Mechanical Engineering Department
Carlos III University

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_L multiplied by the dynamic coefficient ψ and the two most unfavourable horizontal effects S_H, set aside impact effects, multiplied by an increase factor γ_c:

$$\gamma_c \left(S_G + \psi S_L + S_H\right)$$

  - Increasing factor γ_c [UNE 58132-2] : Depends on the elevator classification group

Elevator group	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
γ_c	1,00	1,02	1,05	1,08	1,11	1,14	1,17	1,20

STRUCTURAL CALCULATION: CASE I

$$\gamma_c \left(S_G + \psi S_L + S_H\right)$$

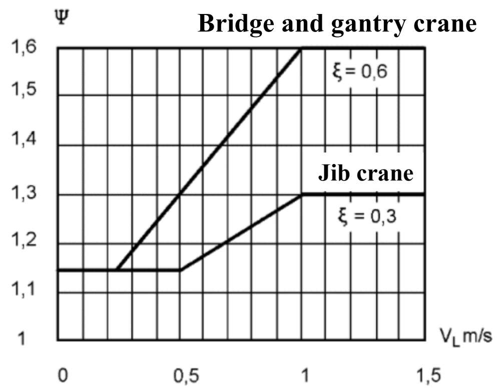
- **Dynamic coefficient ψ:** takes into account
  - The service load lifting.
  - The accelerations and decelerations in the lifting process.
  - The vertical impacts due to the rolling in the track.

$$\Psi = 1 + \xi V_L$$

V_L is the lift speed in m/s

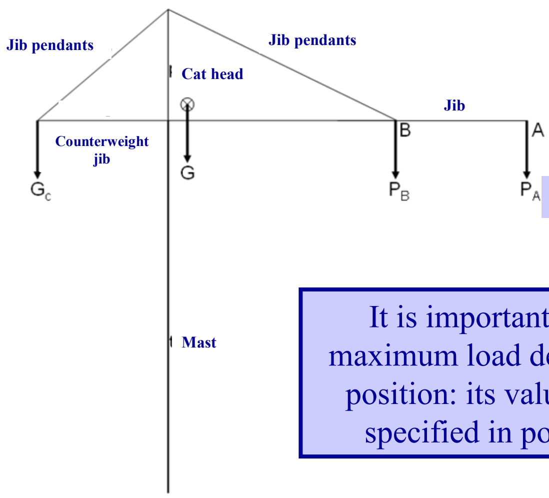
ξ is an experimental coefficient obtained by carrying out several tests in different elevators

STRUCTURAL CALCULATION: CASE I



CRANES I

STRUCTURAL CALCULATION: TOWER CRANE



G: crane weight

P_i=Q+Pc (load+trolley)

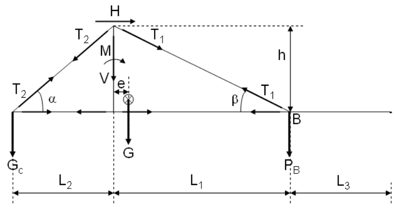
G_c: counterweight weight

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

STRUCTURAL CALCULATION: TOWER CRANE

Above structure

The jib pendants are subject to traction, while the cat head is subjected to compression, flexure and shear



Traction forces in the jib ties

$$T_1=\frac{P_B}{sen(\beta)} \Rightarrow T_1=\frac{\psi\cdot P_B}{sen(\beta)} \Rightarrow \sigma_1=\frac{T_1}{A_1}$$

$$T_2=\frac{G_c}{sen(\alpha)} \Rightarrow T_2=\frac{G_c}{sen(\alpha)} \Rightarrow \sigma_2=\frac{T_2}{A_2}$$

Forces in the cat head are:

$$V=T_1\cdot sen(\beta)+T_2\cdot sen(\alpha)$$
$$H=T_1\cdot cos(\beta)-T_2\cdot cos(\alpha)$$
$$M=H\cdot h$$

$$\left\{\begin{array}{l}\sigma_c=\dfrac{V}{A_p}\\ \sigma_f=\dfrac{M}{W_{pf}}\\ \tau=\dfrac{H\cdot m}{b\cdot I_z}\end{array}\right.$$

