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Significance of chain quality in work safety

From the point of view of the working environment, the quality of the chain used in lifting devices is very important. An important element in hoists and cranes is the short link chain, which largely affects the safety of the worker operating the crane. The article discusses the basic elements affecting the quality and safety of a chain. This analysis clearly shows that, when choosing a supplier, users of these products should be guided not only by the price but, above all, the certificates and attestations that the manufacturer provides for the product.

Key words: *chain, hoist/winch, quality, work safety*

1. INTRODUCTION

The work environment exerts a great influence on the health and quality of life of the employee, as it is made up of a set of material and psycho-social factors that the employee comes into contact with during their work or preparation for it. The material factors of the work environment include (among others) the premises of an enterprise or institution, buildings, rooms, machines, tools, and devices along with factors of a physical and chemical nature (e.g., microclimate, lighting, vibrations, noise, mechanical factors, and chemical or dust substances) as well as biological agents. In contrast, psychosocial (non-material) factors in the work environment include psychological demands, organizational factors, employee participation, interpersonal relationships, career development, and organizational culture, among others [1, 2].

The article discusses one of the elements of the work environment in the industry affecting worker safety; namely, the hoisting equipment, an important operational element of which is a chain.

Cranes are a group of lifting and transporting devices used to move loads, animals, and people vertically or horizontally for short distances in intermittent motions. In the classic literature [3], we can distinguish jacks, lifts, trolleys, gantries, and cranes in the division of hoisting equipment. Due to the issues raised in the present article, the authors are interested in cranes, which are divided into such devices as winches and hoists, among others. These two devices (cranes) are designed for the vertical lifting of a load by means of a rope or chain with the use of a gripping element, usually a hook; the difference between them consists of the attachment of the supporting structure. Depending on the design, these devices can be used in various areas such as heavy construction and the automotive or wood industries [4].

In many cranes (especially hand-operated ones), chains are used as the lifting element. The chains are also used as components of hoisting chains for tying and hanging loads on the hooks of manual and mechanical lifts.

Chains used in cranes as lifting elements can be divided into two types: link chains and plate link chains (also known as Gall's chains) – Figure 1. These two types of chains are called technical chains, which are irreplaceable in many branches of industry and economy and are designed to carry larger loads.

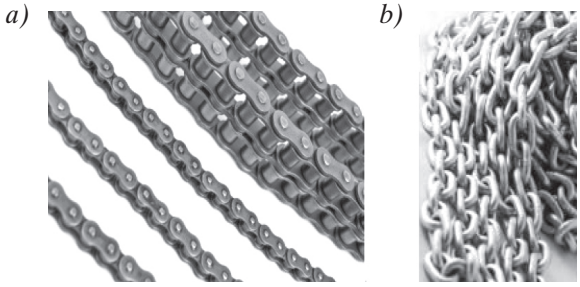

Fig. 1. Gall's roller drive chain (a); link lifting chain (b)

The basic characteristic of a chain is the so-called chain size. This value is defined as the product of the

diameter of the bar from which the link is made (d) and the largest internal dimension "p" called the chain pitch. In addition, the link is characterized by the following values: "a" – the internal length measured in the link's light; "b" – the outer link width; and "L11p" – the internal length of a chain with 11 links [5]. The dimensions of a link are presented in Figure 2. Depending on the length of the link, we divide chains into short- and long-linked ones. A short-link chain is a chain whose link length does not exceed 5 times the diameter of the rod from which the link is made (d) and the width (b) is not greater than 3.5 times the diameter of the bar. If the link length exceeds 5 times the diameter of the bar (d), a chain is classified as a long-link one.

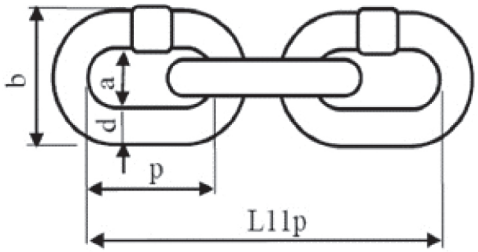

Fig. 2. Dimensions of link/chain [5]

Short-link chains are used in a number of mechanical devices, mainly as drive chains cooperating with socket wheels and support slings in hoists. Chains with long links are general-purpose chains and are used especially in the mining industry.

In the article, attention will be given to chains with short links, which are used primarily in hoists and winches.

Depending on the type of drive, hoists can be divided into manual, electric, and pneumatic devices. On the other hand, the division due to the type of band used divides these devices into chain or rope ones. Examples of such hoists are presented in Figure 3.

