



SAPIENZA  
UNIVERSITÀ DI ROMA

# AIAS 2008

XXXVII CONVEGNO NAZIONALE



## **Resistenza statica torsionale di connessioni acciaio – alluminio di aste innovative per perforazioni**

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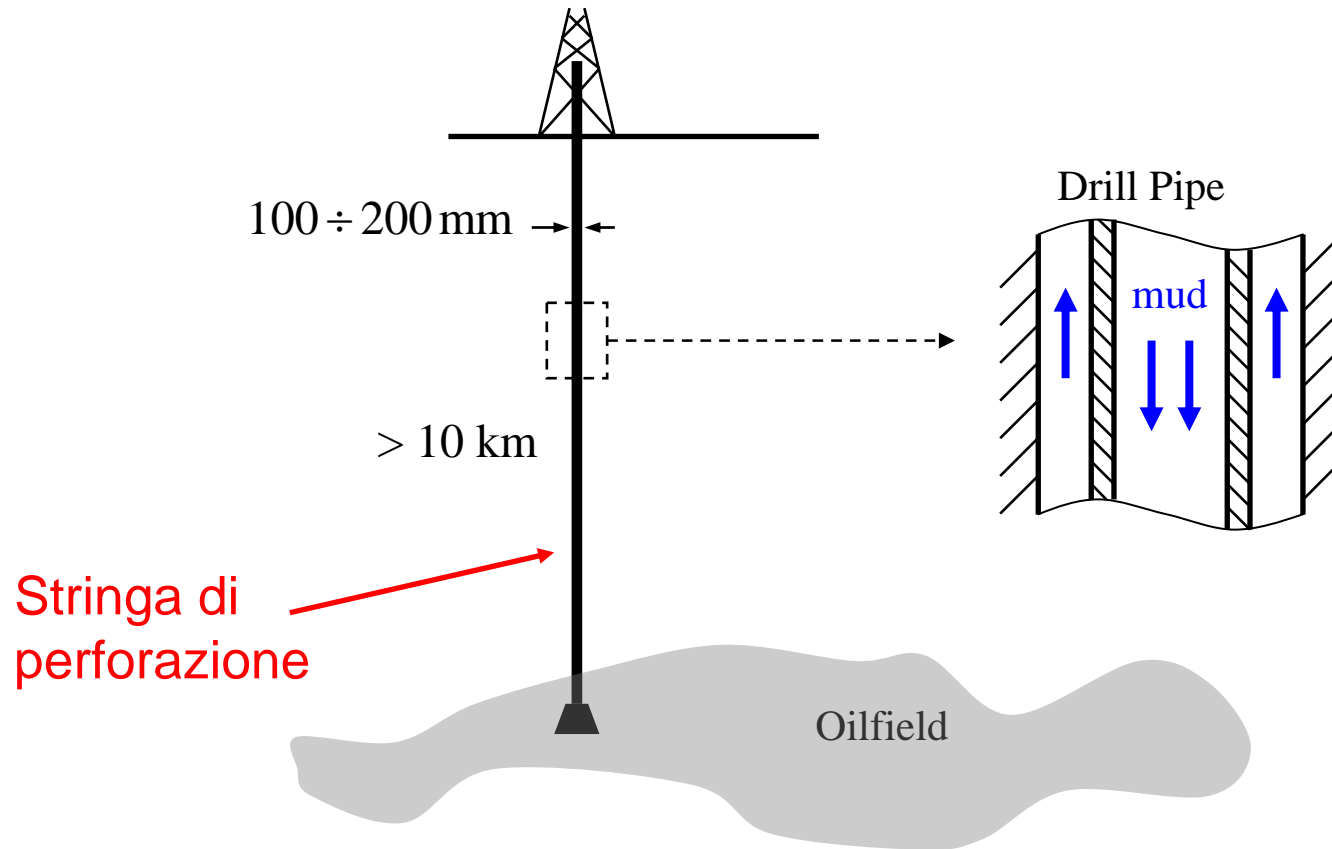
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DIMNP Università di Pisa

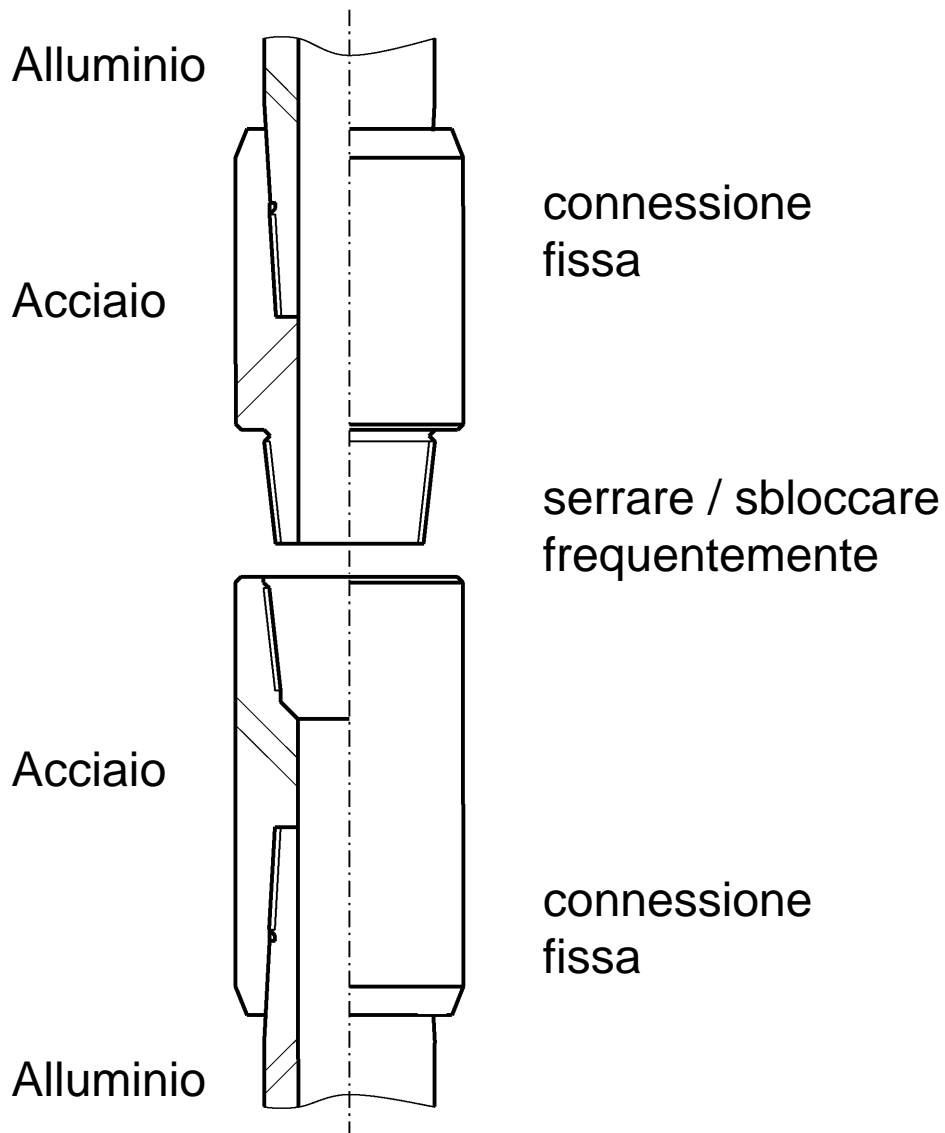
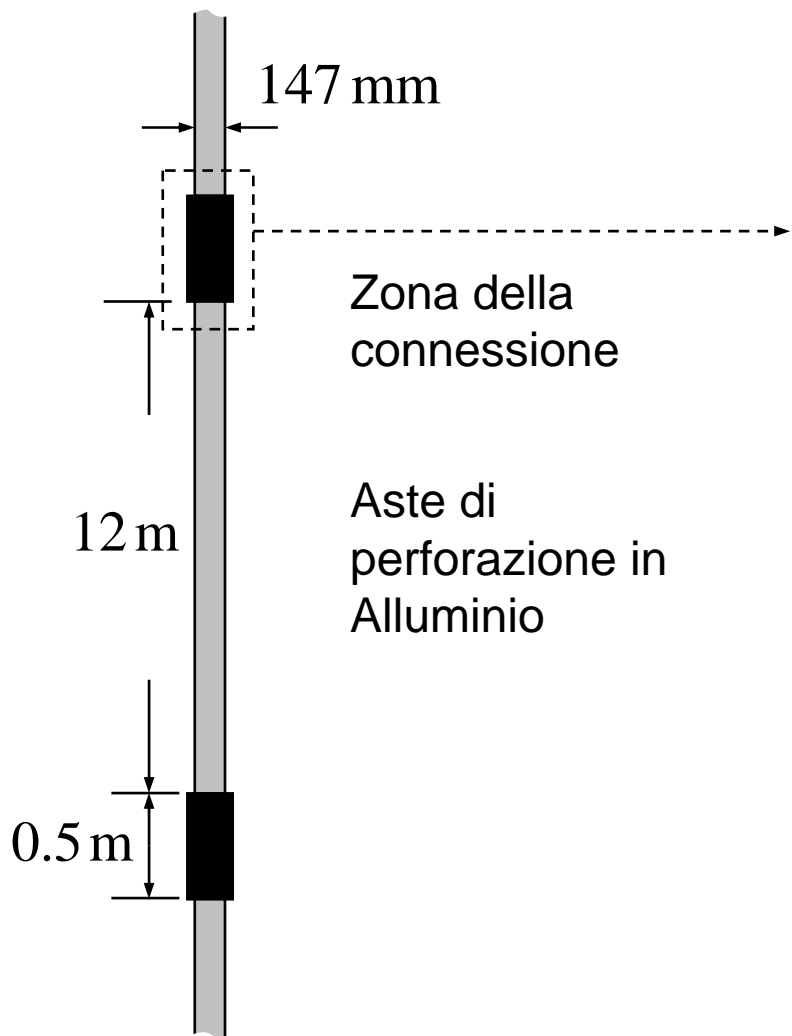
ENI SpA, Exploration and Production (MI)