Von Misses

$$\sigma_T=\sqrt{\sigma^2+3\tau^2}$$

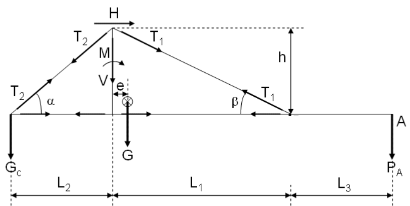
$$\Rightarrow \sigma_T=\sqrt{(\sigma_f+\sigma_c)^2+3\tau^2}$$

m: first moment of the principal area

STRUCTURAL CALCULATION: TOWER CRANE

Above structure

The jib is subjected to flexure and shear forces:



Von Misses

$$M_{pl,f}=P_A\cdot L_3 \qquad V_{pl,c}=P_A$$
$$\Rightarrow M_{pl,f}=\psi\cdot P_A\cdot L_3 \qquad V_{pl,c}=\psi\cdot P_A$$
$$\Rightarrow \sigma_f=\frac{\psi\cdot P_A\cdot L_3}{W_{pf}} \qquad \tau=\frac{\psi\cdot P_A\cdot m}{b\cdot I_z}$$
$$\Rightarrow \sigma_T=\sqrt{\sigma_f^2+3\tau^2}$$

STRUCTURAL CALCULATION: TOWER CRANE

Mast

The mast is subjected to flexure and compression forces

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

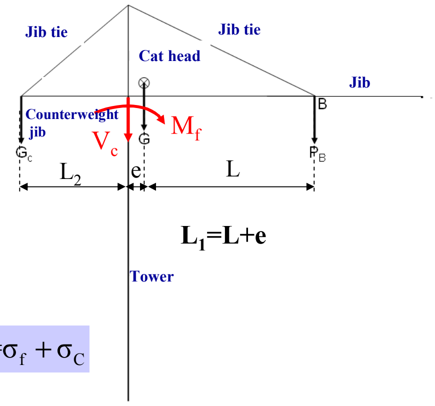
⇓

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

⇓

$$\sigma_f = \frac{\psi \cdot P_B \cdot L_1 - G_c \cdot L_2 + G \cdot e}{W_{mf}}$$
$$\sigma_c = \frac{\psi \cdot P_B + G_c + G}{A_m}$$

⇒ $\sigma_T = \sigma_f + \sigma_C$



$L_1 = L + e$

STRUCTURAL CALCULATION: CASE I

$$\gamma_c \left(S_G + \psi S_L + S_H \right)$$

- **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

$$\gamma_c \left(S_G + \psi S_L + S_H\right)$$

- 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

STRUCTURAL CALCULATION: CASE I

Desired speed [m/s]	(a) Low and medium speed with large travelling		(b) Medium and high speeds (usual applications)		(c) High speed with great accelerations	
	Time to accelerate [s]	Acceleration [m/s²]	Time to accelerate [s]	Acceleration [m/s²]	Time to accelerate [s]	Acceleration [m/s²]
4,00			8,00	0,50	6,00	0,67
3,15			7,10	0,44	5,40	0,58
2,50			6,30	0,39	4,80	0,52
2,00	9,10	0,22	5,60	0,35	4,20	0,47
1,60	8,30	0,19	5,00	0,32	3,70	0,43
1,00	6,60	0,15	4,00	0,25	3,00	0,33
0,63	5,20	0,12	3,20	0,19		
0,40	4,10	0,098	2,50	0,16		
0,25	3,20	0,078				
0,16	2,50	0,064				

STRUCTURAL CALCULATION: CASE I

$$\gamma_c \left(S_G + \psi S_L + S_H\right)$$

- 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 = $\sum m_i d_i^2$
α: Angular acceleration

