

SESSION A:

EARTH MOVING AND TRANSPORTATION MACHINERY

Comparative overview of determining service classes of industrial cranes according to relevant standards and guidelines

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ABSTRACT

The service class of a crane is one of the key parameters in crane design and can be determined according to various standards. In domestic practice, the classification according to the JUS M.D1.020 standard was prevalent for a long time, defining four crane service classes based on the number of working cycles and operating time. In the past, many renowned crane manufacturers based their classification on the DIN 15020 standard, which is predicated on FEM (Fédération Européenne de la Manutention) guidelines (which consider operating time and load spectrum as the dominant classification parameters). Older versions of ISO standards are also closely linked to FEM guidelines and provide service classes equivalent to these recommendations. With the introduction of the EN 13001 series of standards and ISO 4301-1:2016, the number of operating cycles has a more significant impact on crane classification. Unfortunately, in domestic engineering practice, the newly adopted standards for industrial cranes are still not widely applied due to various uncertainties. The aim of this paper is to resolve certain uncertainties regarding the definition of crane service classes and to present, in a concise form, a comparison and the relationship between parameters according to current standards and guidelines. A brief overview of the withdrawn JUS M.D1.020 standard is also included.

KEYWORDS

Service class, Crane design, Crane classification, Classification of parameters.

1. INTRODUCTION

The service class of a crane represents one of the most important parameters in the process of designing, sizing, and assessing the service life of industrial cranes. In addition to rated capacity, lifting height, span or outreach, the service class is determined at the very beginning of the design process. The service class defines the intensity and frequency of use, the load spectrum, and the operating conditions, all of which directly influence the selection and calculation of structural elements, drive mechanisms, as well as fatigue assessment and reliability analysis.

In domestic engineering practice, [1] was long used for crane classification. It provided a relatively simple, though limited, system based mainly on the number of working cycles and operating time. Many lifting-equipment manufacturers also applied [2], which classifies service based on operating time and load spectrum. At the same time, [3] was used for cycle-based classification, while [4] was aligned with [2]. A-classes for complete cranes, based on the total number of working cycles are introduced in [5], while retaining time-based classification for hoisting mechanisms from [2]. Standard [6] was harmonized with [5], whereas [7] classifies cranes by the total number of working cycles and defines an expanded range of A-classes. The introduction of [8] marked a major shift in service classification. These standards classify cranes according to the total number of working cycles over the design life and combine this approach with limit-state design and advanced load factors. This method provides greater accuracy and better reflects actual operating conditions, but it also requires a more thorough understanding of the relevant parameters and calculation procedures. Despite the formal adoption of EN standards, domestic engineering practice still shows inconsistent use of different methodologies and uncertainty about their relationships and equivalence.

2. THE IMPORTANCE OF CORRECTLY DETERMINING THE SERVICE CLASS OF INDUSTRIAL CRANES

Industrial cranes include several drive mechanisms, such as hoisting, travelling, and slewing, each with its own service class. Because hoisting generates the greatest load effects, the hoisting mechanism's service class also determines the service class of the supporting structure, that is, of the crane as a whole. In structural safety verification during crane design, safety and dynamic factors must be selected according to the crane type, the design method used, and the assigned service class. In addition, the dimensioning of components such as drums, sheaves, ropes, and wheels depends not only on the applicable standard but also on the crane's service class. An incorrect service class can lead to oversized components, but more importantly, it can result in undersized critical elements. As noted in [10], standards [4] and [13] do not require fatigue calculations for wire ropes; rope bending cycles are not considered in design, and sizing is based only on a static safety factor.

In addition to improving safety, consistent service classification of drive mechanisms, their components, and the supporting structure helps ensure that elements selected and sized for the assigned service class have approximately equal durability in terms of operating time or number of working cycles. Another benefit of classifying individual drive mechanisms and their components is the improved clarity and mutual understanding between users and manufacturers of lifting equipment when ordering or replacing specific elements.

In practice, used industrial cranes are often sold and refurbished for continued operation over many additional years. Such sales usually involve relocating the crane, which changes the operating conditions under which it continues service after refurbishment. Therefore, it is essential to understand the service class and the parameters it includes.