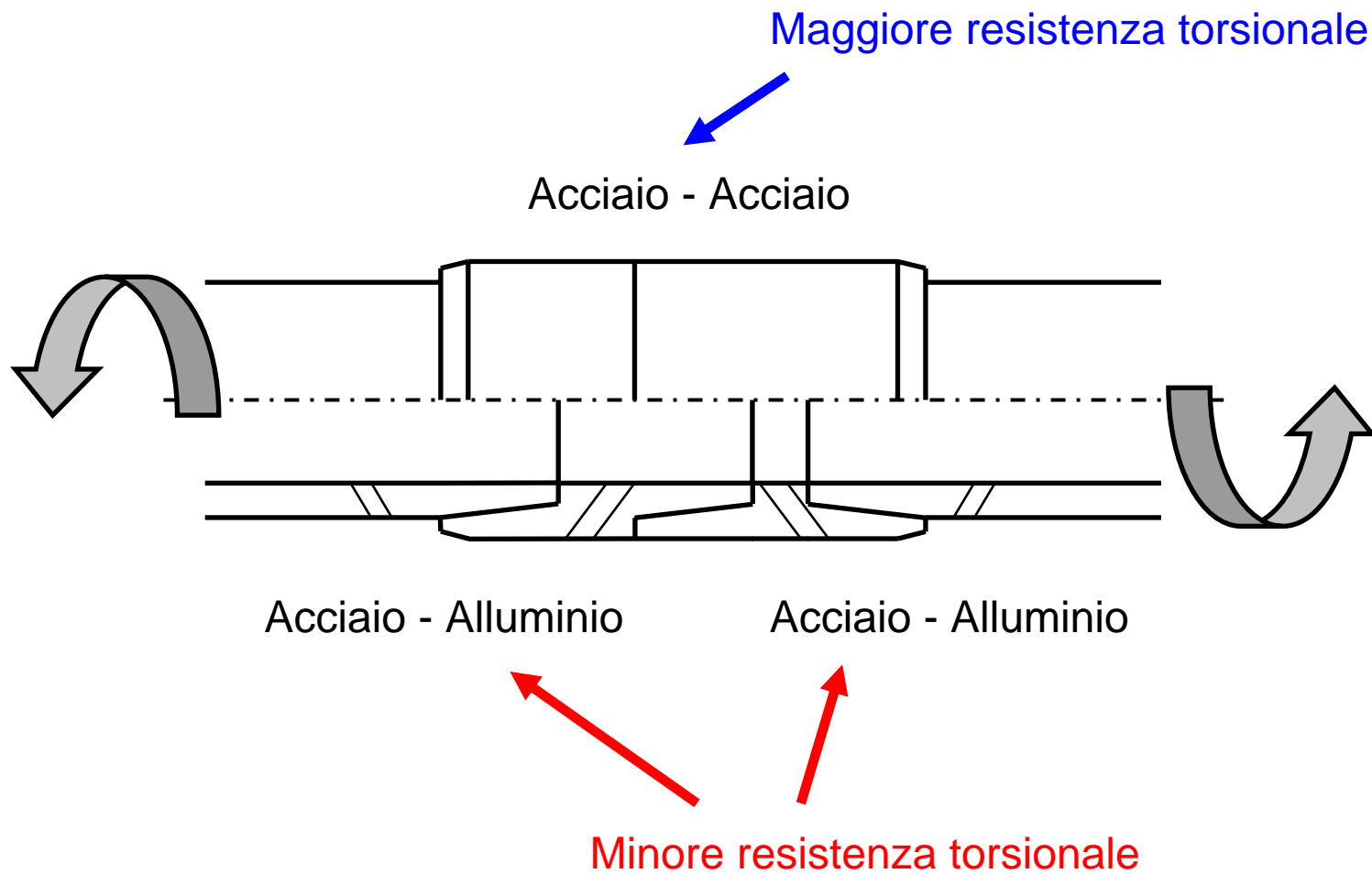
# Perforazione petrolifera



# Aste di perforazione / Connessione

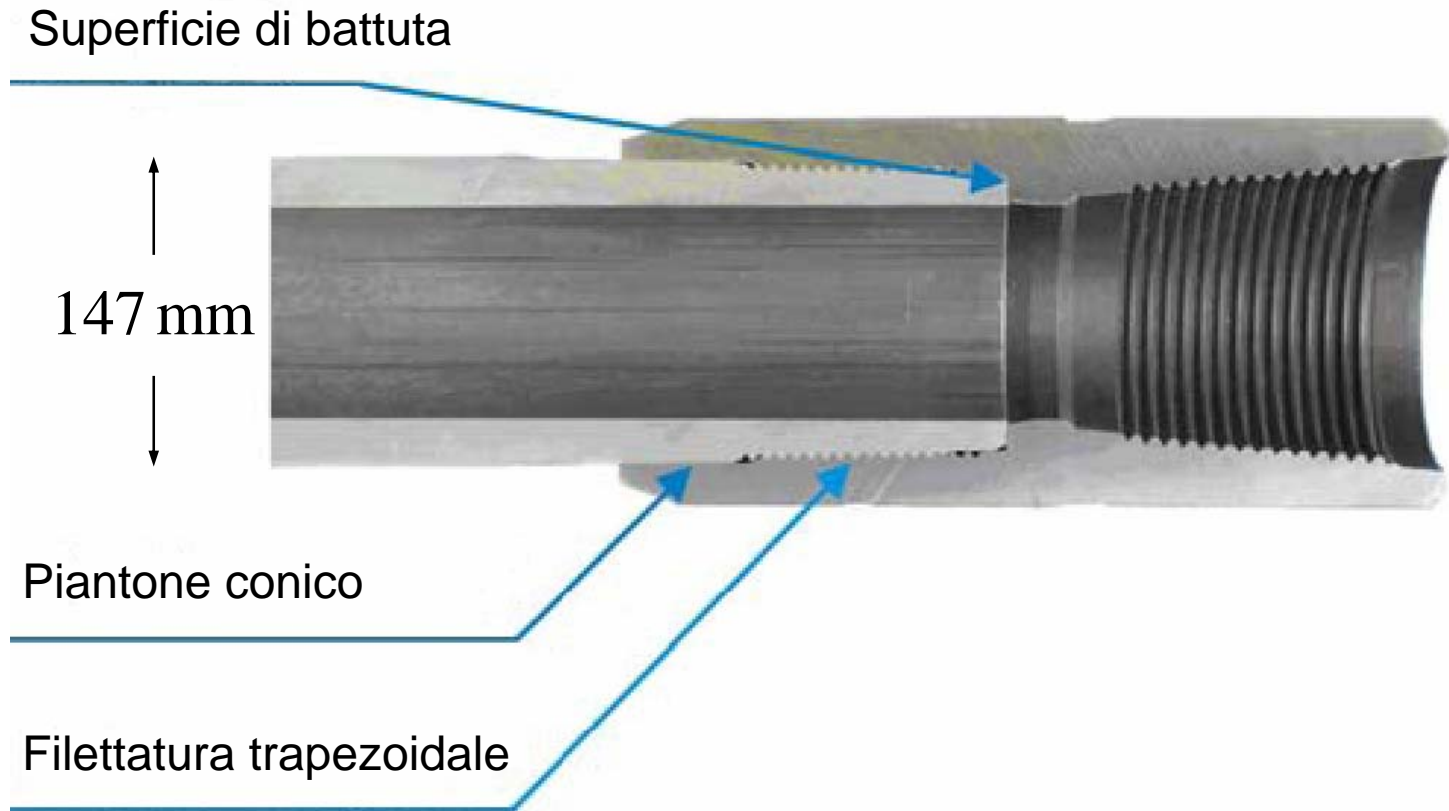


# Sollecitazione di torsione

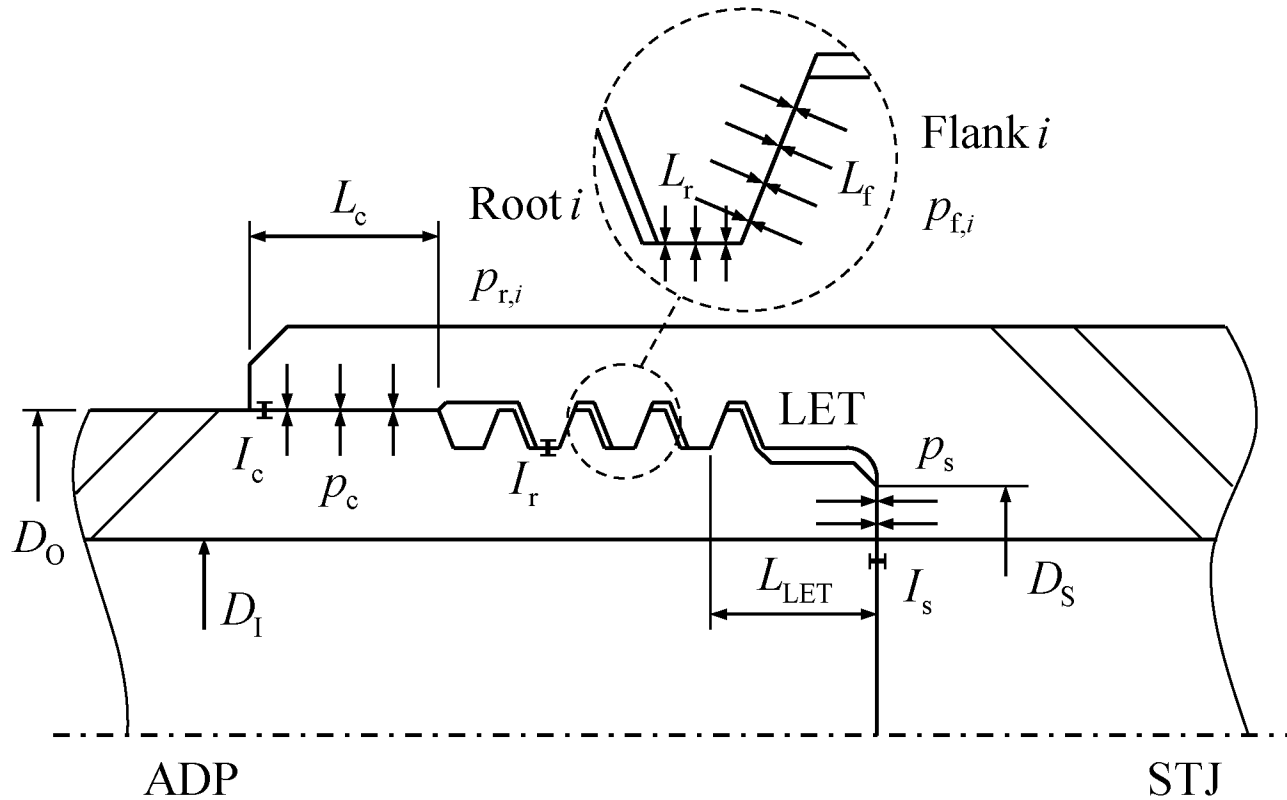


# Connessione alluminio-acciaio

Aluminum Drill Pipe to Steel Tool Joint connection



# Interfacce di contatto fra le due parti



Interferenze:

- diametrali  $I_c, I_r$

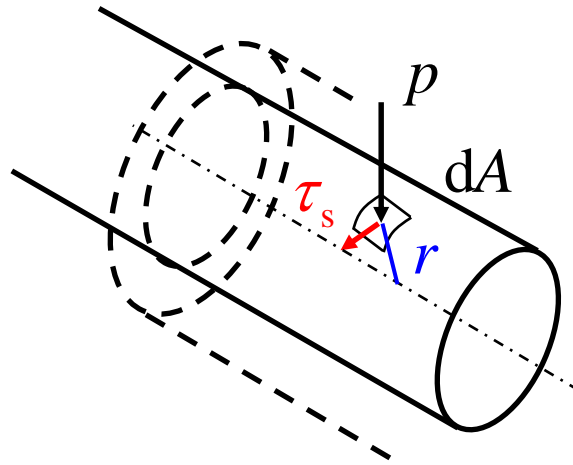
- assiale  $I_s$

pressioni di contatto:

- diametrali  $p_c, p_{r,i}$

- assiali  $p_{f,i}, p_s$

# Resistenza torsionale della connessione



Condizione limite  
di slittamento:

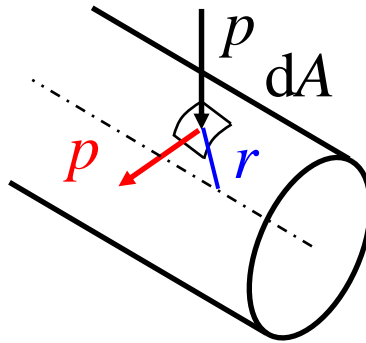
$$\tau_s = f_s p$$

