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Selection of motors

5.8.1. Criteria for motor selection (IEC 60034-1)

When selecting motors for an application, at least the following details need to be considered:

-required powers-the thermal power is also included in these required powers,

-maximum rated torque and maximum acceleration torque,

-cyclic duration factor,

-number of cycles/hour,

-type of control (type of braking),

-speed regulation,

-type of power feed,

-degree of protection, (environment conditions),

-ambient temperature,

-altitude.

The motor has to comply with the following two dimensioning requirements:

-the thermal calculation according to clause 5.8.1.3.

-the required maximum torque:

•for hoisting mechanisms according to clause 5.8.2.1.

•for horizontal motions according to clause 5.8.3.1.

NOTE: Additional or different criteria may be needed depending on the driving system.

NOTE: Selection of motors for inverter drives is defined in clause 5.8.4, which also covers the dimensioning of inverter drives.

If the required torque diagrams, in order to define the mean equivalent torque (cl. 5.8.1.3.1.) are not available, these can be assessed respectively with the help of tables T 5.8.2.2a. and T 5.8.3.2a

5.8.1.1 Remarks on the selection of motors

The selection of the motor should be agreed with the manufacturer in taking into account the torque and powers calculated in the following clauses and the real operating conditions of the motor.

In the event of electronic power control, the definition of the motors has to be made in cooperation with the manufacturer, taking into account the cooling system and the speed range.

In cases where two or more mechanisms drive the same motion, the following shall be considered:

-both static and dynamic synchronisation of the motions according to the needs of the application

-necessary interlocks between the mechanisms to ensure safe operation

-both static and transitional asymmetrical loading of the mechanisms and consequently needed adequate dimensioning of motors and other drive components

5.8.1.2. Degree of protection (IEC 60034-5)

The degree of protection for all motors shall be according to EN 60204-32 clause 15.2. In case of water condensation risk, care should be taken that the water condensation drain holes remain open.

5.8.1.3. Thermal calculation of the motor

5.8.1.3.1.Mean equivalent torque In order to carry out the thermal calculation, the mean equivalent torque must be determined as a function of the required torque during the working cycles, by the formula:

$$M_{ed} = \sqrt{\frac{M_1^2 * t_1 + M_2^2 * t_2 + \cdots + M_n^2 * t_n}{t_1 + t_2 + \cdots + t_n}}$$

