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Advances in winch system for defence applications

O.R. Nandagopan *, P. Vinod

Defence Research & Development Organisation, Bangalore, India

* Corresponding e-mail address:nandagopan@npol.drdo.in

ABSTRACT

Purpose: Winch systems are commonly used in many applications starting from fishing industries to highly advanced defence, space and nuclear sectors. This paper discusses advances in development of winch system for defence applications focusing on the towed array sonar winches for deployment and retrieval of towed sonar wet end from naval ships.

Design/methodology/approach: In order to meet the requirements, the winch designer is required to bring innovations through latest technologies and thereby incorporate advancements in the Mechanical engineering field.

Findings: Based on experience of the authors, the advancements from raw material to drive transmission system to health monitoring concepts are discussed along with the technology up gradation in winch systems.

Practical implications: The functional requirements for defence applications are something uncommon compared to civilian applications.

Keywords: Winch system; Towed sonar

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MANUFACTURING AND PROCESSING

1. Introduction

Winch systems are commonly used in many applications starting from fishing industries to advanced defence, space and nuclear fields. It is one of the widely used mechanical systems. The purpose is to lift or pull a payload using electro hydraulic or electric drives. The payload will be based on the customer requirements. It can be catches of fishes for fishing boat, building materials for construction industries, handling of critical equipments or rescuing of personnel or towing of wet end of towed sonar system for defence. The intensity of safety requirement varies depending on the field of application. In case of defence applications, the complexity increases in Naval systems considering its exposure to marine environments, mission critical requirements, safety of the sonar system and ship. The winch system under discussion is a ship based one, intended to be part of towed sonar system, where in payload is multiple sensors housed in a flexible tube, named as "towed array" or sensors housed in an enclosure named as "towed body" with umbilical connectivity using tow cables with the parent ship. In stowed condition, the towed array and tow cables are wound on the winch drum and during operation, the towed

array and tow cables are deployed and speed of deployment is to be maximum considering the anti-submarine warfare.

2. Literature study

Winch system is a common mechanical engineering based system. However, very limited literatures are seen for towed sonar winch systems specifically for defence applications. In order to exploit the recent advancements in winch related technologies, literature study was carried out sub system level also.

Martijn Schols et., presents an overview of the benefits of the use of synthetic rope winches as a direct replacement to wire-rope winches in ultra-deep water applications, which is similar to the present topic of interest [1]. Paper authored by Graser on wire line winch system, describes a subsea wire line winch system designed to work over subsea wells from a dynamically positioned work vessel in North Sea conditions. This paper gives comparison with other options based on applications [2]. A customized winch system software is developed and named as WINyas. The software clearly discusses design procedure on various sub systems of winch [3]. Sameer and Lijo Vijayan have developed an algorithm for winding of multiple payload over winch [4]. Sameer et al., have applied Analytic Hierarchy method in the development of winch system and benefit has been brought out in the paper [5]. Dobosy and Lukacs have elaborately studied various properties of S690QL material considering its application on high strength requirement. Focus is given on welding properties and fatigue resistance [6]. Anuradha and Singh have made detailed survey on the literatures of the Variable Frequency Drive. Total 66 papers are considered. It is a general literature bringing out more details of VFD [7]. Pawar and Kulkarni presented the advantages of planetary gear systems over other gear boxes. The comparison of planetary gear system over helical gears systems is done on the basis of volume, weight and torque density [8].

3. Construction of winch system

In general, a winch system essentially consists of a cable drum, spooling system, hydraulic and electrical drive elements, drive transmission system, braking system and its supporting structure apart from electrical controls and accessories. Hydraulic power pack is added if the winch system is an electro hydraulic based system. In addition to these elements, health or critical parameter monitoring sensors are placed in various locations to monitor different parameters like speed of cable drum, temperature of drive elements, electrical current and hydraulic flow rating, cable payout length and cable tension values. In order to monitor these parameters and to operate winch system, a closed circuit control system generally referred as “Winch Control System” is employed. A typical block diagram of a winch system is shown in Figure 1.

