SAWE Paper No. 3562
Category No. 25

PARAMETRIC ESTIMATION OF ANCHOR HANDLING / TOWING WINCHES

by
Stein Bjørhovde
Runar Aasen
BAS Engineering AS / ShipWeight

For Presentation at the
71st Annual Conference
of
Society of Allied Weight Engineers, Inc.
Bad Gögging and Manching – Bavaria, Germany –
05-10, May, 2012

Table of Contents

Table of Figures and Tables

Parametric Estimation of Anchor Handling/ Towing Winch
PAPER No: 3562

Abstract

Anchor Handling Tug vessels (AHT) are ships built to handle anchors for oil rigs, in addition to towing the platforms into position and in some cases operate as Emergency Rescue and Recovery Vessel (ERRV). Compared to ordinary offshore supply vessels, AHTs are characterized by large winches for towing and anchor handling, open stern for landing of anchors and a large bollard pull.

The winch packages for anchor handling tug vessels are large and heavy constructions with weight that varies from 150 to 900 tonnes and may represent as much as 15% of the lightship weight for the vessel. In addition to significant weight, it also influences a lot on the vertical center of gravity (VCG) og thereby the stability of the ship. Also the longitudinal center of gravity (LCG) is significantly influenced by the layout and positioning of this equipment.

Experience shows that it might be difficult to identify reliable weight and center of gravity (CoG) for this special made equipment from fabricators and suppliers in an early design phase. Based on this we want to study which parameters are relevant for estimating weight and CoG for anchor handling / towing winches, and how these parameters can be combined in mathematical formulas that can be used in regression based estimation.

The advantage of using regression is among others the quantification of uncertainty (standard deviation) related to each specific estimation method and thereby the possibility to decide which methods that are the most precise, and to evaluate whether parametric estimation can be used at all. An evaluation of the uncertainty requirements will be performed as well.

Stein Bjørhovde is one of the founders and head of development of BAS Engineering. Mr. Bjørhovde has a Master of Science Degree in Ship Design, and has been developing the weight engineering software ShipWeight since 1993. He has also been involved in development of other weight control software, in addition to being a consultant doing weight estimation and monitoring in the offshore industry. He has more than 15 years experience in weight estimation of new ship designs for several Norwegian and international ship designers and yards.

Runar Aasen is one of the founders and technical sales manager of BAS Engineering, a SAWE corporate member. Mr. Aasen has a Master of Science Degree in Ship Design, has been extensively involved in the development of weight engineering software and user support for the last fourteen years, and became a SAWE Fellow Member in 2006. Since 1996, BAS Engineering has provided ship designers and builders around the world with naval architecture and mass properties support. BAS Engineering's ShipWeight software entered the US market for the first time in 1998 and has since been adapted by major US shipyards and designers.

Foreword

The data background and experience presented in this paper is coming from information obtained from working within the Norwegian maritime industry the last 15 years. A huge part of the Norwegian designers, shipyards and ship equipment manufacturers are related to the oil offshore industry and production of anchor handling tug supply vessels. Although limited to a small geographic area, many regard this as one of the leading places in the world when it comes to the construction of offshore vessels and we believe that the data presented will be relatively valid also outside this area. Due to proprietary data and competitive situations, the background data has to be generalized and presented anonymously, unfortunately. The same goes for some of the statements of this paper.

Introduction and Background

In our experience, when the early weight and center of gravity estimation of an anchor handling supply vessel turns out to be wrong compared with the results of the final inclining test, a miscalculation of the anchor handling / towing (AHT) winch equipment seems to be a very common error when the deviation is analyzed.

An error in the weight calculation of the AHT equipment can be quite critical to the vessel because the weight of this in some cases can account for more than 15 % of the total vessel weight. In addition to this, the center of gravity of the AHT equipment is sometimes located high up from the baseline.

This can be critical because of the relative high position of the vertical center of gravity (VCG) of the equipment, compared to the VCG of the overall lightship. The relative high position of the equipment combined with its significant mass gives a moment that can make a large impact on the lightship VCG if calculated wrong. And the calculation of the lightship VCG is a key parameter for the calculation of the stability of the ship.