$$T_s = \int f_s p r dA$$

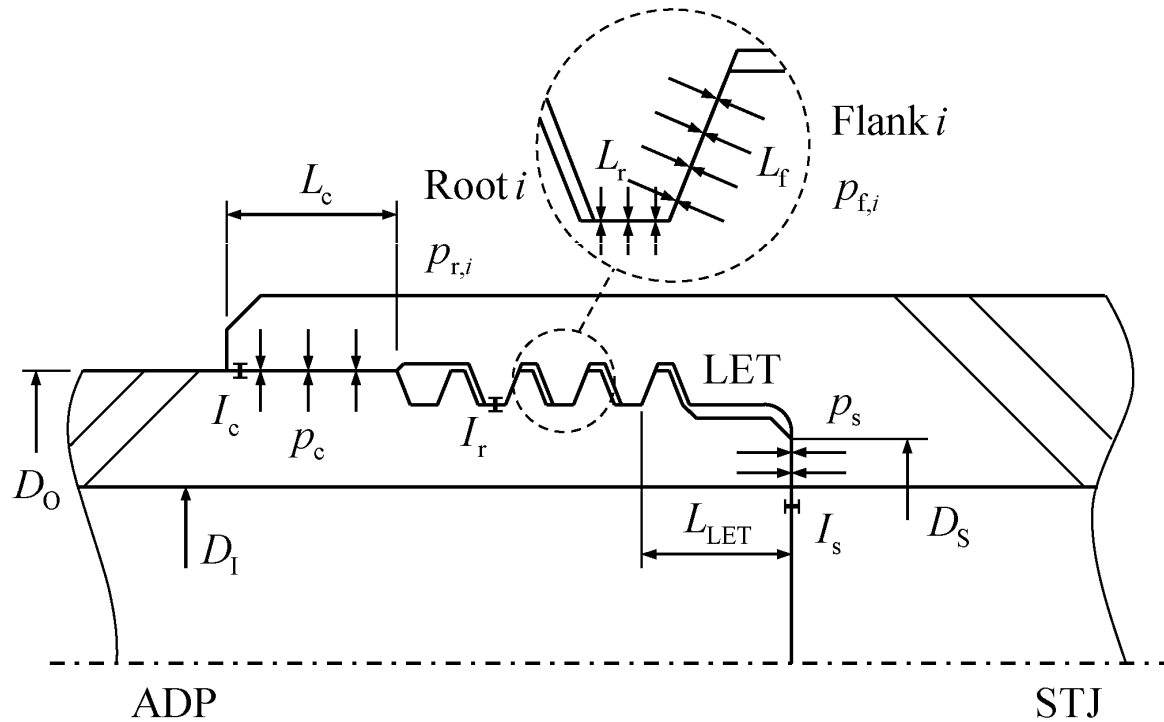
# Resistenza torsionale a coef. di attrito unitario

$$T_s = f_s T_1$$

$$T_1 = \int p r dA$$



# Resistenza torsionale a coef. di attrito unitario



$$T_1 = p_c \pi D_O L_c \frac{D_O}{2} + p_s \frac{\pi}{4} (D_S^2 - D_I^2) + \frac{D_S + D_I}{2} + \sum_1^{n_r} p_{r,1} \pi D_O L_r \frac{D_O}{2} + \sum_1^{n_f} p_{f,1} \pi D_O L_f \frac{D_O}{2}$$

# Resistenza torsionale a coef. di attrito unitario

$$T_1 = p_c \pi D_o L_c \frac{D_o}{2} + p_s \frac{\pi}{4} (D_s^2 - D_I^2) + \frac{D_s + D_I}{2} + \sum_1^{n_r} p_{r,1} \pi D_o L_r \frac{D_o}{2} + \sum_1^{n_f} p_{f,1} \pi D_o L_f \frac{D_o}{2}$$

