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PROJECT MEMORANDUM

Maximum Capability Ratings for Shackles and Blocks

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Definitions

ABL	Assigned Breaking Load – per UNOLS RVSS Appendix A
BL	Breaking Load
MAOT	Maximum Anticipated Operating Tension - per UNOLS RVSS Appendix A
MPT	Maximum Permissible Tension – per UNOLS RVSS Appendix B
RVSS	UNOLS Research Vessel Safety Standards
WLL	Working Load Limit – also considered Safe Working Load SWL or Rated Load. WLL is often used catalogs.

Issue

The SWL definition in Appendix B, B.2.19 states that:

> *The maximum total load that is allowed on any given component in an OHS during normal operation. This is determined by the designer of the component and reflects the maximum total force on the component, not the line tension.*
>
> *SWL = Yield Load for the material/FS for components*
> *SWL = ABL/FS for the tension member (see Appendix A)*

If this definition is used and the MPT is compared directly to the published WLL for items such as standard shackles and blocks, it would lead to excessively large components.

The underlying purpose of Appendix B is to provide a unified code for operators to follow, establishing safe working practices, and generally fulfill the requirements of 46 CFR Subchapter U. As such, I believe it would be appropriate to size items such as shackles by comparing the MAOT to the WLL. The following sections outline the approach and provide justification for this methodology.

Proposed Approach

The proposed approach is to use the safety factors defined in Appendix A to determine the MAOT for a wire's Assigned Breaking Load (ABL). Assuming an 180˚ wrap on the block provides a load to compare to the published WLL. The standard approach in lifting rigging

is to size the wire rope and/or slings to the anticipated load with a safety factor of at least 5 to the NBL, and shackles are sized such that the calculated load is less than the WLL. This is supported in both the Crosby catalog, and API Recommended Practice 2A.

The Crosby catalog (p. 62, under "Design") states that:

> *The ultimate load is the average load of force at which the product fails or no longer supports the load. The working load limit is the maximum mass of force which the product is authorized to support in general service.*

API RP-2A Planning, Designing, and Constructing Fixed Offshore Platforms; section 2.4.2f – Slings, Shackles and Fittings states:

> *Shackles and fittings should be selected so that the manufacturer's rated working load is equal to or greater than the static sling load, provided the manufacturer's specifications include a minimum factor of safety of 3 compared to the minimum breaking strength.*

In the case of the overboard handling systems the MAOT is more analogous to the general service or static load mentioned above. Furthermore, by comparing the MAOT to the WLL a safety factor to yield of at least 1.5 above the NBL of the line is achieved. The difficulty is that MAOT is not typically known for all cases. Therefore, it is assumed that the MAOT can be established by using the RVSS Appendix A safety factors for sizing the line.

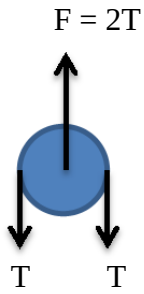
$$T = MAOT = \frac{ABL}{SF_{APP\ A}}$$

Minimum safety factor from Appendix A:

$SF_{APP\ A}=1.5$

Force on shackle assuming 180˚ wrap angle:

$$F = \frac{2 * ABL}{1.5}$$



F should be compared to WLL, substituting WLL into the equation:

$$WLL = 1.33 * ABL$$

ASME B30.26-2010, section 26-1.2 requires the design factor for shackles up to and including a 150 ton rated load shall be a minimum of 5.