STRUCTURAL CALCULATION: CASE I

Inertia forces due to rotation:

$$F = m_e \cdot a$$

Equivalent mass

$$m_e = \sum \frac{m_i d_i^2}{D^2}$$

Tangencial acceleration

$$a = \alpha \cdot D$$

$$F = \alpha \cdot \sum \frac{m_i d_i^2}{D}$$

STRUCTURAL CALCULATION: CASE I

$$\gamma_c\left(S_G+\psi S_L+S_H\right)$$

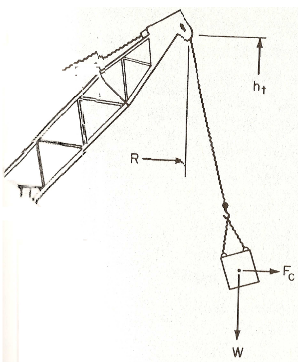
- **Loads due to obliquity:**
  - Tangential forces between the wheels and the rail track.
  - Guide forces.
- A simple translation mechanical model is needed:
  - n pairs of wheels in line.
  - p coupled pairs.

	Coupled (C)	Individual (I)
Fixed/Fixed (F/F)	CFF	IFF
Fixed/Mobile (F/M)	CFM	IFM

STRUCTURAL CALCULATION: CASE I

$$\gamma_c\left(S_G+\psi S_L+S_H\right)$$

- **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

STRUCTURAL CALCULATION: CASE II

- **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:**

$$\gamma_c \left(S_G + \psi S_L + S_H\right) + S_w$$

  - **Overloading due to snow is not considered.**

STRUCTURAL CALCULATION: CASE II

$$\gamma_c \left(S_G + \psi S_L + S_H\right) + S_w$$

- **Wind effect**

$$F = A \cdot p \cdot C_f$$

•A is the net surface, in m^2, 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/m^2, 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

CRANES I

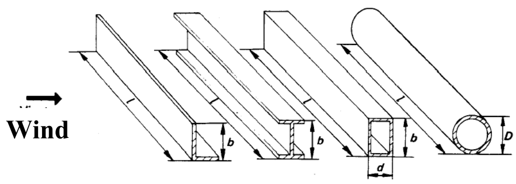
STRUCTURAL CALCULATION: CASE II

C_f: Shape factor [UNE 58-113-85]

Type	Description		Aerodynamic drag coefficient l/b or l/D					
			5	10	20	30	40	50
Simple elements	Metal section in L, in U and flat plates		1,3	1,35	1,6	1,65	1,7	1,9
	Circular metal sections in which $Dv_s < 6$ m²/s		0,75	0,80	0,90	0,95	1,0	1,1
	in which $Dv_s \geq 6$ m²/s		0,60	0,65	0,70	0,70	0,75	0,8
	Square metal sections of more than 350 mm side and rectangular of more than 250 mm x 450 mm	b/d						
		≥2	1,55	1,75	1,95	2,1	2,2	
		1	1,40	1,55	1,75	1,85	1,9	
		0,5	1,0	1,2	1,3	1,35	1,4	
		0,25	0,8	0,9	0,9	1,0	1,0	
Simple lattice work	Flat side metal section		1,7					
	Circular metal sections in which $Dv_s < 6$ m²/s		1,2					
	in which $Dv_s \geq 6$ m²/s		0,8					
Machine room, etc	Square structures filled (air cannot flow beneath the structure)		1,1					

CRANES I

STRUCTURAL CALCULATION: CASE II



$$\text{Aerodynamic coefficient} = \frac{\text{Element length}}{\text{Section height facing wind}} = \frac{l}{b} \text{ or } \frac{l}{D}$$

$$\text{Section proportion} = \frac{\text{Section height facing wind}}{\text{Section width parallel to wind}} = \frac{b}{d}$$

STRUCTURAL CALCULATION: CASE II

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

Type of crane	Wind speed m/s	Wind pressure kPa/m²
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)	14	0,125
Every normal crane installed in exteriors	20	0,25
Dock cranes that should continue operation in case of strong wind	28,5	0,50

$p = 0{,}613 \cdot 10^{-3} \cdot v_s^2 \;\; [kPa]$

STRUCTURAL CALCULATION: CASE II

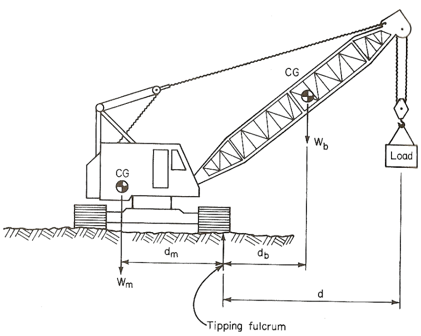
$$\gamma_c \left(S_G + \psi S_L + S_H \right) + S_w$$