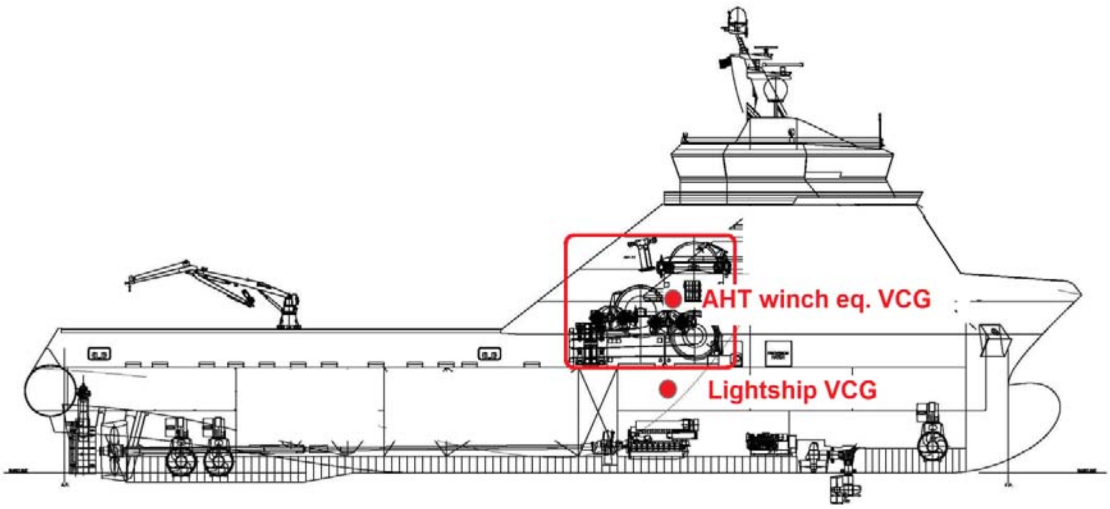

Figure 1: Position of AHT Winch CG

As an example, a typical lightship VCG would be 8.5 m from the base line, while the AHT equipment might be located with a VCG of 12.5 m, giving a moment arm of 4 meters. The total weight of the AHT equipment would typically have a value of about 500 tonnes, and an error of 10% on the AHT equipment weight will add an incorrect moment of 50 x 4 = 200 [tm] to the calculation of the global VCG. On a vessel with lightship of 3500 tonnes and VCG at 8.5 meter, such an error would shift the VCG by 5 cm alone. A 30 cm miscalculation of the local VCG of the AHT equipment would add another 5 cm to the error of the lightship, giving a total error of 10 cm.

Consequences of Erroneous Calculation

So what is the consequence of miscalculating the lightship weight by 50 tonnes? The margins are continuously decreasing due to a tougher market situation, and new rules for "Clean Design" have also decreased the margins (typically it is the GZ curve area criterion that is critical for an anchor handler tug).

At the design stage, it would not be uncommon for a modern anchor handler tug supply to have a weight margin of 5 % and only 30 cm margin on the VCG. 5 % weight margin on a 3500 tonnes AHT is 175 tonnes. This means that an error of the AHT equipment similar to the one described in the introduction chapter of this paper could reduce your vessels' margin for the lightship by about 30 % for both weight and VCG in one go.

In addition, one could mention that some AHT designs are to some extent sensitive in the respect that they are too responsive (too high accelerations) with regards to sea-motion, making them an uncomfortable working place for the crew. Also for this reason, a 10 cm change in the lightship VCG can be very little desirable.

Finally, the trend is clearly that the size and weight of the AHT equipment is getting larger and larger due to market demands of increasingly more powerful winches (since oil production is happening on deeper and deeper water), but the size of the vessels are not necessarily increasing proportionally in size. This means that the importance of a good AHT estimation is not getting less significant in future.

What to Estimate?

When estimating AHT winch equipment weight and CoG, what makes sense to include in the estimation? Ultimately you want to include not only the winches, but also all the additional weights of the equipment that follows the installation of the AHT winches. You want to know what is the total impact of weight and center of gravity of the installation of the winches.