3. OVERVIEW OF STANDARDS AND GUIDELINES FOR CRANE CLASSIFICATION

Crane classification is defined by several standards, with additional guidance provided by related guidelines. The following section reviews crane classification under the most relevant standards and guidelines.

3.1. JUS M.D1.020

This standard was issued in 1964 and for decades represented the basis for crane classification in domestic engineering practice, which is why cranes classified according to it can still be found in operation today. The standard defines four service classes, determined according to two primary and four secondary parameters.

Table 1 shows two primary parameters, n – number of working cycles and T_t – theoretical operating time.

Table 1: Two primary parameters of classification according to [1]

Service classes		n	T_t [h]
name	number		
light	1	to 16	to 0.5
medium	2	over 16 to 32	over 0.5 to 1
heavy	3	over 32 to 63	over 1 to 2
very heavy	4	over 63	over 2

The theoretical operating time is calculated according to the following formula:

$$T_t = T_s \cdot \left(\frac{q_r}{100} \right)^3 \quad (1)$$

Table 2 shows the other four secondary parameters, q_r – relative load, T_s – actual working hours per day, V_t – theoretical service life and T_g – annual actual working time.

Table 2: Four secondary parameters of classification according to [1]

Service classes		q_r [%]	T_s [h]	V_t [h]	T_g [h]
name	number				
light	1	to 56	2.8 to 5.6	2000	to 2000
medium	2	50 to 63	4 to 8	4000	over 2000 to 3000
heavy	3	56 to 70	5.6 to 11.2	8000	over 3000 to 4000
very heavy	4	over 63	8 to 16	16000	over 4000

Reference [9] notes that, under this standard, the service class is not determined by a combined assessment of all parameters. Instead, it is established using two essential parallel parameters, while the remaining four parameters serve only as

guidance. The standard further states that the governing parameter is the one that results in the higher, that is, more severe class. This raises a possible uncertainty as to whether all six parameters are given equal importance in classification. Reference [9] also points out the limited importance assigned to the crane's load condition, as illustrated by the relative load parameter, q_r . According to this criterion, an estimation error of only 7% may shift a crane from the 1st to the 4th service class, or vice versa. In addition, when calculating the actual annual operating time, the standard does not specify the number of days per year, whereas the calculation of theoretical service life assumes all 365 days rather than the substantially lower number of actual working days.

3.2. FEM 1.001

This is the third edition, published in 1998, and it remains valid today. The guidelines classify cranes as complete units into A-classes and serial hoisting mechanisms into M-classes, in harmonization with [6]. For A-class determination, two independent parameters are used: the number of working cycles and the load spectrum. Their combination yields a single overall class. The class based on the number of working cycles is designated U and is determined by the total number of working cycles over the crane's service life, as shown in Table 3.

Table 3: Classes U of total numbers of crane working cycles

Class of utilization	Total duration of use (number n_{max} of hoisting cycles)		
U0		$n_{max} \leq$	16 000
U1	16 000	$< n_{max} \leq$	32 000
U2	32 000	$< n_{max} \leq$	63 000
U3	63 000	$< n_{max} \leq$	125 000
U4	125 000	$< n_{max} \leq$	250 000
U5	250 000	$< n_{max} \leq$	500 000
U6	500 000	$< n_{max} \leq$	1 000 000
U7	1 000 000	$< n_{max} \leq$	2 000 000
U8	2 000 000	$< n_{max} \leq$	4 000 000
U9	4 000 000	$< n_{max}$	

The load spectrum class is determined using the load spectrum factor, which is calculated according to:

$$k_p = \sum \left[(n_i / n_{max}) \cdot (m_i / m_{lmax})^3 \right] \quad (2)$$

where:

- m_l – loads;
- m_{max} – safe working load;
- n_i – number of hoisting cycles in respect of which the hoisted load is greater than or equal to m_i ;
- n_{max} – number of hoisting cycles determining the total duration of use.

The load spectrum classes are presented in Table 4.

