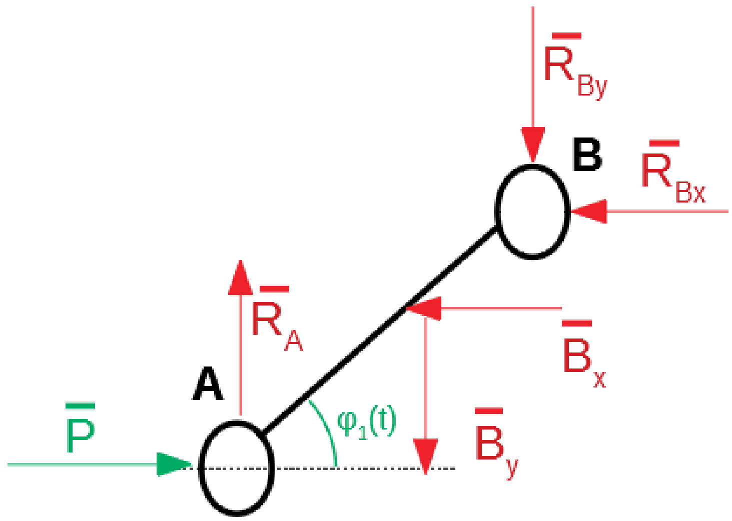
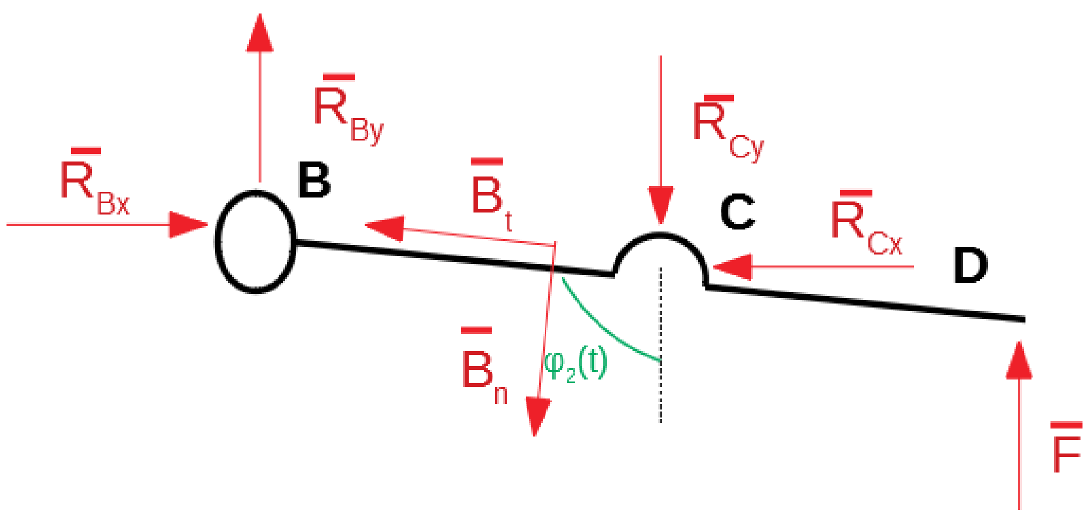
End Effector Dynamic Analysis



$$\begin{cases} \Sigma F_x: \quad P - R_{Bx} - B_x = 0 \\ \Sigma F_y: \quad R_A - R_{By} - B_y = 0 \\ \Sigma M_A: \quad l_{AB} \sin\varphi_1(t) R_{Bx} - l_{AB} \cos\varphi_1(t) R_{By} - l_{Acm} \sin\varphi_1(t) B_x - l_{Acm} \cos\varphi_1(t) B_y = 0 \end{cases}$$

$$\Rightarrow \begin{cases} R_{Bx} = P - B_x \\ R_A - R_{By} = B_y \\ l_{AB} \tan\varphi_1(t) R_{Bx} - l_{AB} R_{By} = l_{Acm} B_y - l_{Acm} \tan\varphi_1(t) B_x \end{cases}$$



$$\begin{cases} \Sigma F_x: \quad R_{Bx} - R_{Cx} - \sin\varphi_2(t) B_t^x + \cos\varphi_2(t) B_n^x = 0 \\ \Sigma F_y: \quad R_{By} - R_{Cy} + F - \cos\varphi_2(t) B_t^y - \sin\varphi_2(t) B_n^y = 0 \\ \Sigma M_C: \quad -l_{BC} \cos\varphi_2(t) R_{Bx} + l_{BC} \sin\varphi_2(t) R_{By} - l_{CD} \sin\varphi_2(t) F + l_{Bcm} B_n = 0 \end{cases}$$