Typically an AHT Winch package will include some or all of the following weights:

- Towing/anchor handling winch(es)
- Secondary winch(es)
- Spare wire(s)
- Spooling equipment
- Mounting equipment
- Chain rollers and guides
- Rope reels
- Hydraulic pumps and valves
- Various minor supporting equipment
- Various bulk and equipment weights (piping, electrical and instrument) and foundations

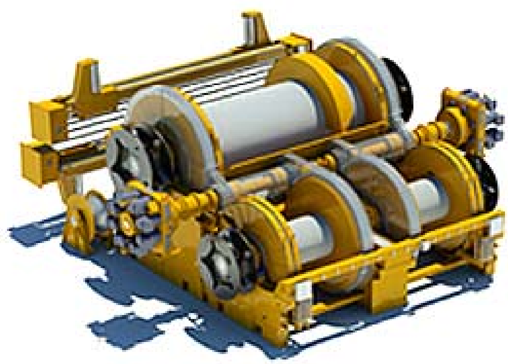

Figure 2: Typical AHT Winch Arrangement

Vendor Weights

One natural source of finding the weight of the AHT winch is to ask the supplier of the equipment. In the tender phase of a project there may not be time to contact the vendor and get weight data from the supplier. A bigger problem can sometimes be that the weight given from some suppliers are not very accurate and not very well defined with regards to what is included in the weight.

When the vendor weight of winches repeatedly is given in very round numbers, like exactly 200 tonnes or exactly 300 tonnes, this is an indication that the given numbers are not very accurate. Another problem is that it sometimes can be hard to understand from the vendor documentation what is included in the weight and what has been left out.

In our opinion, uncritical use of vendor weights is part of the problem with the errors seen in estimation of AHT winches. A parametric estimation based upon verified as-built weights for the complete AHT winch including all associated equipment may therefore be a preferred way of obtaining an early phase weight.

Parametric Estimation

The above indicates that in an early phase it may not only be faster to estimate the weights of AHT winch packages parametrically, but it also may add accuracy in taking away some of the uncertainty connected with the vendor data. And even when presumable good vendor data is at hand, parametric estimation is a quick and good way of quality checking the vendor data and raise questions if deviations are large.

In a nutshell, parametric estimation means calculating the weight (or center of gravity) by using a formula where the parameters and one (or more) coefficients are input and the weight is the result of the equation. The parameters are obtained from the design and the coefficients are taken from historical data. Further explanation of parametric estimation is beyond the scope of this paper.

For more detailed information and discussion about parametric estimation we may recommend SAWE paper 3505 “Early Stage Weight and CoG Estimation using Parametric Formulas and Regression on Historical Data”.

Which Parameters Should Be Used for the Estimation?

When considering which parameters to use for the estimation, a key point is to make use of parameters that are available at an early stage of the project. If you develop a method that requires parameters that is not obtainable at the time of estimation, you are no good.

The parameters that we have decided to investigate in this paper are the following:

- Pull
- Number of winches
- Volume of winches and wire
- Area of winches excluding flange
- Area of winces including flange

The pull parameter is most often available from the very beginning as this is often a request from the ship owner.

As for the number of winches, area and volume, these parameters can often be calculated from the General Arrangement (GA) drawing, which is usually the first drawing made available for a new project.

Plotting Parameters versus Weight

The parameters mentioned above have been investigated by plotting them in diagrams showing the relationship between the parameter and the AHT winch weight. Also, combination of some of the parameters have been checked and plotted in graphs in similar way.

A regression line has been inserted into all graphs to visualize the correlation between the parameter and the weight. The R^2-value has been calculated and shown in the graph to quantify the correlation between the parameter and the weight of the AHT Winch.

Graphs and relationships has been set up between the parameter and the weight of the winches only, and also between the parameters and the weight of the total winch package – winch weight and winch equipment weights.

Analyzing the Results

The R^2-value, sometimes called the coefficient of determination, is a very common way in statistics of investigating how well the input of one or more parameters can be used to predict the outcome of other parameters. The value of R^2 can vary between 0 and 1, where 0 means no relation between the data in the graph, while 1 means absolute relation between the data in the graph. The value only takes into account the relation between the data in the graph, and one should take into account that more often than not the data in the graph will only represent a sample of real life data and adding more data to the graph could change the value of R^2.

There are many opinions on what should be regarded as a "good" value of R^2, but it seems to be a common rule of thumb that $R^2 > 0.7$ shows good relation between data, while $R^2 < 0.7$ is not. We will use this rule as guidance when checking the results from our graphs. Further discussion of R^2 will not be done in this paper, but the internet is full of information on the topic for the interested reader.