Table 4: Classes of load spectrum

Symbol	Cubic mean value
Q1	$k_p \leq 0.125$
Q2	$0.125 < k_p \leq 0.250$
Q3	$0.250 < k_p \leq 0.500$
Q4	$0.500 < k_p \leq 1.000$

Finally, the crane is assigned to one of the service classes listed in Table 5.

Table 5: Service classes according to [5]

Load spectrum	Class of utilization									
	U0	U1	U2	U3	U4	U5	U6	U7	U8	U9
Q1	A1	A1	A1	A2	A3	A4	A5	A6	A7	A8
Q2	A1	A1	A2	A3	A4	A5	A6	A7	A8	A8
Q3	A1	A2	A3	A4	A5	A6	A7	A8	A8	A8
Q4	A2	A3	A4	A5	A6	A7	A8	A8	A8	A8

Despite the publication of newer standards, this method remains one of the most widely used by crane manufacturers. Its main advantage is its simplicity and the clearly defined parameters for calculating the load spectrum factor. For this reason, newer ISO and EN standards, although expanded with additional classes, have retained the U and Q classifications.

3.3. ISO 4301-1:2016

This standard builds on the 1986 edition, which was harmonized with [5] recommendations, but the latest version no longer classifies hoisting mechanisms into M-classes. It also expands the A-class system: instead of the previous eight classes (A1 to A8), it defines fifteen classes, from A03 to A11. Classification is based on the number of working cycles (U-classes) and the load spectrum factor (Q_p -classes). In this edition, the number of Q_p -classes increases from four to six. The load spectrum factor is calculated in the same way as in FEM 1.001, and the Q_p -classes are shown in Table 6.

Table 6: Classes Q_p of load spectrum factors

Symbol	Load spectrum factor K_p			
Q_{p0}	0.313	K_p	$\leq$	0.0313
Q_{p1}				
Q_{p2}				
Q_{p3}	0.0625	K_p	$\leq$	0.125
Q_{p4}	0.125	$< K_p$	$\leq$	0.250
Q_{p5}	0.250	$< K_p$	$\leq$	0.500
	0.500	$< K_p$	$\leq$	1.000

It should be noted that the former Q1 class in [5] has been divided into three classes: Q_{p0} , Q_{p1} , and Q_{p2} . The overall service class A is then determined by combining the U-class and the Q_p -class, as shown in Table 7.

Table 7: Classes A for group classification

Load spectrum class	Class of utilization									
	U0	U1	U2	U3	U4	U5	U6	U7	U8	U9
Q_{p0}	A03	A02	A01	A0	A1	A2	A3	A4	A5	A6
Q_{p1}	A02	A01	A0	A1	A2	A3	A4	A5	A6	A7
Q_{p2}	A01	A0	A1	A2	A3	A4	A5	A6	A7	A8
Q_{p3}	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9
Q_{p4}	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Q_{p5}	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11

If the U-class and Q_p -class are unknown, classification may be based on the number of full-load cycles, as shown in Table 8.

Table 8: Design basis by classes

A- class	Design number of full load cycles, C_f
A03	500
A02	1 000
A01	2 000
A0	4 000
A1	8 000
A2	16 000
A3	31 500
A4	63 000
A5	125 000
A6	250 000
A7	500 000
A8	1 000 000
A9	2 000 000
A10	4 000 000
A11	8 000 000

Annex B of this standard outlines a procedure for converting the M-classes defined in the 1986 edition into the A-classes used in the current version.

In addition to A-classes, the standard also defines D-classes for average linear and angular displacements and P-classes for the average number of accelerations.

3.4. FEM 9.521

These guidelines provide a more detailed procedure for converting the time-based M-classes from [2] and [5] into the cycle-based A-classes from [7], and vice versa. They largely restate the content of [10] and include several examples of service-class conversion.

The method to transform time-based classification into cycle-based classification:

$$M \rightarrow \left(\frac{T_f}{K_m} \right) \cdot \left(\frac{1}{\alpha} \right) \cdot \left(\frac{1}{t_{av}} \right) \cdot K_p = C_f \rightarrow A \quad (3)$$

where:

- T_f – the total duration of use under full load [h];
- K_m – load spectrum factor by [5] and [6];
- α – drive utilization, this parameter describes the ratio between the duration of the cycle with load for the displacement and the average cycle time;
- t_{av} – average cycle time;
- K_p – load spectrum factor by [7].

