The SafeWinch: 'Lifeline' to safe towing

Joining Profitability, Reliability and Safety

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1) Introduction

In the past few years, the engineering company IMC and the winch manufacturing company Kraaijeveld have joined forces to develop a new type of winch, with an enhanced safety performance. Following a systematic analysis of principles, a completely new mechanical design was defined, centered around a ratchet freewheel and a slipping clutch. By this new simple design, the overload of a towline can be easily tackled by a locking ratchet and a slipping clutch, whilst instantaneously also a slack towline can be retrieved by a motor with the open ratchet. Already at an early development stage, Smit was contacted to cooperate and co-develop the winch. After thorough prototype testing, the 40 t BP tractor Thamesbank of Smit was upgraded with a SafeWinch. In the last half year the winch was successfully tested both in port operations and at sea.
Based on these results, Smit has recently signed at the International Tug and Salvage conference in Singapore a letter of intent, see fig. 1, for further joint research on the winch and especially operation in exposed conditions at sea (like expected to be required when developing new LNG terminals offshore).

Fig. 1 : Signing letter of intent, Ben Vree (l) of Smit and Kees Kraaijeveld of Kraaijeveld Winches

Recently, the SafeWinch also received further international recognition by winning the international Seatrade Award in the category Safety at Sea. On 21st of April, this award was received from HRH The Princess Royal in the Guildhall London, see fig. 2.

2) Owner Requirements

Whether it is a ship, or a component of the ship, all designs should start with a close look at the customer and his requirements, in shipping referred to as owner requirements. In general, for a new design the following three objectives apply, which will be expanded hereafter using the **P**rofitable, **R**eliable and **S**afe approach:

Fig. 2 : Dr. Markus van der Laan receiving the Award from Her Royal Highness, The Princess Royal

2.1 Profitable

For a profitable operation of a ship or tug, there are a number of essential components. First, it should be a cost-effective solution. Second, it should do the right, required thing in the market. And finally it should be done at equal or lower initial and running cost …
Or to increase profitability even further: Doing even more than the basic requirements to really meet the underlying customer's objectives...

2.2 Reliable

An analysis of reliability consists of an investigation of available redundancy in the whole system and trying to prevent any possible single occurrence leading to failure. In towing operations, many components are double (engines, thrusters etc), however, the main critical single components are both the winch and the towline. Failure on one of these will result in the loss of the assisted tow.

2.3 Safe

The analysis of risk can be divided into various categories by zooming out; starting from the crew on deck, moving on to the whole tug, and finally up to the level of the assisted ship and the whole towing operation. Safe towing means clearly having a safe winch and a safe towline.

From the PRS approach it is clear that both the winch and the towline are of crucial importance to maintain a 'lifeline' connection during the assistance.

3) Winches

Looking at present winches, there are in principles three types; the conventional winch with tow in the brake, the constant tension winch with tow in the drive and the new render / recovery winches with 'automatic' change from tow in the drive to tow in the brake. Although all have their specific advantages, there are also significant disadvantages in the area of profitability, reliability and safety.

3.1 Conventional Winch

This winch is a basic, low cost solution for towing with a drum, a brake and a drive. Towing is performed with the brake on, pull is performed by connecting the drive and pay out is performed by lowering the brake force (and in some cases disconnecting the drive). However, the simple design also includes various disadvantages: An overload will lead to towline failure and when operated wrongly, the winch drive may be potentially damaged.

Further, the operation is rather slow and quick release is not always guaranteed in emergency conditions.

3.2 Constant Tension Winch

This winch is based on an 'expensive' large motor connected to the drum. This arrangement offers proper reaction to slow movements in the towline, but does not counter large dynamic motions, which may lead to costly damages to the motor.
In addition, the operational cost is relative high and most important, there is only a limited release speed available in emergencies under load (which may lead to accidents).

3.3 Render Recovery Winch

This winch is a relative new development and automatically switches between brake and drive. The winch consists of a 'very expensive' large drive and brake system. This arrangement offers a (slow) pull under high load, but also a full and rapid release in any emergencies. Due to the complex mechanical and control system, the reaction time takes a few seconds and malfunction may occur due to the complexity and number of components.