- **Snow overloading:**
  - **It is not considered**
- **Temperature effect:**
  - **Only when the elements cannot freely expand**
  - **Temperature limit -20 ºC + 45 ºC**

STRUCTURAL CALCULATION: CASE III

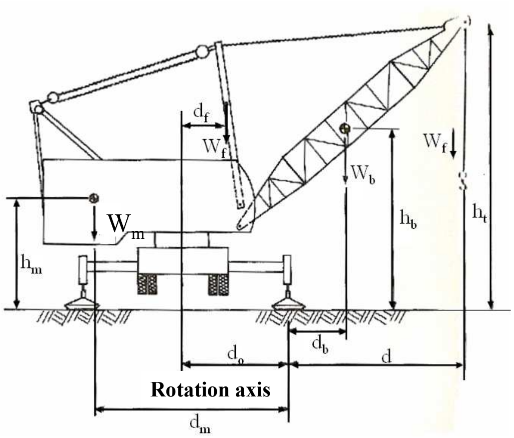
- **CASE III: Elevator subjected to exceptional loads**
  a) Elevator out of service subjected to maximum wind.
  b) Elevator in service subject to impact.
  c) Elevator subjected to static and dynamic tests.

STABILITY



$$W_m d_m > W_b d_b + W\,d$$

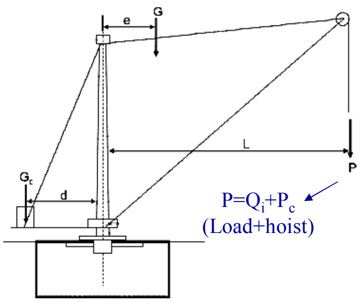
STABILITY



$$W_m d_m + W_f\left(d_o - d_f\right) > W_b d_b + W_r d$$

COUNTERWEIGHT CALCULATION

It is usually calculated so that it counteracts the half of the material moment and the jib moment ⇒ $G_c \cdot d = G \cdot e + (P_c + \frac{Q}{2}) \cdot L$



$P=Q_i+P_c$
(Load+hoist)

Moment: $M_f = (P_c + Q_i) \cdot L + G \cdot e - G_c \cdot d$

$$M_f = (P_c + Q_i) \cdot L + G \cdot e - \left(G \cdot e + (P_c + \frac{Q}{2}) \cdot L\right) = \left(Q_i - \frac{Q}{2}\right) \cdot L$$

Most unfavourable situations:

- Without load: $Q_i=0$ — $M_f = -\frac{Q}{2} \cdot L$
- With load: $Q_i=Q$ — $M_f = \frac{Q}{2} \cdot L$

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

CLASSIFICATION

Crane and elevators 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

Clase de utilización	Número máximo de ciclos de maniobra	Observaciones
U_0	$1{,}6 \times 10^4$	Utilización ocasional
U_1	$3{,}2 \times 10^4$	
U_2	$6{,}3 \times 10^4$	
U_3	$1{,}25 \times 10^5$	
U_4	$2{,}5 \times 10^5$	Utilización regular en servicio ligero
U_5	5×10^5	Utilización regular en servicio intermitente
U_6	1×10^6	Utilización regular en servicio intensivo
U_7	2×10^6	Utilización intensiva
U_8	4×10^6	
U_9	Más de 4×10^6	

CLASSIFICATION OF THE EQUIPMENT

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

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

↓

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

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

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_{max} is the maximum load that the equipment is authorized to lift (safe working load).