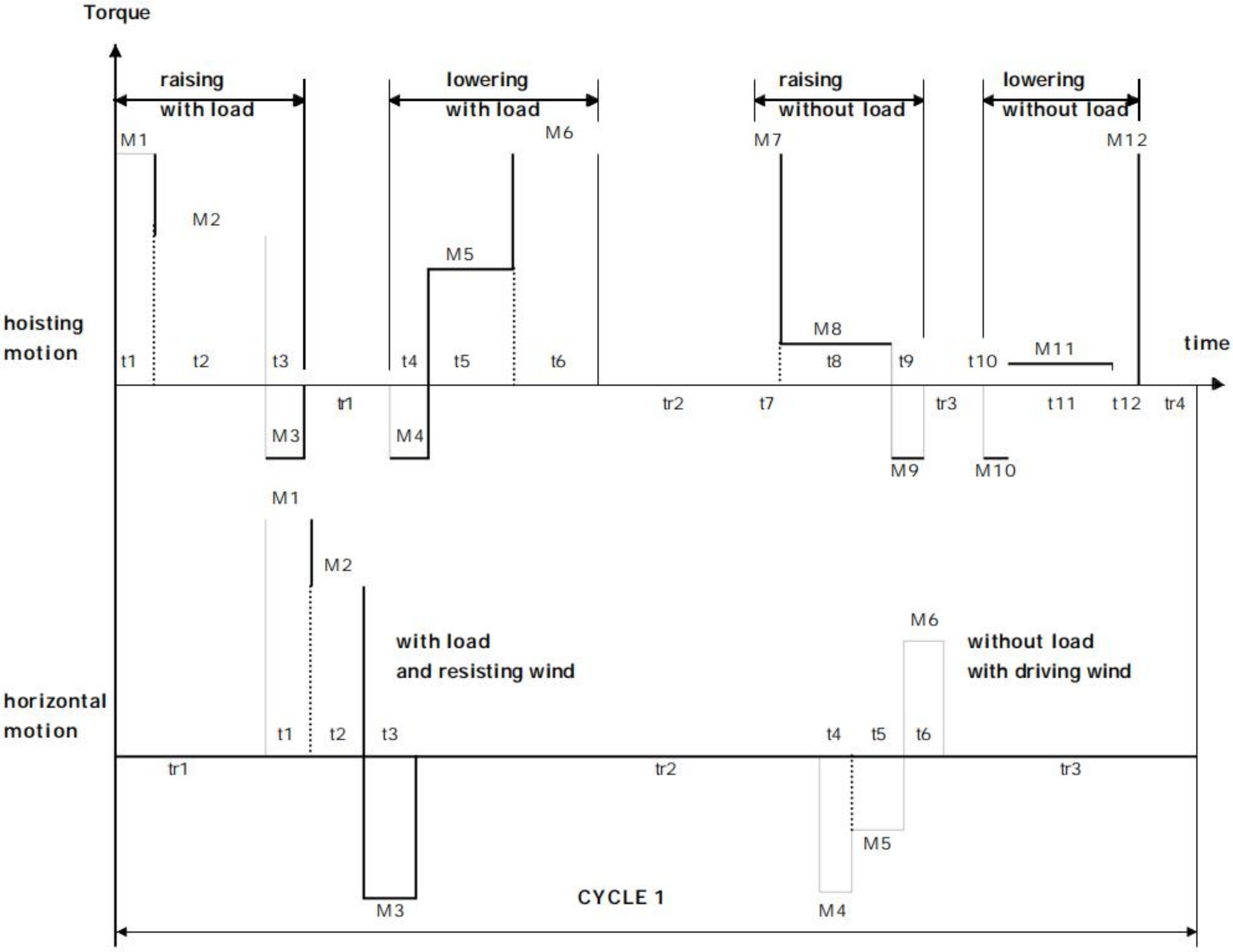
Where:

$t_1, t_2, \ldots, t_n$ are the durations of the time periods during which the different torque values are produced; periods of rest are not taken into account.

M_1, M_2, ... M_n are the calculated torque values taking into account all the inertia forces including the one of the rotor mass of the motor.

In case of variable loads at least 10 successive working cycles must be taken into account (see definition 2.1.2.2.).

Diagram 5.8.1.3.1. shows an example of the torque for 2 different operating cycles.



