) FSW tool



Tool
shoulder

Tool pin

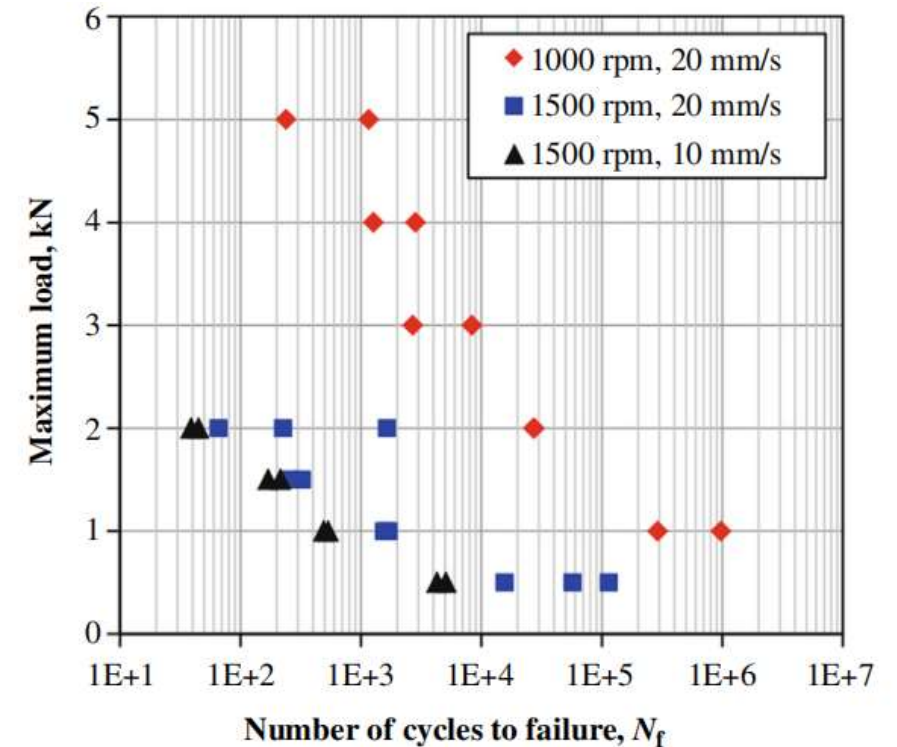
Fonte: Jordon, Rao, Amaro, Allison. Fatigue in Friction Stir
Welding. Butterworth-Heinemann 2019



Welding Process Parameters	FSBW	FSLW	FSSW
Tool rotation rate (rpm)	X	X	X
Tool shoulder plunge depth (mm)	X	X	X
Tool shoulder plunge rate (mm/min)	X	-	X
Tool dwell time (s)	X	X	X
Tool traverse speed (mm/min)	X	X	-
Tool tilt angle (in degrees)	X	X	-
Tool rotation direction (with respect to traverse direction)	X	X	-
Tool offset from weld line	X	-	-