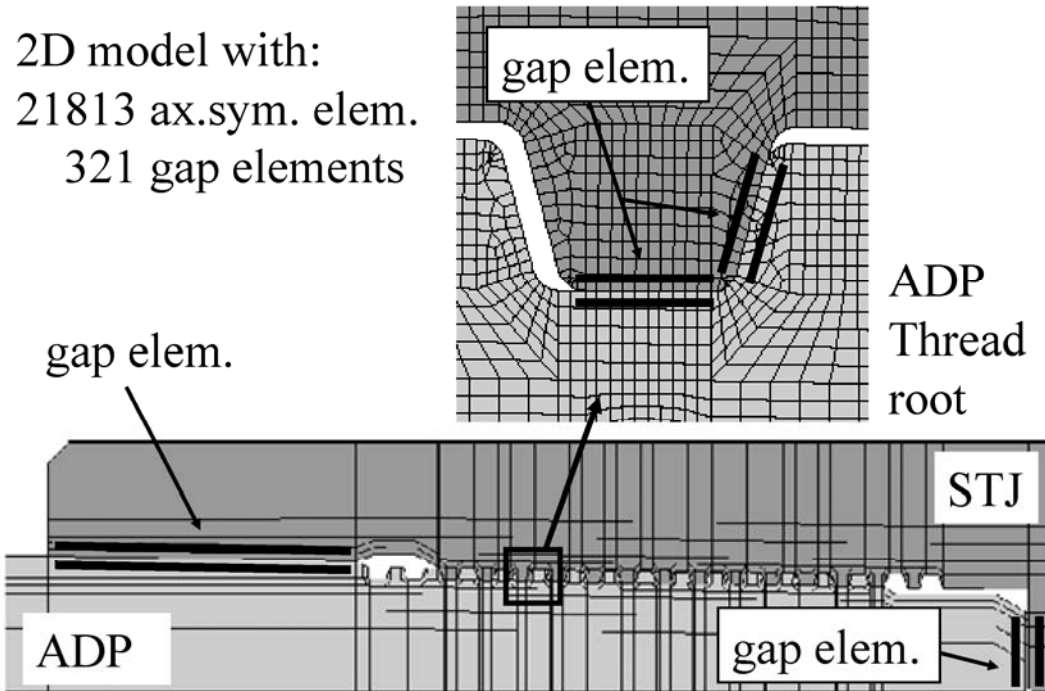
Linearità (con ottima approssimazione)  
fra **pressioni di contatto** e **interferenze**

$$T_1 = C_1 I_c + \cancel{C_2 (I_r - I_c)} + C_3 I_s$$

$$T_1 = C_1 I_c + C_3 I_s$$

# Resistenza torsionale a coef. di attrito unitario

Modello FEM



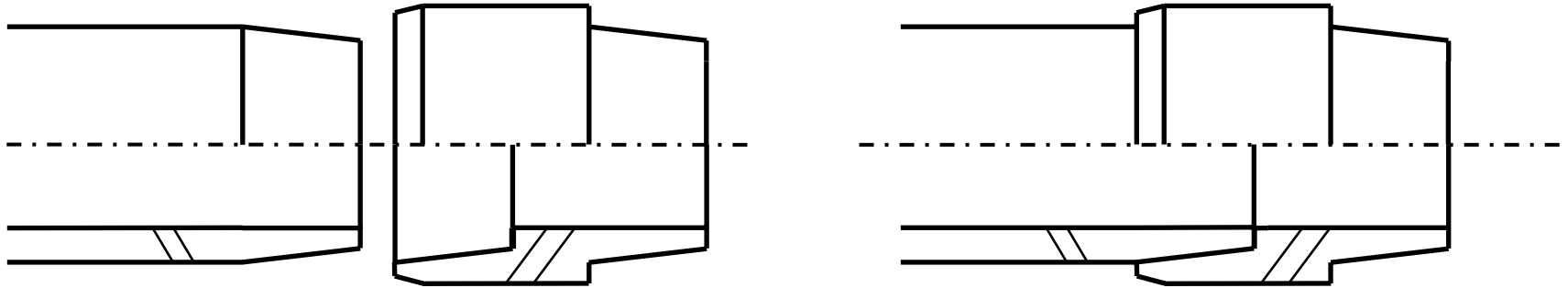
$$T_1 = C_1 I_c + C_2 (I_r - I_c) + C_3 I_s$$

$$C_1 = 435 \text{ kN m / mm}$$

$$C_2 = 270 \text{ kN m / mm}$$

$$C_3 = 670 \text{ kN m / mm}$$

# Assemblaggio della connessione



Tecniche di assemblaggio:

- a caldo (warm assembling)
- a freddo (cold assembling)