Graph plots background data

A total of 15 anchor handling tug supply vessels was the basis for setting up the test of the parameters versus weight, with the following characteristics:

- Ship length PP: Between 66 and 110 meters
- Ship breadth: Between 14 and 24 meters
- Depth to maindeck: Between 7.5 and 11 meters
- Bollard pull: Between 150 and 350 tonnes
- Total AHT-winch equipment weights (incl. eq.): Between 150 and 880 tonnes

Vessel				No. off winches			Pull		
Description	AHT wgt. (incl.eq.)	Bollard pull	Winch wgt.	Towing winches	2ndary winches	Anchor/ Special Drum	Towing winches	Secondary winches	Anchor/ Special Drum
Anchor Handling Tug	879	350	610	2	2	1	600	170	500
Anchor Handling Tug	716	350	563	2	2	1	600	170	500
Anchor Handling Tug	818	338	571	2	2	1	600	170	500
Work Ship	646	275	410	1	1	1	400	400	500
Supply Vessel Anchor Handling	559	280	350	2	2	1	400	170	500
Supply Vessel Anchor Handling	559	270	350	2	2	1	400	170	500
Supply Vessel Anchor Handling	559	275	350	2	2	1	400	170	500
Anchor Handling Tug	534	183	368	2	2	1	400	138	400
Supply Vessel Anchor Handling	446	194	256	2	1	1	400	138	400
Supply Vessel Anchor Handling	518	284	350	2	2	1	400	170	500
Anchor Handling Tug	482	304	410	2	2	1	400	134	500
Anchor Handling Tug	452	204	254	2	2	1	400	134	400
Anchor Handling Tug	437	286	365	2	1	1	500	63	400
Anchor Handling Tug	316	222	284	2	0	1	400	0	500
Anchor Handling Tug	148	148	121	2	3	1	300	15	270

Table 1: Historical AHT winch data

All weights in the table above are in metric tonnes.

Plotting Parameters against Winch Weights (incl. relevant Equipment)

Below are the results from the plotting of winch weights against relevant parameters when using the weight of the winches including the relevant equipment. Winch weights in metric tonnes are shown on the Y-axis:

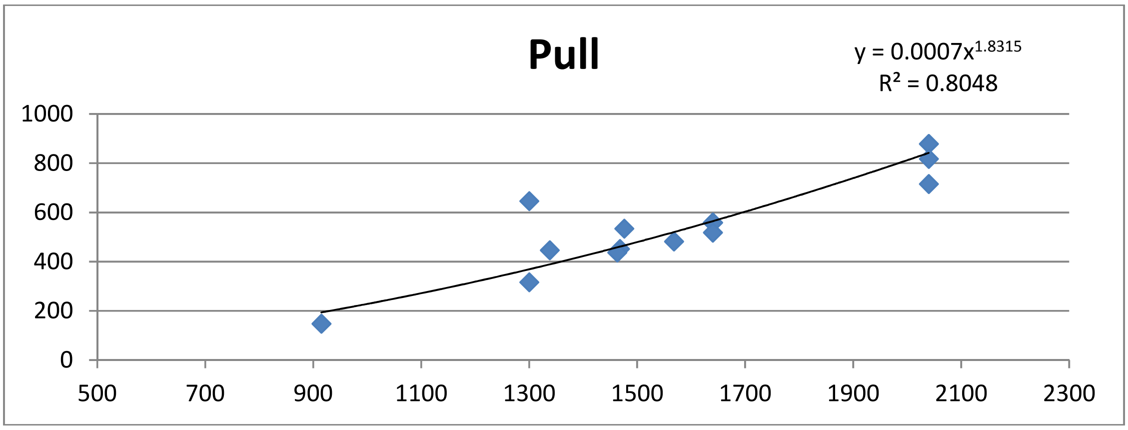

Figure 3: Plotting Pull (x) against AHT winch weight (y)