CLASSIFICATION OF THE EQUIPMENT : LOAD LEVEL

Estado de carga	Coeficiente nominal del espectro de las cargas K_p	Observaciones
Q1 – Ligero	0,125	Aparato que levanta raramente la carga máxima de servicio y corrientemente cargas muy pequeñas
Q2 – Moderado	0,25	Aparato que levanta con bastante frecuencia la carga máxima de servicio y corrientemente cargas pequeñas
Q3 – Pesado	0,50	Aparato que levanta con bastante frecuencia la carga máxima de servicio y corrientemente cargas medianas
Q4 – Muy pesado	1,00	Aparato que corrientemente maneja cargas próximas a la carga máxima de servicio

CLASSIFICATION OF THE COMPLETE EQUIPMENT

Estado de carga	Coeficiente nominal del espectro de las cargas K_p	Clases de utilización y número máximo de ciclos de maniobra del aparato									
		U_0	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9
Q1 – Ligero	0,125	A1	A1	A1	A2	A3	A4	A5	A6	A7	A8
Q2 – Moderado	0,25	A1	A1	A2	A3	A4	A5	A6	A7	A8	A8
Q3 – Pesado	0,5	A1	A2	A3	A4	A5	A6	A7	A8	A8	A8
Q4 – Muy pesado	1,0	A2	A3	A4	A5	A6	A7	A8	A8	A8	A8

CRANES I

CLASSIFICATION OF THE COMPLETE EQUIPMENT

Ejemplos de clasificación de aparatos completos

Categoría de grúa	Designación del aparato	Clasificación del aparato		
		Clase de utilización	Estado de carga	Grupo de clasificación
1	Grúa para utilización ocasional	U1	Q2	A1
	Grúa para parque de almacenamiento de material	U3	Q1	A2
	Grúa de mantenimiento para plataformas petrolíferas	U3	Q2	A3
	Grúa de pontón para la reparación naval	U4	Q2	A4
2	Grúa torre de obra autodesplegable	U3	Q2	A3
	Grúa torre de obra de montaje por elementos	U4	Q2	A4
3	Grúa para muelle de armamento de astillero	U4	Q2	A4
	Grúa de puerto para carga de contenedores	U4	Q2	A4
	Grúa de dique	U4	Q3	A5
	Grúa de cuchara (mordaza)	U5	Q3	A6

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.

CLASSIFICATION OF THE MECHANISM: USAGE

Clase de utilización	Duración total de servicio h	Observaciones
T_0	200	Utilización ocasional
T_1	400	
T_2	800	
T_3	1600	
T_4	3200	Utilización regular en servicio ligero
T_5	6 300	Utilización regular en servicio intermitente
T_6	12 000	Utilización regular en servicio intensivo
T_7	25 000	Utilización intensiva
T_8	50 000	
T_9	100 000	

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.

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

t_i is the mean service duration of the mechanism when subjected to individual loads.
$T_{t\,i}$ is the sum of the individual durations in all load level
P_i is the individual load level of the mechanism
P_{max} is the maximum load applied to the mechanism

CLASSIFICATION OF THE MECHANISM: APPLIED LOAD

Estado de carga	Coeficiente nominal del espectro de cargas K_m	Observaciones
L1 – Ligero	0,125	Mecanismo sometido excepcionalmente a la carga máxima de servicio y normalmente a cargas muy pequeñas
L2 – Moderado	0,25	Mecanismo sometido con bastante frecuencia a la carga máxima de servicio y corrientemente a cargas pequeñas
L3 – Pesado	0,50	Mecanismo sometido con bastante frecuencia a su carga máxima de servicio y corrientemente a cargas medias
L4 – Muy pesado	1,00	Mecanismo corrientemente sometido a su carga máxima de servicio

CLASSIFICATION OF THE MECHANISM

Estado de carga	Coeficiente nominal del espectro en cargas K_m	Clases de utilización del mecanismo									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
L1 – Ligero	0,125	M1	M1	M1	M2	M3	M4	M5	M6	M7	M8
L2 – Moderado	0,25	M1	M1	M2	M3	M4	M5	M6	M7	M8	M8
L3 – Pesado	0,5	M1	M2	M3	M4	M5	M6	M7	M8	M8	M8
L4 – Muy pesado	1,0	M2	M3	M4	M5	M6	M7	M8	M8	M8	M8

