CRANES

TRANSPORTATION

INTRODUCTION

- **Crane**: device used to lift or lower materials in the vertical direction and to move them horizontally while being hanged.
- UNE 58-104-87. Part 1. Types of transport elevators:
  - According to design.
  - According to movement possibilities.
  - According to device control.
  - According to orientation possibilities.
INTRODUCTION

• The dynamic structural calculation allows to determine the stress of the elevator during its operation.
• Phases:
  1. Find the external forces and their combination, that act on the structure.
  2. Displacement, stress and reaction calculation of each of the components applying the adequate calculation process.
  3. Verification of the obtained values of elasticity, resistance and stability.

Nowadays: Finite element programs are used

INTRODUCTION

• Loads to be considered:
  – Principal loads acting on the structure for the motionless elevator. The worst loads are:
    • Normal operation load: service load + accessories
    • Self weight: crane components weight (set aside operation load)
  – Loads due to vertical movements:
    • Accelerations or decelerations
    • Vertical impacts due to the rollers
  – Loads due to horizontal movements:
    • Accelerations or decelerations
    • Centrifugal force
    • Lateral effects due to rolling
    • Impact effects
  – Loads due to changes in climate:
    • Wind, snow and temperature effects
  – Various loads:
    • Dimensioning of rails and aisles
**STRUCTURAL CALCULATION: CASE I**

• **CASE I: Without wind:**
  - The next loads are considered: static due to self weight $S_G$, forces due to service load $S_s$ multiplied by the dynamic coefficient $\psi$ and the two most unfavourable horizontal effects $S_H$, set aside impact effects, multiplied by an increase factor $\gamma_c$:

\[
\gamma_c \left( S_G + \psi S_L + S_H \right)
\]

- Increasing factor $\gamma_c$ [UNE 58132-2]: Depends on the elevator classification group

<table>
<thead>
<tr>
<th>Elevator group</th>
<th>$A_1$</th>
<th>$A_2$</th>
<th>$A_3$</th>
<th>$A_4$</th>
<th>$A_5$</th>
<th>$A_6$</th>
<th>$A_7$</th>
<th>$A_8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_c$</td>
<td>1.00</td>
<td>1.02</td>
<td>1.05</td>
<td>1.08</td>
<td>1.11</td>
<td>1.14</td>
<td>1.17</td>
<td>1.20</td>
</tr>
</tbody>
</table>

• **Dynamic coefficient $\psi$:** takes into account
  - The service load lifting.
  - The accelerations and decelerations in the lifting process.
  - The vertical impacts due to the rolling in the track.

\[
\Psi = 1 + \xi V_L
\]

$V_L$ is the lift speed in m/s

$\xi$ is an experimental coefficient obtained by carrying out several tests in different elevators
STRUCTURAL CALCULATION: CASE I

Bridge and gantry crane

\[ \xi = 0.6 \]

Jib crane

\[ \xi = 0.3 \]

\[ V_L \text{ m/s} \]

0 0.5 1 1.5

It is important to know the maximum load depending on the position: its values are usually specified in points A and B.

\[ P_i = Q + P_c \]

(load+trolley)

G: crane weight

G_c: counterweight weight
The jib pendants are subject to traction, while the cat head is subjected to compression, flexure and shear.

Traction forces in the jibs:
- $T_1 = \frac{P_h}{\sin(\beta)}$
- $T_2 = \frac{G_i}{\sin(\alpha)}$

Forces in the cat head are:
- $V = T_1 \cdot \sin(\beta) + T_2 \cdot \sin(\alpha)$
- $H = T_1 \cdot \cos(\beta) - T_2 \cdot \cos(\alpha)$
- $M = H \cdot h$

Von Misses:
- $\sigma_{\text{Von Misses}} = \sqrt{\sigma_z^2 + 3\tau^2}$

The jib is subjected to flexure and shear forces:

- $M_{pl,f} = P_A \cdot L_1$
- $V_{pl,s} = P_A$

Von Misses:
- $\sigma_{\text{Von Misses}} = \sqrt{\sigma_z^2 + 3\tau^2}$
Mast

\[ M_f = P_B \cdot L_1 - G_c \cdot L_2 + G \cdot e \]
\[ V_c = P_B + G_c + G \]

\[ M_f = \psi \cdot P_B \cdot L_1 - G_c \cdot L_2 + G \cdot e \]
\[ V_c = \psi \cdot P_B + G_c + G \]

\[ \sigma_f = \frac{\psi \cdot P_B \cdot L_1 - G_c \cdot L_2 + G \cdot e}{W_{m/f}} \]
\[ \sigma_c = \frac{\psi \cdot P_B + G_c + G}{A_{m}} \]

The mast is subjected to flexure and compression forces.

\[ \gamma_c \left( S_G + \psi S_L + S_H \right) \]

- Loads due to horizontal movements:
  - Accelerations and decelerations due to translations movements of the crane
  - Acceleration or decelerations due to movements of the load
  - Centrifugal force
  - Lateral effects due to rolling (loads due to obliquity)
STRUCTURAL CALCULATION: CASE I

\[ \gamma_e (S_G + \psi S_L + S_H) \]

- Accelerations or decelerations of movements:
  - Accelerations/decelerations due to translation movements of the crane
    \[ H = \frac{a}{g} \cdot V \]
  - The acceleration/deceleration value depends on:
    - The desired speed
    - Time to accelerate/decelerate
    - Usage of the elevator

<table>
<thead>
<tr>
<th>Desired speed [m/s]</th>
<th>(a) Low and medium speed with large travelling</th>
<th>(b) Medium and high speeds (usual applications)</th>
<th>(c) High speed with great accelerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.00</td>
<td>8.00</td>
<td>0.50</td>
<td>6.00</td>
</tr>
<tr>
<td>3.15</td>
<td>7.10</td>
<td>0.44</td>
<td>5.40</td>
</tr>
<tr>
<td>2.50</td>
<td>6.30</td>
<td>0.39</td>
<td>4.80</td>
</tr>
<tr>
<td>2.00</td>
<td>9.10</td>
<td>0.22</td>
<td>5.60</td>
</tr>
<tr>
<td>1.60</td>
<td>8.30</td>
<td>0.19</td>
<td>5.00</td>
</tr>
<tr>
<td>1.00</td>
<td>6.00</td>
<td>0.15</td>
<td>4.00</td>
</tr>
<tr>
<td>0.63</td>
<td>5.20</td>
<td>0.12</td>
<td>3.20</td>
</tr>
<tr>
<td>0.40</td>
<td>4.10</td>
<td>0.098</td>
<td>2.50</td>
</tr>
<tr>
<td>0.25</td>
<td>3.20</td>
<td>0.078</td>
<td></td>
</tr>
<tr>
<td>0.16</td>
<td>2.50</td>
<td>0.064</td>
<td></td>
</tr>
</tbody>
</table>
STRUCTURAL CALCULATION: CASE I

\[ \gamma_c (S_\alpha + \psi S_\xi + S_H) \]

- Accelerations or decelerations of the load movement:
  - Inertia force of the load (with weight W):
    \[ F = \frac{Wa}{g} = ma \]
  - Rotational movement:
    \[ T = J \alpha \]
    - \( T \): Inertia moment
    - \( J \): Inertia polar moment = \( \sum m_i d_i^2 \)
    - \( \alpha \): Angular acceleration

Inertia forces due to rotation:

\[ F = m_e \cdot a \]

- Equivalent mass
  \[ m_e = \sum \frac{m_i d_i^2}{D^2} \]
- Tangential acceleration
  \[ a = \alpha \cdot D \]

\[ F = \alpha \cdot \sum \frac{m_i d_i^2}{D} \]
**STRUCTURAL CALCULATION: CASE I**

\[ \gamma_c (S_G + \psi S_L + S_H) \]

- **Loads due to obliquity:**
  - Tangential forces between the wheels and the rail track.
  - Guide forces.
- **A simple translation mechanical model is needed:**
  - n pairs of wheels in line.
  - p coupled pairs.