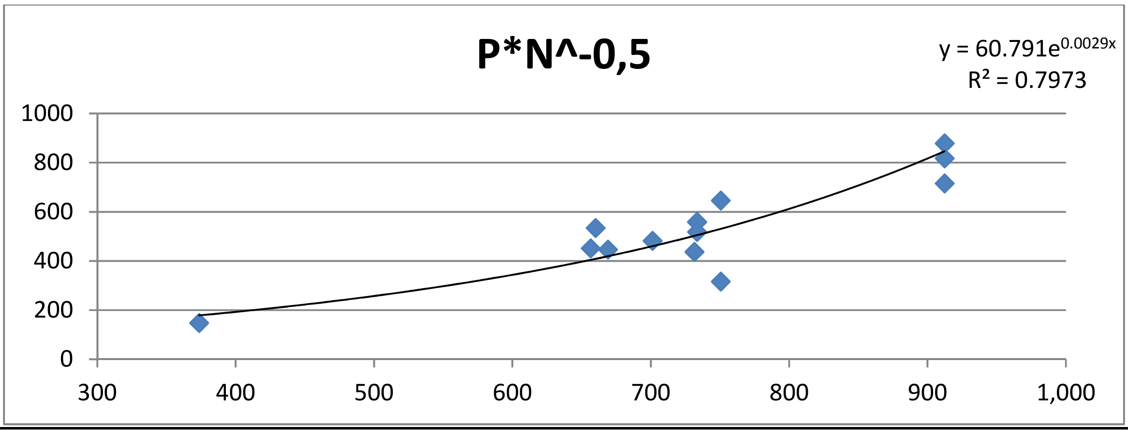

Figure 4: Plotting Pull * by square root of N (number of winches) against AHT winch weight

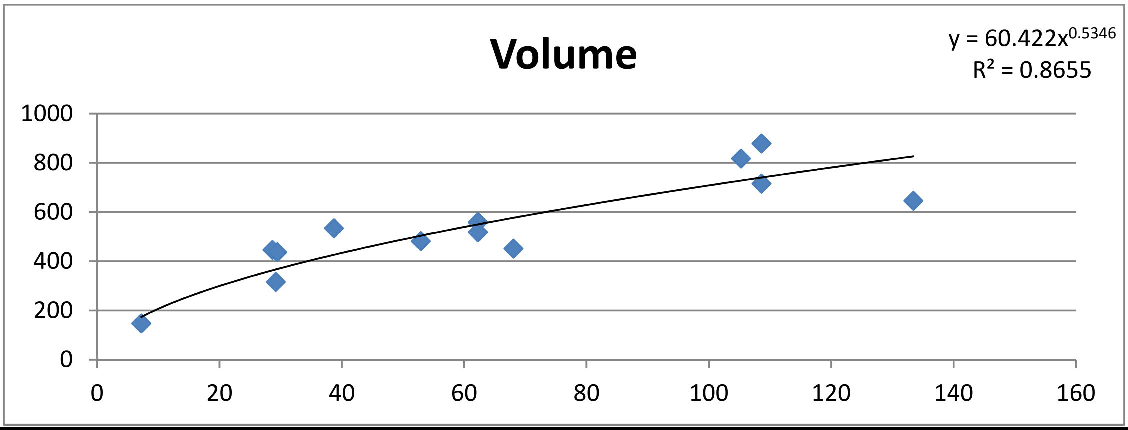

Figure 5: Plotting Volume of winch [m^3] (x) against AHT winch weight (y)

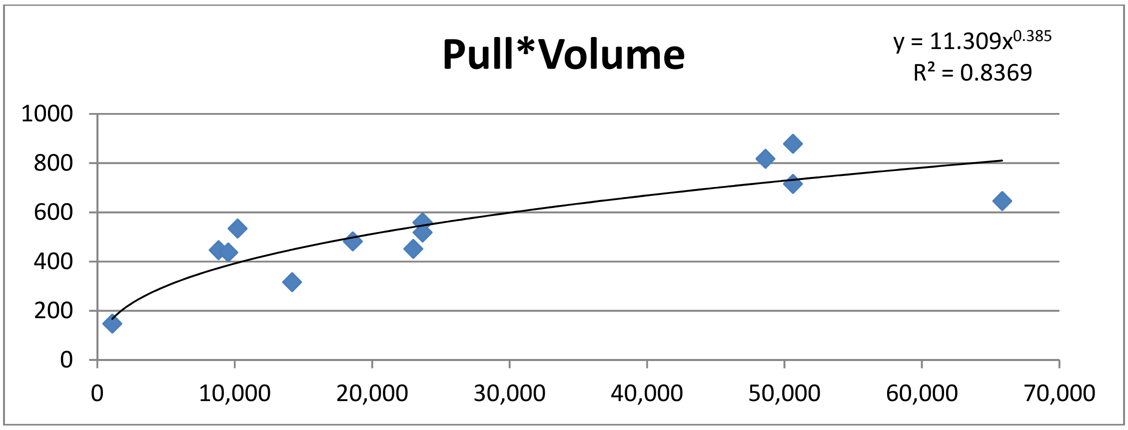

Figure 6: Plotting Pull * Volume (x) against AHT winch weight (y)