Very few shackles in UNOLS fleet will exceed 150 ton rated load (WLL) and therefore should have a factor of safety of 5 from WLL to the ultimate load (P_{ult}). Note that Crosby shackles have a factor of 6 up to 200 tons WLL.

$$WLL = \frac{P_{ult}}{5}$$

$$P_{ult} = 6.65 * ABL$$

The exact material used for shackles is not known, however except for a few stainless steels (such as 304 or 316) $Sy > \frac{Su}{2}$. Therefore at a minimum:

$$P_{yield\_shackle} = \frac{6.65 * ABL}{2} = 3.32 * ABL$$

Shackle yield load is over 1.5 to the breaking load of the wire using this approach. Similarly blocks typically have a factor of 4 to ultimate from the WLL and by ASME B30.26 proof load should be at least 1.5. This results in:

$$P_{yield\_block} = 2.66 * ABL$$

Again a safety factor of over 1.5 from breaking load to yield. This may be less appropriate for blocks as it is not known if the limiting material is steel, however it is quite likely.

MPT Determination

Given the above approach either the required WLL for a wire breaking load, or the MPT of shackle or block could be calculated. Note that the required capacities and load limits are restricted such that the proof load, 2 x WLL for shackles and 1.5 x WLL for blocks, is not exceeded.

Shackles

$$WLL_{required} = 2 * \frac{ABL}{SF_{AppA}} * \frac{1}{2204 \frac{lbf}{mT} * 0.70}$$

Side Loaded Shackles - not free to rotate with load						
			Minimum Required WLL for Shackle			
			Appendix A Safety Factor			
Cable Size	**Wire BL** (lbs)	SF =	1.5 (mT)	2 (mT)	2.5 (mT)	5 (mT)
0.225 EM	5,200		4.5	3.4	3.4	3.4
0.322 EM	9,600		8.3	6.2	6.2	6.2
0.680 EM	40,000		34.6	25.9	25.9	25.9
0.681 FO	46,000		39.8	29.8	29.8	29.8
3/16"	4,000		3.5	2.6	2.6	2.6
1/4"	5,900		5.1	3.8	3.8	3.8
1/2"	25,700		22.2	16.7	16.7	16.7
9/16"	32,500		28.1	21.1	21.1	21.1

Assumptions:
1. 180˚ w rap on sheave hanging from shackle
2. 30% reduction in capacity for side loading of shackle up to 45˚.
3. Shackle loading limited so that Proof Load > 2 x BL x 0.7
4. Shackles conform to ASME B30.26, Rigging Hardw are

In-LIne Loaded Shackles - free to rotate with load						
			Minimum Required WLL for Shackle			
			Appendix A Safety Factor			
Cable Size	**Wire BL** (lbs)	SF =	1.5 (mT)	2 (mT)	2.5 (mT)	5 (mT)
0.225 EM	5,200		3.1	2.4	2.4	2.4
0.322 EM	9,600		5.8	4.4	4.4	4.4
0.680 EM	40,000		24.2	18.1	18.1	18.1
0.681 FO	46,000		27.8	20.9	20.9	20.9
3/16"	4,000		2.4	1.8	1.8	1.8
1/4"	5,900		3.6	2.7	2.7	2.7
1/2"	25,700		15.5	11.7	11.7	11.7
9/16"	32,500		19.7	14.7	14.7	14.7

Assumptions:
1. 180˚ w rap on sheave hanging from shackle
2. 30% reduction in capacity for side loading of shackle up to 45˚.
3. Shackle loading limited so that Proof Load > 2 x BL x 0.7
4. Shackles conform to ASME B30.26, Rigging Hardw are

$$MPT = \frac{WLL * 2204 \frac{lbf}{mT} * 0.70}{2} * SF_{APPA}$$

Side Loaded Shackles - not free to rotate with load					
Shackle	**MPT for App A Safety Factors**				
WLL	SF =	1.5	2	2.5	5
(mT)		(lbs)	(lbs)	(lbs)	(lbs)
0.5		579	771	771	771
0.75		868	1,157	1,157	1,157
1		1,157	1,543	1,543	1,543
1.5		1,736	2,314	2,314	2,314
2		2,314	3,086	3,086	3,086
3.25		3,761	5,014	5,014	5,014
4.75		5,496	7,328	7,328	7,328
6.5		7,521	10,028	10,028	10,028
8.5		9,835	13,114	13,114	13,114
9.5		10,992	14,657	14,657	14,657
12		13,885	18,514	18,514	18,514
13.5		15,621	20,828	20,828	20,828
17		19,671	26,228	26,228	26,228
25		28,928	38,570	38,570	38,570
35		40,499	53,998	53,998	53,998