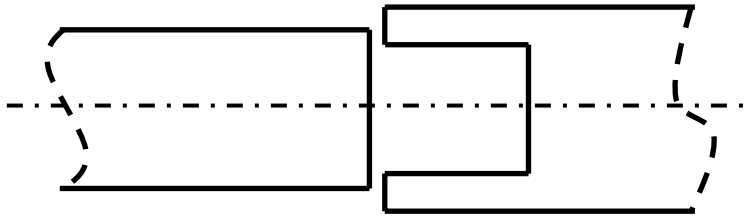
# Assemblaggio a caldo

- sviluppato dalla russa AQUATIC
- attualmente utilizzata



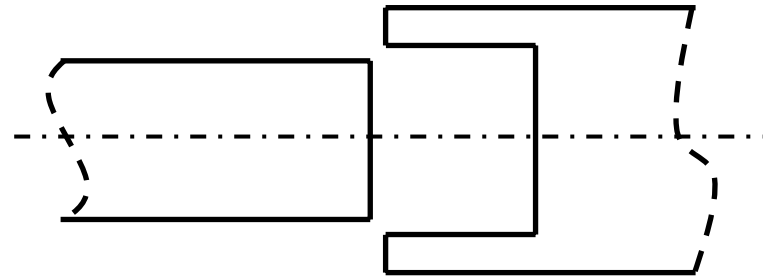
# Assemblaggio a caldo

Iniziale interferenza diametrale



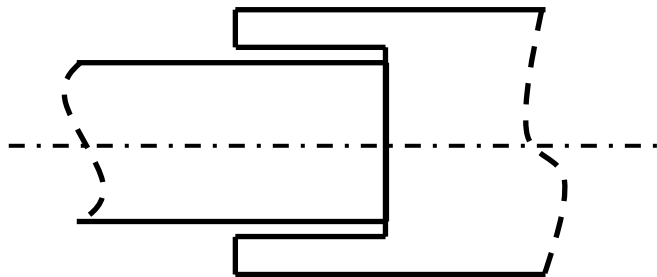
(a)  $\Delta T = 0^\circ\text{C}$

Differenza di temperature



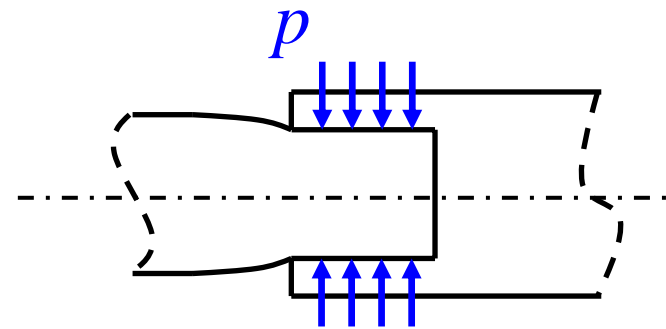
(b)  $\Delta T = 240^\circ\text{C}$

Assemblaggio senza forzamento



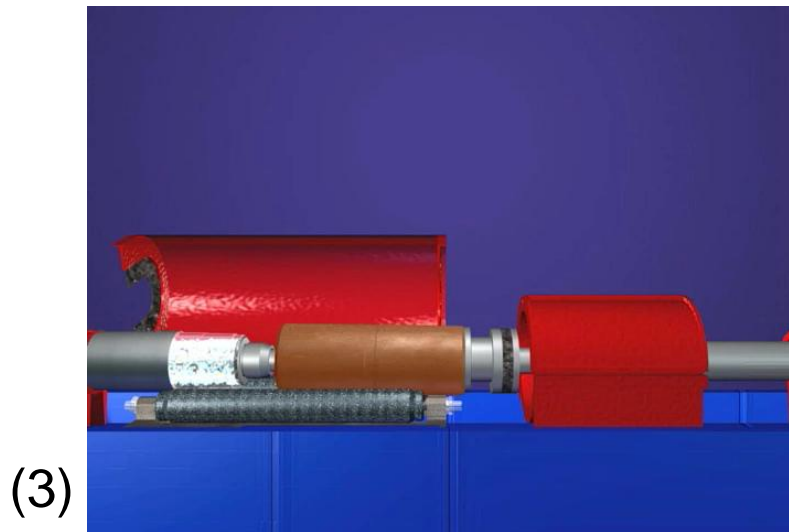
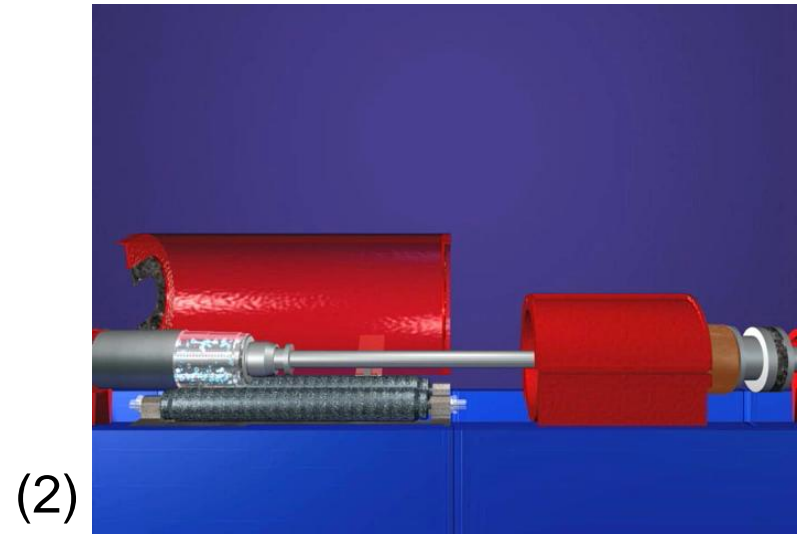
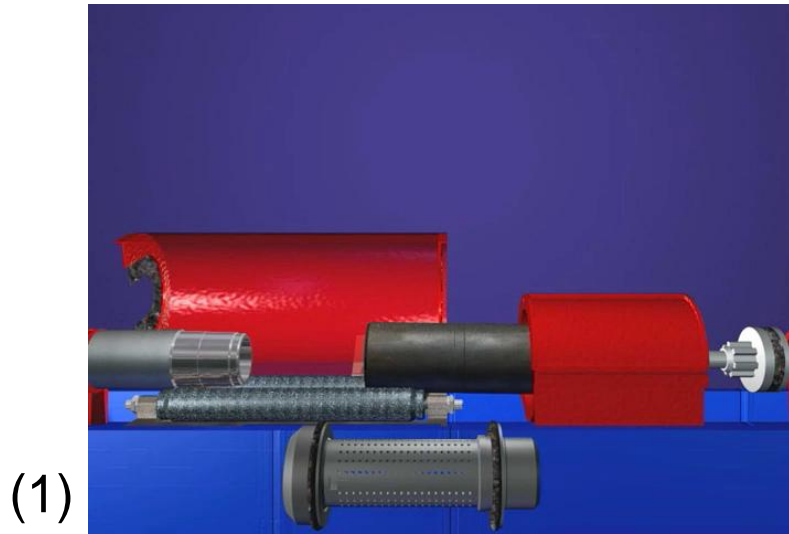
(c)  $\Delta T = 240^\circ\text{C}$

Pressioni di contatto



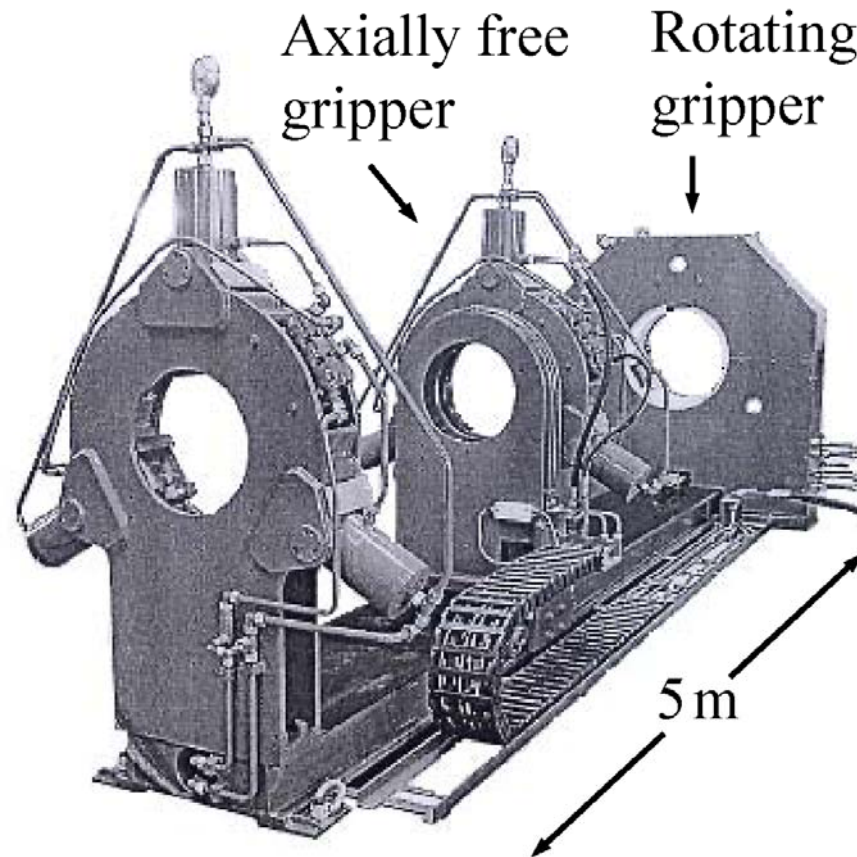
(d)  $\Delta T = 0^\circ\text{C}$

# Assemblaggio a caldo



[HotAssembling\\_AQUATIC.avi](#)

# Prove di svitamento, assembl. a caldo



Attrezzatura utilizzata, CMA Canavera srl (Torino)

# Prove di svitamento, assembl. a caldo

Test 1

$$I_c = I_r = 0.38 \text{ mm}$$

$$\Delta T = 240^\circ \text{C}$$

$$T_s = 61 \text{ kNm}$$

$$\left. \begin{array}{l} T_s = f_s T_1 \\ T_1 = C_1 I_c + C_3 I_s \end{array} \right\} \begin{array}{l} \approx 0 \\ \searrow \end{array} \rightarrow f_s = 0.29$$

Test 2

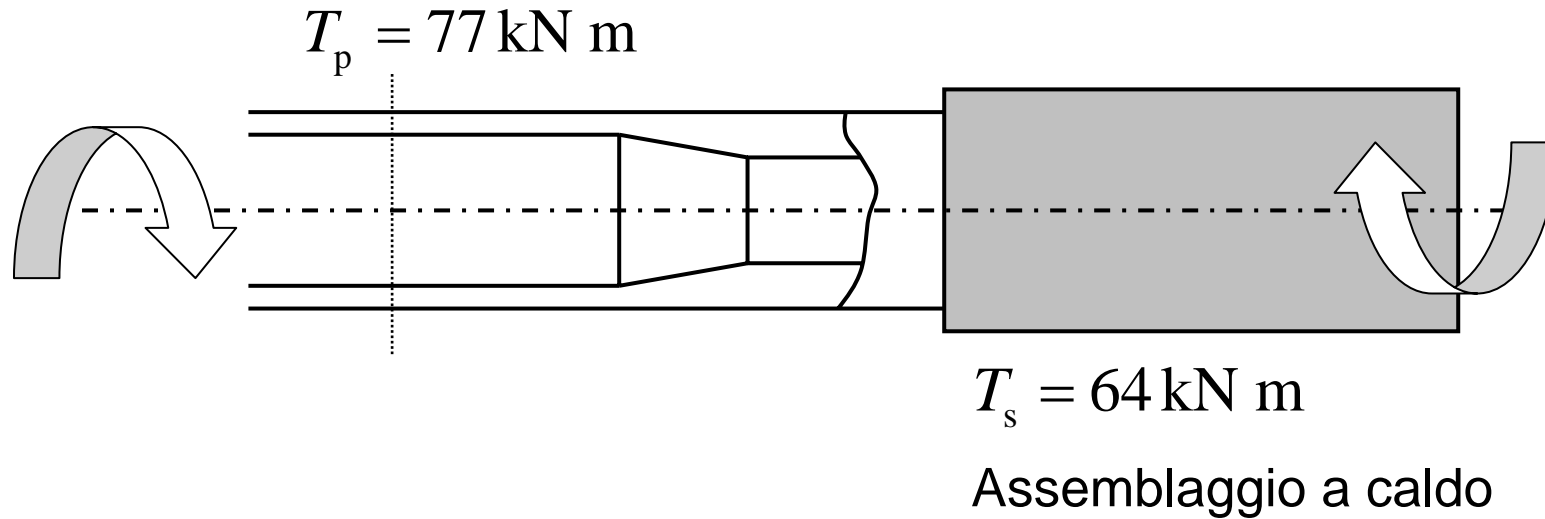
$$I_c = I_r = 0.38 \text{ mm}$$

$$\Delta T = 240^\circ \text{C}$$

$$T_s = 67 \text{ kNm}$$

$$\left. \begin{array}{l} T_s = f_s T_1 \\ T_1 = C_1 I_c + C_3 I_s \end{array} \right\} \begin{array}{l} \approx 0 \\ \searrow \end{array} \rightarrow f_s = 0.31$$