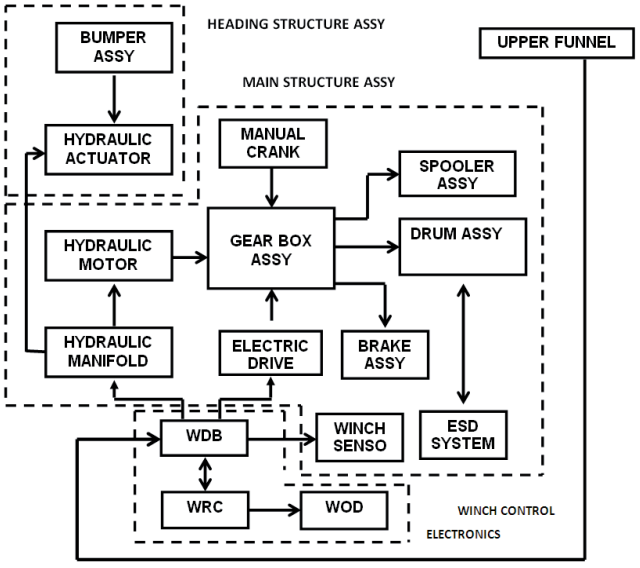

Fig. 1. Winch block diagram

Cable drum is used for winding and de-winding of cable with or without sensors. A spooling system is to wind the cable uniformly over the width of cable drum, thereby avoiding a misrap of cable. This is one of the very critical design requirement for safety and operation of winch system. In order to drive the cable drum, appropriate drive elements like hydraulic motor or electrical motor is added.

A drive transmission system is included to transfer the torque from one point to another in the winch system and to adjust the torque at different locations. A typical drive transmission system is a gear box to control the output torque and speed from the input drives. In order to reduce the speed or stop the winch cable drum, a brake system is incorprated in the winch system. Winch structures are provided mainly to support the drum and transfer the tow loads to the platform and to interact all subsystem. A photograph of a typical ship based winch system is shown in Figure 2.

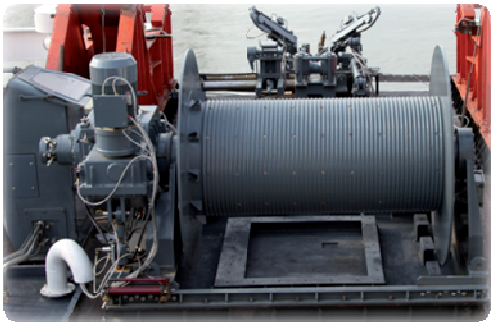

Fig. 2. Typical ship based winch system

4. Advancements

In recent days, technologies in many areas have grown manifold and there by designers can bring out better, compact systems to achieve functional requirements. Even though much advancements are implemented in the system, a few of the very important are discussed. It is the imagination of designers to configure and design winch systems bringing advanced technology components/sub systems.

4.1. Raw material

In marine environment, corrosion is one of the main factors, degrading the life of the system. Apart from design parameters, generally in order to account the corrosion factor, designer used to add an allowance over and above design based values. This leads to over design, increases cost and uncertainty in the life of the system. In recent days, high strength and high corrosion resistant steels are commercially available and manufacturing process are also established with these raw materials. This reduces the maintenance cost and increased life of the system. Some of these materials are: S690QL and WELDOX steel. In the winch system under discussion, these materials are used for structural part.

4.2. Automatic Depth Management System (ADMS)

An innovative idea of ADMS is implemented. The functional requirement is to maintain the depth of payload within the tolerance while towing, when the ship varies the speed or due to any other operational requirements. In order to achieve this, a closed loop control system is implemented. The depth of payload is decided based on the given characteristics of tow cable like density per unit length, buoyancy and speed of the ship. In case if the ship increases speed, the payload depth reduces (ie. tends to surface) and vice versa when ship speed decreases. In that scenario, the winch is automatically activated in the closed loop system. Depth sensors kept in the towed array continuously monitor depth of the towed array and cross checks with the permissible limit. In case of any deviation from the permissible limit, the brake system is released and winch is operated automatically to release additional tow cable or retrieve tow cable. Data on ship speed is taken from ship and payout of cable is calculated from encoder feedback and verified by algorithm provided in the control system. A monograph is prepared for the given configuration of tow cable, for each ship speed with the pay out of the cable, depth of payload is estimated. As per the best of knowledge of the author, first time, such an innovative concept is proved in the system. Figure 3 explains concept of ADMS.