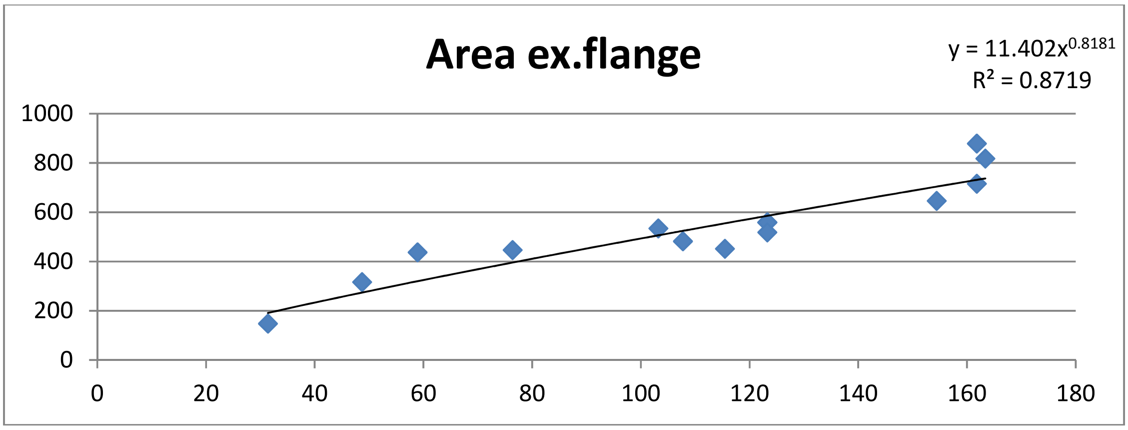

Figure 7: Area of winch drum (x) against AHT winch weight (y)

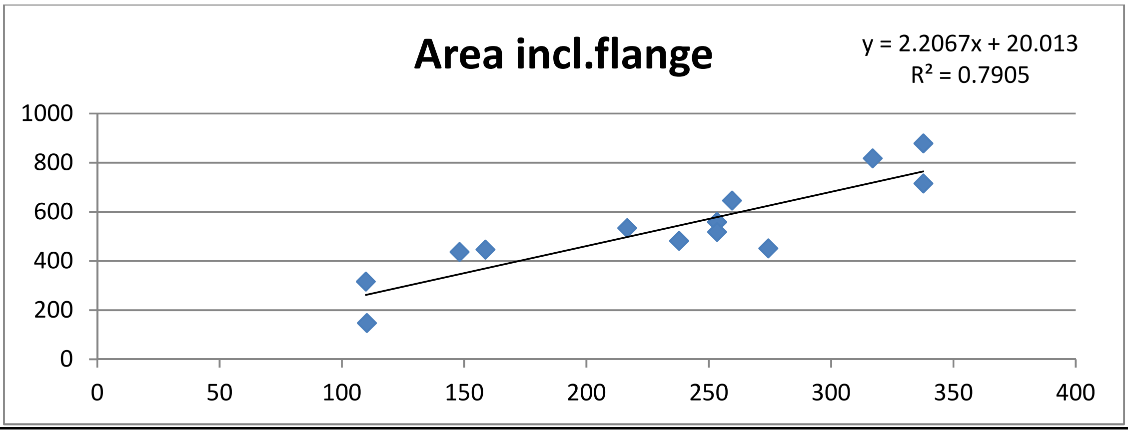

Figure 8: Area of drum and flange (x) against AHT winch weight (y)