4) SafeWinch concept

4.1 Background: Fault Tree Analysis

In order to investigate the safety of a winch during assistance and escorting, the well-known Fault Tree Analysis approach is used. In this approach, the risk is described in all contributing events and sub events. The combined risk is defined as a combination of the failure of the tug side and of the ship side.
Without going in too much detail, the main sub-events are:

- Prevent slack towline : Risk for Crew / Propulsion Loss
- Prevent overload : Break of towline / Risk for Crew / Damage

A third main sub-event, however on a slightly lower level, is human operation. In many incidents and accidents, human error and failure have contributed to the final accident. Therefore, integral safety in the design should as much as possible integrate human (inter)action.

4.2 New design

Considering the previous mentioned winch aspects, a new winch is designed, starting from a functional perspective: Pulling is essentially different from paying out and therefore both functions are split. The heart of the new winch is formed by a patented ratchet free wheel system, which automatically separates the torque depending on the applied direction of the ratchet.
The towline moment is first guided through a clutch and then through the ratchet; depending on the direction of rotation the ratchet directs the torque either into the drive or the "earth", see fig. 3:

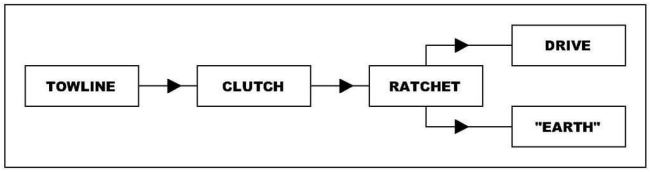

Fig. 3 : Flow diagram of SafeWinch principle

The winch functions as follows:

- Overload: The excess pull force is released by a clutch connected via the ratchet to the earth.
- Slack towline: The towline can be instantaneously retrieved by the drive connected to the ratchet and clutch.

This arrangement fully tackles both the event of a slack towline and an overload event by an intrinsic-safe-design. The effect on the towline load is shown in the following figures:
Fig 4 shows the original towline load with at the top the "overload" area and at the bottom the "slack wire" area.
Fig. 5 shows the remaining load when a SafeWinch is used, with at the top loads removed by the "slipping clutch" and at the bottom loads removed by the "cable pull".