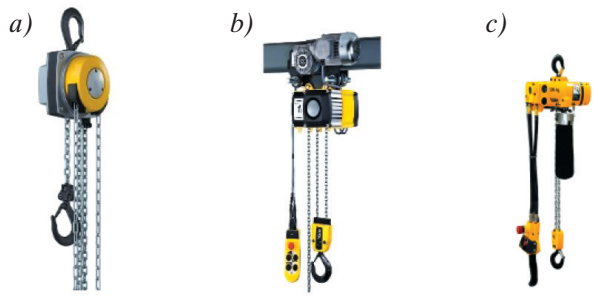

Fig. 3. Examples of hoist types: a) yale lift 360 manual chain hoist; b) CPV electric drive chain hoist; c) CPA 1–13 pneumatic drive chain hoist

Chains with short links for lifting loads can be used in many industrial and economic sectors, including in the underground excavations of mines as well as in areas with coal dust and methane explosion hazards, among others.

There are several manufacturers of such chains on the Polish market: Pewag Poland Sp. z o.o., Grupa RUD, THIELE, and Retezarna a.s., among others.

2. LEGAL REQUIREMENTS FOR CHAINS WITH SHORT LINKS

In the mining industry, chain hoists are used for short-distance transport, which enables the assembly of machine and equipment components as well as the transfer of materials. Due to the difficult operating conditions in limited spaces of excavations and assembly chambers, hoisting equipment intended for the mining industry must be characterized by high lifting speed, low weight, small dimensions, and operational safety in addition to the appropriate lifting capacity [6].

An important operating element in these devices is the chain, which largely determines the safety of the worker operating the crane. Each chain used in industry within the European Union must comply with Directive 2006/42/EC of the European Parliament and of the Council of May 17, 2006, on machinery, which refers to the safety and protection of the health of workers working with devices and machines whose moving element is a chain, among other things. Therefore, chains intended for lifting loads that are normally used in the EU (including Poland) must be manufactured in accordance with the above directive and with the requirements of such standards as:

- EN 818-2 + A1. The standard for medium tolerance chains for chain clamps – Class 8 (800 MPa) characterized by the ratio of safety factors 4 : 2.5 : 1 (breaking force/test force/load capacity). The chain must be tested. The temperature limits are –40° to +400°C.
- EN 818-7 + A1. The standard describing the requirements for the chain of a hoist/chain winch depending on the design, weight of the load, and environment in which it is used.

A *T* chain used in hoists/winches with manual drives or in hoists with low speed motor drives that do

not work under abrasive conditions. The chain safety factor should have a ratio of 4 : 2.5 : x (breaking force/test force/load capacity in accordance with ISO 4301-1 drives). The chain should be calibrated and tested. The temperature limits are –40°C to +200°C.

A DAT chain is used in hoists/winches with motor drives that reach high speeds combined with high work intensity in places where resistance to abrasion is required; this is connected with increasing the durability of the chain. The safety factor should have a ratio of 4 : 2.5 : x (breaking force/test force/load capacity in accordance with ISO 4301-1 drives). The chain should be calibrated and tested. The temperature limits are –20°C to +200°C.

A DT chain used in hoists/winches with motor drives operating in abrasive working conditions. The safety factor should have a ratio of 4 : 2.5 : x (breaking force/test force/load capacity in accordance with ISO 4301-1 drives). The chain should be calibrated and tested. The temperature range is –10°C to +200°C.

In addition, the following technical standards and legal acts are in force in Poland, whose fulfilment guarantees the chain user's safety. These are (among others) such documents as:

- PN-G-46732:1997: *Mining chain hoists – calibrated short-link chains*;
- *Safety requirements considering the provisions of the "Geological and Mining Law" Act of June 9, 2011* (Journal of Laws of 2017, item 2126, as amended);
- *Regulation of the Minister of Economy of June 28, 2002, on work health and safety, operation, and specialized fire protection in underground mining facilities* (Journal of Laws of 2002, No. 139, Item 1169);
- *Act of December 12, 2003, on general product safety* (Journal of Laws of December 31, 2003);
- PN-EN 10025:2002: *Hot-rolled products made of structural steel*;
- PN-EN ISO 643:2013-06: *Steel – Micrographic grain size determination*;
- PN-EN ISO 6507-1:2018-05: *Metals – Vickers hardness measurement – Part 1: Test method*.

3. TECHNICAL REQUIREMENTS FOR CHAINS WITH SHORT LINKS

The Retezarna a.s. company has chains of standard sizes in its offer, which are presented in Table 1. In addition to the standard sizes, custom chains can be produced at the customer's special request [5].

Link chains are made of steel with tensile strengths suitable for any given chain class. They consist of links welded in fire or electrically.