Assumptions 1. 180˚ w rap on sheave hanging from shackle
2. 30% reduction in capacity for side loading of shackle up to 45˚.
3. Shackle loading limited so that Proof Load > 2 x BL x 0.7
4. Shackles conform to ASME B30.26, Rigging Hardw are

In-LIne Loaded Shackles - free to rotate with load					
Shackle	**MPT for App A Safety Factors**				
WLL	SF =	1.5	2	2.5	5
(mT)		(lbs)	(lbs)	(lbs)	(lbs)
0.5		827	1,102	1,102	1,102
0.75		1,240	1,653	1,653	1,653
1		1,653	2,204	2,204	2,204
1.5		2,480	3,306	3,306	3,306
2		3,306	4,408	4,408	4,408
3.25		5,372	7,163	7,163	7,163
4.75		7,852	10,469	10,469	10,469
6.5		10,745	14,326	14,326	14,326
8.5		14,051	18,734	18,734	18,734
9.5		15,704	20,938	20,938	20,938
12		19,836	26,448	26,448	26,448
13.5		22,316	29,754	29,754	29,754
17		28,101	37,468	37,468	37,468
25		41,325	55,100	55,100	55,100
35		57,855	77,140	77,140	77,140

Assumptions 1. 180˚ w rap on sheave hanging from shackle
2. 30% reduction in capacity for side loading of shackle up to 45˚.
3. Shackle loading limited so that Proof Load > 2 x BL x 0.7
4. Shackles conform to ASME B30.26, Rigging Hardw are

Blocks

$$WLL_{required} = 2 * \frac{ABL}{SF_{AppA}} * \frac{1}{2204 \frac{lbf}{mT}}$$

Cable Size	Wire BL (lbs)	SF =	Minimum Required WLL for Block (Appendix A Safety Factor) 1.5 (mT)	2 (mT)	2.5 (mT)	5 (mT)
0.225 EM	5,200		3.1	3.1	3.1	3.1
0.322 EM	9,600		5.8	5.8	5.8	5.8
0.680 EM	40,000		24.2	24.2	24.2	24.2
0.681 FO	46,000		27.8	27.8	27.8	27.8
3/16"	4,000		2.4	2.4	2.4	2.4
1/4"	5,900		3.6	3.6	3.6	3.6
1/2"	25,700		15.5	15.5	15.5	15.5
9/16"	32,500		19.7	19.7	19.7	19.7

Assumptions:
1. 180˚ wrap on block sheave
2. Block loading limited so that Proof Load > 2 x BL
3. Blocks conform to ASME B30.26, Rigging Hardware
4. Proof load assumed to be 1.5 x Rated Load

$$MPT = \frac{WLL * 2204 \frac{lbf}{mT}}{2} * SF_{APPA}$$

Block WLL (mT)	SF =	MPT for App A Safety Factors 1.5 (lbs)	2 (lbs)	2.5 (lbs)	5 (lbs)
1		1,653	1,653	1,653	1,653
2		3,306	3,306	3,306	3,306
4		6,612	6,612	6,612	6,612
8		13,224	13,224	13,224	13,224
12		19,836	19,836	19,836	19,836
15		24,795	24,795	24,795	24,795
20		33,060	33,060	33,060	33,060
25		41,325	41,325	41,325	41,325
30		49,590	49,590	49,590	49,590

Assumptions
1. 180˚ wrap on block sheave
2. Block loading limited so that Proof Load > 2 x BL
3. Blocks conform to ASME B30.26, Rigging Hardware
4. Proof load assumed to be 1.5 x Rated Load