Journal of Science, Computing and Engineering Research (JSCER)
Volume-8, Issue-6, June 2025.
DOI: *https://doi.org/10.46379/jscer.2025.080606*

Comparative Review of Improvements in the Design of Winch

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Article Information

Received : 11 June 2025
Revised : 13 June 2025
Accepted : 14 June 2025
Published : 17 June 2025

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Abstract— This Winch is driving equipment for lifting and descending the heavy objects and widely used in the field of engineering mechanisms. It is designed as pulling devices, consisting of rope winding around a horizontal drum turned typically by motor. It is classified into seven major types depending on drive system, such as electrical winch, mechanical drum-style winch, mechanical capstan-style winch, hydraulic winch, mechanical hand-operated winch, mechanical portable winch and hybrid winch. A winch is made up of many components like drum, shaft, rope, winch gearbox and drive system etc.. It is extensively used for pulling heavy load and can be found in mines and marine application. Winches are the fundamental element, for example, in crane and mooring systems for activating cable cars, lifts and as a matter of fact, whenever dynamic pull is required from a flexible rope. It is necessary to improve the conventional design of winches to achieve the strong pull and precise control during winching operation. This review is conducted to study the areas of improvement in the design of winch system to develop the high performance winch for different field of engineering applications.

Keywords: Winch, Pulling device, horizontal drum, rope.

Citation: Loma Verma, Anil Suman, "Comparative Review of Improvements in the Design of Winch", Journal of Science, Computing and Engineering Research, 8(04), April 2025.

I. INTRODUCTION

A Winch is a mechanical device that is used to pull in (wind up) or let out (wind out) or otherwise adjust the tension of a rope or wire rope. Winches are designed as pulling devices, consisting of rope winding around a horizontal rotating drum. It can be manually driven or by electric, hydraulic, pneumatic or internal combustion drive depending on the application, and the driving device are coupled to the drum directly or indirectly according to the availability of torque and torque requirement. It may include a brake mechanism that prevents it from unwinding. The rope is usually stored on the winch, but a similar machine that does not store the rope is called a capstan. The operation of system can be conducted by using convention or nonconvention methods. Convention method consist of mainly human effort or force distributed by human and the cost of operation is cheaper because it does not consist of high tech equipment and also low in maintenance. Non convention system is for most technologies that we see today which the entire burden is been carried out by a machine. Efficiencies rate are also greater then convention system but the maintenance can be high due to the system it have. Winch is selected for particular application depending on the maximum load to be pulled.It is widely used in heavy duty vehicle recovery operation in military application. There are several winches on almost every boat or ship where they are used to pull anchor or mooring lines, halyards and sheets.

II. LITERATURE REVIEW

John L'Espoir worked on the hydraulically operated winch system, generally known as hydraulic winch. He stated that hydraulic winches can be used as mechanical draw works in portable water well machineries. The first hydraulic rig builted by EDSI featured a DP winch as the main drum and a Braden BG6 as an auxiliary winch. The Braden Gearmatic is a planetary winch with internal brake and all hydraulic rig designed to drill 20 inch diameter holes, 1500 feet deep to provide clean drinking water. Braden PD12 Planetary gear winch is used for removing sand, water, and rust from drilled hole. The author introduced the jib winch, jib boom winch and truck front winch type hydraulic winches. The author concluded that the hydraulic draw works are very smooth and reliable in operation and can be used as draw works to handle the heavy load. [1] P. Srinivas and Dr. B.S.R Murthy have designed and developed A.C. draw works with variable frequency drive for E-2000 Oil rig. An oil rig is structure housing equipment used to drill into underground reservoirs for oil or natural gas where hydraulic winches can be used as a draw

works. The draw works is a special purpose winch of an Oil Rig, which is used for drawing in and out, the casing