<table>
<thead>
<tr>
<th>Fixed/Fixed (F/F)</th>
<th>Coupled (C)</th>
<th>Individual (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed/Mobile (F/M)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Loads due to centrifugal forces:**
  - Effects of the cable inclination

\[ F_c = \frac{WR}{g} \left( \frac{\pi n}{30} \right)^2 \]

- W: Load
- R: Radius
- n: Rotating speed
- g: gravity acceleration
• **CASE II: Normal operation with service limit wind**
  
  – To the loads considered in CASE I it is added the effect of service limit wind $S_w$ and, if needed, the load due to variation in temperature:

  \[ \gamma_c (S_u + \psi S_L + S_H) + S_w \]

  – Overloading due to snow is not considered.

• **Wind effect**

  \[ F = A \cdot p \cdot C_f \]

  • $A$ is the net surface, in m², of the considered element, that is, the solid surface projection over a perpendicular plane in the wind direction.
  • $C_f$ is a shape factor, in the wind direction, for the considered element.
  • $p$ is the wind pressure, in kN/m², and it is calculated by means of the following equation:

  \[ p = 0.613 \cdot 10^{-3} \cdot v_s^2 \text{ [kPa]} \]

  where $v_s$ is the calculated wind speed in m/s
### STRUCTURAL CALCULATION: CASE II

**Cf** Shape factor [UNE 58-113-85]

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Aerodynamic drag coefficient b/D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simple elements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal section in L, in U and flat plates</td>
<td>1,3 1,35 1,6 1,65 1,7 1,9</td>
<td></td>
</tr>
<tr>
<td>Circular metal sections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>in which ( \nu_c &lt; 6 \text{ m/s} )</td>
<td>0,75 0,80 0,90 0,95 1,0 1,1</td>
<td></td>
</tr>
<tr>
<td>in which ( \nu_c \geq 6 \text{ m/s} )</td>
<td>0,60 0,65 0,70 0,75 0,8</td>
<td></td>
</tr>
<tr>
<td>Square metal sections of more than 350 mm side and rectangular of more than 250 mm x 450 mm</td>
<td>b/d 1 0,5 0,25</td>
<td>1,5 1,55 1,7 1,75 1,8</td>
</tr>
<tr>
<td>Circular metal sections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>in which ( \nu_c &lt; 6 \text{ m/s} )</td>
<td>1,2</td>
<td></td>
</tr>
<tr>
<td>in which ( \nu_c \geq 6 \text{ m/s} )</td>
<td>0,8</td>
<td></td>
</tr>
<tr>
<td>Flat side metal section</td>
<td>1,7</td>
<td></td>
</tr>
<tr>
<td>Simple lattice work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Square structures filled (air cannot flow beneath the structure)</td>
<td>1,1</td>
<td></td>
</tr>
</tbody>
</table>

### Diagram

Wind direction and aerodynamic coefficients:

- Element length: \( \frac{1}{b} \) or \( \frac{1}{D} \)
- Section height facing wind: \( b \)
- Section width parallel to wind: \( d \)
- Section proportion: \( \frac{b}{d} \)
STRUCTURAL CALCULATION: CASE II

Speeds and pressures of service wind [UNE 58-113-85]

<table>
<thead>
<tr>
<th>Type of crane</th>
<th>Wind speed m/s</th>
<th>Wind pressure kPa/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranes which can be protected against wind and designed exclusively for light wind (for example, low height cranes with an easily folding jib to the ground)</td>
<td>14</td>
<td>0,125</td>
</tr>
<tr>
<td>Every normal crane installed in exteriors</td>
<td>20</td>
<td>0,25</td>
</tr>
<tr>
<td>Dock cranes that should continue operation in case of strong wind</td>
<td>28,5</td>
<td>0,50</td>
</tr>
</tbody>
</table>

\[ p = 0.613 \cdot 10^4 \cdot \frac{v^2}{w} \text{ [kPa]} \]