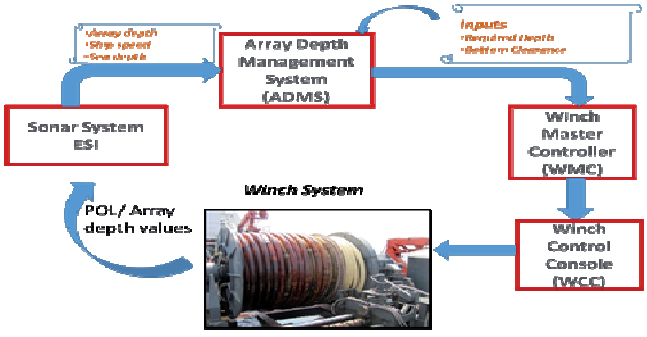

Fig. 3. Block diagram of ADMS

4.3. Multiple diameters of towed array and tow cable

In most of the winch systems, a wire rope or cable of uniform diameter is used in practice. However, the present system warrants multiple diameters of array and tow cable. This necessitated automatic sensing of array and cable diameters and accordingly controls the opening of the spooler vertical roller mechanism. This is very important and critical requirement to ensure smooth winding of cable/array over the winch drum. Any disruption in the winding will damage the cable and ultimately total system. The speed of spooling shaft (diamond screw shaft) will be varied based on the array/cable diameter. In order to achieve this, power is tapped from main gear box through chain drive and with the spooler gear box, the speed of spooler shaft is varied, thereby smooth winding of different diameter based array and cable is achieved. Figure 4 shows the photograph of a multi diameter payload.

Fig. 4. A photograph showing multi diameter payload

4.4. Roller/Sheave based handling system

The winch system on discussion was configured with roller based array and cable handling system. The effectiveness of the handling system is based on tow cable, load carrying member of array and cable, method of handling pay load, vulnerability of joints against drag load etc. However in general, it is essential to support/guide array or cable using sheaves to ensure proper bending radius of same. Based on the author's field experience and considering critically of the system, it is recommended to use sheave based systems to reduce potentiality of damage. Figure 5 is 3D modelling of sheave based winch system. Figures 6 and 7 indicate the implementation of roller based handling system and sheave based handling system respectively.

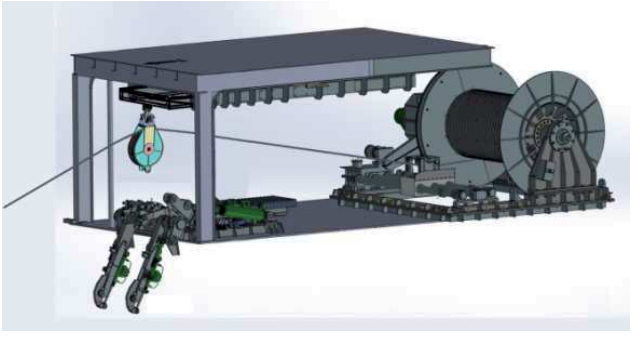

Fig. 5. 3D Modelled winch with a sheave based handling system

Fig. 6. Roller based handling system

Fig. 7. Sheave based handling system

4.5. Variable Frequency Drive (VFD) Technology

Most of the heavy winch systems are electro hydraulic based systems, where winch is operated with a hydraulic motor with prime mover as electrical motor. Speed and torque required at the winch drum from hydraulic motor is achieved using gear transmission drive with necessary speed reduction and increase in torque. The advantage of the hydraulic based system is to vary the speed and maintain torque based on the gear box configuration. However, in recent days, VFD based electrical motors are well proven and available for use. This has made high impact in winch system also, whereby hydraulic based drive is being replaced with electrical based drive. The VFD based drive is used to control speed by varying frequency and achieving less maintenance and leak proof system. This makes the winch system compact and of onboard installation quick.

4.6. Planetary gear box with hypoid based bevel gears

In most of the civilian application based winch systems, only one power drive is used for functional requirement. This is, to reduce cost and also have simple winch system. However, in case of defence application, considering its criticality of the system, it is essential to have redundancy of drive system to ensure reliable winch system. In this line, the winch system under discussion is configured with electro hydraulic as primary drive, independent electrical drive as secondary drive and manual drive as one another drive. This calls for complicated gear drive system, where multiple input drives to cater for redundancy requirements are needed. Hence planetary gear system is introduced in

the present winch. Even in the planetary gear, in order to achieve higher gear reduction, hypoid based bevel gears are recommended to get compact and light weight winch system.

5. Conclusions

This paper discusses in general on the winch systems and brings out recent advances implemented in the winch system for defence applications. These advancements have made a great impact on winch system towards aiming for a reliable, trouble free and fully automatic operation. In order to achieve automation, number of sensors are in-built with feedback control mechanism.

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