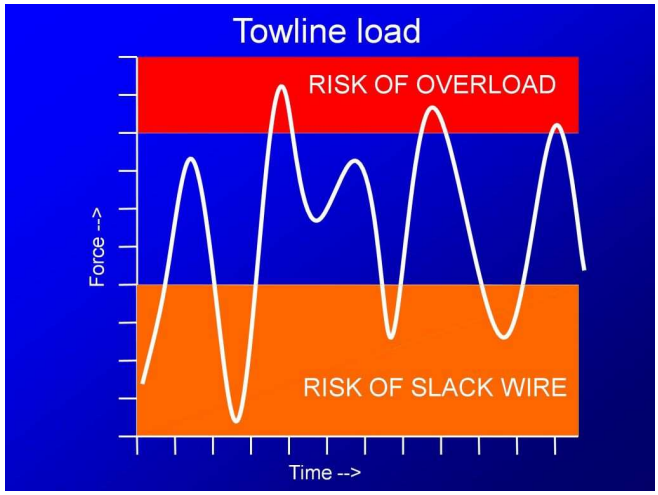

Fig. 4 : Typical towline load in dynamic conditions

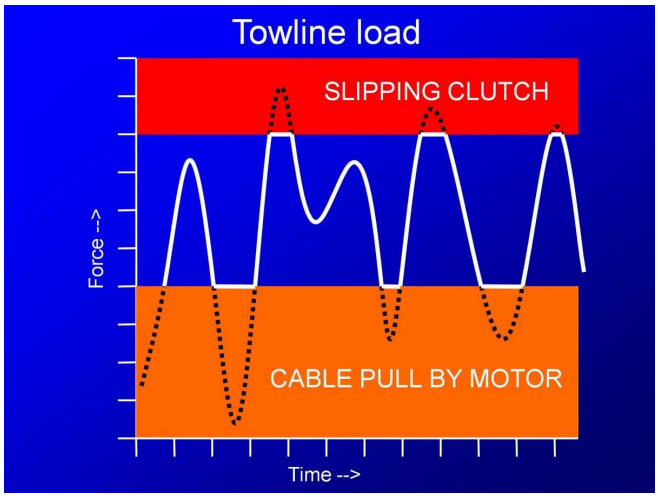

Fig. 5 : Typical remaining towline load when a SafeWinch is used

The components of the SafeWinch are schematically shown in Fig. 6, from left to right: Towline + drum, clutch, ratchet, gear and drive.

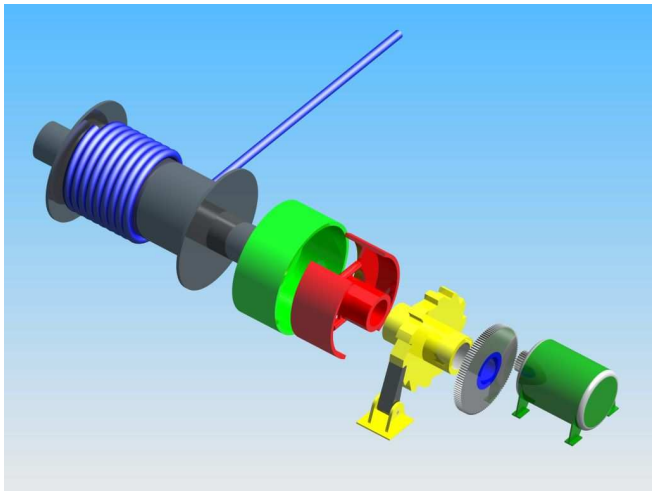

Fig. 6 : Schematic exploded view of components SafeWinch

5) SafeWinch designed to satisfy the owner requirements

Although at the start of the project, the owner/operator requirements were rather basis and general, during the project the requirements gradually became clearer and could be summarized in the following points together with the relevant action of the SafeWinch:

5.1 Prevent overload

Any overload should be instantly prevented by a slipping clutch with as short as possible delay time. The SafeWinch is based on a reliable mechanical slipping of friction material and does not require control systems to activate during a release. Typical response time for this mechanical system is therefore within 1 second.

Hereby high loads and even snap loads are prevented and the towline will no longer break. And prevention of towline breaking minimizes the risk of loss of the tow, danger for the crew and tug (loss).

5.2 Prevent slack towline

In order to prevent a slack towline, the winch should instantaneously retrieve the slack towline with as short as possible delay time. The SafeWinch uses a hydraulic (or electric) powered motor and gear box, set at a given torque. As soon as the line pull lowers below this torque value, the drive will directly start to retrieve, again without the need for any control system to act. Typical response time is in range of 1 – 2 seconds.
By preventing the slack towline, a snap load afterwards is prevented (risk and peak load) and also the risk of entanglement of the towline on deck or even in the propeller is minimized.

5.3 Protect the expensive drive (motor + gear)

Central feature of the SafeWinch is the ratchet, which automatically protects the drive against overload by taking the overload through the locked ratchet into the 'earth'. This arrangement not only prevents direct damage in case of a single peak overload, but also reduces wear and maintenance on the winch.

5.4 Facilitate operations

Human operation of the winch shall be practical and easy. The controls are set up for minimum attention of the master by automatic instantaneous response to overloads and slack towlines and minimum risk of human failure by two simple turning wheels. When the max slip value is set below the strength of the bollard of the assisted ship, damage to the bollard or even loss of towing connection is prevented.
Even in large waves and dynamic conditions the SafeWinch provides adequate response, enabling the master to fully concentrate on his prime task: Manouvring the tug. However, the master can always directly and easily intervene by changing the slip or pull value, when considered necessary.

5.5 Low Cost

The SafeWinch is of a completely different design by using proven components into this new arrangement. These simple mechanical components form the base of a low cost design, without compromising on essential quality.
The winch cuts off peak loads and this leads to the central theme:

⇨ Lower peaks mean lower wear and longer lasting.

