Selection Criteria and Design of a Chain used for Lifting Application

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Abstract— Lifting chain is designed for use with hoists, cranes, winches, and other material handling equipment. It is also used in rigging slings and for lashing. There are two standard grades for lifting chain: grade 80 lifting chain and grade 100 lifting chain. Grade 80 lifting chain is made from alloyed steel and is specifically designed for overhead lifting applications. This grade of lifting chain has a good strength-to-weight ratio and excellent durability. Grade 100 lifting chain is also made of alloyed steel, but is hardened and tempered for superior durability and fatigue resistance. Most Grade 100 lifting chain is made of Herc-Alloy 800, a heat-treated alloy with very high strength. Although many types of chain fittings are available, Grade 80 fittings should not be used with Grade 100 chain. Selecting lifting chain requires an analysis of performance specifications. Lifting chain size is measured in inches (in.) or millimeters (mm). Common sizes include 7/32 in. (5.5 mm), 9/32 in. (7.0 mm), 5/16 (8.0 mm), 3/8 (10.0 mm), 1/2 in. (13.0 mm), 5/8 in. (16.00 mm), 3/4 in. (20.0 mm), 7/8 in. (26 mm), and 1 1/4 in. (32.0 mm). Nominal dimensions include inside length and inside width. Other important considerations for choosing lifting chain are the approximate number of links per foot (ft.) and the approximate weight (lbs.) per 100 ft. When working with lifting chain, working load limit and rated capacity vary with the angle of use and the number of lifting chain used in a sling. For example, a single 5.5 mm lifting chain may be rated for 2100 lbs. at 90 degrees. A double 5.5 mm lifting chain may be rated for 60, 45, or 30 degree use with working loads of 3600, 3000, and 2100 lbs. respectively. Lifting chain should meet requirements from organizations such as the U.S. Occupational Safety and Health Administration (OSHA), the American Society for Testing Materials (ASTM), and the International Standards Organization (ISO). Working load limits for Grade 80 and Grade 100 lifting chain are based on a 4 to 1 design factor from ISO. By testing all these parameters of chain we can easily select the required dimension of chain link for lifting purpose.

Key words: Lifting Chain, Grade 80, Grade 100, ASTM, OSHA, ISO

I. INTRODUCTION

Chains are extensively used in many different sectors of industry. According to their intended use there exist two major chain types. The first type is designed for transferring power in machines, so the links need to mesh with the teeth of the sprockets. A well-known example is the roller chain, which is used to drive the wheels in a bicycle. The second major type is designed for lifting, pulling or securing. Such link chains consist of a moving series of interconnected links or shackles, which are often torus-shaped and usually made of metal It is a well-known problem that link chains are susceptible to wear. Due to the applied normal force and the relative movement between the shackles the chain wears out. This wear leads to thickness reduction of the shackles, resulting in a loss of strength. This can cause chain fracture, to detrimental effect. For example, if the lifting chains of a hoist break dangerous situations could occur. For this reason they should be inspected thoroughly. These chains are used in bicycle locks, anchor chains, hoists, etc.

A chain is manufactured from hot rolled bar formed into short, uniform links of round bar formed into shape and welded to closure. The barrels of the links are the two parallel straight edges, including the welded join. Chains are generally fitted with a hammerlock end to join them to rings or hooks. Multiple lengths of chain can be joined onto a single ring to form a multi-leg sling.

Chain slings are rugged, robust and strong, however they are heavy, bulky and can be damaging to soft or finished surfaces. The strength of a chain sling relies on spreading load equally across all the links of the sling. Point loading of slings, where slings are wrapped around sharp corners should be avoided by packing the sling.

II. SELECTION OF CHAIN SLINGS

Chain slings come in a variety of lengths and combinations of hooks and components, depending on the lifting application. The chain manufacturers have specified a variety of chain testing and safety standards in American Society of Mechanical Engineers (ASME) B30.9, ASTM-A906, and the National Association of Chain Manufacturers. Any chain sling used for lifting must have suitable characteristics for the type of load hitch and environment used and must be in accordance with ASME B30.9, Sections 9-1.5 and 9-1.8.

The working load limits (WLL), or rated capacity of chains and slings, is determined by the "grade" of the chain and its components. For overhead lifting, only high-grade alloy steel chains and components may be used. These devices must meet a variety of strict quality standards such as minimum breaking strength, fatigue testing, and heat resistance.

The most commonly used chains for overhead lifting are rated at Grade 80, however, the industry is moving to the safer and stronger Grade 100 and Grade 120 chains. The WLL and lifting capacity increases as the grade increases. For example, a 3/8 inch Grade 80 chain has a WLL of 7100 pounds, a 3/8 inch Grade 100 chain has a WLL of 8800 pounds, and a 3/8 inch Grade 120 chain has a WLL of 10,600 pounds—50% higher than Grade 80. For safety reasons, each chain and sling is rated with a 4:1 design factor. The 3/8 inch Grade 80 chain with a WLL of 7100 pounds is pull tested to 14,200 pounds and has a minimum breaking load of 28,400 pounds.

