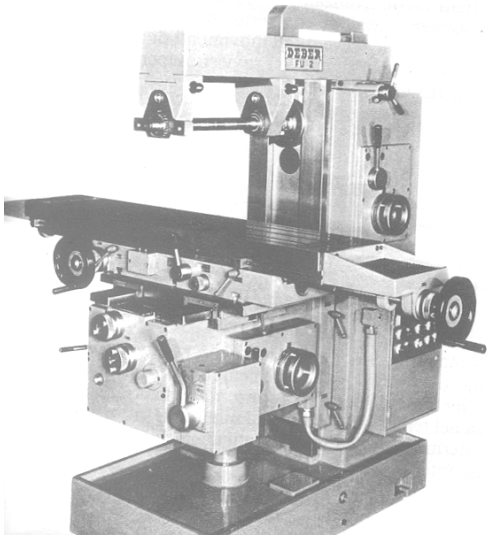
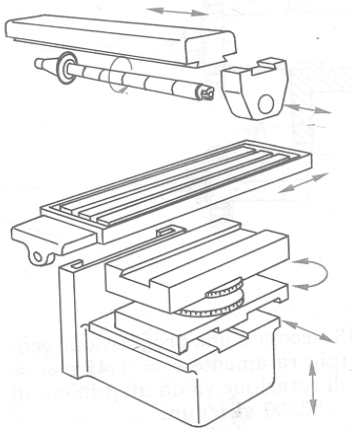
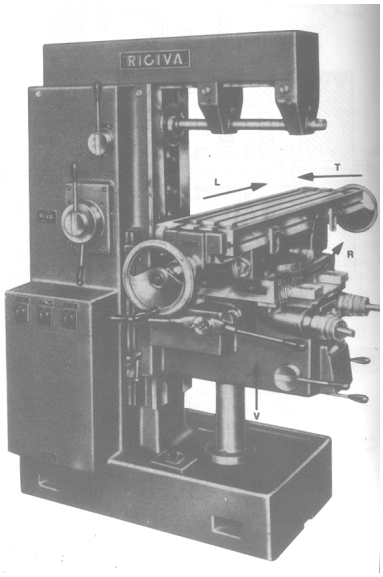
FRESATRICE ORIZZONTALE