# Limitata resistenza dell'assembl. a caldo

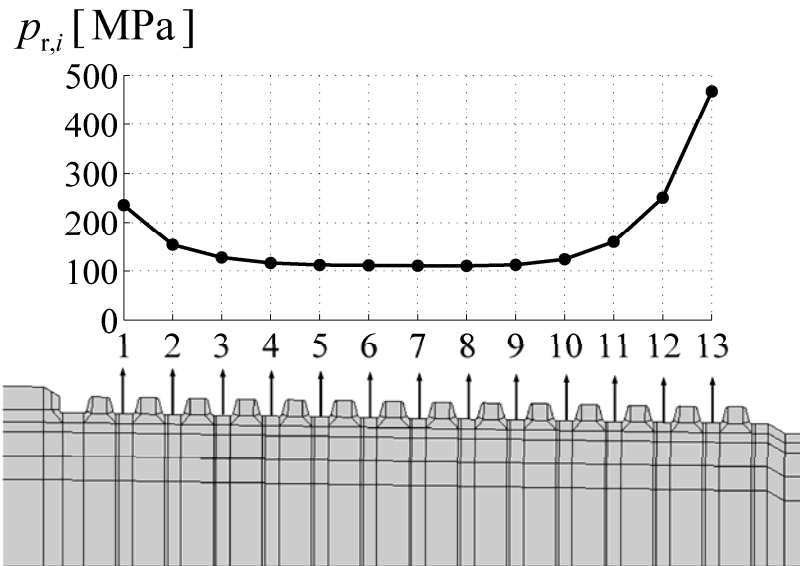


$$T_s < T_p$$

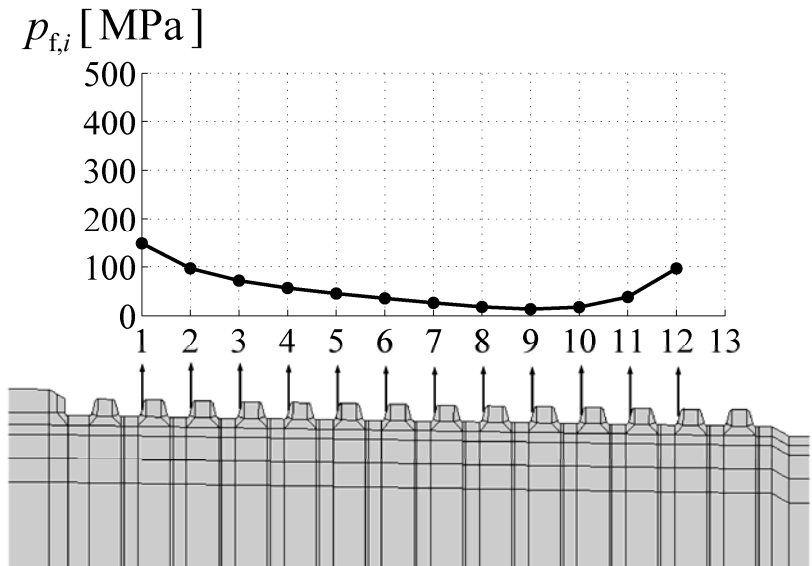
Interferenza assiale pressoché nulla  $\approx 0$

$$T_s = f_s (C_1 I_c + C_3 I_s)$$

# Limitata interferenza assiale assembl. a caldo



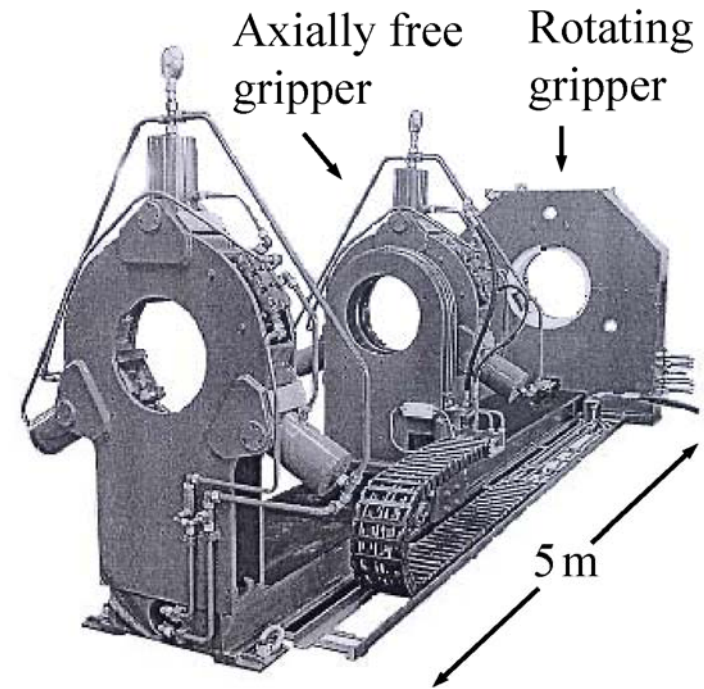
Pressione sul fondo filetto



Pressione sul fianco del filetto

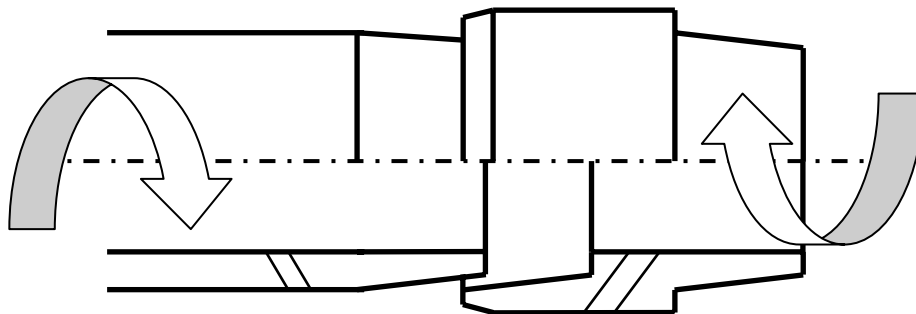
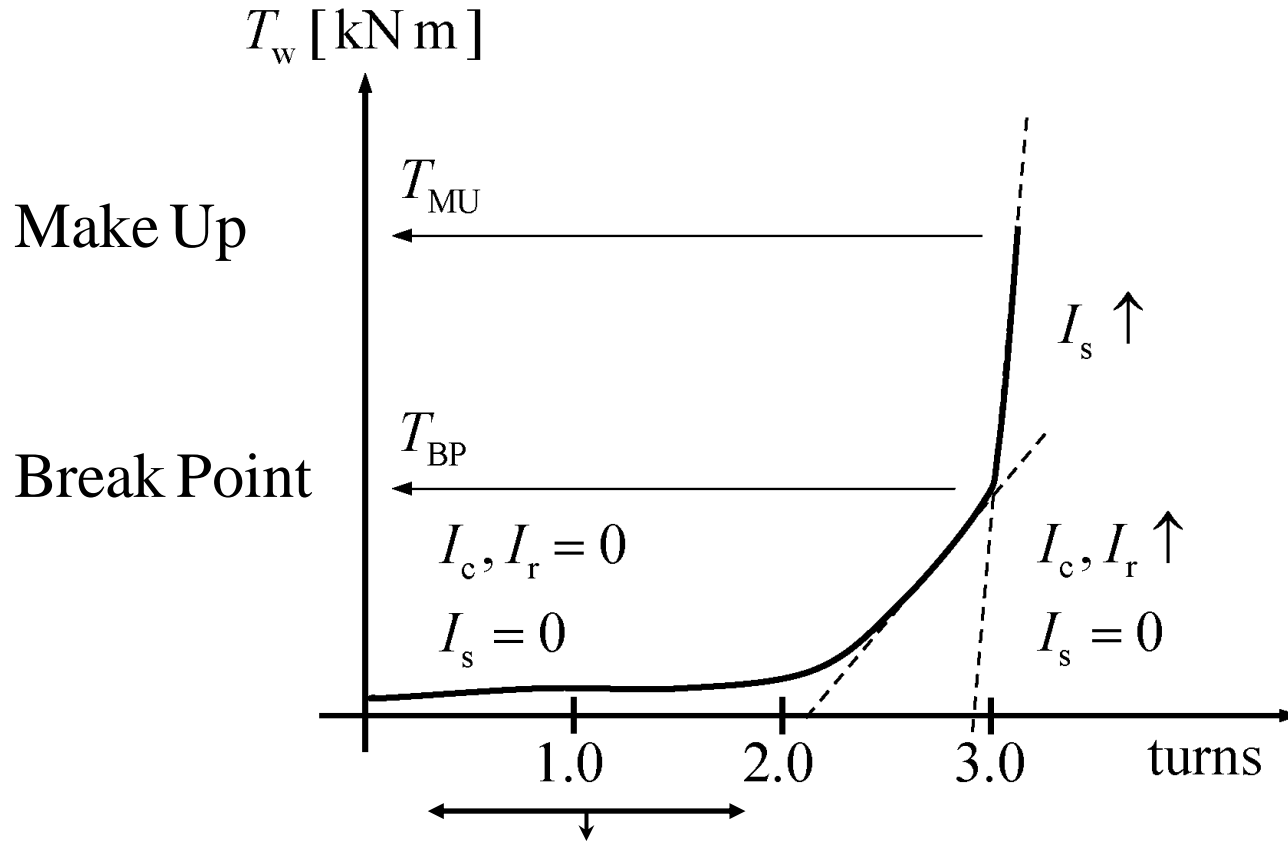
# Assemblaggio a freddo