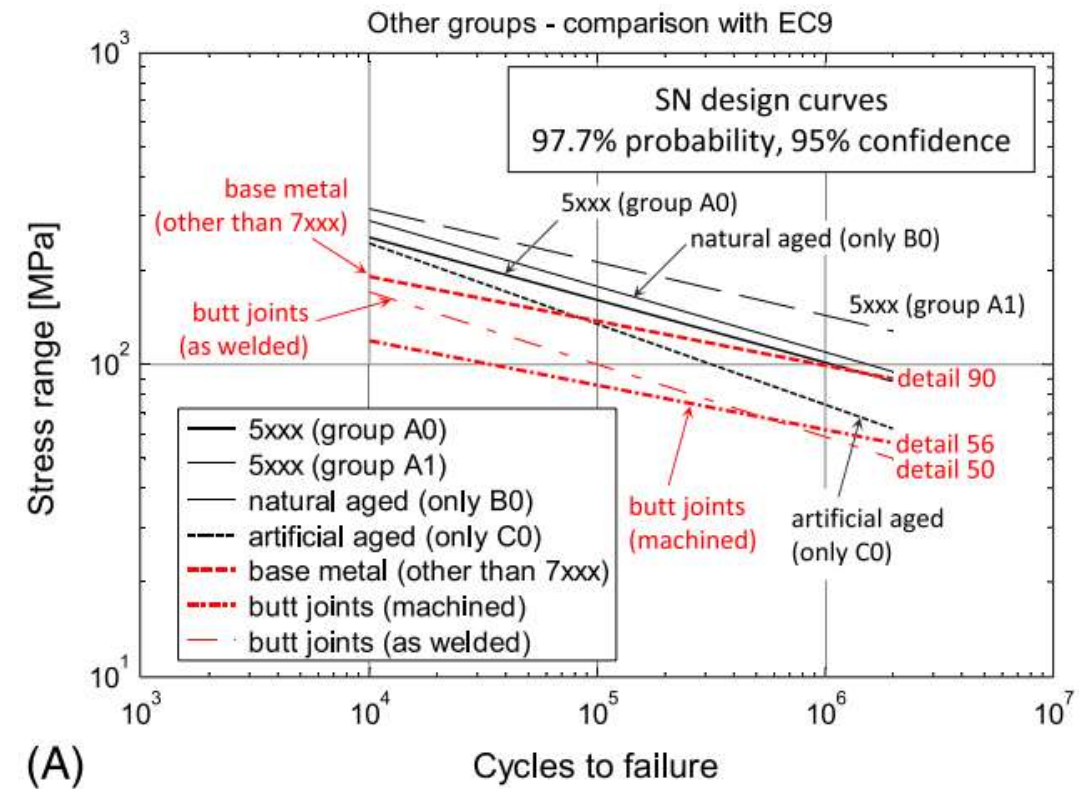
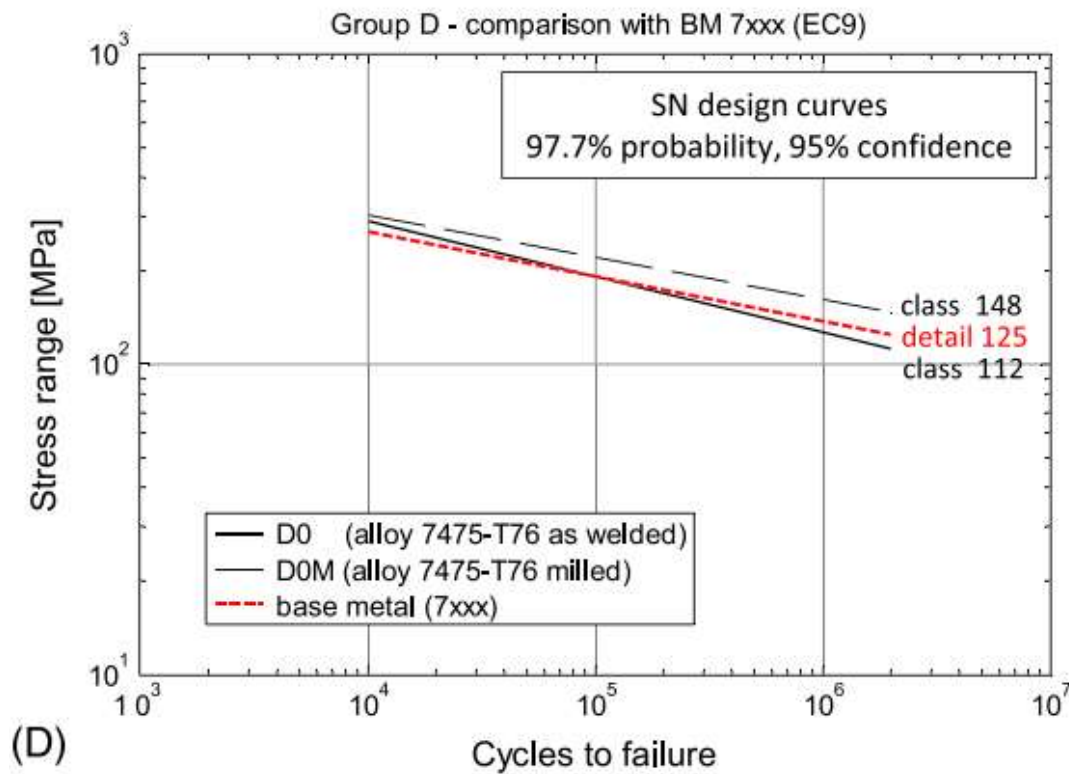
X, critical parameter; -, not applicable.