Fresatrice Orizzontale UNIVERSALE

Piattaforma girevole sulla slitta trasversale



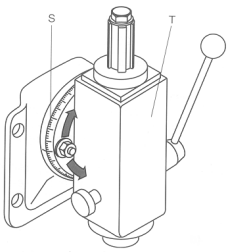


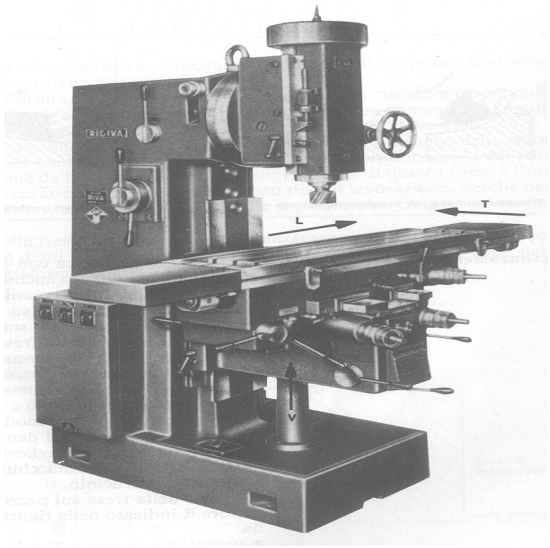
FRESATRICE VERTICALE

Albero verticale

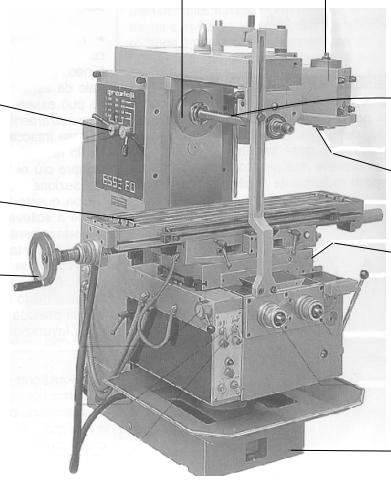
o

inclinabile





Fresatrice Universale: componenti



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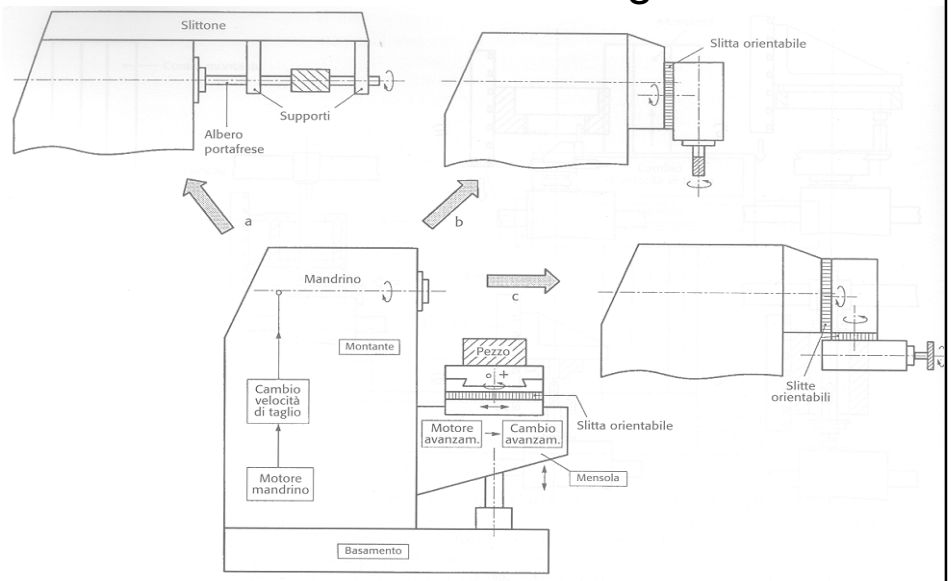
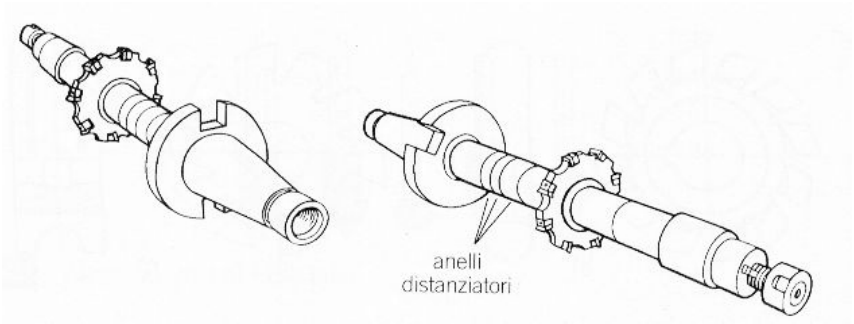
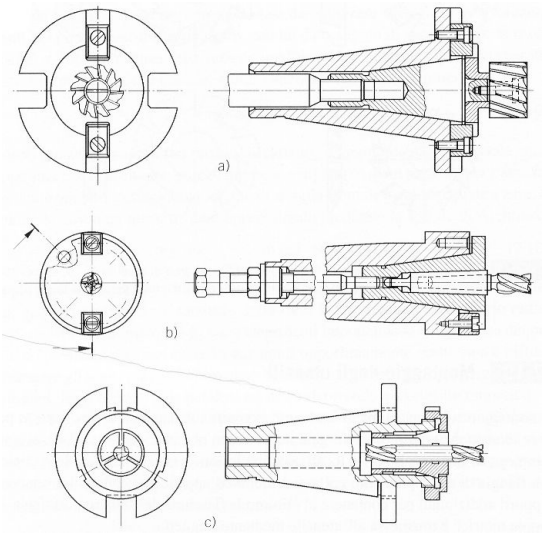


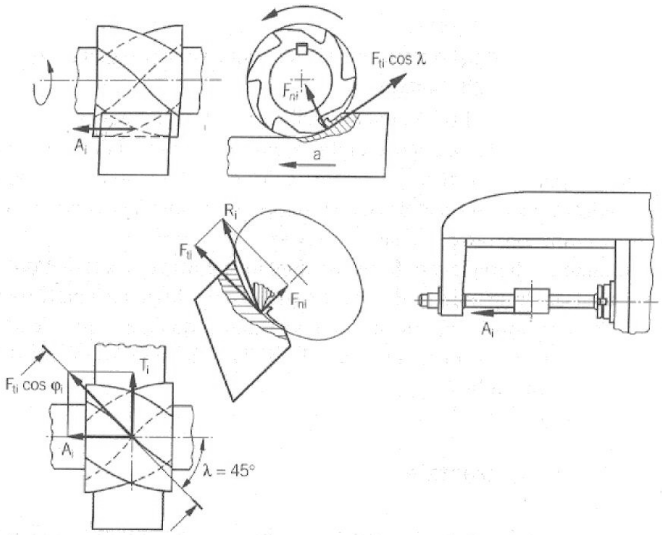
MONTAGGIO FRESA



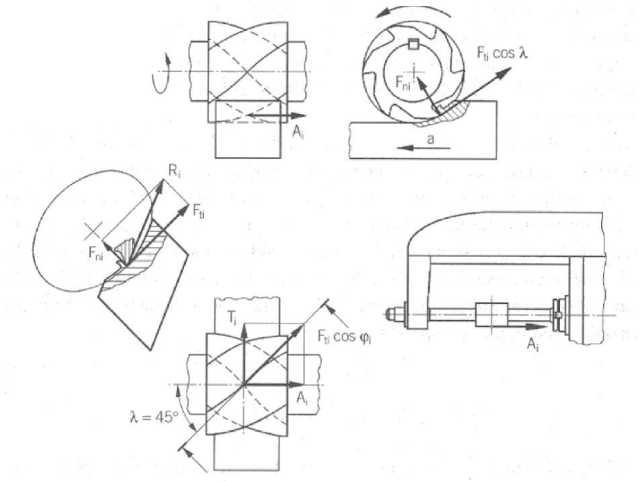
MONTAGGIO FRESA



ELICA DESTRA/TAGLIO DESTRO



ELICA SINISTRA/TAGLIO DESTRO



PARAMETRI DI TAGLIO

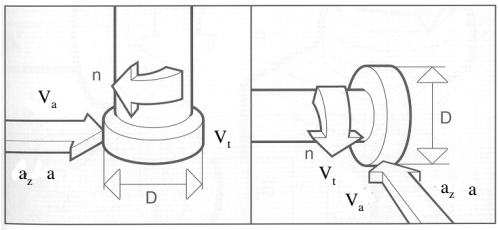
Velocità di rotazione del mandrino ***n*** [giri/min]