- sviluppato da UniPi – ENI – CMA – Protech Centreform
- forzamento torsionale facilitato da opportuno composto
- dopo solidificazione elevato coefficiente di attrito statico

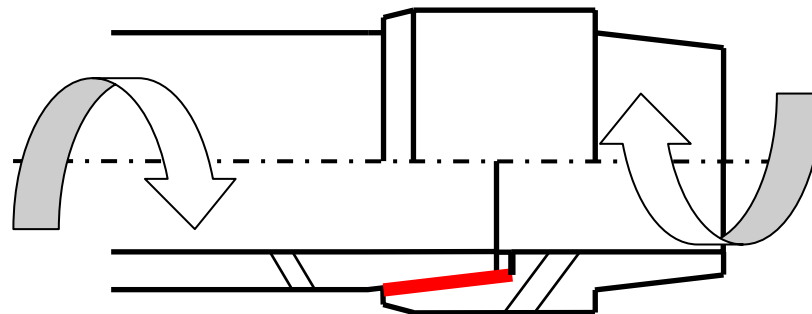
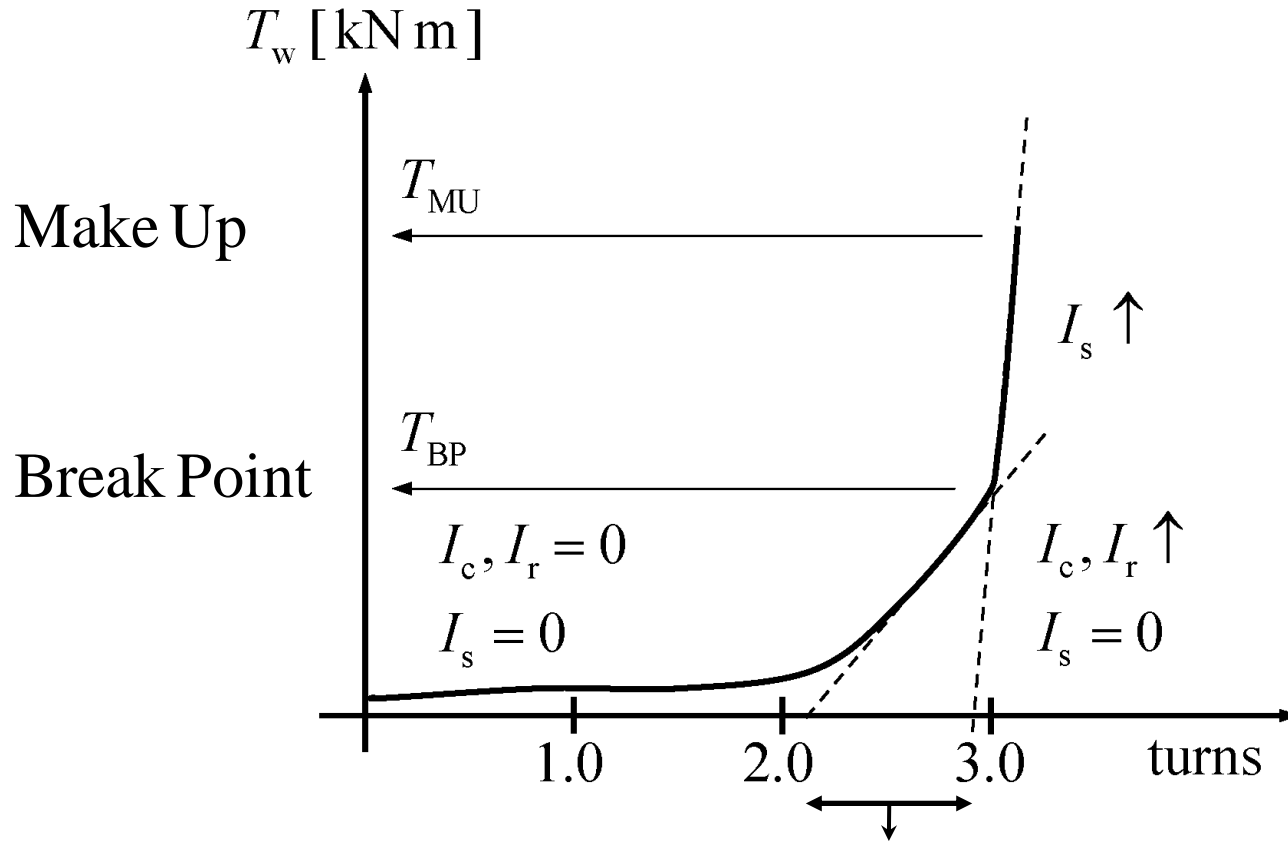


CMA Canavera Srl

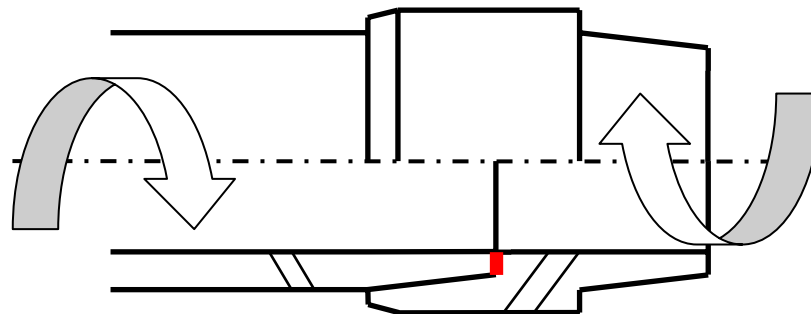
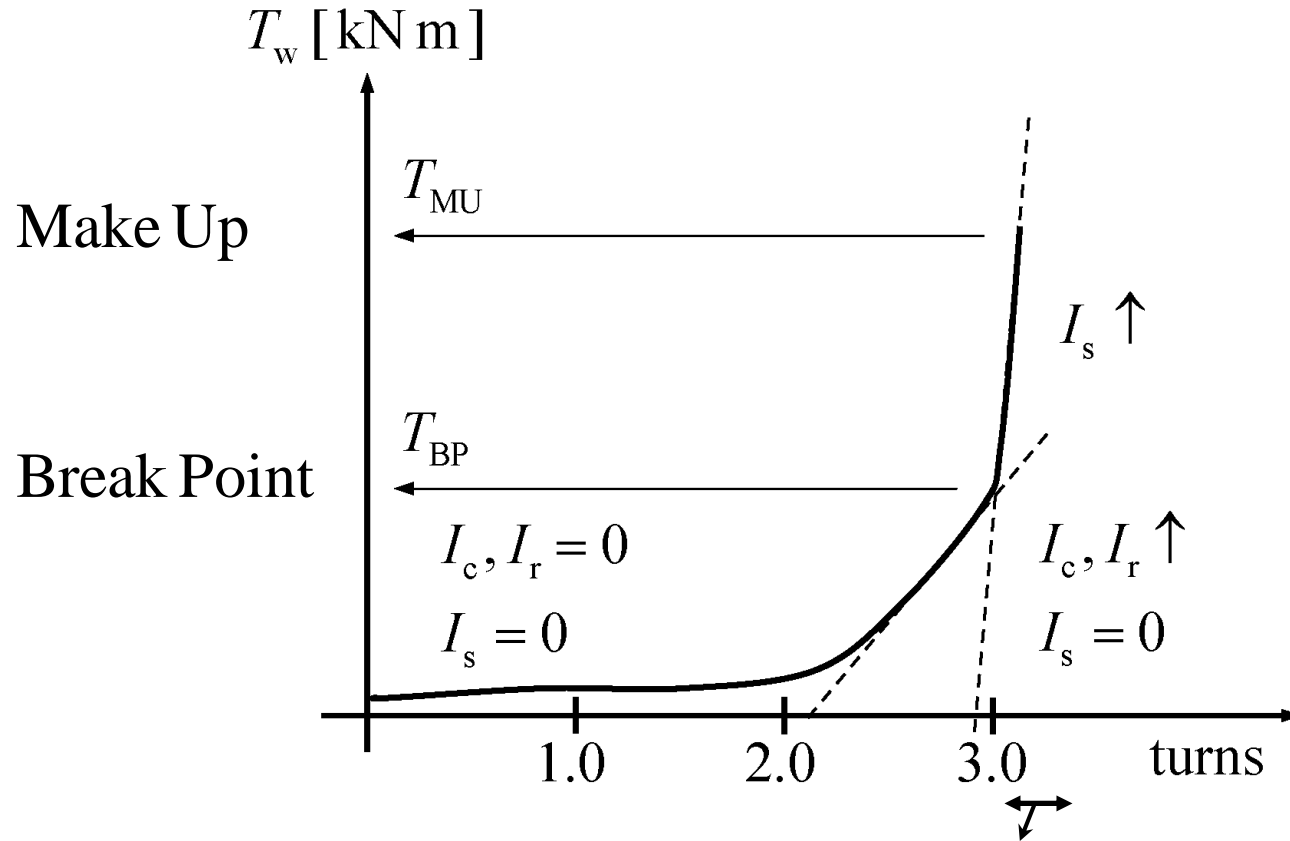
# Fasi dell'assemblaggio a freddo