FSLW di lamiera AZ31	Carico monoassiale R=0,1
Provini ad osso di cane	Variano velocità di rotazione e di traslazione



Fonte: Jordon, Rao, Amaro, Allison. Fatigue in Friction Stir Welding. Butterworth-Heinemann 2019

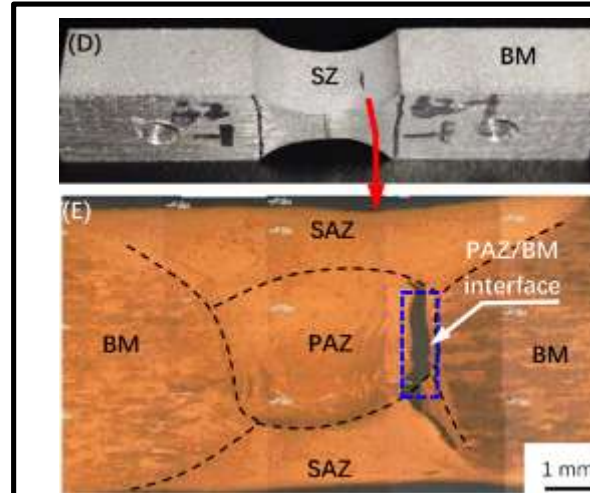
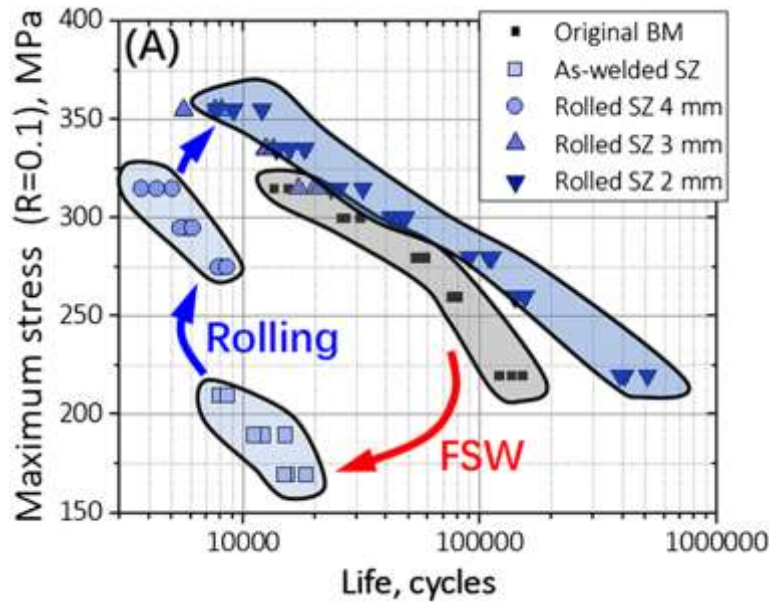
Leghe Alluminio 2XXX, 5XXX, 6XXX, 7XXX	Invecchiamento naturale e artificiale, fresatura
Carico monoassiale con R costante	Prove di fatica in controllo di tensione



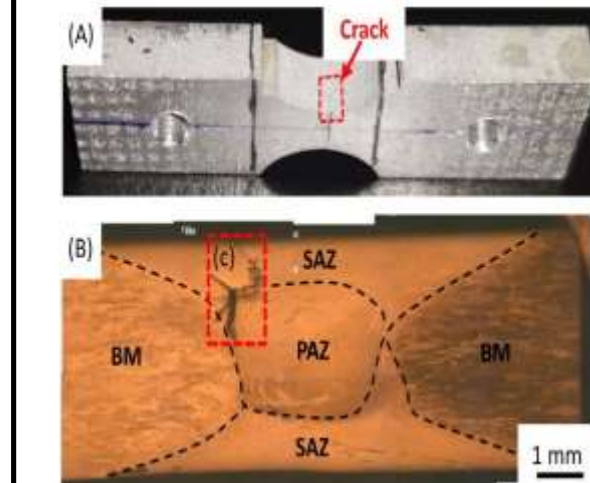
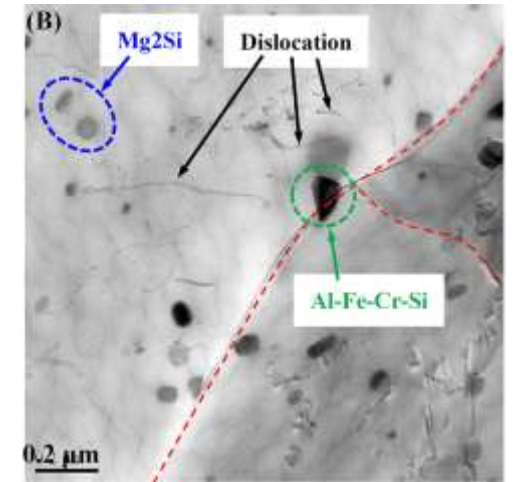
Fonte: Maggiolini E, Benasciutti D, Susmel L, Hattingh DG, James MN, Tovo R. Friction stir welds in aluminium: Design S- N curves from statistical analysis of literature data. *Fatigue Fract Eng Mater Struct*. 2018;41:2212–2230.