Velocità di taglio v_t [m/min]

Avanzamento al dente a_z [mm/dente*giro]

Avanzamento al giro ***a*** [mm/giro]

Velocità di avanzamento V_a [mm/min]



$$V_t = \frac{\pi \times D \times n}{1000} \text{ (m/min)}$$

$$n = \frac{v_t \times 1000}{\pi \times D} \text{ (giri/min)}$$

PARAMETRI DI TAGLIO

- La velocità di taglio:

$$v_t = \frac{\pi D n}{1000} \quad \left[\frac{\text{m}}{\text{min}}\right]$$

D = diametro della fresa [mm]
n = velocità angolare [g/min]

Materiale del pezzo	Frese cilindriche e frontali	Frese a disco	Frese a profilo costante	Frese a codolo
Leghe di magnesio	400	400	250	300
Leghe di alluminio	250	250	160	200
Ottone	60	60	40	50
Ghisa dolce	40	40	25	30
Ghisa semidura	25	25	16	20
Ghisa malleabile	20	20	12	18
Acciaio dolce	20	20	12	18
Acciaio con R_m 400- 500 MPa	20	20	12	18
Acciaio con R_m 500-700 MPa	16	16	10	12
Acciaio con R_m 700-900 MPa	16	16	10	12
Acciaio con R_m 900-1200 MPa	12	12	8	10

PARAMETRI DI TAGLIO

- Velocità di avanzamento:

$$V_a = Z \cdot a_z \cdot n \quad \left[\frac{mm}{min}\right]$$

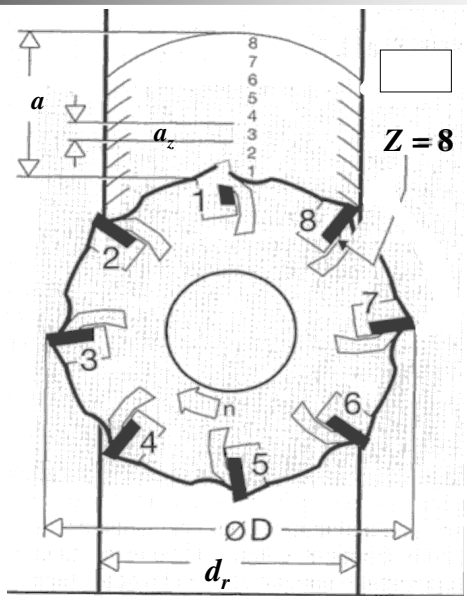
a_z = avanzamento al dente [mm/giro*dente]

Z = numero di denti della fresa

n = velocità angolare [giri/min]

Materiale del pezzo	Frese cilindriche e frontali	Frese a disco	Frese a profilo costante	Frese a codolo
Acciai non legati con R_m = 600 MPa	0,20	0,06	0,04	0,05
Acciai non legati con R_m = 600÷900 MPa	0,16	0,06	0,03	0,04
Acciai bonificati con R_m = 1100 MPa	0,10	0,05	0,02	0,02
Acciai bonificati con R_m = 1300 MPa	0,08	0,04	0,01	0,01
Ghisa grigia HB = 1800 MPa	0,25	0,08	0,05	0,08
Ghisa grigia HB > 1800 MPa	0,16	0,06	0,04	0,06
Rame	0,25	0,10	0,05	0,08
Ottone duro	0,20	0,08	0,04	0,05
Bronzo	0,16	0,06	0,05	0,04
Leghe leggere di alluminio	0,10	0,08	0,04	0,05

Materiale del pezzo	Materiale dell'inserto	Velocità di taglio (m/min)	Avanzamento per dente (mm)
Acciaio R_m = 600 ÷ 850 MPa	P25-P40	120	0,3
Acciaio R_m = 850 ÷ 1200 MPa	P20-P30	80	0,2
Ghisa grigia HB < 1800 MPa	K10-K20	100	0,3
Ghisa grigia HB > 1800 MPa	K10-K20	80	0,2
Ottone-bronzo	K10-K30	180	0,5
Leghe leggere	K10-K20	500	0,3