Both K_m and K_p are load spectrum factors, but they are calculated differently.

The method to transform cycle-based classification into time-based classification:

$$A \rightarrow \left(\frac{C_f}{K_p} \right) \cdot \alpha \cdot t_{av} \cdot K_m = T_f \rightarrow M \quad (4)$$

As shown in [10], converting between M-classes and A-classes can be problematic. Changes in lifting height or hoisting speed alter the average working-cycle duration, t_{av} . For example, when converting class M5 to an A-class, reducing the lifting height from 12 m to 6 m and increasing the hoisting speed from 4 m/min to 20 m/min changes the classification from A2 to A6.

3.5. SRPS EN 13001-1:2016

In addition to crane classification, this European standard establishes the general principles for crane design using the limit-state method. It defines the U, Q (Q_p), D, and P classes in alignment with [7]. Although the standard does not provide a table combining the U and Q classes into A-classes, these classes may still be considered applicable in this context. Its main focus, however, is the definition of S-classes, which describe the stress-time history and are essential for fatigue-strength verification. S-classes are also defined in [14], which specifies requirements for verifying the structural integrity of crane steel structures. A more detailed analysis of S-classes and fatigue-strength verification is left for future research.

4. EXAMPLE OF DETERMINING THE SERVICE CLASS ACCORDING TO DIFFERENT STANDARDS

For the purposes of the example, an existing single girder workshop overhead crane shown in Fig. 1 is used.



Figure 1: Single girder bridge crane

The basic parameters of the crane are presented in Table 9.

Table 9: Basic crane parameters

rated capacity of crane	$m_Q = 3.2 \text{ t}$
dead load	$m_{DSK} \approx 32 \text{ kg}$
span	$L = 8.91 \text{ m}$
lifting height	$h = 5 \text{ m}$
load speed	$v_{max} = 11.3 \text{ m/min}$
precision load speed	$v_{min} = 1.3 \text{ m/min}$
operating conditions	standard

The crane is used to transport cast weights within the workshop hall. The mass of a single weight ranges from 460 to 470 kg. It operates 5 hours per day and performs 20 working cycles per hour: 5 cycles with one weight ($m_1 = 468 \text{ kg}$), 10 cycles with four weights ($m_2 = 1864 \text{ kg}$), 3 cycles with five weights ($m_3 = 2328 \text{ kg}$), and 2 cycles with six weights ($m_4 = 2796 \text{ kg}$).

4.1. Classification of the Crane in the Service Class According to JUS M.D1.020

Number of working cycles per hour:

$$n = 20 \quad (5)$$

Actual working hours per day

$$T_s = 5 \text{ h} \quad (6)$$

Number of working cycles per day:

$$p = n \cdot T_s = 20 \cdot 5 = 100 \quad (7)$$

The theoretical operating time

$$T_t = T_s \cdot \left(\frac{q_r}{100} \right)^3 = 5 \cdot \left(\frac{52.4}{100} \right)^3 = 0,72 \quad (8)$$

Relative load:

$$q_r = \frac{Q_s}{Q_n} \cdot 100\% = \frac{1678}{3200} \cdot 100\% = 52.4\% \quad (9)$$

Average load per day:

$$Q_s = \frac{Q_1 + Q_2 + Q_3 + Q_4}{p} = \frac{p_1 \cdot m_1 + p_2 \cdot m_2 + p_3 \cdot m_3 + p_4 \cdot m_4}{p} = \frac{25 \cdot 468 + 50 \cdot 1864 + 15 \cdot 2328 + 10 \cdot 2796}{100} \approx 1678 \text{ kg} \quad (10)$$

Based on the calculated parameters, the crane is classified as service class 2, which is consistent with the design documentation.

4.2. Classification of the Crane in the Service Class According to FEM 1.001

Determination of the U-class:

Number of working cycles during the service life of the crane:

$$n_{max} = p \cdot N_{wd} \cdot N_y = 100 \cdot 260 \cdot 10 = 260000 \quad (11)$$

Number of working days per year:

$$N_{wd} = 260 \text{ days} \quad (12)$$

Design service life:

$$N_y = 10 \text{ years} \quad (13)$$

Based on the total number of working cycles over the crane's service life, the crane is classified as U5.