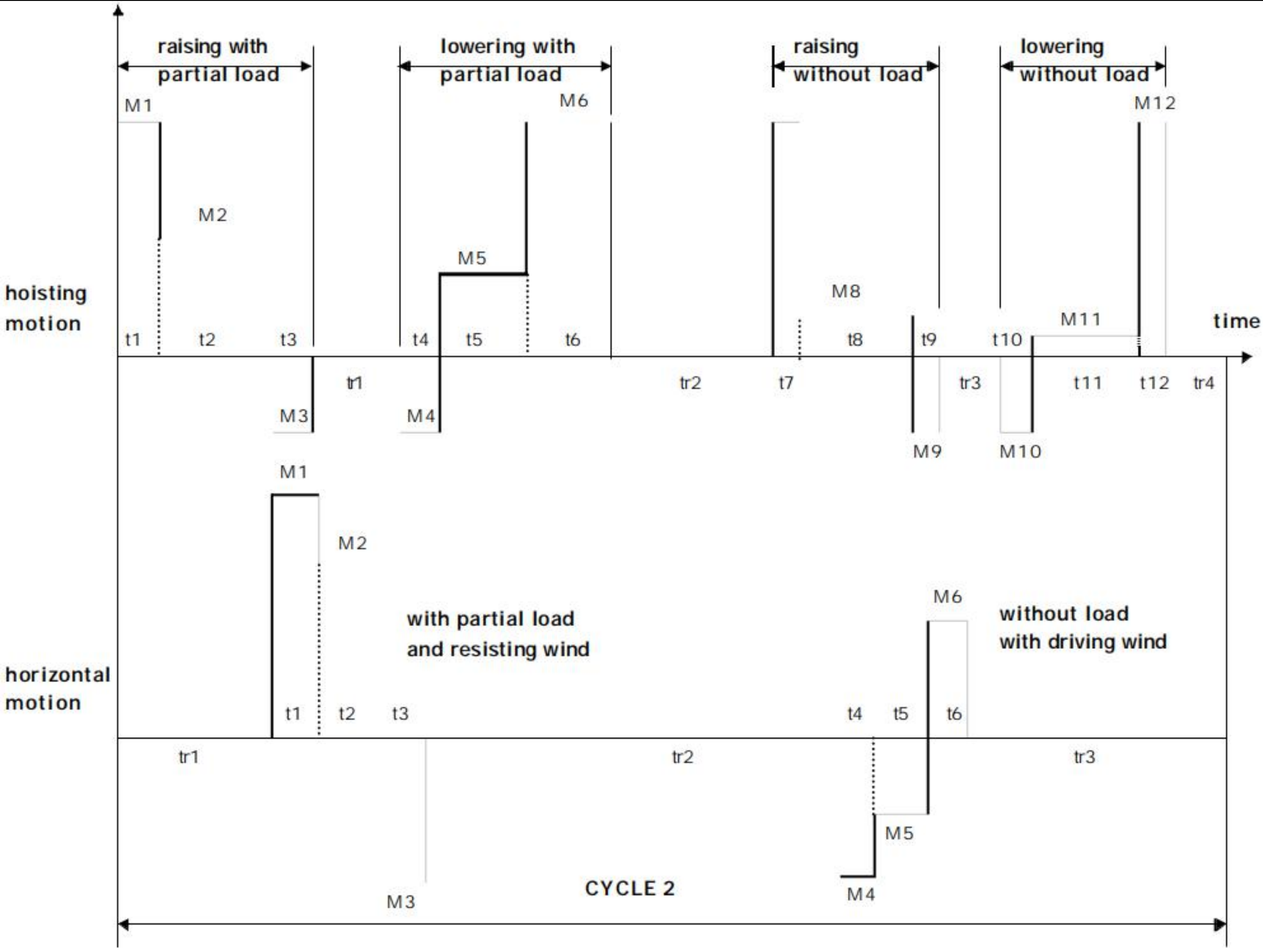


Diagram 5.8.1.3.1.

Typical torques for 2 different operating cycles:

Hoisting motion		Horizontal motion	
tr: rest time M1,M4,M7,M10,	starting torque	tr: rest time M1,M4	starting torque
M2,M8,	hoisting torque raising	M2	working torque with wind
M3,M6,M9,M12	braking torque	M3, M6	braking torque
M5,M11,	hoisting torque lowering	M5	torque without load with wind

5.8.1.3.2 Mean equivalent power

$$P_{med} = \frac{M_{med} \times n_m}{9550}$$

Where:

M_{med}= mean equivalent torque[N.m]

N_m=speed of motor [1/min]

If the motor is rated for S3-duty and the rating corresponds to the actual use in the particular application, then the motor can be selected according to the calculated mean equivalent power.

For S1-rated squirrel cage motors, the thermal dimensioning shall be carried out according to the method described in clause 5.8.1.4. (NOTE: applies only for direct starting motors).

For the motor selection, the mean equivalent power P med should be corrected as a function of altitude if it exceeds

1000 m and the ambient temperature if it deviates from 40 °C (See 5.8.1.5.).

5.8.1.4. Squirrel cage motors with direct starting

The following inequality has to be fulfilled for the thermal dimensioning of squirrel cage motors:

$$C_k(1-\eta_N)*P_N*T>(1-\eta_{mcy})*P_{mcy}*t_N+(P_N*t_E*I_N*I_D/I_N)-(J*n_{mcy}^2*10^{-3}/182)$$

NOTE: Subscript "cy" refers to cycle.