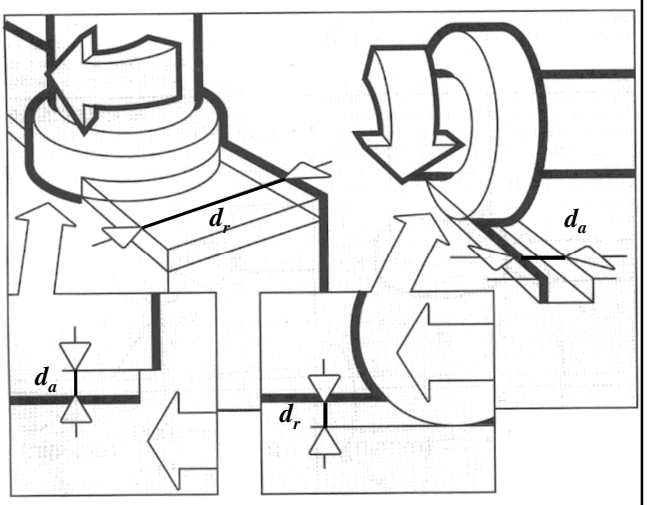


$Z = 8$ $\quad a = 8\, a_z$

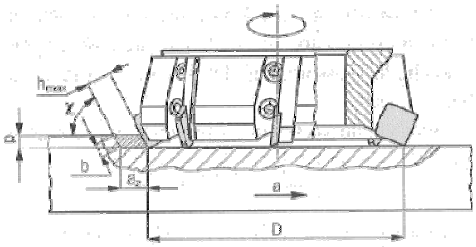
PARAMETRI DI TAGLIO

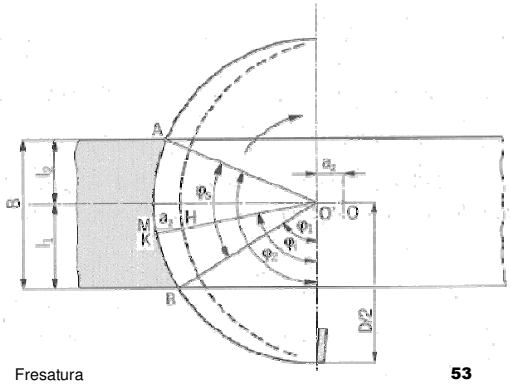
La profondità di taglio assiale $\mathbf{d_a}$ in f. frontale o profondità di taglio radiale $\mathbf{d_r}$ in f. periferica è lo spessore di materiale da asportare.

La profondità di taglio radiale $\mathbf{d_r}$ in f. frontale o profondità di taglio assiale $\mathbf{d_a}$ in f. periferica è la dimensione occupata dall'utensile sulla superficie del pezzo.

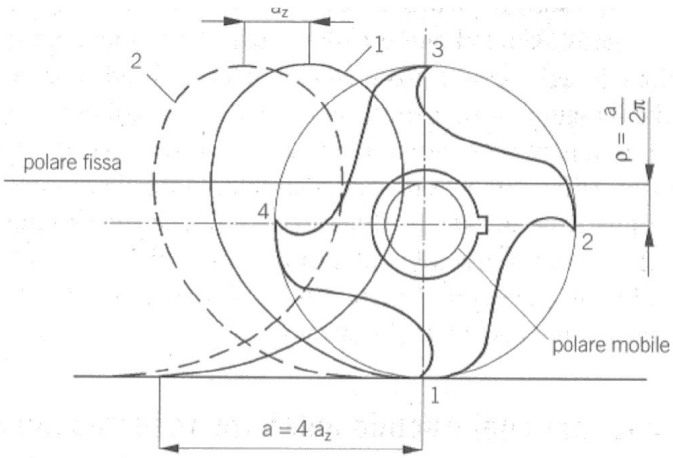


PARAMETRI DI TAGLIO IN FRESATURA FRONTALE

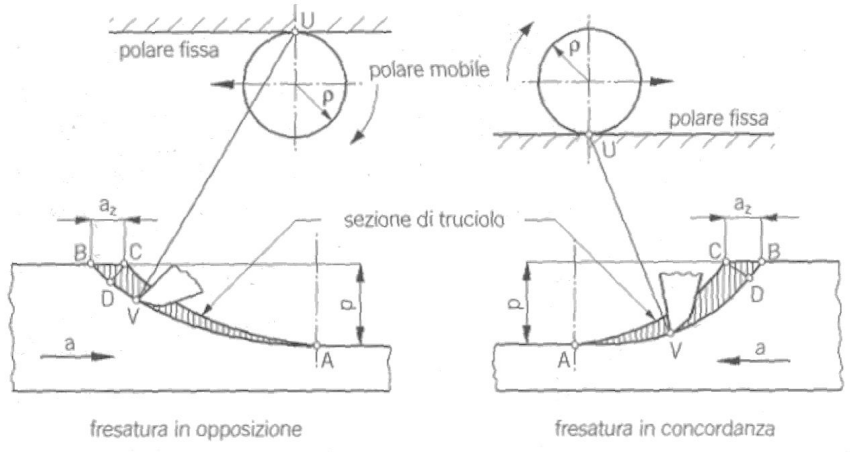




CINEMATICA SISTEMA UTENSILE-PEZZO



CINEMATICA SISTEMA UTENSILE-PEZZO



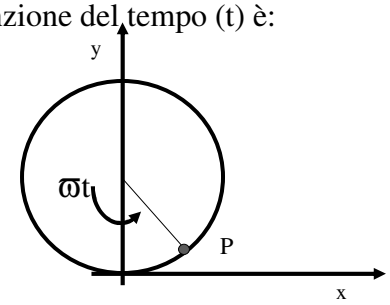
TRAIETTORIA DI SPOSTAMENTO NELLA FRESATURA PERIFERICA

Un punto P sul dente percorre una traiettoria composta dai seguenti moti:

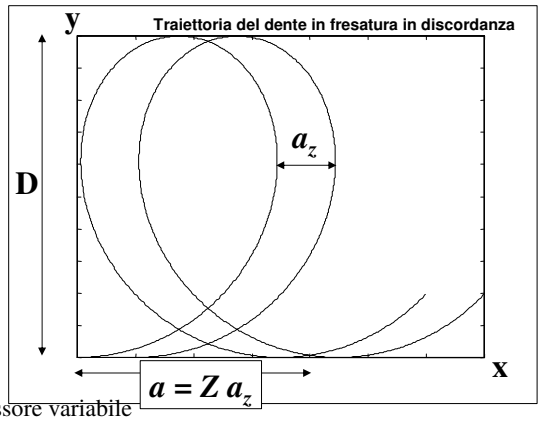
- rotatorio rispetto l'asse della fresa;
- traslatorio nella direzione x.