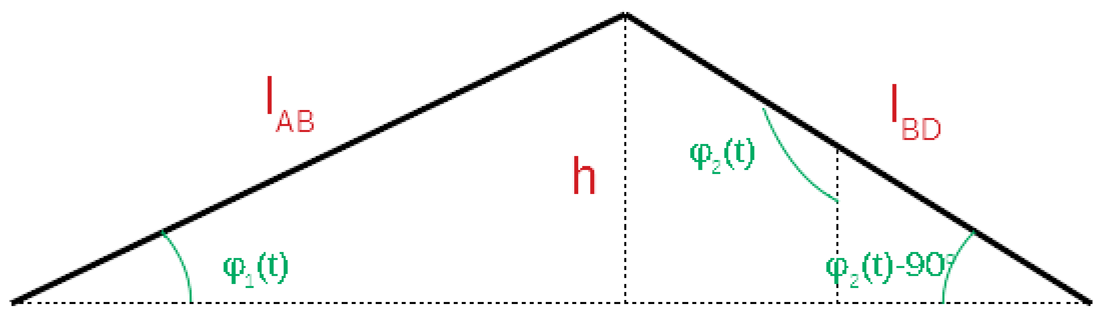
$$\Rightarrow \begin{cases} R_{Bx} - R_{Cx} = \sin\varphi_2(t) B_t^x - \cos\varphi_2(t) B_n^x \\ R_{By} - R_{Cy} = \cos\varphi_2(t) B_t^y + \sin\varphi_2(t) B_n^y - F \\ -l_{BC} \cos\varphi_2(t) R_{Bx} + l_{BC} \sin\varphi_2(t) R_{By} = l_{Bcm} B_n - l_{CD} \sin\varphi_2(t) F \end{cases}$$

The inertial force vectors were chosen based on the previous analysis of accelerations.

Next we will put the formulas in matrix form so they may be used in Matlab.

$$\begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 \\ 0 & l_{AB}\tan\varphi_1(t) & -l_{AB} & 0 & 0 \\ 0 & 1 & 0 & -1 & 0 \\ 0 & 0 & 1 & 0 & -1 \\ 0 & -l_{BC}\cos\varphi_2(t) & l_{BC}\sin\varphi_2(t) & 0 & 0 \end{bmatrix} \begin{bmatrix} R_A \\ R_{Bx} \\ R_{By} \\ R_{Cx} \\ R_{Cy} \end{bmatrix} = \begin{bmatrix} P \\ 0 \\ 0 \\ 0 \\ -F \\ -l_{CD}\sin\varphi_2(t)F \end{bmatrix} + \begin{bmatrix} -B_x \\ B_y \\ l_{Acm}B_y - l_{Acm}\tan\varphi_1(t)B_x \\ \sin\varphi_2(t)B_t^x - \cos\varphi_2(t)B_n^x \\ \cos\varphi_2(t)B_t^x + \sin\varphi_2(t)B_n^y \\ l_{Bcm}B_n \end{bmatrix}$$

To further reduce the number of variables, we may relate the two angles $\varphi_1(t)$ and $\varphi_2(t)$.



$$\begin{cases} \sin\varphi_1(t) = \dfrac{h}{l_{AB}} \\ \sin(\varphi_2(t) - 90) = \dfrac{h}{l_{BD}} \end{cases} \Rightarrow \quad l_{AB}\sin\varphi_1(t) = l_{BD}\cos\varphi_2(t) \quad \Rightarrow \quad \varphi_2(t) = arcos\left(\frac{l_{AB}}{l_{BD}}\sin\varphi_1(t)\right)$$

For a static analysis we may exclude the inertial force matrix. This static analysis is only sufficient for when the gripper mechanism including the arm is stationary. The same applies for the dynamic analysis as any kinematics of the arm aren't included.

As the clamping strength of the end effector while the arm is in motion is an integral part of contraption, these calculations do not fully represent the behavior of the entire system. The next part of the analysis will include the dynamics of the next three degrees of freedom.