Lamiera 6 mm Alluminio 6061
saldata per FSW su entrambi i lati
e poi laminata a diversi spessori

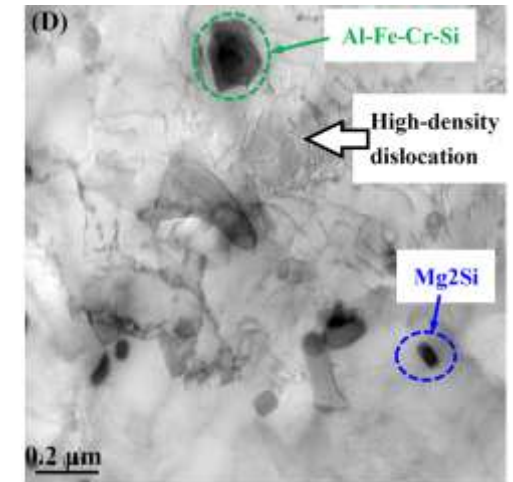
Provini ad osso di cane sottoposti
a carichi monoassiali con $R=0,1$



post
saldatura



post
saldatura e
laminazione

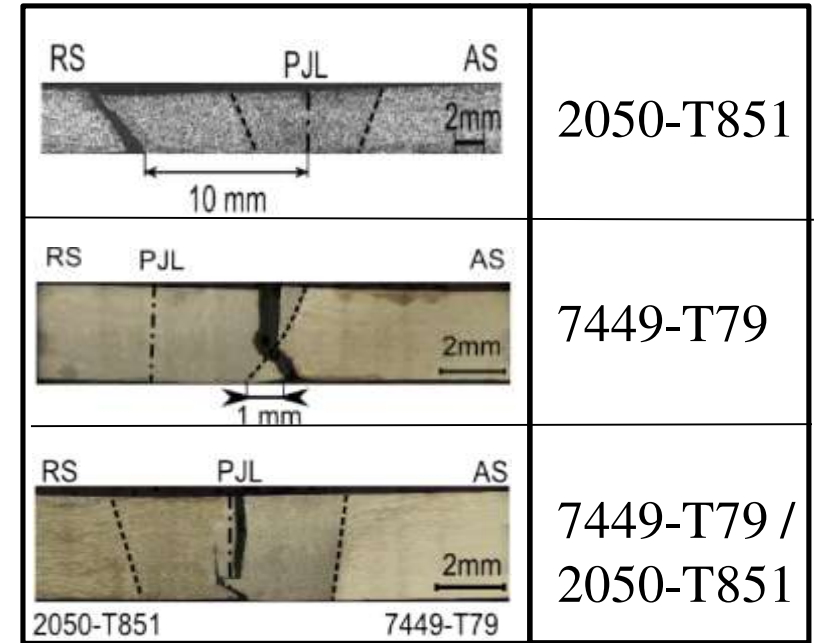
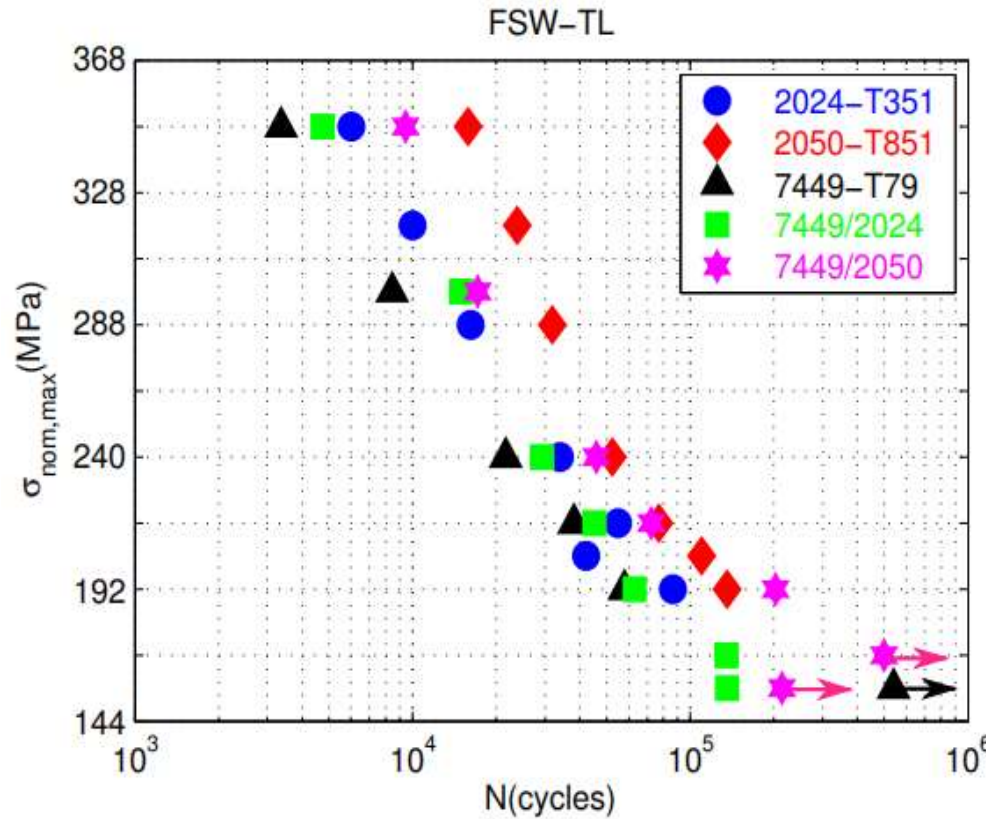


Fonte: Du, Pan, Chen, Tian. Effect of rolling process on fatigue performance of stir zone of AA6061-T6 double-side friction stir welding joint. Fatigue Fract Eng Mater Struct, 2021; 44:748-761.

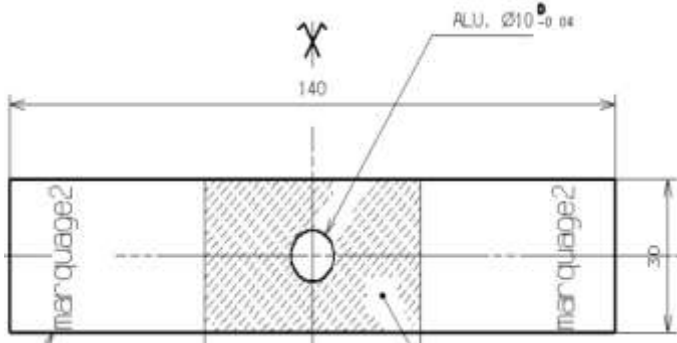
Leghe di alluminio
2024, 2050, 7449 e
saldature bimateriali
tra di esse

Cicli di carico
monoassiale con $R=0,1$

Provini anodizzati,
verniciati, intagliati e
saldati per simulare
condizioni industriali



Luogo di frattura
cambia col materiale



Fonte: Younes Demmouche. Étude du comportement en fatigue d'assemblages soudés par FSW pour applications aéronautiques. Autre. Ecole nationale supérieure d'arts et métiers - ENSAM, 2012



- Resistenza a fatica migliore di un 40/50% rispetto alle saldature tradizionali (MIG,TIG...)
- Saldature bimateriali che mostrano resistenza a fatica superiore all'Eurocodice 9 e sono quindi utilizzabili industrialmente
- Risparmio energetico rispetto alle saldature tradizionali del 30/40%
- Letteratura presente soprattutto per leghe di alluminio e acciai