L'espressione della traiettoria in funzione del tempo (t) è:

$$\begin{cases} y = \dfrac{D}{2}\left(1-\cos\omega t\right) \\ x = \dfrac{D}{2}\sin\omega t + V_a t \end{cases}$$



Il punto immediatamente vicino a P seguirà la stessa traiettoria ma spostata della quantità a_z



CICLOIDE

Si osserva che:

- il truciolo ha spessore variabile
- sul pezzo rimane una traccia di passo a_z caratterizzata da un'altezza cresta-valle determinabile geometricamente

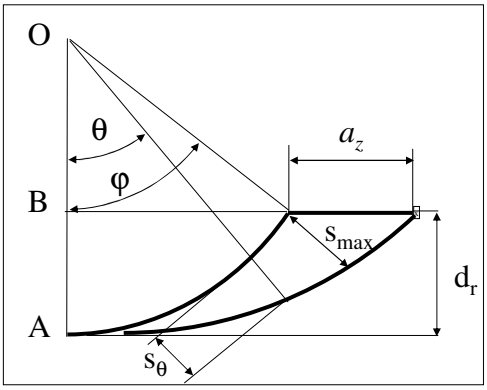
SPESSORE DI TRUCIOLO ISTANTANEO E MEDIO

Lo spessore del truciolo all'istante *t* vale:

$$s_\theta = a_z \cdot \sin\theta$$

Poiché lo spessore del truciolo varia, anche la sezione (per dente) di truciolo varia ed all'istante *t* vale:

$$S_\theta = s_\theta \cdot d_a$$



Il valore medio dello spessore s_m del truciolo vale:

$$s_m = \frac{1}{\varphi}\int_0^{\varphi} s_\theta d\theta = \frac{1}{\varphi}\int_0^{\varphi} a_z sin\theta d\theta = \frac{a_z}{\varphi}(1-\cos\varphi)$$

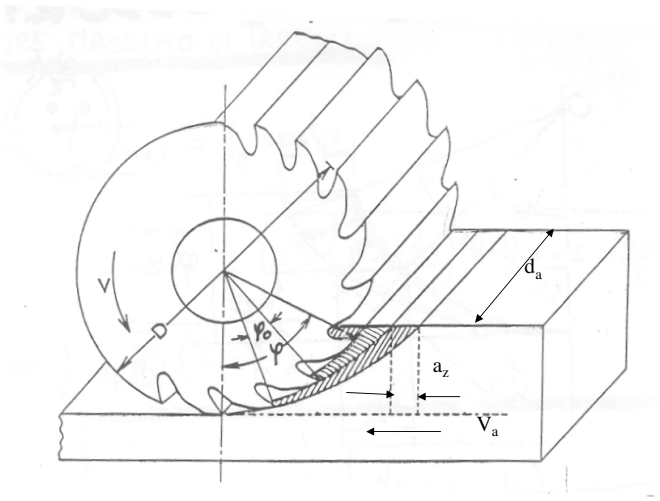
ma $$OB = \frac{D}{2} - d_r = \frac{D}{2}\cos\varphi$$

$$\cos\varphi = 1 - \frac{2d_r}{D}$$

Spessore di truciolo medio $$s_m = \frac{2a_z}{\varphi}\frac{d_r}{D} \quad (\varphi\ in\ rad)$$

Sezione di truciolo media $$S_m = s_m \cdot d_a = \frac{2a_z}{\varphi}\frac{d_r}{D}\cdot d_a$$

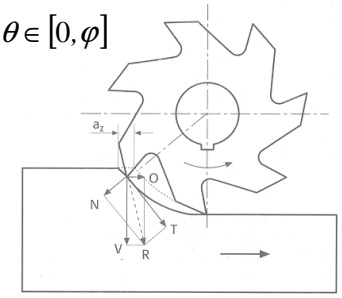
numero di denti in presa z



$$z = \frac{\varphi}{\varphi_0}$$

Fresatura Periferica: POTENZA

■Riprendendo la scomposizione delle forze nella fresatura periferica, per un dente in posizione: $\theta \in [0, \varphi]$



$$T_\theta = p_s S_\theta$$

$$M_\theta = p_s S_\theta \cdot \frac{D}{2}$$

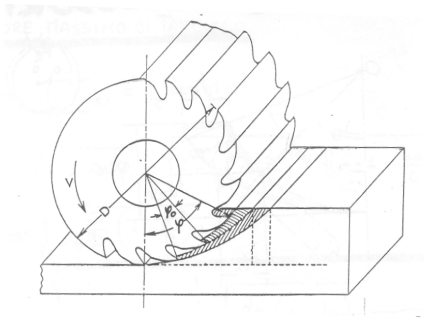
$$M_t = \sum_\theta p_s \frac{D}{2} S_\theta \approx z\, p_s \frac{D}{2} S_m = z\, p_s \frac{D}{2}\, s_m\, d_a$$