- **Snow overloading:**
  - It is not considered

- **Temperature effect:**
  - Only when the elements cannot freely expand
  - Temperature limit -20 °C + 45 °C
• **CASE III: Elevator subjected to exceptional loads**
  a) Elevator out of service subjected to maximum wind.
  b) Elevator in service subject to impact.
  c) Elevator subjected to static and dynamic tests.

\[ W_{m} d_{m} > W_{b} d_{b} + W d \]
STABILITY

\[ W_m d_m + W_i (d_o - d_f) > W_b d_b + W_f d \]

COUNTERWEIGHT CALCULATION

It is usually calculated so that it counteracts the half of the material moment and the jib moment

\[ G_z \cdot d = G \cdot e + (P_e + \frac{Q}{2}) \cdot L \]

Moment:

\[ M_i = (P_i + Q_i) \cdot L + G \cdot e \cdot (P_e + \frac{Q}{2}) \cdot d \]

Most unfavourable situations:

- Without load: \( Q = 0 \)
  \[ M_i = \frac{Q}{2} \cdot L \]
- With load: \( Q = Q \)
  \[ M_i = \frac{Q}{2} \cdot L \]

With this type of counterweight the mast, with and without load, has a uniform solicitation in a favourable way.
CLASSIFICATION

Cranes and elevator classification allows to establish the design of the structure and of the mechanisms. It is used by manufacturers and clients so that a specific elevator operates within certain required service conditions.

**Elevator classification**

Used by the client and the manufacturer to achieve a fixed elevators service conditions.

**Mechanism classification**

It gives the manufacturer information of how to design and verify the elevator so that it has the desired service life for the operation service conditions.

CLASSIFICATION OF THE EQUIPMENT

**CLASSIFICATION OF THE EQUIPMENT** (standard 58-112-91/1)

- **Number of cycles of a manoeuvre**
- **Load spectrum coefficient**

A manoeuvre cycle begins when the load is prepared to be lifted and finishes when the elevator is prepared to lift the next load.

- The total number of manoeuvre cycles is the sum of all of the cycles carried out during the elevator life.
- The user expects that the elevator’s manoeuvre number of cycles is achieved during its life.
- The total number of manoeuvre cycles has a relationship with the usage factor:
  - The manoeuvre spectrum has been conveniently divided in 10 usage classes.
### Classification of the Equipment: Total Number of Cycles

<table>
<thead>
<tr>
<th>Clase de utilización</th>
<th>Número máximo de ciclos de maniobra</th>
<th>Observaciones</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_0$</td>
<td>$1.6 \times 10^6$</td>
<td>Utilización ocasional</td>
</tr>
<tr>
<td>$U_1$</td>
<td>$3.2 \times 10^6$</td>
<td></td>
</tr>
<tr>
<td>$U_2$</td>
<td>$6.3 \times 10^4$</td>
<td></td>
</tr>
<tr>
<td>$U_3$</td>
<td>$1.25 \times 10^3$</td>
<td></td>
</tr>
<tr>
<td>$U_4$</td>
<td>$2.5 \times 10^5$</td>
<td>Utilización regular en servicio ligero</td>
</tr>
<tr>
<td>$U_5$</td>
<td>$5 \times 10^5$</td>
<td>Utilización regular en servicio intermitente</td>
</tr>
<tr>
<td>$U_6$</td>
<td>$1 \times 10^5$</td>
<td>Utilización regular en servicio intensivo</td>
</tr>
<tr>
<td>$U_7$</td>
<td>$2 \times 10^6$</td>
<td></td>
</tr>
<tr>
<td>$U_8$</td>
<td>$4 \times 10^5$</td>
<td>Utilización intensiva</td>
</tr>
<tr>
<td>$U_9$</td>
<td>Más de $4 \times 10^6$</td>
<td></td>
</tr>
</tbody>
</table>

### Classification of the Equipment

**Clasificación del Equipamiento (standard 58-112-91/1)**

<table>
<thead>
<tr>
<th>Number of cycles of a manoeuvre</th>
<th>Load spectrum coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The load condition is the number of times a load is lifted, which is suitable to the elevator capacity.