Determination of the Q-class:

$$\begin{aligned} k_p &= \frac{n_1}{n_{max}} \cdot \left(\frac{m_{l1}}{m_{lmax}} \right)^3 + \frac{n_2}{n_{max}} \cdot \left(\frac{m_{l2}}{m_{lmax}} \right)^3 + \frac{n_3}{n_{max}} \cdot \left(\frac{m_{l3}}{m_{lmax}} \right)^3 + \frac{n_4}{n_{max}} \cdot \left(\frac{m_{l4}}{m_{lmax}} \right)^3 = \\ &= \frac{p_1 \cdot N_{wd} \cdot N_y}{n_{max}} \cdot \left(\frac{m_{l1}}{m_{lmax}} \right)^3 + \frac{p_2 \cdot N_{wd} \cdot N_y}{n_{max}} \cdot \left(\frac{m_{l2}}{m_{lmax}} \right)^3 + \frac{p_3 \cdot N_{wd} \cdot N_y}{n_{max}} \cdot \left(\frac{m_{l3}}{m_{lmax}} \right)^3 + \frac{p_4 \cdot N_{wd} \cdot N_y}{n_{max}} \cdot \left(\frac{m_{l4}}{m_{lmax}} \right)^3 = \end{aligned} \quad (14)$$

$$\begin{aligned}
&= \frac{25 \cdot 260 \cdot 10}{260000} \cdot \left(\frac{468}{3200}\right)^3 + \frac{50 \cdot 260 \cdot 10}{260000} \cdot \left(\frac{1864}{3200}\right)^3 + \frac{15 \cdot 260 \cdot 10}{260000} \cdot \left(\frac{2328}{3200}\right)^3 + \frac{10 \cdot 260 \cdot 10}{260000} \cdot \left(\frac{2796}{3200}\right)^3 = \\
&= \frac{65000}{260000} \cdot \left(\frac{468}{3200}\right)^3 + \frac{130000}{260000} \cdot \left(\frac{1864}{3200}\right)^3 + \frac{39000}{260000} \cdot \left(\frac{2328}{3200}\right)^3 + \frac{26000}{260000} \cdot \left(\frac{2796}{3200}\right)^3 = \\
&= 0.00078 + 0.099 + 0.058 + 0.067 = 0,225
\end{aligned}$$

According to the load spectrum factor, the crane belongs to class Q2. By combining classes U5 and Q2, the crane is classified into service class A5, which is consistent with the recommended grouping based on the intended use of the crane.

4.3. Classification of the Crane in the Service Class According to ISO 4301-1:2016

Because the U-classes defined in [5] are harmonized with those in [7], the utilization class based on the total number of service-life cycles remains U5. The Q_p -class, however, differs from the Q-classes in [5], although the load spectrum factor is calculated in the same way. With $K_p = k_p = 0.225$, the crane is classified as Q_p3 . Combining U5 and Q_p3 yields service class A5. This classification is consistent with the framework of [12] for bridge and gantry cranes.

5. CONCLUSION

Over the past two decades, crane service class definitions have changed, mainly due to national standardization practices. Most European manufacturers now classify cranes and their mechanisms according to ISO standards and FEM guidelines, as most national standards have been harmonized with current international standards. However, many industrial cranes designed under former Yugoslav standards remain in service across Serbia and other countries of the former Yugoslavia. Therefore, understanding technical parameters defined in these withdrawn standards, particularly service class, remains important for users and designers involved in maintenance, reconstruction, and modernization. Practical assessment of the remaining service life of such cranes primarily requires an accurate comparison between the service-class parameters defined in withdrawn national standards and those used in current international standards, which are based on a more advanced theory of material fatigue. This paper provides a concise overview of the key parameters defined in the relevant standards and guidelines and, through a classification example, demonstrates their application in determining crane service class. Because the theoretical background is much broader and more complex than can be covered here, future research will address the design approach for new cranes in accordance with the EN 13001 series of standards.

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