The same applies equally to the towing components: Lower peaks mean lower wear and longer lasting. Especially modern synthetic towlines are critical on fatigue performance induced by peak loads and may contribute to high operational cost.

6) Product development with Smit

6.1 Development process

The investigation started with detailed motion and strength calculations and followed by real life dynamic testing. First a 1:5 scale SafeWinch model was mounted on a small boat and tested in waves to validate the functioning and mechanics. Next a real size SafeWinch prototype was constructed and thoroughly tested; a large shovel was used to offer the required dynamic pull to simulate real life loads, see fig. 7.

Fig. 7 : Dry testing of real size SafeWinch prototype with large shovel

6.2 Modification Thamesbank

After successfully completion of the 'land' tests with the shovel, Smit agreed to upgrade one of their conventional winches on the Thamesbank to a SafeWinch. The Thamesbank is a 40 t BP tractor tug, operated in port of Rotterdam area.

The upgrading consisted of the following actions: The brake clutch side was dismantled and the existing friction clutch was replaced by a new stronger twin shoe clutch. Further, between the clutch and the end support a new ratchet system was mounted and finally new bridge controls were fitted to operate the winch safely. The main bridge winch controls consist of two turning 'wheels', the large one is for setting the clutch slip value and the small one is for setting the motor pull value. Although extremely simple in appearance, the crews gave their preference for this layout to operate the winch, simple and clear.

The modified winch on the aft deck is shown in fig. 8.

Fig. 8 : The upgraded SafeWinch on the Thamesbank of Smit showing the new twin shoe clutch and the ratchet arrangement.

6.3 Regular test in port

After the installation of the components, the tug first performed a number of trials whilst pulling on a fixed bollard. Especially, sailing away at a speed of 4 knots with a slack towline caused initially some high human stress levels! But soon this new feature was accepted when seeing how gently the system slips (see downloadable video).

After adjustments of the whole installation, the tug has been in operation in Rotterdam from October 2007 onward and a large number of assistances have been performed safely, see e.g. fig. 9.

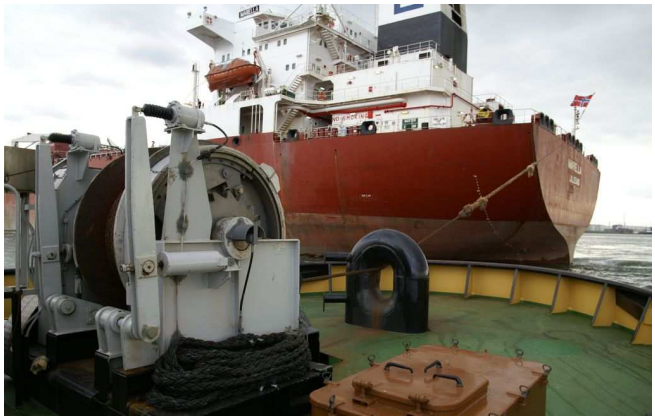

Fig. 9 : SafeWinch at work in harbour assistances

6.4 Dynamic sea tests

Early 2008 marked the first trials at sea of the SafeWinch, using another tug to simulate the assisted ship. A whole range of assistances and dynamic movements were tested. The towline load was continuously measured and the output showed clearly that the peak loads were cut off and the occurrences of slack towline prevented.

Not only the mechanics seemed to be right, but also the 'feeling' of the crew: starting with some, in shipping common skepticism, the scene turned quickly into an enthusiasm of doing certain operations one could not have dreamed of before … (see downloadable video).

Fig. 10 : Dynamic sea tests, SafeWinch cuts off peak loads and prevents slack wire

6.5 Evaluation

The extensive testing of the Thamesbank offered a large amount of data and experiences. These were all thoroughly analyzed and evaluated with Smit.

The following two load measurement figures, 11 & 12, show clearly the effect of the slipping clutch and the motor pull. The winch responds nearly instantaneously by slipping and pulling, as can be seen on the horizontal time axis in seconds.