- Depending on the available information of the number and weight of the loads to be lifted during the elevator life:
  - Lack of indications: manufacturer and client have to achieve an agreement.
  - If the information is available: the load spectrum coefficient of the elevator can be calculated.
CLASSIFICATION OF THE EQUIPMENT: LOAD LEVEL

\[
K_p = \sum \left[ \frac{C_i}{C_T} \left( \frac{P_i}{P_{\text{max}}} \right)^3 \right]
\]

- \(C_i\) is the mean number of cycles of manoeuvre for each different load level.
- \(C_T\) is the total of the individual cycles for every load level.
- \(P_i\) are the values of the individual loads characteristic of the equipment service operation.
- \(P_{\text{max}}\) is the maximum load that the equipment is authorized to lift (safe working load).

---

### CLASSIFICATION OF THE EQUIPMENT: LOAD LEVEL

<table>
<thead>
<tr>
<th>Estado de carga</th>
<th>Coeficiente nominal del espectro de las cargas</th>
<th>Observaciones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 – Ligeria</td>
<td>0,125</td>
<td>Aparato que levanta rara vez la carga máxima de servicio y corrientemente cargas muy pequeñas</td>
</tr>
<tr>
<td>Q2 – Moderado</td>
<td>0,25</td>
<td>Aparato que levanta con bastante frecuencia la carga máxima de servicio y corrientemente cargas pequeñas</td>
</tr>
<tr>
<td>Q3 – Pesado</td>
<td>0,50</td>
<td>Aparato que levanta con bastante frecuencia la carga máxima de servicio y corrientemente cargas medianas</td>
</tr>
<tr>
<td>Q4 – Muy pesado</td>
<td>1,00</td>
<td>Aparato que corrientemente maneja cargas próximas a la carga máxima de servicio</td>
</tr>
</tbody>
</table>


### CLASSIFICATION OF THE COMPLETE EQUIPMENT

<table>
<thead>
<tr>
<th>Estado de carga</th>
<th>Coeficiente nominal del espectro de las cargas $X_p$</th>
<th>Clases de utilización y número máximo de ciclos de maniobra del aparato</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 – Ligero</td>
<td>0,125</td>
<td>U1, U2, U3, U4, U5, U6, U7, U8, U9</td>
</tr>
<tr>
<td>Q2 – Moderado</td>
<td>0,25</td>
<td>A1, A2, A3, A4, A5, A6, A7, A8</td>
</tr>
<tr>
<td>Q3 – Pesado</td>
<td>0,5</td>
<td>A1, A2, A3, A4, A5, A6, A7, A8</td>
</tr>
<tr>
<td>Q4 – Muy pesado</td>
<td>1,0</td>
<td>A2, A3, A4, A5, A6, A7, A8, A8</td>
</tr>
</tbody>
</table>

### Ejemplos de clasificación de aparatos completos

<table>
<thead>
<tr>
<th>Categoría de grúa</th>
<th>Designación del aparato</th>
<th>Clasificación del aparato</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Clase de utilización</td>
</tr>
<tr>
<td>1</td>
<td>Grúa para utilización ocasional</td>
<td>U1</td>
</tr>
<tr>
<td></td>
<td>Grúa para perque de almacenamiento de material</td>
<td>U3</td>
</tr>
<tr>
<td></td>
<td>Grúa de mantenimiento para plataformas petrolíferas</td>
<td>U3</td>
</tr>
<tr>
<td></td>
<td>Grúa de pontón para la reparación naval</td>
<td>U4</td>
</tr>
<tr>
<td>2</td>
<td>Grúa torre de obra autoexpansible</td>
<td>U3</td>
</tr>
<tr>
<td></td>
<td>Grúa torre de obra de montaje por elementos</td>
<td>U4</td>
</tr>
<tr>
<td>3</td>
<td>Grúa para muelle de arranque de astillero</td>
<td>U4</td>
</tr>
<tr>
<td></td>
<td>Grúa de puente para carga de contenedores</td>
<td>U4</td>
</tr>
<tr>
<td></td>
<td>Grúa de dique</td>
<td>U4</td>
</tr>
<tr>
<td></td>
<td>Grúa de cuchara (mordaza)</td>
<td>U5</td>
</tr>
</tbody>
</table>
CLASSIFICATION OF THE MECHANISM