$$P_t = \frac{M_t \varpi}{\eta} = z \frac{p_s}{\eta} \frac{D}{2} s_m d_a \varpi$$

$$z = \frac{\varphi}{\varphi_0} = \frac{Z}{2\pi}\varphi$$

$$s_m = \frac{2a_z}{\varphi}\frac{d_r}{D}$$

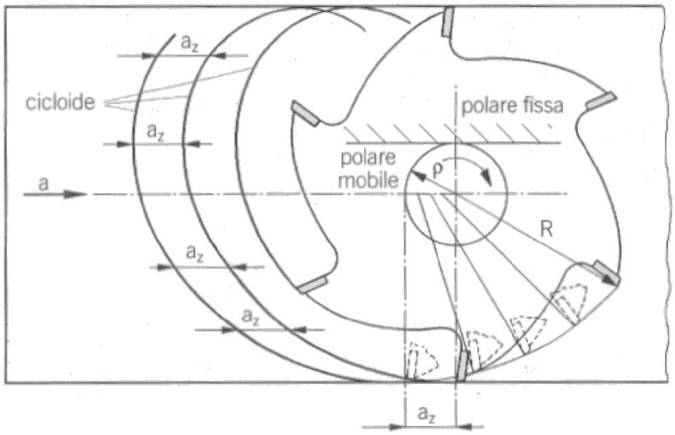
$$\varpi = 2\pi n$$



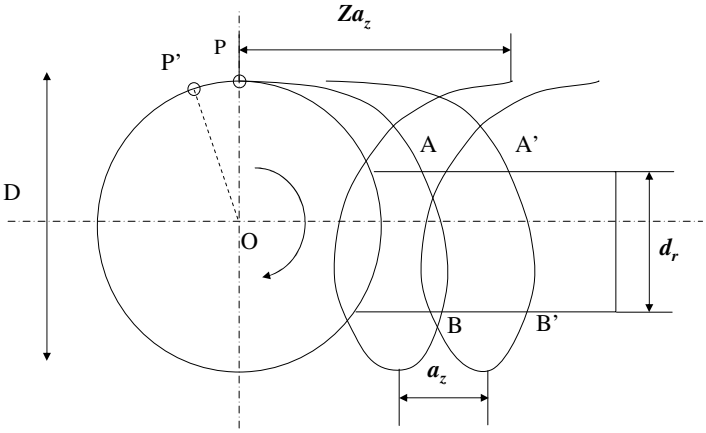
$$P_t = \frac{p_s}{\eta}\frac{Z}{2\pi}\varphi\frac{D}{2}d_a\frac{2a_z}{\varphi}\frac{d_r}{D}2\pi n = Z \cdot \frac{p_s}{\eta} \cdot d_a \cdot d_r \cdot a_z \cdot n$$

$$P_t = \frac{p_s \cdot d_a \cdot d_r \cdot V_a}{\eta}$$

CINEMATICA DEL SISTEMA UTENSILE-PEZZO



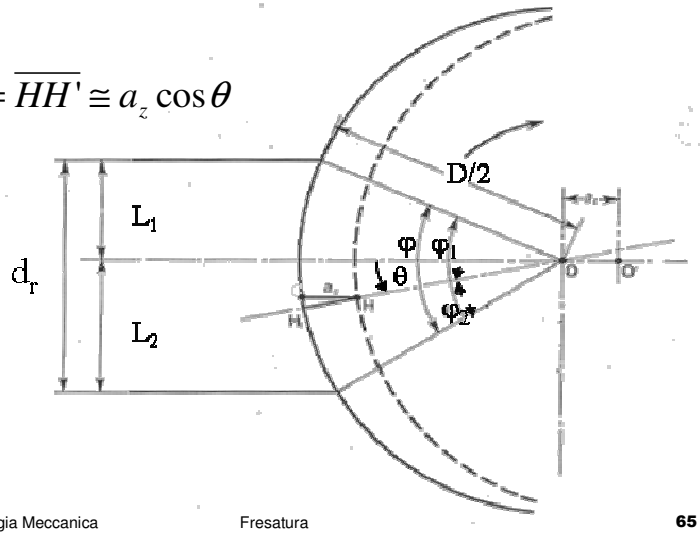
TRAIETTORIA IN FRESATURA FRONTALE



Considerando il piccolo valore di a_z si possono approssimare AB e A'B' con archi di circonferenze di raggio D/2.

Spessore e sezione di truciolo in fresatura frontale

$$s_\theta = \overline{HH'} \cong a_z \cos\theta$$



$$s_m = \frac{1}{\varphi}\int_{-\varphi_2}^{\varphi_1} h_\theta d\theta = \frac{a_z}{\varphi}\int_{-\varphi_2}^{\varphi_1} \cos\theta d\theta = \frac{a_z}{\varphi}\left[sin\varphi_1 - sin(-\varphi_2)\right] = \frac{a_z}{\varphi}\left[sin\varphi_1 + sin\varphi_2\right]$$

