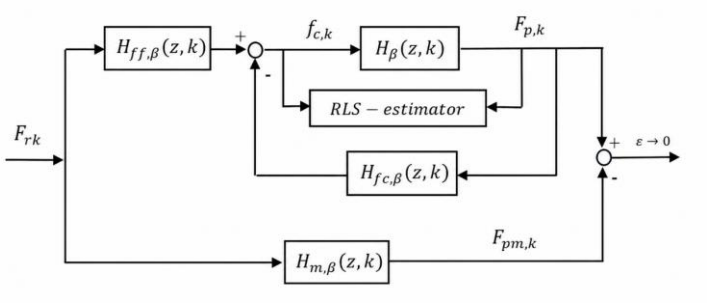
Adaptive approaches for milling forces control

1) Adaptive basic model reference control scheme



Transfer function under β-FROH

$$H_\beta(z) = \frac{B_\beta(z)}{z^{\delta}\beta A(z)} = \frac{z-\beta}{z} Z[h_o(s)G_c(s)] + \frac{\beta(z-1)}{z} Z\left[h_o(s)\frac{G_c(s)}{s}\right] = \frac{B_\beta(z)}{z^{\delta}\beta\left(z-e^{T/\tau_m}\right)\left(z-e^{T/\tau_c}\right)}$$

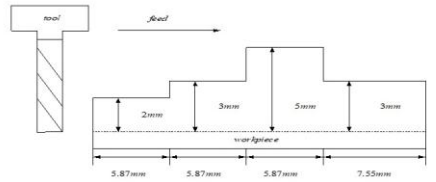
Control law:

$$f_c(k) = t_0F_r(k) + t_1F_r(k-1) + t_2F_r(k-2) - \left(\frac{\widehat{b_1}}{\widehat{b_0}}\right) f_c(k-1) - \left(\frac{\widehat{b_2}}{\widehat{b_0}}\right) f_c(k-2) - s_0F_p(k) - s_1F_p(k-1)$$

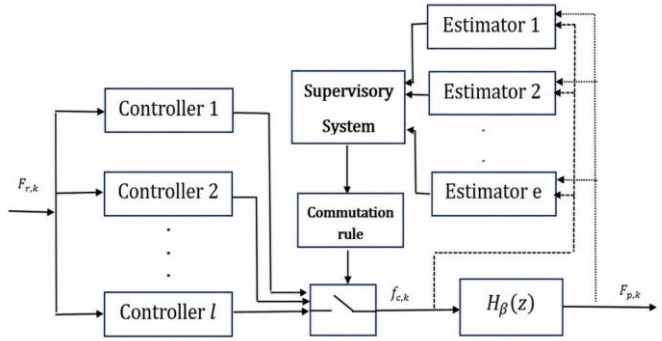
$$s_0 = \frac{a_{1m}-\widehat{a_1}}{\widehat{b_0}},\ s_1 = \frac{a_{3m}-\widehat{a_3}}{\widehat{b_o}},\ t_o = \frac{b_{o,m}}{\widehat{b_o}},\ t_1 = \frac{b_{1,m}}{\widehat{b_o}},\ t_2 = \frac{b_{2,m}}{\widehat{b_o}}$$

Process parameters

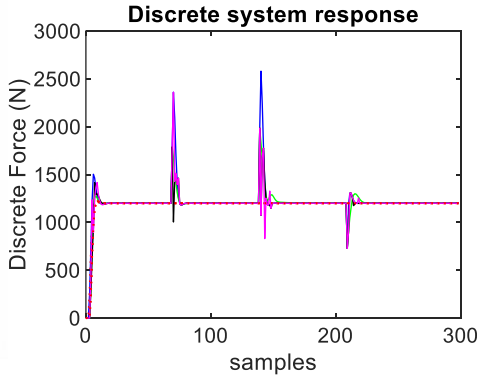
Cutting & tool			Material	Model		Model reference		Control
S_s	r	N_t	K_c	$\tau_c = 1/N_tS_{s_2}$	τ_m	$\omega_n = 2.5/3T$	ξ	$T = 1/S_{s_2}$
715 rpm	4	4	$1200\ ^N/_{mm^2}$	0.021s	0.1 ms	$9.93 rad/s$	0.8	0.0839 s