Grade 80 alloy chain slings are often selected when operating under high temperature or rigged conditions that would abrade or destroy other types of slings. They are flexible, durable, long lasting, ductile, easy to inspect, collapsible for convenient storage, and will adhere securely to the contours of a load. The most advantageous feature of

a chain sling is its ability to be repaired/ nearly any damaged component discovered during an inspection can be repaired and restores to useful condition.

Every chain or chain sling is only as strong as its weakest link, so it is very important that every component of the sling meets WLL. All chains and components must be marked by the manufacturer with a grade from which the load rating can be determined. It is important to note that a number of factors such as lifting at an angle, wrapping the chain around a load, or extreme temperature reduce the WLL of the sling substantially. These factors must be considered when determining what type of sling is necessary to lift a load.

III. WORKING LOAD LIMITS OF SLINGS

Observing the WLL is a critical safety aspect in all overhead lifting operations. Exceeding the WLL of a chain sling can cause chain failure and, consequently serious injury. To avoid hazards, consider:

- Always accurately determine the load, force, or weight that is to be lifted or carried with the chain sling.
- Do not attempt to use a chain sling without complete and accurate knowledge of the force or weight carried by each part of the sling. Even if the sling as a whole may be within the WLL, non-uniform center of gravity locations can result in unbalanced loading conditions.
- Include all applicable capacity reduction factors when determining the WLL. These factors can substantially reduce the ability of the chain sling to carry a load safely.
- Do not use slings at angles of less than 30 degrees, as measured from the horizontal plane.
- Chemically active environments can reduce the strength and WLL of an alloy steel chain sling, or even make the sling unusable.
- Shock or impact loading can substantially increase the chain sling's force to a level well beyond the WLL.
- Consult an engineer for approval prior to performing a lifting application if the load's weight or chain sling's WLL is unknown.
- All general purpose slings should be rated by the uniform load method as shown in the table below.
- Working load limit: the maximum mass which a sling is designed to support in general service.
- Manufacturing proof force (MRF) or Proof load: A load to which the chain sling shall be subjected to, in the finished condition or a load applied as a test to a section of the sling.

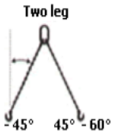
Chain size mm	Single leg 	Endless 	Two leg  0° - 45°	45° - 60°	Three and Four Leg  0° - 45°	45° - 60°
7	1.5	2.5	2.1	1.5	3.1	2.2
8	2.0	3.1	2.8	2.0	4.2	3.0
10	3.15	5.0	4.25	3.15	6.7	4.75
13	5.3	8.5	7.5	5.3	11.2	8.0
16	8.0	12.5	11.2	8.0	17.0	11.8
20	12.5	20.0	17.0	12.5	26.5	19.0
22	15.0	23.6	21.2	15.0	31.5	22.4
26	21.2	33.5	30.0	21.2	45.0	31.5
32	31.5	50.0	45.0	31.5	67.0	47.5

Table 1: Uniform Load Method of Rating

*All loads show in tonnes

Nominal size d_n mm	Chain type T	DAT	D
	Working load limits (WLL) t		
3	0,28	0,22	0,14
4	0,5	0,4	0,25
5	0,8	0,63	0,4
6,3	1,2	1	0,63
7,1	1,6	1,2	0,8
8	2	1,6	1
9	2,5	2	1,25
10	3,2	2,5	1,6
11,2	4	3,2	2
12,5	5	4	2,5
13	5,3	4,2	2,6
14	6	5	3
16	8	6,3	4
18	10	8	5
20	12,5	10	6,3
22	15	12,5	7,5
Mean stress N/mm^2	200	160	100

Table 2:Working load limit

Nominal size d_n mm	MPF kN min.	BF kN min.
3	7,1	11,3
4	12,6	20,1
5	19,6	31,4
6,3	31,2	49,9
7,1	39,6	63,3
8	50,3	80,4
9	63,6	102
10	78,5	126
11,2	98,5	158
12,5	123	196
13	133	212
14	154	246
16	201	322
18	254	407
20	314	503
22	380	608

Table 3: Manufacturing proof forces (MRF) and breaking forces (BF)

A. Formulae and Rounding Rules for Calculation of WLL, MPF and BF:

- for mean stress of 200.*N/mm2*, WLL = 0,032 035 3 d_n^2 , in tonnes;
- for mean stress of 160 *N/mm2*, WLL =0,025 628 2 d_n^2, in tonnes;
- For mean stress of 100 *N/mm2*, WLL = 0,016017 7 d_n^2, in tonnes.