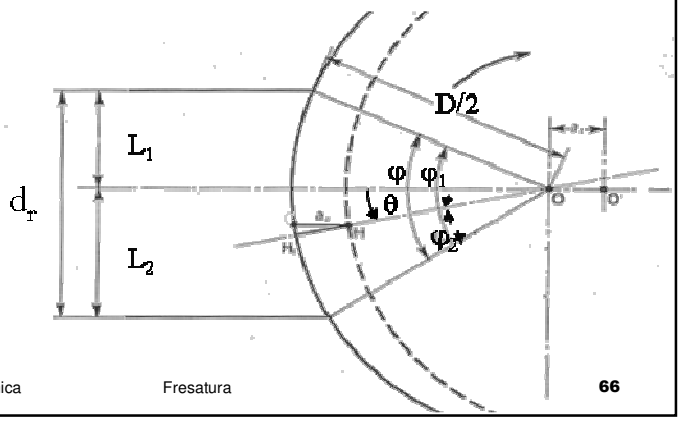
ma $\frac{D}{2} sin\varphi_1 + \frac{D}{2} sin\varphi_2 = d_r$

s_m= spessore medio

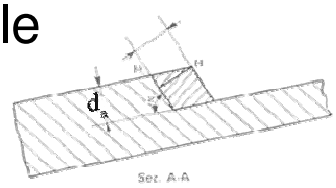
$$s_m = 2\frac{a_z}{\varphi}\frac{d_r}{D}$$

$$s_{\max} = a_z$$

$$S_m = 2\frac{a_z}{\varphi}\frac{d_r}{D} d_a$$



Spessore e sezione di truciolo in fresatura frontale



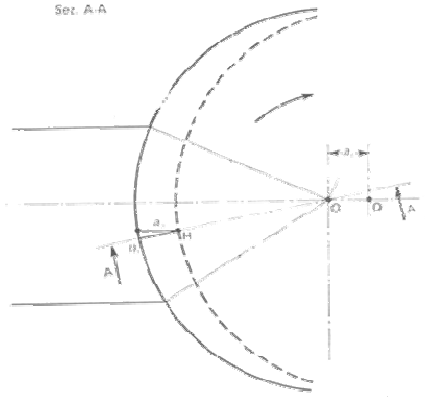
Se $\chi \neq 90°$

$$s_\theta = \overline{HH'} sin\chi$$

$$s_m = 2\frac{a_z}{\varphi}\frac{d_r}{D} sin\chi$$

$$s_{max} = a_z sin\chi$$

$$S_m = 2\frac{a_z}{\varphi}\frac{d_r}{D} d_a$$



Fresatura Frontale: POTENZA

Nota la sezione S_m e che $z = \frac{Z}{2\pi}\varphi$

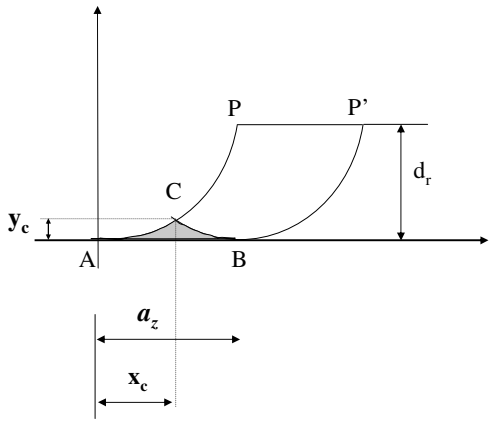
$$M_t \cong z\, p_s S_m \frac{D}{2} = \frac{Z}{2\pi}\varphi \cdot p_s \cdot 2\frac{a_z}{\varphi}\frac{d_r}{D} \cdot \frac{D}{2} = Z\frac{p_s}{2\pi} a_z d_r d_a$$

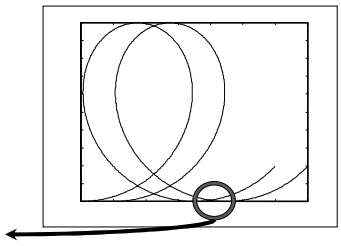
$$P_t = \frac{M_t \varpi}{\eta} = Z\frac{p_s}{2\pi} a_z d_r d_a \frac{2\pi n}{\eta}$$

$$Z \cdot a_z \cdot n = V_a$$

$$P_t = \frac{p_s \cdot d_a \cdot d_r \cdot V_a}{\eta}$$

Fresatura Periferica: RUGOSITÀ TEORICA



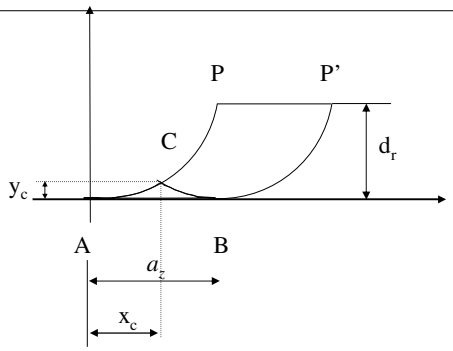


Per ragioni di simmetria:

$$x_c = \frac{a_z}{2}$$

Determiniamo il parametro della curva t_c per cui vale la precedente equazione:

$$\begin{cases} y = \dfrac{D}{2}\left(1 - \cos \varpi t\right) \\ x = \dfrac{D}{2} \sin \varpi t + V_a t \end{cases}$$



$$\frac{a_z}{2} = \frac{D}{2} \sin \varpi t_c + V_a t_c$$

Poiché: $sin\varpi t_c \cong \varpi t_c$ per il piccolo valore di a_z

$$t_c = \frac{a_z/2}{\varpi R + V_a} = \frac{a_z/2}{V_t + V_a}$$

$$\varpi t_c = \frac{\varpi \cdot a_z/2}{\varpi R + Za_z n} = \frac{\varpi \cdot a_z/2}{\varpi R + Za_z \frac{\varpi}{2\pi}} = \frac{a_z/2}{R + Z\frac{a_z}{2\pi}}$$