# Fasi dell'assemblaggio a freddo



# Fasi dell'assemblaggio a freddo



# Fasi dell'assemblaggio a freddo

$$\left. \begin{array}{l} \text{Break Point} \\ I_s = 0 \\ T_{\text{BP}} = f_w (C_1 I_c + C_3 I_s) \end{array} \right\} \rightarrow f_w \text{ (coef. di attrito dinamico 'wet')}$$

su 18 test:

$$f_w = 0.15 \pm 0.06$$

$$\left. \begin{array}{l} \text{Make Up} \\ T_{\text{MU}} = f_w (C_1 I_c + C_3 I_s) \end{array} \right\} \rightarrow I_s$$

# Prove di svitamento assembl. a freddo

15 test (su 18):

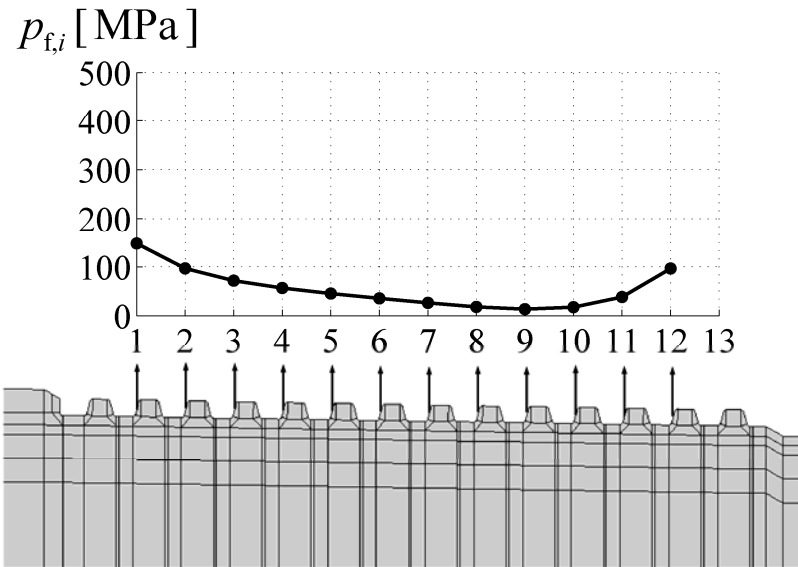
$T_s > 90 \text{ kN m}$  (limite dell'attrezzatura)

Coeff. di attrito statico mediato dal Composto solidificato

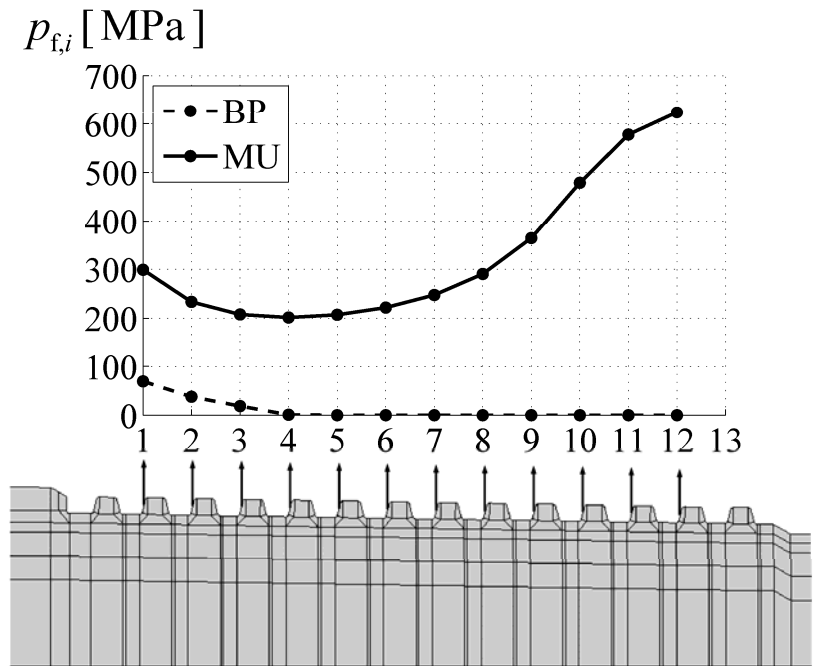
$$T_s = f_{s,C} (C_1 I_c + C_3 I_s) \rightarrow f_{s,C}$$

$$f_{s,C} > 0.3$$

# Elevata interferenza assiale assembl. a freddo

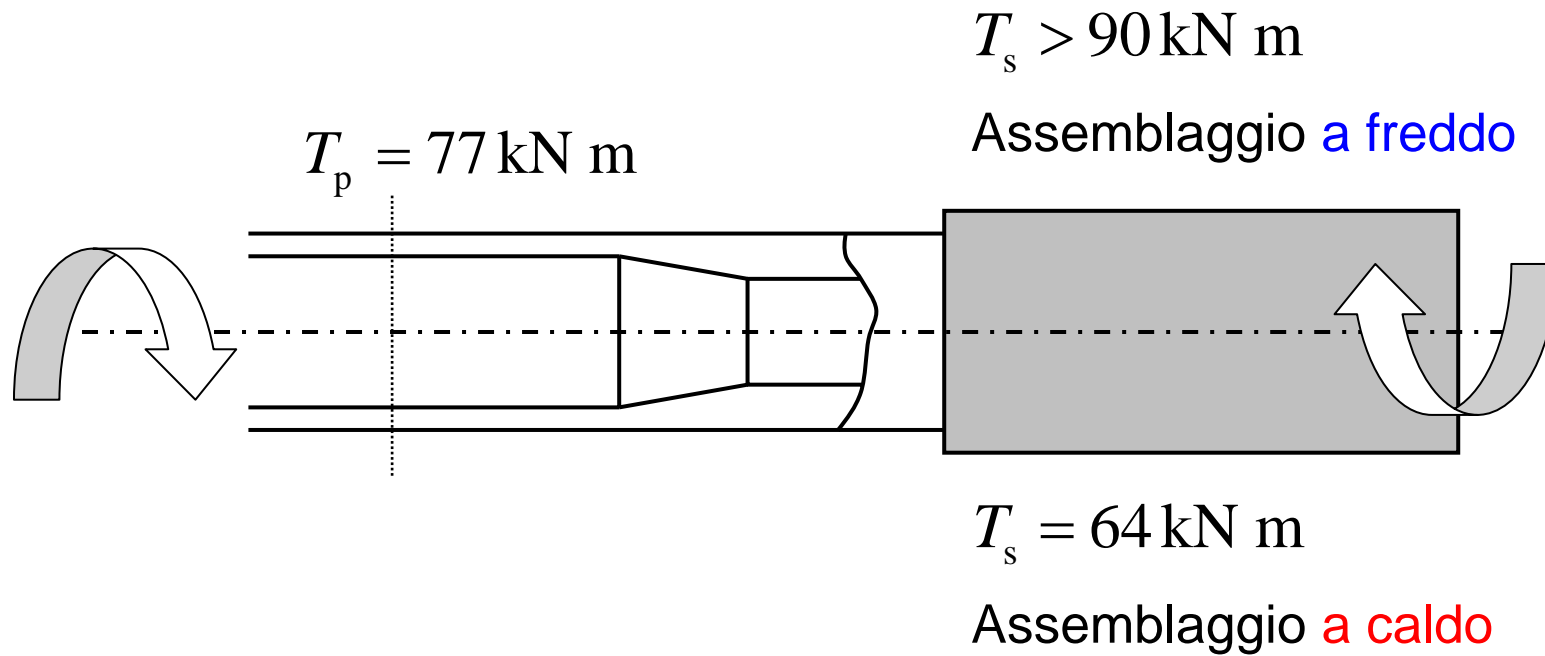


Pressioni fianchi filetto  
assembl. **a caldo**



Pressioni fianchi filetto  
assembl. **a freddo**

# Limitata resistenza dell'assembl. a caldo



# Conclusioni

- Assemblaggio a caldo / a freddo
- Svantaggi assemblaggio a freddo:
  - necessità di applicare il composto
  - non perfetta ripetibilità del processo
- Vantaggi assemblaggio a freddo:
  - no sollecitazione termica sulla parte in alluminio
  - possibilità di imprimere una significativa interferenza assiale
  - **maggiore** resistenza torsionale