IV. DIMENSION OF CHAIN LINK

A selection of nominal sizes is given in Table 1

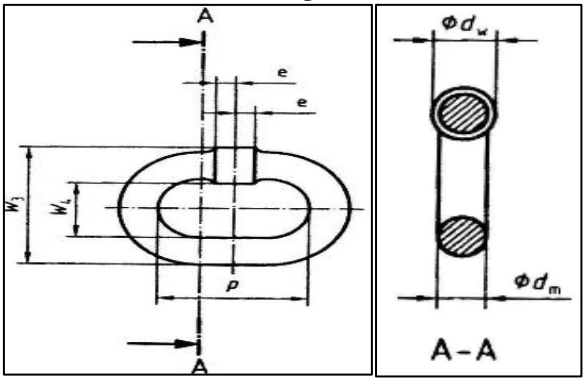


Fig:1 link and chain dimension

L = multiple pitch length
P= internal link length (pitch)
D_m= measured diameter of the material, except at the weld
D_w= measured diameter of the material at the weld
E= length affected by welding, on either side of the centre of the link
W_3 = external link width over the weld
W_4= external link width at the weld

Dimension		Pitch		Width		Gauge length $11 \times p_n$		Weld diameter
nominal d_n	tolerance	nominal p_n	tolerance [a]	internal W_4 min.	external W_3 max.	nominal	tolerance [a]	d_w max.
3	± 0,2	9	+0,18 0	3,6	10,2	99	+0,5 0	3,3
4	± 0,2	12	+0,25 0	4,8	13,6	132	+0,6 0	4,3
5	± 0,2	15	−0,3 0	6	17	165	+0,8 0	5,4
6,3	± 0,2	19	+0,4 0	7,2	20,4	209	+1 0	6,5
7,1	± 0,3	21	+0,4 0	8,4	23,8	231	+1,1 0	7,6
8	± 0,3	24	+0,5 0	9,6	27,2	264	+1,3 0	8,6
9	± 0,4	27	+0,5 0	10,8	30,6	297	+1,4 0	9,7
10	± 0,4	30	+0,6 0	12	34	330	+1,6 0	10,8
11,2	± 0,4	34	+0,7 0	13,2	37,4	374	+1,8 0	11,9
12,5	± 0,5	38	+0,8 0	14,4	40,8	418	+2,0 0	13
13	± 0,5	39	+0,8 0	15,6	44,2	429	+2,1 0	14
14	± 0,6	42	+0,8 0	16,8	47,6	462	+2,2 0	15,1
16	± 0,6	48	+0,9 0	19,2	54,4	528	+2,5 0	17,3
18	± 0,9	54	+1,0 0	21,6	61,2	594	+2,9 0	19,4
20	± 1	60	+1,2 0	24	68	660	+3,2 0	21,6
22	± 1,1	66	+1,3 0	26,4	74,8	726	+3,5 0	23,8

NOTE In this table, typical dimensions for a range of nominal sizes are given calculated and rounded in accordance with the formulae in annex A, and based upon a nominal pitch of 3 d_n. Other nominal sizes may be used, provided the dimensions and tolerances are calculated in accordance with annex A. While the nominal link pitch is based upon 3 d_n, this may be varied up to a maximum of 3.2 d_n, also subject to the tolerances specified in annex A.

[a] These tolerances are usually divided into + 2/3 and − 1/3 for both the individual link and the standard gauge length.

Table 4: Typical Dimension

A. Approximate mass of grade T hoist chain

Nominal size d_n mm	Mass kg/m ≈
4	0,35
5	0,54
6	0,8
7	1,1
8	1,4
9	1,8
10	2,2
11	2,7
12	3,1
13	3,7
14	4,3
16	5,6
18	7
20	8,7
22	10,5

Table 5: mass of grade T Hoist chain

V. CHAIN USES OF GRADE T, OAT AND OT TYPE

- Type T - hand-operated hoists or power-driven hoists with slow speeds. Where the working environment does not involve abrasive conditions.
- Type OAT - power-driven hoists where chain speeds are high, in combination with high working capacity. And where wear resistance is required to give longer chain life.
- Type OT - power-driven hoists used in abrasive conditions.

VI. HOW TO READ THE LABEL

Each chain sling is supplied with a certificate and an identification tag. The identification tag includes the name of the manufacturer, the grade of chain, the nominal chain size, the number of chain legs, the length (reach) of the sling, the rated loads for the sling assembly, and the angle upon which the rating is based. Always look for proper and clear identification, especially the WLL. Some manufacturers also provide sling warning kits that can be attached to a chain sling. The owner and user of the chain sling are responsible for maintaining and repairing the sling and its identification tags.

- Only trained individuals are allowed to use chains slings as specified by OSHA 1926.20 (a)(4)
- Operate a chain sling in strict accordance with OSHA 1910.184 and ASME B30.9
- No portion of the body shall be placed between the sling and the load or the sling and the crane or hoisting hook
- In no circumstance shall personnel stand or pass under a suspended load
- Slings may be shortened or lengthened only by methods approved by the manufacturer or a qualified person
- Sharp edges in contact with the sling should be padded to protect the sling
- Slings shall not be constricted, bunched, or pinched by the load, hook, or any fitting.

VII. CONCLUSION

In this paper, we have given a brief description of how to select the right chain link for lifting purpose. Based on the lifting load value and type of chain sling and angle between chains we can select the proper chain type. Environmental condition also affects the life and capacity of chain so operating condition should also be taken into account while selecting chain. Periodic inspection and maintenance is necessary tool for longer usage of chain and safety purpose.

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