piping, drill bits and other equipment used in the exploration of oil. The main objective of the design modification of AC Draw Works is to increase the efficiency by replacing the chain and sprockets with gear box, with a view to make the system compact and also to reduce its cost and weight. The A.C. draw works with variable frequency drive overcomes the drawbacks of D.C. motor drive and has increased speed range at constant voltage. The main objective of change and development of some of the features in existing E-2000 draw works, which is been now operated by chain driven system (had 6 different speeds only) is replaced by a gear driven system (16 speeds). The design has been modified and the final analysis of AC draw works shows that the AC draw works is within the designed limits. The dimensions of the drum shaft and the spool drum and the deflection of the housing plate is acceptable. The modified design carried out for E-2000 Oil Rig. The authors concluded that changes are made to minimize the cost factor and maintenance cost, thereby making the system compact, reduces its weight when compared [2] . Jennifer M. Lincoln, Devin L. Lucas, Robert W. McKibbin, Chelsea C. Woodward, John E. Bevan were proposed the method of Reducing Commercial Fishing Deck Hazards with Engineering Solutions for Winch Design. They described the "Prevention through Design" process to mitigate one serious machinery entanglement hazard posed by a capstan deck winch. During their study authors found that, the capstan winch provides no entanglement protection and the hydraulic controls are usually out of reach of the entangled person, hence NIOSH personnel met with fishermen and winch manufacturers to discuss various design solutions to mitigate these hazards. Authors have developed an emergency-stop ("e-stop") that incorporated a momentary contact button that when pushed, switches a safety-relay that energizes the solenoid of an electrohydraulic valve stopping the rotating winch. By this work, authors have given example of practical engineering control which effectively protects workers from a hazardous piece of equipment by preventing injuries due to entanglement. The author concluded that the engineering controls are the most desirable type of intervention because they separate the worker from the hazard and decrease the possibility of an incident occurring. This "prevention through design" approach should prove effective in providing tools for this dangerous industry to prevent injuries on deck, and hopefully inspire others to apply similar ideas to these types of hazards. [3] Zhou Entao and Yang Wenlin investigated motion tracking feed forward control for hydraulic winch. Hydraulic winch is widely used in the field of engineering mechanism. The driving device of hydraulic winch is a hydraulic motor which controlled by electronic hydraulic proportional valve. The response speed of hydraulic winch deeply affects the control precision when the hydraulic winch needs to track a specific movement. Motion tracking feed forward control of hydraulic winch is designed to improve the control precision of hydraulic winch motion tracking. It is shown in the test of hydraulic winch motion tracking feed forward control that the non-linear of hydraulic winch decreases the control precision of motion tracking. The author concluded that hydraulic winch is a non-linear system, which the model parameter is changing frequently and decreases the efficiency of hydraulic winch motion tracking feed forward control. Hence adaptive feed forward control which based on the parameters identification of hydraulic winch is investigated. The motion tracking test and simulation test show that the hydraulic winch motion tracking adaptive feed forward control which based on the hydraulic system parameters identification gains high efficiency of motion tracking. [4] B.A. Griffin investigated High Performance Winch and Synthetic Rope Systems for Workboats, Tug Boats, and Commercial Marine Applications. He introduced winch systems with Ultra High Molecular Weight Polyethylene (UHMWPE) rope, with special reference to ship assist and tanker escort winches, ropes, and fittings for tugboats in the 4000 hp to 10000 hp range. High strength nylon and polyester fibers was used for rope construction in the 1950's. The strength to weight ratio of these new synthetics allowed ropes to replace steel cables in some applications, with great savings in weight and manpower, and with significant increases in vessel and operator safety. However, it was not until the development of Ultra High Molecular Weight Polyethylene (UHMWPE) fibers and rope constructions in the 1980's and early 1990's that ropes possessing the same strength to diameter ratio as steel wire rope became routinely available. In addition to strength, UHMWPE ropes have a low elasticity approaching that of wire, or about 1% stretch at 40% of rated breaking strength, at a weight of about one seventh that of wire. When compared to nylon and polyester, the UHMWPE ropes have greater innate resistance to abrasion. The many advantages of UHMWPE over wire rope, and other synthetic constructions of polyester and nylon in high force situations, have presented several important challenges to marine equipment designers and manufacturers, owners and operators of commercial vessels, and working sailors. UHMWPE rope, and deck fitting systems are used for scientific deployment aboard oceanographic research vessels, fixed and temporary towing

and mooring of oil production facilities, mooring of merchant ship etc.[5] Xiangzhen Yan, Lisong Zhang, Qingzhi Yan and Xiujuan Yang analyzed the feasibility and performance parameters about the application of expansion bushing connection in drum on lifting winch. lifting winch drum was designed for the largest rope force of 14.5 tons, 28 mm wire rope diameter, 650 mm main roller diameter, 1150 mm Drum body length, 220 mm drum shaft diameter. Drum shaft and body have larger structure size and the bear torque is also greater. The connection between drum shaft and body should be designed as expansion bushing connection and use expansion bushing. Inside diameter is 220 mm and