$(1-\eta_N)*P_N*T$	loss energy of the motor working at its rated power (S1) during a time T
$(1-\eta_{mcy})*P_{mcy}*t_N$	loss energy of the motor during the time t_N(constant speed) in a cycle
$(P_N*t_E*I_D/I_N)-(J*n_{mcy}^2*10^{-3}/182)$	loss energy of the motor during the starting and braking phases
C_k	correction factor linked to the type of motor
P_N	nominal power [kW] of the motor in continuous (S1) duty
η_N	efficiency of the motor at P_N
P_{mcy}.	$M_{mcy}*n_{mcy}/9\,550$ [kW]
n_{mcy}	speed of motor [1/min] for power P_{mcy}
M_{mcy}	mean resisting torque [N.m] calculated in the same manner as M_{med} (see clause 5.8.1.3.1) but not including the starting and braking phases.
η_{mcy}	efficiency of the motor at power P_{mcy}
T	total time of cycle [s], $= t_N + t_E + t_r$
E_D	cyclic duration factor (see clause 5.8.1.6.) $= 100*(t_N+t_E)/T$
t_N	operating time [s] at constant speed during one cycle.
t_E	equivalent time [s] of starting and braking during one cycle, $=(\pi/30)*n_{mcy}*J/M_{acc}/(d_{ccy}+0{,}5*d_{icy}+3*f_{cy})$
t_r	total rest (idle) time [s] during one cycle.
J	total inertia of masses in motion referred to the motor shaft [kgm2].
d_{ccy}	the number of complete starts during one cycle
d_{icy}	the number of impulses during one cycle
f_{cy}	the number of electrical brakings during one cycle
M_{acc}	the mean accelerating torque [Nm], $= M_{Dmcy} - M_{mcy}$
M_{Dmcy}	mean starting torque of motor [Nm]

The following data has to be indicated by the motor manufacturer:

P_N	nominal power [kW] of motor in continuous (S1) duty
$\eta_{1/4\ ...\ 5/4}$	efficiency for 1/4 PN ... 5/4 PN powers
J_M	moment of inertia of motor [kgm2]
$n_{1/4\ ...\ 5/4}$	speed of motor at 1/4 PN ... 5/4 PN [1/min]
M_{Dmcy}	mean starting torque of motor in [Nm]
I_D/I_N	ratio between the starting current and the current at P_N P_N
C_K	correction factor linked to the type of motor

In case the Ck factor is not mentioned in the manufacturer's catalogue, Ck shall be taken equal to 1 for motors of polarity equal or above 4. 5.8.1.5. Power correction in function of ambient temperature and altitude

These corrections are depending from the type of motor, the cooling method and the insulation class.

The precise calculation can only be made by the motor manufacturer in supplying them with the following indications:

-P_{med} without correction

-value of ambient temperature

-Altitude

The thermal dimensioning can be based on the formulas below and on the values of k indicated in Diagram 5.8.1.5:

$$P'_{med} = P_{med} / k \quad \text{or} \quad P'_{mcy} = P_{mcy} / k \text{ (for squirrel cage motors)}$$

P'_{mcy} or P'_{med} = required nominal power of motor as function of altitude and ambient temperature.