L'altezza cresta-valle vale

$$y_c = R(1 - cos\varpi t_c) = R\left(1 - \sqrt{1 - sin^2\varpi t_c}\right) \cong R\left(1 - \sqrt{1 - (\varpi t_c)^2}\right) \cong$$

$$\cong R\left[1 - \left(1 - \frac{\varpi^2 t_c^{\,2}}{2}\right)\right] \cong \frac{R}{2}\left(\varpi^2 t_c^{\,2}\right) = \frac{R}{2}\left(\frac{2\pi\, a_z / 2}{2\pi\, R + Z\, a_z}\right)^2 = \frac{R}{2}\frac{\pi^2 a_z^2}{(2\pi\, R + Z\, a_z)^2}$$

$$R_{max} \cong 1000 \cdot \frac{R}{2}\frac{\pi^2 a_z^2}{(2\pi\, R + Za_z)^2}$$

Con
a_z [mm]
R [mm]
R_{max} [μm]

Se $2\pi R >> Z\, a_z$

$$R_{\max} \cong 1000 \cdot \frac{a_z^2}{8R}$$

$$R_a \cong \frac{1}{4} R_{max}$$

FRESATURA IN DISCORDANZA

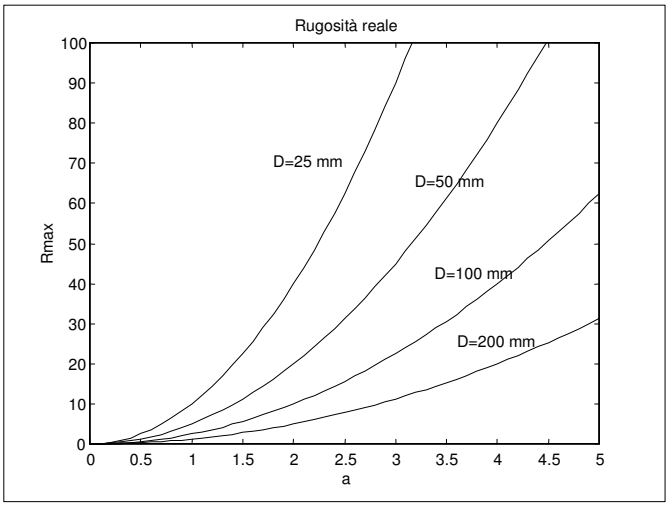
Rugosità Reale

Sperimentalmente si verifica che il valore della rugosità reale è superiore :

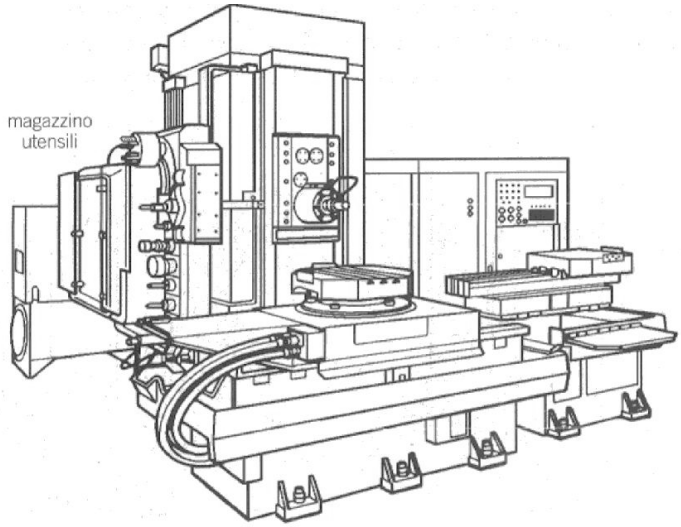
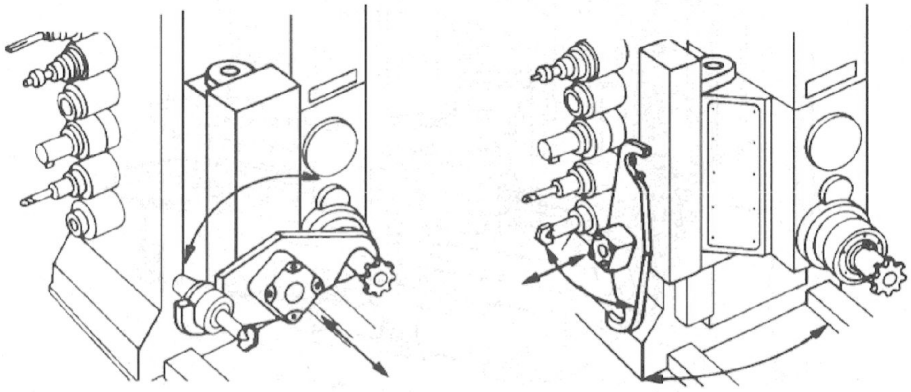
$$a_z \Rightarrow a$$

$$R_{\max} \cong \frac{a^2}{8R}$$

$$R_a \cong \frac{1}{4} R_{max}$$



Centro di lavoro



Magazzino utensili