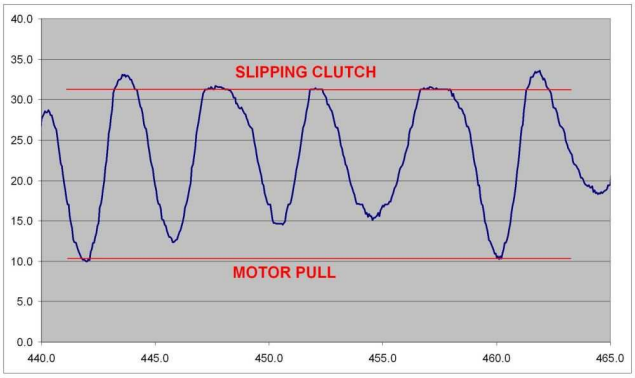

Fig. 11 : Towline load measurements (Clutch 32 / Pull 10 ton)

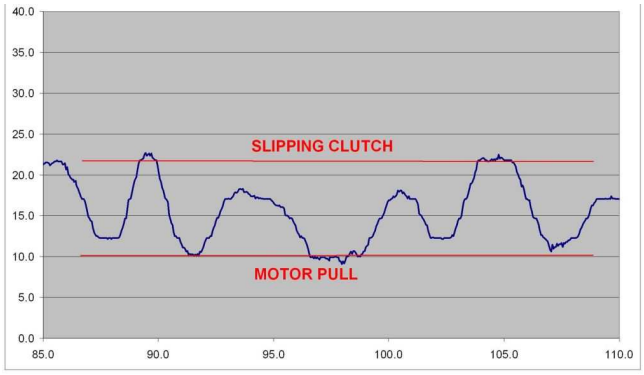

Fig. 12 : Towline load measurements (Clutch 22 / Pull 10 ton)

The evaluation summarized three questions:

1) Does SafeWinch work in port and at sea ?
2) Is the operation of the SafeWinch simple and easy ?
3) Does the SafeWinch offer Safe & Reliable Towing?

The answers to these questions can be summarized as follows:

1) A clear YES: The clutch prevents peaks loads and the motor prevents slack towlines
2) Yes, although the crew should get used to these new opportunities.
3) Yes, a large improvement by ensuring a safe and reliable towline connection.

Following this positive evaluation, Smit has already ordered a number of SafeWinches for their newbuildings.

6.6 Benchmark

When compared to present winches (see Ch. 3), the SafeWinch offers:

- Large improvements on Safety and Reliability compared to a conventional winch
- A price range between Conventional and Constant Tension (depending on chosen parameters)
- A performance far beyond Constant Tension and beyond the more expensive Render Recovery winch

Looking back to the original set of P, R, S criteria, the SafeWinch offers:

- Profitable : Yes, extended use in dynamic conditions at relative low initial cost and reduced running cost
- Reliability: Yes, towing guaranteed in adverse conditions
- Safety: Yes, for crew, the tug and the assisted ship

7) Conclusions

- Ranging from small harbour tug to large sea going escort tug, there is a clear Profitable, Reliable and Safe solution: The SafeWinch.
- The SafeWinch ensures the 'lifeline' to safe towing, both for the assisted vessel and the tug.
- The SafeWinch is composed of proven quality components and tailor made to suit the required operation profile of the owner.
- The major advantages of the SafeWinch appear when operating in relative high waves (swell) in combination with relative short towline lengths.
- Offshore exposed LNG terminals seem to be the ideal application of the SafeWinch.
- The potential of extended operations in waves still needs to be fully explored.
- Application of the SafeWinch is not limited to tugs only, but can be applied to all kind of boats in exposed conditions, ranging from small workboats to large vessels.

Acknowledgements

The authors wishes to express his sincere thanks and appreciation to the following contributors to the 'SafeWinch' project: Project partner Kraaijeveld Winches and Smit, the crews of the Thamesbank, Shipyard Damen, SenterNovem, Holland Marine Equipment, Syntens, Lloyd's Register, Bureau Veritas, Det Norske Veritas, Germanischer Lloyd, American Bureau of Shipping.

For more information and downloads of pictures, please visit www.safewinch.com.