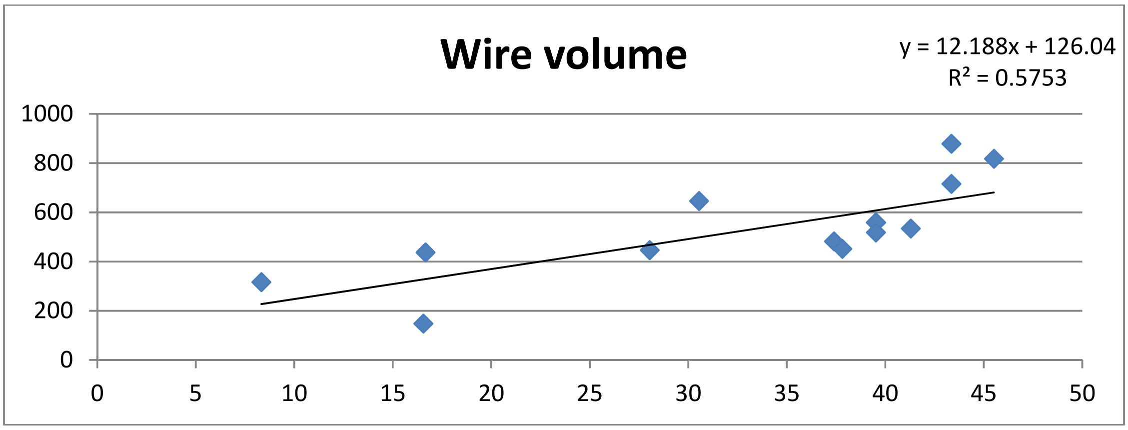

Figure 9: Volume of wire (x) against AHT winch weight (y)

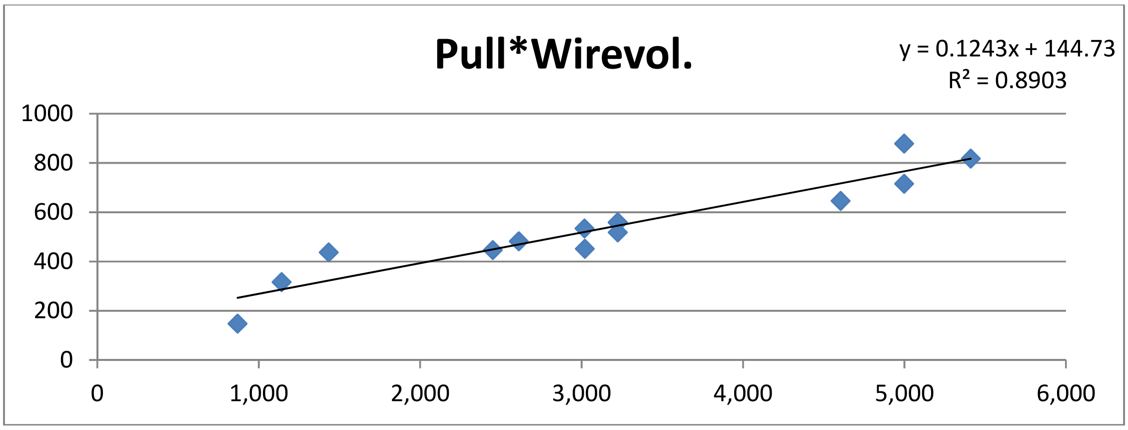

Figure 10: Pull * Volume of wire (x) against AHT winch weight (y)

As mentioned before, the interesting part here is to look at the R^2 values. If we summarize them in a table we get:

Parameters	R^2
Pull	0.80
Pull * $N^{-0.5}$	0.80
Volume	0.87
Pull*Volume	0.84
Area of drum	0.87
Area of drum and flange	0.79
Wire volume	0.57
Pull*Wire-volume	0.89

Table 2: R-square values

From this table we see that there is actually a quite good correlation between all of the tested parameters and the winch weight. The only one that shows a significantly less value than the other are the test of weight against wire volume, still we will not abandon this method at this point since the data basis is limited and there is a correlation after all.

Making a Test Case (or Two)

We will now try to make a parametric estimation of a couple of AHT winches based upon the equations derived from the graphs above.