CRANES I

CLASSIFICATION OF THE MECHANISM

Ejemplos de clasificación de los mecanismos

Categoría de la grúa	Designación del aparato	Clasificación de los mecanismos														
		Clase de utilización					Estado de carga					Grupo de clasificación				
		Movimiento[1)]					Movimiento[1)]					Movimiento[1)]				
		L	O	R	D	T	L	O	R	D	T	L	O	R	D	T
1	Grúa para utilización ocasional	T1	T1	T1	T1	T1	L2	L3	L2	L2	L3	M1	M2	M1	M1	M2
	Grúa para parque de almacenamiento de material	T3	T3	T2	T2	T1	L1	L3	L1	L1	L3	M2	M4	M1	M1	M2
	Grúa de mantenimiento para plataformas petrolíferas	T3	T3	T2	T2	T1	L1	L3	L2	L2	L3	M3	M4	M2	M2	M2
	Grúa de pontón para reparación naval	T4	T4	T3	T3	T2	L2	L3	L2	L2	L3	M4	M5	M3	M3	M3
2	Grúa torre de obra autodesplegable	T3	T3	T2	T2	T1	L2	L3	L3	L2	L3	M3	M4	M3	M2	M2
	Grúa torre de obra de montaje por elementos	T4	T4	T3	T3	T2	L2	L3	L3	L2	L3	M4	M5	M4	M3	M3
3	Grúa para muelle de armamento de astillero	T4	T4	T3	T3	T5	L2	L3	L2	L2	L3	M4	M5	M3	M3	M6
	Grúa de puerto para carga de contenedores	T4	T4	T3	T4	T2	L2	L2	L2	L2	L2	M4	M4	M3	M4	M2
	Grúa de dique	T4	T4	T3	T3	T4	L3	L3	L3	L3	L3	M5	M5	M4	M4	M5
	Grúa de cuchara (mordaza)	T5	T5	T4	T5	T2	L3	L3	L3	L3	L3	M6	M6	M5	M6	M3

[1)] L: Elevación; O: Orientación; R: Cambio de alcance;

D: Traslación del carro; T: Traslación del aparato.

CLASSIFICATION

Crane with hook:

Clase de utilización	Número máximo de ciclos de maniobra	Observaciones
U_0	$1{,}6 \times 10^4$	Utilización ocasional
U_1	$3{,}2 \times 10^4$	
U_2	$6{,}3 \times 10^4$	
U_3	$1{,}25 \times 10^5$	
U_4	$2{,}5 \times 10^5$	Utilización regular en servicio ligero
U_5	5×10^5	Utilización regular en servicio intermitente
U_6	1×10^6	Utilización regular en servicio intensivo
U_7	2×10^6	Utilización intensiva
U_8	4×10^6	
U_9	Más de 4×10^6	

CLASSIFICATION

Crane with hook: Usage class U_5

Lift cylce

- 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 s

CLASSIFICATION

Total length usage of the machine:

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

t_{mc} = cycle mean length [s]
N = Number of cycles

Clase de utilización	Número máximo de ciclos de maniobra	Observaciones
U_0	$1{,}6 \times 10^4$	Utilización ocasional
U_1	$3{,}2 \times 10^4$	
U_2	$6{,}3 \times 10^4$	
U_3	$1{,}25 \times 10^5$	
U_4	$2{,}5 \times 10^5$	Utilización regular en servicio ligero
U_5	5×10^5	Utilización regular en servicio intermitente
U_6	1×10^6	Utilización regular en servicio intensivo
U_7	2×10^6	Utilización intensiva
U_8	4×10^6	
U_9	Más de 4×10^6	

$$T = \frac{5 \cdot 10^5 \cdot 150}{3600} \approx 20835 \text{ horas}$$

CLASSIFICATION

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]

Load lift
Movement of the load
Rotation
Lowering
Unhook the load
Unloaded lift
Rotation
Movement of the load
Unloaded lowering
Hook a new load