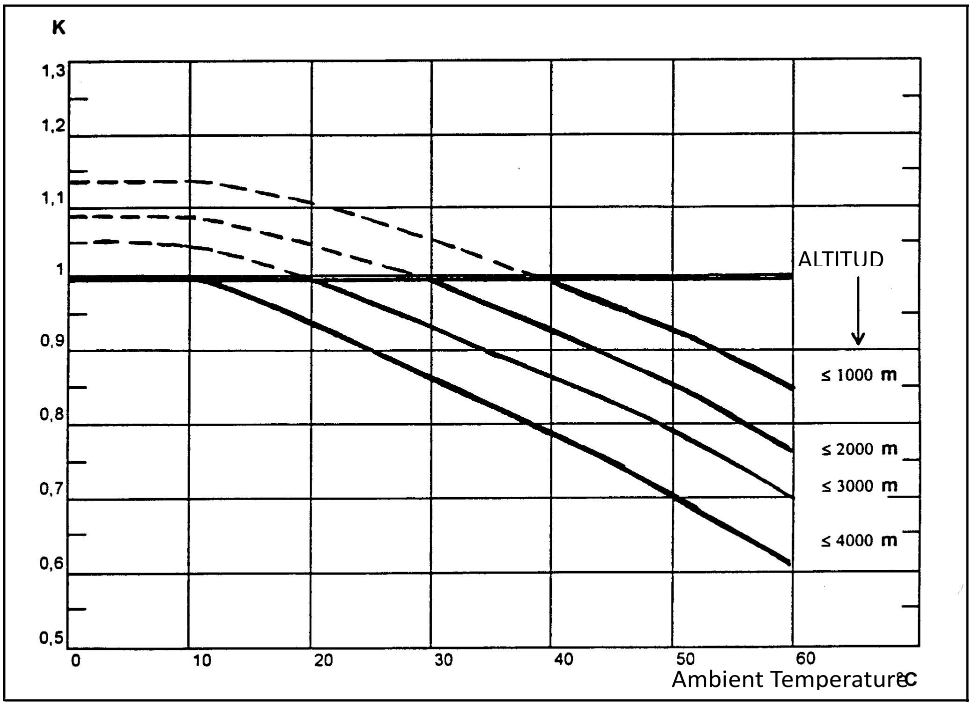


Diagram 5.8.1.5 = Correction factor k as function of ambient temperature and altitude

Note 1: The k > 1 coefficient values are to be applied only by agreement between the motor manufacturer and the hoisting appliances manufacturer.

Note 2: The ambient temperature shall be indicated above an altitude of 1000 m.

5.8.1.6 Cyclic duration factor and number of working cycles per hour

The cyclic duration factor is given by the following formula:

ED = Operating time / (Operating time + idle time) * 100(%)

The operating time and the number of operations per hour of the motors as well as the number of working cycles of the crane, are an important base for the thermal definition of the motors and which should be agreed between the user and the manufacturer of the crane. In case it is not possible to give these indications in a precise manner, it should be referred to tables T 5.8.2.2 a and T 5.8.3.2 a.

5.8.2 Motors for vertical motions

5.8.2.1 Determination of required torque

For a hoisting motor, the required power to raise the maximum nominal load (P Nmax) is defined in kW in taking account of the configuration of the transmission and of the reeving according to the following formula:

$$P_{Nmax} = L * VL * 10_{-3} * \eta$$

Where:

L = maximum nominal permissible lifting force [N]

VL = lifting speed [m/s]

η = efficiency of machinery

The required torque to raise the maximum nominal load is:

$$M_{N\,\max} = \frac{P_{N\,\max} \times 9550}{n}$$

n = rotation speed of the motor [1/min]

In order to be able to develop the necessary torque for acceleration, for lifting the test load or for compensating for variations in the mains voltage and frequency, the torque developed by the motor must satisfy the following minimum condition:

-For squirrel cage motors with direct starting:

$$\frac{M_{\min}}{M_{N\,\max}} \geq 1.6$$

Where M_{min} is the minimum torque of the motor during starting.

-For slip ring motors:

$$\frac{M_{\min}}{M_{N\,\max}} \geq 1.9$$

with M_{max} being the maximum torque of the motor.

-For all types of motors which are fed by voltages and /or variable frequencies:

$$\frac{M_{\min}}{M_{N\,\max}} \geq 1.4$$

The mechanical braking torque at the motor shaft (MF) should at least be equal to:

Static $M_F \geq 2 * M_{Nmax} * \eta^2$ Dynamic $M_F \geq 1.6 * M_{Nmax} * \eta^2$

Definition of the braking torque:

-Static: is the required minimum torque to prevent the SWL (safe working load) rotating the machinery.

-Dynamic: is the braking torque produced by the brake during the whole duration of a braking cycle.

In case electrical braking is applied, it shall be capable to slow down the load in complete safety.

5.8.2.2. Cyclic duration factor and number of cycles per hour

In the case where no precise indications are given, the values mentioned in Table T 5.8.2.2.a can be chosen.

