# 7. FLYWHEEL

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|---|---|
| **COEFFICIENT OF FLUCTUATION OF ENERGY:** $C_E = \dfrac{Max\ fluctuation\ of\ energy}{Energy\ Supplied\ in\ a\ cycle}$ | $\begin{matrix} Energy\ Supplied \\ in\ a\ cycle \end{matrix} = \int_0^{\begin{matrix} Cycle \\ Time \end{matrix}} T_{Supply} d\theta = T_{mean} \begin{matrix} Cycle \\ Time \end{matrix}$ <br> Where, $T_{Supply} = f(\theta)$ |

From conservation of energy, $Net\ Energy\ Supplied\ per\ cycle = Net\ Energy\ Required\ per\ cycle$

$$C_E = \frac{Max\ fluctuation\ of\ energy}{Energy\ Supplied\ in\ a\ cycle} = \frac{(\Delta KE)_{max}}{Net\ Energy\ Supplied\ per\ cycle} = \frac{(\Delta KE)_{max}}{Net\ Energy\ Required\ per\ cycle}$$

**CENTRIFUGAL STRESS IN FLYWHEEL (RIM/ RING TYPE):**

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| Centrifugal Force in element, <br> $dF_C = \rho(dV)r\omega^2 = \rho(rd\theta\ bt)r\omega^2$ <br> At equilibrium, $\sum F_y = 0$ <br> $\int_0^{\pi} dF_C \sin\theta = 2\sigma bt \Rightarrow \sigma = \rho\omega^2 r^2 = \rho v^2$ | $b =$ Radial thickness of the flywheel, <br> $t =$ Axial Width of the flywheel, <br> $v =$ Linear Velocity of the flywheel at $r$, <br> $\omega =$ Angular Velocity of the flywheel, <br> $\rho =$ Density of the rim material, <br> $\sigma =$ Centrifugal Stress, |

**OBSERVATIONS:**

1. **FUNCTION-TIME PERIOD:** At the X-Time period the mean of the function becomes zero.

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| $\sin n\theta - 2\pi/n$ | $\cos n\theta - 2\pi/n$ | $\tan n\theta - \pi/n$ |

2. $\boldsymbol{T_{Flywheel} = I_{Flywheel}\alpha_{Flywheel} = T_{Fluctuation} = T_{Supply} - T_{Load} = T_{Supply} - T_{mean} = f(\theta)}$

For Max fluctuation of energy or crank Position/ Angle at which flywheel will be subjected to maximum acceleration or retardation,

$$\boldsymbol{dT_{Flywheel}/d\theta = 0 \Rightarrow \theta_{max\ or\ min}\ can\ be\ obtain}$$

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|---|---|---|
| $\theta_{max\ or\ min} = +ve\ CCW$ | $\theta_{max\ or\ min} = -ve\ CW$ | $\theta' = \theta_{max\ or\ min} \pm Time\ period\ of\ f(dT_{Flywheel}/d\theta = 0)$ |

**Amplitude of** $\boldsymbol{T_{Flywheel}, T_{Flywheel} = \sqrt{Sqare\ of\ coefficient\ of\ f(\theta)}}$

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| If $T_{Flywheel}\big\|_{\theta'} > 0$, Flywheel is accelerating. | If $T_{Flywheel}\big\|_{\theta'} < 0$, Flywheel is retarding. |

3. **Isolated Location:** At isolated locations, $T_{Supply} = T_{Load}$.

From the figure, Energy of the flywheels,

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| $E_B = E_A + A_1 = E_{max}$ | $E_C = E_B - A_1 = E_A = E_{min}$ | $E_D = E_A + A_1 = E_{max}$ | $E_E = E_A = E_{min}$ |

$$(\Delta KE)_{max} = E_{max} - E_{min} = A_1 = \int_{\theta_A}^{\theta_B} (T_{Supply} - T_{Load})\, d\theta = I\omega_{mean}^2 C_S$$

**PUNCHING MACHINE:**

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|---|---|
| Angle turned by the crank in 1 cycle $= 2\pi$ (Forward + Return Stroke) | |
| $t =$ Thickness of the plate, | $0 \le \theta \le \theta_1$: Tool moves in air, |
| $\theta_1 \le \theta \le \theta_2$: Punching operation, | $\theta_2 \le \theta \le 2\pi$ : Tool moves in air, |

1 cycle consist of Ideal Stroke (when tool is moving in the air so it has to overcome the air resistance only) and Punching Stroke (During it the tool have to overcome shear resistance of the place)

$$\begin{matrix} Net\ area\ of\ T_{Load}\ vs\ \theta \\ diag.\ in\ a\ cycle \end{matrix} = \begin{matrix} Net\ energy\ required \\ in\ the\ cycle\ (E) \end{matrix} = \int_0^{2\pi} T_{Supply} d\theta$$

$$\begin{matrix} Net\ energy\ supplied \\ by\ a\ motor\ in\ a\ cycle \end{matrix} = 2\pi T_{motor} = 2\pi T_{mean} = E$$

$$\begin{matrix} Net\ energy\ required \\ in\ the\ cycle(E) \end{matrix} = \begin{matrix} Net\ energy\ required\ during \\ (Ideal + Punching)\ Stroke \end{matrix} \left(\because \begin{matrix} Energy \\ Balance \end{matrix}\right)$$

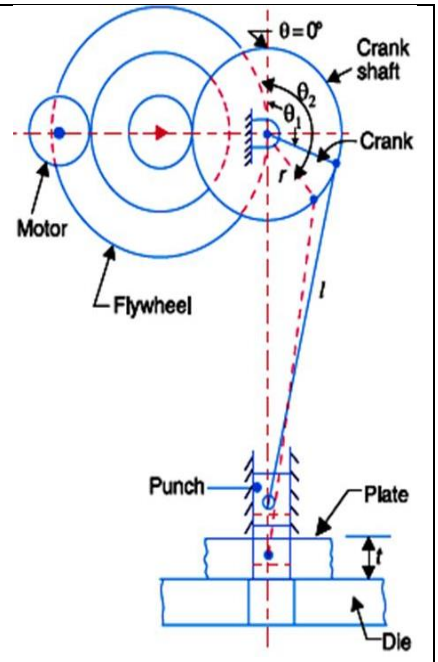
Energy stored by flywheel in idle stroke $= A_1 + A_3$

Energy Supplied by flywheel during punching stroke $= A_2$

Flywheel is energy reservoir. So, from the energy balance, $A_1 + A_3 = A_2$

$$\begin{matrix} Net\ energy\ required \\ during\ punching \end{matrix} = \begin{matrix} Net\ energy \\ Supply\ By\ motor \end{matrix} + \begin{matrix} Net\ energy\ Supplied\ By \\ Flywheel\ during\ Punching \end{matrix}$$

$$= \frac{E}{2\pi}(\theta_2 - \theta_1) + A_2 = \frac{E}{2\pi}(\theta_2 - \theta_1) + (\Delta KE)_{max}$$




$$\frac{\theta_2 - \theta_1}{2\pi} = \frac{t}{2 * Stroke\ Length} = \frac{Punching\ time}{Cycle\ time}$$

**SPECIAL CASE:** If there is no energy consumption during the ideal stroke,

$$\begin{matrix} Net\ energy\ required \\ in\ the\ cycle(E) \end{matrix} = \begin{matrix} Net\ energy\ required \\ during\ punching \end{matrix}$$