CLASSIFICACIÓN OF THE MECHANISMS (standard 58-112-91/1)

Usage of work equipment  Mechanism load level

It is calculated for the planned service duration in hours

- Maximum service duration can be computed by means of the mean daily service, in hours, of the number of working days per year and the number of the planned years of service.
- A mechanism is considered to be on service when it is on movement.

<table>
<thead>
<tr>
<th>Clase de utilización</th>
<th>Duración total de servicio h</th>
<th>Observaciones</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₀</td>
<td>200</td>
<td>Utilización ocasional</td>
</tr>
<tr>
<td>T₁</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>T₂</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>T₃</td>
<td>1600</td>
<td></td>
</tr>
<tr>
<td>T₄</td>
<td>3200</td>
<td>Utilización regular en servicio ligero</td>
</tr>
<tr>
<td>T₅</td>
<td>6 300</td>
<td>Utilización regular en servicio intermitente</td>
</tr>
<tr>
<td>T₆</td>
<td>12 000</td>
<td>Utilización regular en servicio intensivo</td>
</tr>
<tr>
<td>T₇</td>
<td>25 000</td>
<td></td>
</tr>
<tr>
<td>T₈</td>
<td>50 000</td>
<td>Utilización intensiva</td>
</tr>
<tr>
<td>T₉</td>
<td>100 000</td>
<td></td>
</tr>
</tbody>
</table>
CLASSIFICATION OF THE MECHANISM

CLASSIFICACIÓN OF THE MECHANISMS (standard 58-112-91/1)

Use of work equipment

Loads applied to the mechanism

The load level is a feature that shows how much a mechanism is subjected to a maximum load, or only to low loads.

\[ k_m = \sum \left[ \frac{t_i}{T_i} \left( \frac{P_i}{P_{\text{max}}} \right)^3 \right] \]

- \( t_i \) is the mean service duration of the mechanism when subjected to individual loads.
- \( T_i \) is the sum of the individual durations in all load level
- \( P_i \) is the individual load level of the mechanism
- \( P_{\text{max}} \) is the maximum load applied to the mechanism

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CLASSIFICATION OF THE MECHANISM: APPLIED LOAD

<table>
<thead>
<tr>
<th>Estado de carga</th>
<th>Coeficiente nominal del esfuerzo de carga ( E_n )</th>
<th>Observaciones</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 - Ligerio</td>
<td>0.125</td>
<td>Máquinas sometidas excepcionalmente a la carga media de servicio y normalmente a cargas muy pequeñas</td>
</tr>
<tr>
<td>1.2 - Moderado</td>
<td>0.25</td>
<td>Máquinas sometidas con bastante frecuencia a la carga máxima de servicio y con frecuencia a cargas pequeñas</td>
</tr>
<tr>
<td>1.3 - Pesado</td>
<td>0.30</td>
<td>Máquinas sometidas con bastante frecuencia a su carga máxima de servicio y con frecuencia a cargas medias</td>
</tr>
<tr>
<td>1.4 - Muy pesado</td>
<td>1.00</td>
<td>Máquinas sometidas con regularidad a su carga máxima de servicio</td>
</tr>
</tbody>
</table>
## CLASSIFICATION OF THE MECHANISM