Lift mechanism

Slewing mechanism

Movement mechanism

CLASSIFICATION

Lift mechanism

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

63%

Slew mechanism

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

25%

Travelling mechanism

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

10%

CRANES I

CLASSIFICATION

T (h)	Valores de α_i 1,00	0,63	0,40	0,25	0,16	0,10	Clases de utilización del mecanismo
130	130	82	52	33	21	13	
195	195	123	78	49	31	20	
260	260	164	104	65	42	26	
325	325	205	130	81	52	33	
390	390	246	156	98	62	39	
520	520	328	208	130	83	52	
650	650	410	260	163	104	65	T0
780	780	491	312	195	125	78	
1 040	1 040	655	416	260	166	104	
1 300	1 300	819	520	325	208	130	
1 565	1 565	986	626	391	250	157	
1 825	1 825	1 150	730	456	292	183	
2 085	2 085	1 314	834	521	334	209	
2 605	2 605	1 641	1 042	651	417	261	T1
3 125	3 125	1 969	1 250	781	500	313	
3 645	3 645	2 296	1 458	911	583	365	
4 165	4 165	2 624	1 666	1 041	666	417	
5 210	5 210	3 282	2 084	1 303	834	521	T2
6 250	6 250	3 938	2 500	1 563	1 000	625	
7 290	7 290	4 593	2 916	1 823	1 166	729	
8 335	8 335	5 251	3 334	2 084	1 334	834	
10 415	10 415	6 561	4 166	2 604	1 666	1 042	T3
12 500	12 500	7 875	5 000	3 125	2 000	1 250	
14 585	14 585	9 189	5 834	3 646	2 334	1 459	
16 665	16 665	10 499	6 666	4 166	2 666	1 667	
→ 20 835	20 835	**13 126**	8 334	**5 209**	3 334	**2 084**	T4
25 000	25 000	15 750	10 000	6 250	4 000	2 500	
29 165	29 165	18 374	11 666	7 291	4 666	2 917	
33 335	33 335	21 001	13 334	8 334	5 334	3 334	
41 665	41 665	26 249	16 666	10 416	6 666	4 167	T5
50 000	50 000	31 500	20 000	12 500	8 000	5 000	
58 335	58 335	36 751	23 334	14 584	9 334	5 834	
66 665	66 665	41 999	26 666	16 666	10 666	6 667	
83 335	83 335	52 501	33 334	20 834	13 334	8 334	T6
100 000	100 000	63 000	40 000	25 000	16 000	10 000	
116 665	116 665	73 499	46 666	29 166	18 666	11 667	
133 335	133 335	84 001	53 334	33 334	21 334	13 334	
166 665	166 665	104 999	66 666	41 666	26 666	16 667	T7
200 000	200 000	126 000	80 000	50 000	32 000	20 000	
>200 000	>200 000	>126 000	>80 000	>50 000	>32 000	>20 000	
							T8
							T9

Total duration of the mechanism in hours:

Lift mechanism α_i=0.63

T_i=13126 h ⇨ **T7**

Slew mechanism α_i=0.25

T_i=5209 h ⇨ **T5**

Travelling mechanism α_i=0.10

T_i=2084 h ⇨ **T4**

ENGINES

- **Power calculation:**

Power

Lift movements

$$P_e = \frac{G_2 \cdot V}{4500 \cdot \eta} \quad [CV]$$

Travelling movements

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

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

CRANES I

ENGINES

Torque needed to accelerate:

Starting torque = resistance torque + acceleration torque

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

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

$$M_w = \frac{716 \cdot P_t}{n_1} \text{ [daNm]}$$

$$M_b = \frac{\sum GD_1^2 \cdot n_1}{375 \cdot t_a} \text{ [daNm]}$$

n_1: engine speed in rpm
ΣGD_1^2: inertia torque sum referred to engine axis
t_a: acceleration time:
Lift, cierre cuchara = 2 s
Trolley travelling or bridge crane, rotation = 4 s
Gantry travelling = 6 s