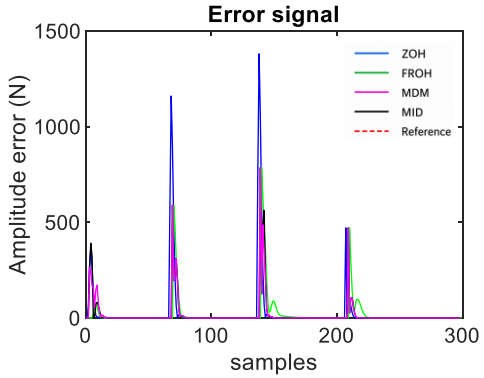


2) Multi-estimation adaptive control scheme 1

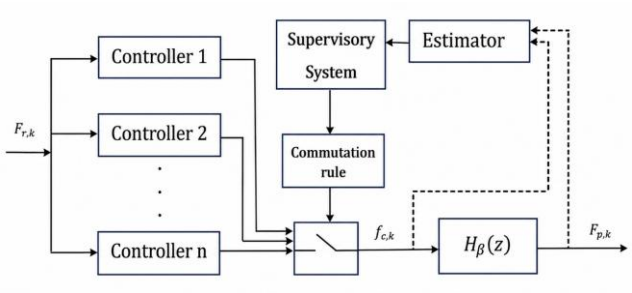


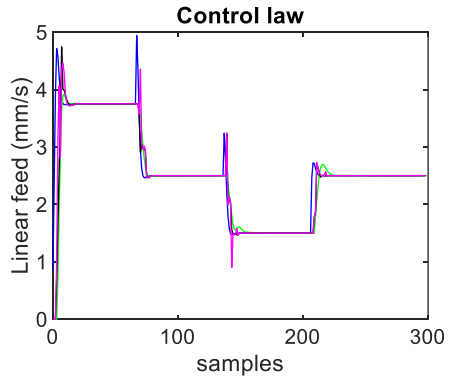
Outputs

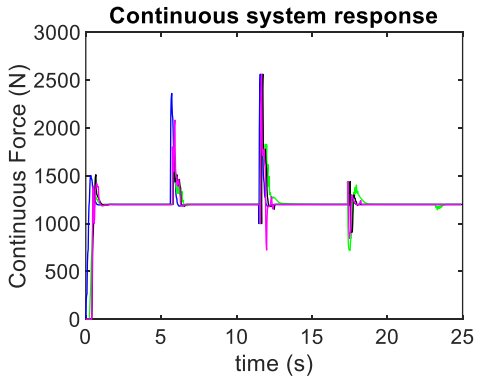




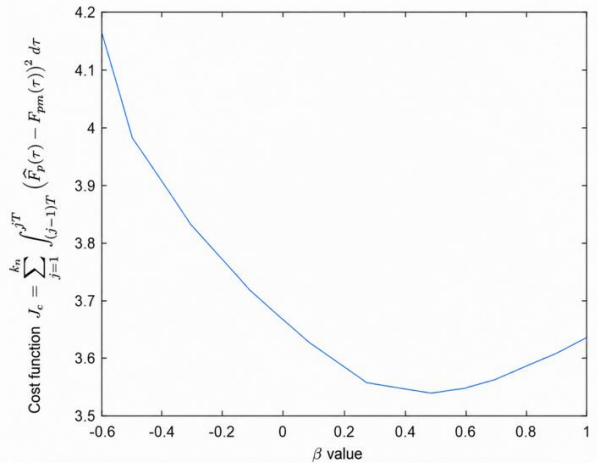
3) Multi-estimation adaptive control scheme 2







Value of the cost function as a function of the β



- Novel adaptive β-FROH control for milling force regulation.
- Multi-estimation schemes for robust controller selection.
- Accurate peak force tracking under varying cutting conditions.
- Reduced transient peaks and inter-sample oscillations.
- Improved machining stability and surface quality.