<table>
<thead>
<tr>
<th>Estado de carga</th>
<th>Coeficiente nominal del espectro en cargas ( K_{Dx} )</th>
<th>Clases de utilización del mecanismo</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( T_0 )</td>
<td>( T_1 )</td>
</tr>
<tr>
<td>L1 – Ligero</td>
<td>0,125</td>
<td>M1</td>
</tr>
<tr>
<td>L2 – Moderado</td>
<td>0,25</td>
<td>M1</td>
</tr>
<tr>
<td>L3 – Pesado</td>
<td>0,5</td>
<td>M1</td>
</tr>
<tr>
<td>L4 – Muy pesado</td>
<td>1,0</td>
<td>M2</td>
</tr>
</tbody>
</table>
Crane with hook:

<table>
<thead>
<tr>
<th>Crane de utilización</th>
<th>Número máximo de ciclos de manejo</th>
<th>Observaciones</th>
</tr>
</thead>
<tbody>
<tr>
<td>U₀</td>
<td>$1.6 \times 10^4$</td>
<td>Utilización ocasional</td>
</tr>
<tr>
<td>U₁</td>
<td>$3.2 \times 10^4$</td>
<td></td>
</tr>
<tr>
<td>U₂</td>
<td>$6.3 \times 10^4$</td>
<td></td>
</tr>
<tr>
<td>U₃</td>
<td>$1.25 \times 10^5$</td>
<td>Utilización regular en servicio intermitente</td>
</tr>
<tr>
<td>U₄</td>
<td>$2.5 \times 10^5$</td>
<td></td>
</tr>
<tr>
<td>U₅</td>
<td>$5 \times 10^5$</td>
<td>Utilización regular en servicio intermitente</td>
</tr>
<tr>
<td>U₆</td>
<td>$1 \times 10^6$</td>
<td>Utilización regular en servicio intermitente</td>
</tr>
<tr>
<td>U₇</td>
<td>$2 \times 10^6$</td>
<td></td>
</tr>
<tr>
<td>U₈</td>
<td>$4 \times 10^6$</td>
<td>Utilización intensiva</td>
</tr>
<tr>
<td>U₉</td>
<td>Más de $4 \times 10^6$</td>
<td></td>
</tr>
</tbody>
</table>

**Lift cycle**

- Load lift
- Movement of the load
- Rotation
- Lowering
- Unhook the load
- Unloaded lift
- Rotation
- Movement of the load
- Unloaded lift
- To hook a new load

$t_{mc} = 150 \text{ s}$
Total length usage of the machine:

\[ T = \frac{N \cdot t_{mc}}{3600} \text{[h]} \]

- \( t_{mc} \) = cycle mean length [s]
- \( N \) = Number of cycles

For each of the mechanisms it is defined:

\[ \alpha_i = \frac{t_{mechanism}}{t_{mc}} \]

- \( t_{mechanism} \) = usage time of the mechanism during one cycle [s]
- \( t_{mc} \) = mean duration of one cycle [s]

<table>
<thead>
<tr>
<th>Class of utilization</th>
<th>Number of cycles available</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>( U_0 )</td>
<td>1.0 \times 10^5</td>
<td>Utilización modal</td>
</tr>
<tr>
<td>( U_2 )</td>
<td>3.2 \times 10^5</td>
<td>Utilización seminormal</td>
</tr>
<tr>
<td>( U_3 )</td>
<td>6.5 \times 10^5</td>
<td>Utilización regular en servicio intermedio</td>
</tr>
<tr>
<td>( U_4 )</td>
<td>12.5 \times 10^5</td>
<td>Utilización regular en servicio regular</td>
</tr>
<tr>
<td>( U_5 )</td>
<td>5 \times 10^5</td>
<td>Utilización regular en servicio intensivo</td>
</tr>
<tr>
<td>( U_6 )</td>
<td>1 \times 10^5</td>
<td>Utilización regular en servicio intensivo</td>
</tr>
<tr>
<td>( U_7 )</td>
<td>2 \times 10^5</td>
<td>Utilización intermedia</td>
</tr>
<tr>
<td>( U_8 )</td>
<td>4 \times 10^5</td>
<td>Utilización intemedia</td>
</tr>
<tr>
<td>( U_9 )</td>
<td>Máis de 4 \times 10^5</td>
<td></td>
</tr>
</tbody>
</table>

\[ T = \frac{5 \times 10^5 \cdot 1.50}{3600} = 20835 \text{ horas} \]
CLASSIFICATION