Table 1

Standard chain sizes offered by Retezarna a.s. [5]

Chain size $d \times p$	d		p	a no lower than	b no greater than	Weight of 1 m of chain	Nominal length $L = 11 \times p$	Tolerance	Max. weld diameter
[mm]						[kg]	[mm]		
4 × 12	4	±0.2	12	4.8	13.6	0.35	132	0.6	4.3
5 × 15	5	±0.2	15	6.0	17.0	0.54	165	0.8	5.4
6 × 18	6	±0.2	18	7.2	20.4	0.8	198	1.0	6.5
7 × 21	7	±0.3	21	8.4	23.8	1.1	231	1.1	7.6
8 × 24	8	±0.4	24	9.6	27.2	1.4	264	1.3	8.6
9 × 27	9	±0.4	27	10.8	30.6	1.8	297	1.4	9.7
10 × 30	10	±0.4	30	12.0	34.0	2.2	330	1.6	10.8
11 × 31	11	±0.4	31	13.2	37.4	2.7	363	1.7	11.9
12 × 36	12	±0.5	36	14.4	47.6	3.1	396	1.9	13.0
13 × 39	13	±0.5	39	15.6	44.2	3.7	429	2.1	14.0
14 × 42	14	±0.6	42	16.8	47.6	4.3	462	2.2	15.1
16 × 45	16	±0.6	45	19.2	54.4	5.6	528	2.5	17.3
18 × 54	18	±0.9	54	21.6	61.2	7.0	594	2.9	19.4
20 × 60	20	±1.0	60	24.0	68.0	8.7	660	3.2	21.6
22 × 66	22	±1.1	66	26.4	74.8	10.5	726	3.5	23.8

Welded chains for T-class chain hoists and winches (T, DAT, DT) must be characterized by high quality, excellent usability, and long service life. To achieve this, they must be manufactured with the utmost care so as to ensure safety during their use.

The parameters determining the quality and safety of chains are their mechanical properties and loads, among others. For the production of chains for winches/hoists, steel with mechanical properties in accordance with PN-EN 10025 [7–9] is used so that the final product meets all of the requirements set out by the stringent European norms in accordance with the PN-EN 818-7 and PN-G-46732 standards. The EN8-18-7 + A1: 2008 European standard (which is also in force in Poland) sets out clearly defined requirements for the type of steel the chain is made of, the process in which the steel is made, and what its chemical composition should be. Tables 2 and 3 present the requirements for the content of specific elements in the steel.

In order to protect the chain against aging during its use, the steel should contain at least 0.025% aluminum (Al).

Another important element affecting the safe use of a chain is its quality, with particular attention to deviations from the dimensions that were included in Table 1. In addition, PN-EN 818-7 requires the manufacturer to use a complex program of product quality tests to ensure a chain's safety during its operation. Particular emphasis is placed on the use of the appropriate steel grades as materials from which T-class short chain elements are made. Each delivery to the customer must be marked with the manufacturer's mark, chain thickness, production batch number, chain length, and number of pieces in the series. At the end of every meter of a chain, there is a mark containing the manufacturer's mark, year of production, number denoting the month of production, and chain's class (T, DAT, or DT – for the 818–7 standard; 5.6 or 8 for the PN-G-46732 standard) – Figure 4.

Fig. 4. Mark placed every meter at the ends of a chain

Chains produced by Retezarna a.s. meet the requirements set by the standards for the selected products.

Table 2

Chemical composition of steel for production of hoist chains – alloying elements [7]

Element	Minimum mass share in percent determined in cast analysis		
	type T	type DAT	type DT
Nickel (Ni)	0.40	0.7	0.9*
Chromium (Cr)	0.40	0.40	0.4
Molybdenum (Mo)	0.15	0.15	0.15

* Higher surface hardness and/or greater hardening depth require higher nickel content to avoid brittleness

Table3

Sulphur and phosphorus content in steel for production of hoist chains [7]

Element	Minimum mass share in percent determined in	
	cast analysis	control analysis
Sulfur (S)	0.020	0.025
Phosphorus (P)	0.020	0.025
Total sulfur + phosphorus	0.035	0.045

To emphasize the high quality and safety of use, the chains produced by Retezarna a.s. have the H45 mark (Manufacturer's ID) given by the DGUV Deutsche Gesetzliche Unfallversicherung certification body guaranteeing the product's compliance with the PN-EN 818-7 standard [2, 10]. Figure 5 shows the stamped quality mark on a chain link.