Masses moved linearly

$$GD_1^2 = \frac{(G_1 + G_2) \cdot d^2}{\eta} \text{ [daNm}^2\text{]}$$

Rotating mass

$$GD_1^2 = GD_2^2 \frac{n_2^2}{n_1^2} \text{ [daNm}^2\text{]}$$

$$d = \frac{V}{\pi \cdot n_1} \text{ [m]}$$

V: Mass lineal speed

ENGINES

Potencia nominal según VDE 0530 CV	kW	Tamaño constructivo	Con o sin levanta escobillas	Tensión de servicio V	Tipo	Peso neto kg	Momento de inercia $j=\frac{GD^2}{4}$ kg m²	Valores de servicio a potencia nominal: Velocidad r.p.m.	Rendimiento η %	Factor de potencia cos φ	Intensidad a 380 V A	Par en N. m.	Relación entre par máximo y nominal	Características rotóricas: Tensión V	Intensidad A	[illegible]
1.500 r. p. m. (4 polos)																
5,5	4	–	SIN	220/380	1LS1 133-4AA2.	75	0,03	1 410	77	0,80	99	. 27	2,8	130	21	
7,5	5,5	–	SIN	220/380	1LS1 135-4AA2.	80	0,035	1 410	82	0,85	12	37	2,7	170	22	
10	7,5	–	SIN	220/380	1LS1 163-4AA2.	110	0,068	1 425	85	0,82	16,3	50	3,0	180	27	
15	11	–	SIN	220/380	1LS1 166-4AA2.	125	0,09	1 440	87	0,83	23	74	3,4	260	26	
20	15	180 L	SIN	220/380 500	1LS2 136-4AA2. -4AA3.	215	0,23	1 445	88	0,84	31	101	4	250	37	
25	18,5	200 L	SIN	220/380 500	1LS2 155-4AA2. -4AA3.	285	0,39	1 450	89	0,85	37	124	3,8	215	54	
30	22	200 L	SIN	220/380 500	1LS2 156-4AA2. -4AA3.	305	0,43	1 450	90	0,86	43	148	4	250	54	
40	30	225 M	SIN	220/380 500	1LS2 176-4AA2. -4AA3.	400	0,76	1 455	91,5	0,88	57	201	3,9	165	115	
50	37	250 M	SIN	220/380 500	1LS2 185-4AA2. -4AA3.	555	1,02	1 460	90,5	0,88	71	247	3,8	180	125	
60	45	250 M	SIN	220/380 500	1LS2 186-4AA2. -4AA3.	595	1,16	1 465	91,5	0,88	85	300	4,2	230	121	
82	60	280 S	SIN	220/380 500	1LS2 204-4AA2. -4AA3.	745	1,9	1 470	92,5	0,88	112	392	4	255	145	
100	75	280 M	SIN	220/380 500	1LS2 206-4AA2. -4AA3.	820	2,17	1 475	93	0,89	138	497	4	305	150	
125	90	315 S	SIN	220/380 500	1LS2 224-4AA2. -4AA3.	980	3,1	1 475	93,5	0,89	165	582	3,8	315	175	
150	110	315 M	SIN	220/380 500	1LS2 226-4AA2. -4AA3.	1.070	3,65	1 475	94	0,90	200	712	4	380	175	
180	132	355	SIN	380 500	1LS4 354-4AA1. -4AA3.	1.400	4,9	1 475	93	0,90	240	853	3,6	395	205	
210	155	355	SIN	380 500	1LS4 355-4AA1. -4AA3.	1.450	5,5	1 480	93,5	0,90	280	1.000	3,9	475	198	
250	185	355	SIN	380 500	1LS4 356-4AA1. -4AA3.	1.550	6,2	1 480	94	0,90	330	1.120	4,2	580	192	
315	230	400	SIN	380 500	1LS4 404-4AA1. -4AA3.	2.000	11	1 485	94,5	0,91	405	1.480	3,7	455	305	
390	285	400	SIN	380 500	1LS4 406-4AA1. -4AA3.	2.150	13	1 485	95	0,91	500	1.830	3,9	570	300	
485	355	450/1	SIN	380 500	1LS4 454-4AA1. -4AA3.	2.800	20	1 490	95	0,92	620	2.270	4,1	630	340	
610	450	450/2	SIN	380 500	1LS4 456-4AA1. -4AA3.	3.100	24	1 490	95	0,92	780	2.890	4,1	790	345	

ENGINES

Power needed to overcome wind resistance:

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

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

To select travelling engine:

Engine power $\geq P_t + P_v$ [CV]

Max. motor toruque $\geq M_w + M_b$ [daNm]

To select lift engine:

Engine power $\geq P_e + P_v$ [CV]