**Lift mechanism**
- Load lift
- Movement of the load
- Rotation
- Lowering
- Unload the load
- Rotation
- Movement of the load
- Unload lowering
- Hook a new load

**Slew mechanism**
- Load lift
- Movement of the load
- Rotation
- Lowering
- Unload the load
- Rotation
- Movement of the load
- Unload lowering
- Hook a new load

**Travelling mechanism**
- Load lift
- Movement of the load
- Rotation
- Lowering
- Unload the load
- Rotation
- Movement of the load
- Unload lowering
- Hook a new load

**Load lift**
- Movement of the load
- Rotation
- Lowering
- Unload the load
- Rotation
- Movement of the load
- Unload lowering
- Hook a new load

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Load lift</th>
<th>Movement of the load</th>
<th>Rotation</th>
<th>Lowering</th>
<th>Unload the load</th>
<th>Rotation</th>
<th>Movement of the load</th>
<th>Unload lowering</th>
<th>Hook a new load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lift mechanism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slew mechanism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travelling</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Total duration of the mechanism in hours:**

- **Lift mechanism** \( \alpha = 0.63 \)
  \[ \tau = 13126 \text{ h} \]

- **Slew mechanism** \( \alpha = 0.25 \)
  \[ \tau = 5209 \text{ h} \]

- **Travelling mechanism** \( \alpha = 0.10 \)
  \[ \tau = 2084 \text{ h} \]
**ENGINE**

- **Power calculation:**

\[
P = \frac{G_2 \cdot V}{4500 \cdot \eta} \quad [\text{CV}]
\]

- **Lift movements**
- **Travelling movements**

\[
P = \frac{(G_1 + G_2) \cdot W \cdot V}{4500000 \cdot \eta} \quad [\text{CV}]
\]

- \( G_1 \): self weight (trolley, span, etc.) [daN]
- \( G_2 \): load + accessories [daN]
- \( V \): speed [m/min]
- \( \eta \): mechanical efficiency
- \( W \): friction coefficient
- 7 for rolling bearing
- 20 for friction bearing

**Torque needed to accelerate:**

Starting torque = resistance torque + acceleration torque

**The resistance torque only has to be taken into account for travelling engines**

\[
M_A = M_w + M_b \quad [\text{daNm}]
\]

\[
M_w = \frac{716 \cdot P_i}{n_i} \quad [\text{daNm}]
\]

\[
M_k = \sum \frac{GD_i^2 \cdot n_i}{375 \cdot l_s} \quad [\text{daNm}]
\]

- \( n_i \): engine speed in rpm
- \( \Sigma GD_i^2 \): inertia torque sum referred to engine axis
- \( l_s \): acceleration time:
  - Lift, cierre cachara = 2 s
  - Trolley travelling or bridge crane, rotation = 4 s
  - Gantry travelling = 6 s

\[
d = \frac{V}{\omega} \quad [\text{m}]
\]

\( V \): Mass linear speed

\[
\omega = \frac{2 \pi n}{60} \quad [\text{rad/s}]
\]

\[
\theta = \frac{\pi}{180} \quad [\text{rad}]
\]
Power needed to overcome wind resistance:

\[ P_v = \frac{S \cdot V \cdot F_v}{4500 \cdot \eta} \text{ [CV]} \]

\( F_v \): wind pressure [daN/m²]
\( S \): surface exposed to wind

To select travelling engine:

- Engine power \( \geq P + P_v \) [CV]
- Max. motor torque \( \geq M_w + M_v \) [daNm]

To select lift engine:

- Engine power \( \geq P_v + P_v \) [CV]