Table T.5.8.2.2.a.

Indications for the number of cycles per hour and the cyclic duration factor for the vertical motions

Type of appliance		Particulars concerning nature of use	Number of cycles Per hour	Type of Lifting mechanism ED%
No	Designation			
1	Hand-operated (=not motorised) appliances			
2	Erection cranes		2-25	25-40

3	Erection and dismantlingcranes for power stations, machine shops, etc.		2-15	15-40
4	Stocking and reclaiming transporters	Hook duty	20-60	40
5	Stocking and reclaiming transporters	Grab or magnet	25-80	60-100
6	Workshop cranes		10-50	25-40
7	Overhead travelling cranes,	Grab or magnet	40-120	40-100
	pigbreaking cranes			
	Scrapyard cranes			60
8	Ladle cranes		3-10	40-60
9	Soaking-pit cranes		30-60	40-60
10	Stripper cranes, open-hearth		30	60
	furnace-charging cranes		10	60
11	Forge cranes		6	40
12-a 12-b	Bridge cranes for unloading, bridge cranes for containers Other bridge cranes (with crab and/or slewing jib crane)	a – Hook or spreader duty b – Hook duty	20-60	40-60
13	Bridge cranes for unloading, bridge cranes (with crab and/or slewing jib crane)	Grab or magnet	20-80	40-100 60
14	Drydock cranes, shipyard jib cranes, jib cranes for dismantling	Hook duty	20-50	40
15	Dockside cranes (slewing, ongantry, etc.), floating cranes and pontoon derricks	Hook duty	40 20	60 40
16	Dockside cranes (slewing, on gantry, etc.), floating cranesand pontoon derricks	Grab or magnet	25-60	60-100
17	Floating cranes and pontoon derricks for very heavy loads (usually greater than 100 t)		2-10	S1 (2) or S2 30 min
18	Deck cranes	Hook duty	30-60	40
19	Deck cranes	Grab or magnet	30-80	60
20	Tower cranes		20	40-60
21	Derricks		10	S1 (2) or S2 30 min
22	Railway cranes allowed to run in train		10	40

1) This column comprises only some indicatory typical cases of utilisation

2) It is recommended for S1 and S2 to refer to the definition IEC 60034-1

5.8.3. Motors for horizontal motions

In order to select travel motors correctly, all the necessary torque (or power) values must be considered, taking into account the starting time, the number of starting cycles per hour and the cyclic duration factor. The maximum transmissible torque of the travel motors is limited by the adhesion of the driven travel wheels on their tracks.

5.8.3.1. Determining the necessary torque

-Speed maintaining torque

To determine the torque necessary for maintaining the speed, account has to be taken of the sum of forces (w) resisting to travel resulting from the dead-weight, the load and operating conditions such as:

-deformation of the running surface,

-friction of the wheels on straight sections and in curves,

-wind force,

-gradients in the track,

-necessary traction of power supply cable.

- Acceleration torque (running up to speed).

The acceleration torque shall take into account the sum of the acceleration forces of the mass of lifted load and of the other masses put into motion. The recommended acceleration values are given in Table T 2.2.3.1.1 (booklet 2).

The travel motors must deliver the necessary torque in the following operating conditions:

-Case I for cranes not exposed to wind

-Case II for cranes exposed to wind

The necessary torque can be calculated by the following formulae (see diagram 5.8.1.3.1)

Case I $M_1, \ldots M_n = [a * (m + m_L) + w_0] * v * 60 / (2 * \pi * n_m * \eta)$

Case II

The largest of the values from the results of the following formula shall be taken into account:

$$M_1, \ldots M_n = [a * (m + m_L) + w_8] * v * 60 / (2 * \pi * n_m * \eta)$$

and

$$M_1, \ldots M_n = w_{25} * v * 60 / (2 * \pi * n_m * \eta)$$

where:

a acceleration [m/s^2] (at constant speed a = 0)

$m = m_0 + m_{rot} * \eta$, equivalent mass [kg] of all parts put into motion, excluding the load, which is supposed to be concentrated at the suspension point of the load.