The first attempt will be a 225T bollard pull arrangement, where the total as-built weight is given to be 649 tonnes:

Method	Input	AHT-winch equation	AHT-equip.wgt.			
			Est.wgt.	Actual wgt.	Diff.	Diff.[%]
Pull	1,780	$y = 0{,}0007x^{1{,}8315}$	628	649	-20	-3%
P*N^-0,5	796	$y = 60{,}791e^{0{,}0029x}$	612	649	-37	-6%
Volume	58	$y = 60{,}422x^{0{,}5346}$	529	649	-120	-18%
Pull*Volume	21,413	$y = 11{,}309x^{0{,}385}$	526	649	-123	-19%
Area ex.flange	127	$y = 11{,}402x^{0{,}8181}$	598	649	-51	-8%
Area incl.flange	310	y = 2,2067x + 20,013	703	649	55	8%
Wire volume	58	y = 12,188x + 126,04	830	649	181	28%
Pull*Wirevol.	5,261	y = 0,1243x + 144,73	799	649	150	23%

Table 3: Estimating a 225T bollard pull arrangement

If we look at the results above we will see that the individual result from each method does not give a very satisfactory result, apart from the two first methods (Pull and $P*N^{-0.5}$) where the deviation is 3 % and 6 %. The "Wire volume" method gave the largest deviation – 28 %, which is not too surprising given that this method had the lowest R^2-value.

But if we look at the average results from all methods (628+612+529+526+598+703+830+799)/8 = 653 tonnes, which is only 4 tonnes (or 0.6 %) off the actual as-built. Now getting this spot on has a little to do with luck and coincidence, but getting significantly closer than many of the individual methods is not. This is due to statistical cancellation effects which will be discussed in the next chapter.

Now let's move on to try and use these formulas for a new test case where the bollard pull is higher than the first case, but the arrangement as-built weight is lower than the case above.

The second attempt will be a 250T bollard pull arrangement, where the total as-built weight is given to be 643 tonnes:

Method	Input	AHT-winch equation	AHT-equip.wgt.			
			Est.wgt.	Actual wgt.	Diff.	Diff.[%]
Pull	1,958	$y = 0{,}0007x^{1{,}8315}$	748	643	106	16%
P*N^-0,5	876	$y = 60{,}791e^{0{,}0029x}$	770	643	128	20%
Volume	55	$y = 60{,}422x^{0{,}5346}$	514	643	-129	-20%
Pull*Volume	21,386	$y = 11{,}309x^{0{,}385}$	525	643	-117	-18%
Area ex.flange	128	$y = 11{,}402x^{0{,}8181}$	605	643	-38	-6%
Area incl.flange	262	y = 2,2067x + 20,013	599	643	-44	-7%
Wire volume	47	y = 12,188x + 126,04	704	643	62	10%
Pull*Wirevol.	4,940	y = 0,1243x + 144,73	759	643	116	18%

Table 4: Estimating a 250T bollard pull arrangement

Again, as with our first test case, when we look at the results above, we will see that the individual result from each method does not give a very satisfactory result. This time, the methods involving the pull parameters are turning out to be less accurate, while the volume/area parameter methods seems to fit at least somewhat better.

Once more, let’s look at the average results from all methods (748+770+514+525+605+599+704+759)/8 = 653 tonnes, then again we are only 10 tonnes (or 1.5 %) off the actual as-built. And as with the first test case, some of this we have to credit a bit of luck, but not all – some of this is due to statistical cancellation effects.

Error cancellation

Error cancellation means that if you have methods that are trying to predict the same results, but otherwise unrelated in such a way that the error of one method is not correlating to the outcome of the other method, then a cancellation effect will take place when you average the results from all methods. Ideally, for every method that predicts something too high there is another method predicting the same too low. This will be valid when the error of one method is totally independent on the outcome of another method.

This is not entirely true for the cases we have been looking at above. Some of these methods are clearly correlated, simply because they share some of the same parameters. Still, it looks quite obvious that cancellation effects are present and that results are improved by using several different formulas average the result.

Conclusion and way forward

We've seen from this paper that a good estimation of the anchor handling winch arrangement is vital to the estimation of the overall weight and center of gravity to the vessel. Further, vendor data is often inaccurate and of variable quality on weights and documentation.

Parametric estimation can be a valuable add-on to the data in the early phase, both as a verification of the vendor data and as tender phase estimation when vendor data is not available.

The paper has shown how to use historic data to set up formulas for parametric estimation, carry through the estimation. Finally we have seen the importance of using several methods and utilizing cancellation effects to find the best estimation of the AHT arrangement.

Principles have been shown on how to do parametric estimation of AHT arrangement, but for practical implementation of the methods presented here more and better data should be used as basis for the graph plots and more parameters should be examined.