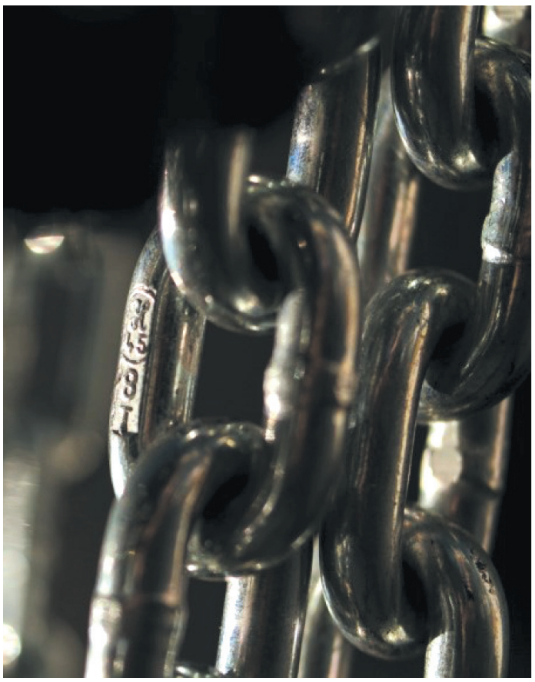

Fig. 5. H 45 quality mark embossed on chain link

Observation of the market of chain suppliers for various types of hoists and winches justifies the opinion that there are suppliers on the market who do not meet the requirements of the EU directive. Inconsistencies can be observed in the Declaration of Conformity, among others, which shows the discrepancy between the qualitative parameters of the chain and requirements contained in the Directive. This is particularly important for high-strength chains; e.g., DAT. The most common nonconformity is the use of inadequate steel; e.g., manganese steel, inadequate proportions of the Ni, Cr, Mo elements, or the absence or insufficient content of aluminum. The authors of the present article emphasize that customers pay particular attention to this issue when choosing a chain manufacturer, as it has a direct impact on the safety of the chain's users.

4. CONCLUSIONS

The development of mechanization systems in various branches of industry (including mining) requires the use of auxiliary devices that facilitate assembly, service, and transport work. Moving heavier and heavier weights requires the use of devices with increasingly better technical parameters. One such device belonging to the so-called "small mechanization" are winches and chain hoists [11]. In addition to the technical and constructional parameters of these devices, the chains with which goods are moved also affect their operation and safety. Therefore, from the point of view of work safety, the quality of the chain used is very important. The present article only indicates the basic elements and determinants that affect the quality of a chain. From this analysis, it is clear that, it should be noted whether the product has a certificate with the designation $\varkappa$ when choosing chains (which is a prestigious certificate ensuring that the manufacturer meets the requirements of the European standards). It is also necessary to verify the mechanical properties of the material from which the chains are made and pay attention to their quality. For each chain intended for hoists and winches, the customer should receive documents such as a declaration of conformity, manual, and inspection certificate. A material certificate is not required, but the chain producer should provide it upon a client's request. Additionally, a confirmation of the quality of the material used and the manufacturing of the chain is the manufacturer's certificate, which is supplied with the product.

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References

[1] https://www.ciop.pl.
[2] Midor K.: *Significance of the quality of short – link chains for work environment*, in: Ulewicz R., Hadzima B. (ed.), *12th International Conference Quality Production Improvement 2018 – QPI'18. Book Series: MATEC Web of Conferences 17 Ave du Hoggar Parc d activites Coutaboeuf BP 112, F-91944 Cedex a, France: EDP Sciences*, 2018.
[3] Piątkiewicz A., Sobolski R.: *Dźwignice*, t. 2, WNT, Warszawa 1977.
[4] www.snoork.pl.
[5] PPUH "Anima" Krzysztof Śleziak: *Warunki techniczne wykonania i odbioru*, nr ANW-17.06/WT.

[6] Cebula D., Kalita M.: *Proces projektowania wciągników łańcuchowych*, "Maszyny Górnicze" 2014, 1: 22–28.
[7] PN-EN 818-7:2002+A1:2008: *Bezpieczeństwo – Łańcuch o ogniwach krótkich do podnoszenia ładunków – Część 7: Dokładny łańcuch dźwignicy – Klasa T (Typy T, DAT i DT).*
[8] PN-G-46732:1997: *Wciągniki górnicze łańcuchowe – Łańcuchy krótkoogniwowe kalibrowane*.
[9] PN-EN 10025:2002: *Wyroby walcowane na gorąco z niestopowych stali konstrukcyjnych – Warunki techniczne dostawy*.
[10] Midor K., Biały W.: *Łańcuch krótkoogniwowy – determinanty wpływające na bezpieczeństwo pracy*, "Systemy Wspomagania w Inżynierii Produkcji" 2018, 7, 1: 497–505.
[11] Kalita M.: *Wciągarka łańcuchowa układaka przewodów kompleksu MIKRUS*, "Maszyny Górnicze" 2013, 3: 21–25.

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