m_L mass of lifted load [kg] 提升负载的质量 [kg]

m_0 mass [kg] of the whole of the elements, excluding the load, undergoing the same horizontal motion as the suspension point of the load. 整个元件的质量 [kg],

$m_{rot} = \Sigma (J * n_x^2 / v^2) / 91,2$,equivalent mass [kg] of the inertia of rotating parts reduced to linear motion,

where:

N_x speed of rotating masses [1/min]

J moment of inertia of all rotating masses[kgm^2]

W_0, W_8, W_{25} total travel resistance [N] (w can also become negative in some cases)

W_0 at zero wind; W_8 at a wind of 80N/m^2; W_{25} at a wind of 250N/m^2

v travel speed [m/min]; n_m rotation speed of motors [1/min]; η overall efficiency of mechanism

The motor shall be selected based on the highest of the calculated torque values (M1, ... Mn) in case I and II.

For slip ring motors used for the horizontal motions, the starting resistances shall be so defined that the minimum torque delivered by the motor is never less than 1,2 times the torque required to maintain the travel speed.

5.8.3.2. Cyclic duration factor and number of cycles per hour

In the case where no precise indications are given, the values mentioned in Table T5.8.3.2.a. can be chosen.

5.8.3.3. Rotation

The calculation is carried out in an analogous fashion to clause 5.8.3.1, angular speeds being substituted for the linear speeds.

5.8.3.4. Span variation

If the span variation in the case of luffing jibs, leads to an elevation or to a lowering of the centre of gravity of the masses put into motion, the calculation can be carried out in an analogous fashion to clause 5.8.3 in inserting into the factor (w) the forces required to the vertical displacement of the centre of gravity.

Table T. 5.8.3.2.a

Indications for the number of cycles per hour and the cyclic duration factor for the horizontal motions

Type of appliance		Particulars concerning nature of use	Number Of cycles Per hour	Type of mechanism ED%		
No.	Designation			Rotation	Crab	Travel
1	Hand-operated appliances					
2	Erection cranes		2-25	25	25-40	25-40
3	Erection and dismantling cranes for power stations,machine shops, etc.		2-15		25	25
4	Stocking and reclaiming transporters	Hook duty	20-60	15-40	40-60	25-40
5	Stocking and reclaiming transporters	Grab or magnet	25-60	40	60	15-40
6	Workshop cranes		10-50		25-40	25-40
7	Overhead travelling cranes, pigbreaking cranes, scrapyard cranes	Grab or magnet	40-120		40-60	60-100
8	Ladle cranes		3-10		40-60	40-60
9	Soaking-pit cranes		30-60	40	40-60	40-60
10	Stripper cranes, open-hearth furnace-charging cranes		30 10		40 40	60 40
11	Forge cranes		6	100	25	25
12-a 12-b	Bridge cranes for unloading, bridge cranes for containers Other bridge cranes (with crab and/or slewing jib crane)	a – Hook or spreader duty b – Hook duty	20-60 20-60	15-40 25-40	40-60 40-60	15-40 25-40
13	Bridge cranes for unloading, bridge cranes (with crab and/or slewing jib crane)	Grab or magnet	20-80	40	40-100	15-60
14	Drydock cranes, shipyard jib cranes, jib cranes for dismantling	Hook duty	20-50	25	40	25-40
15	Dockside cranes (slewing, on gantry, etc.), floating cranes and pontoon derricks	Hook duty	40 20	25-40	40	15-25
16	Dockside cranes (slewing, on gantry, etc.), floating cranes and pontoon derricks	Grab or magnet	25-60	40-60		25-40
17	Floating cranes and pontoon derricks for very heavy loads (usually greater than 100 t)		2-10	15-40		
18	Deck cranes	Hook duty	30-60	40		
19	Deck cranes	Grab or magnet	30-80	60		
20	Tower cranes		20	40-60	25	15-40
21	Derricks		10	25		
22	Railway cranes allowed to run in train		10	25		

1) This column comprises only some indicatory typical cases of utilisation