outside diameter is 285 mm. The number of bolts connecting middle elastic rings of every expansion bushing is 26. Bolt diameter is 16mm. Mechanical property grade is 12.9. The Tightening torque every bolt is 248 N- m. The proportion between inside, outside elastic ring and drum shaft, drum body are H8 / h9 and H8 / e8 respectively. Material is 65Mn. practice showed that the design meets the requirements and works well. Considering the heavy bearing load and big torque for the drum of lifting winch author concluded that the expansion bushing connection should be used in drum shaft in order to enhance the overall security and reliability of drum. [6] Vladimir Solovyov and Alexandr Cherniavsky did the Computational and experimental analysis of trawl winches barrels deformations. The necessary use of heavy duty trawl winches can cause plastic deformation of winch barrels, known as rolling and main reason for such deformation are evenly distributed pressure of wound rope and the ‘‘Running spots’’ of contact stresses near the point of contact between the rope and barrel. As the strain increases with number of cycles and strain accumulation rate depends on the barrel size, material, rope tension and rope stiffness. Therefore a special combination of hardware and software developed, which informs the trawler master about the possibility of plastic deformation and helps him to predict situation that can lead to barrel plastic deformation.[7] Etsujiro Imanishi, Takao Nanjo and Takahiro Kobayashi developed a dynamic simulation model for the wire rope on the tower crane considering both contacts with the winch drum and the dynamic characteristics of the hydraulic system using the finite element method. Rapid winch operation often causes disorderly winding of the wire rope, which is an important quality problem. Dynamic simulation is, therefore, required for design of the hydraulic winch system on construction machinery. They Dynamic simulations are carried out to clarify the major factor of the wire rope looseness that occurs with rapid winch operation. The contact between the wire rope and the winch drum is modelled using by variable-length truss elements and bilinear spring elements. If the winch winding operation is carried out in a disordered winding condition, the wire rope suffers considerable damage. The dynamic behaviour of wire rope that occurs at hydraulic winch stopping is affected by the dynamic characteristics of the hydraulic system. A slow-stopping hydraulic winch system has been proposed, and the system can prevent disordered winding even if the winch is rapidly operated. [8] M. Matejic, M. Blagojevic, V. Marjanovic, R. Vujanac, B. Simic had investigated the tribological aspects of process of winding the steel rope around the winch drum. They focused on the analysis of friction between the steel rope and winch drum during the process of winding and unwinding of rope around the winch drum. As the result of the research, certain mechanisms of winding of the rope from the aspects of the friction force were obtained, and the effects of the forces on the sides of the drum were analysed. They proposed the Mathematical model of steel rope winding around the winch drum, which is used to define the single layered and multi-layered winding. This mathematical model has been developed, which for given initial parameters of winding of the rope gives the friction forces diagrams, perpendicular forces, as well as the comparative friction forces diagram for different coefficients of friction. Using the mathematical model and friction force calculation, it has been shown that the friction force in the rope spooling onto the winch drum process does not depend only on the friction coefficient, but also in the position of the rope during the process. It has been shown that the greatest friction forces occur during the crossing of the rope from one layer to another. With the increase of the friction coefficient, the time needed for the pulling to friction force transfer shortens. [9] P.F. Cabral developed the Electrically driven traction winch of Maximum pulling capacity of a 10 tonne load over inflatable tires in a 15º inclined plan having the range of 50 m and nominal traction speed of 0.5m/s at full load. He described the ideation, design, conventional sizing calculation based on expedite empirical equations and validation of the results by the use of finite elements analyses of the critical components in a traction winch intended for use in marine environment. Their purpose is to provide a reliable and safe means of pulling boats over wheeled dollies out of the water up an inclined plan. The author’s experience in boating has contributed for the initial empirical ideation of the mechanism and concluded that the process of conception and calculation of mechanical systems is one of heavily iterative nature, experience being a very important factor in allowing the engineer to approach the design with empirical initial sizing close to those that

calculations will confirm to be the final component’s characteristics, thus saving precious design time. He also concluded that the sizing equation used to dimension the spur gears (Lewis’ equation) is fairly conservative by comparison with the finite element analyses results. This illustrates the principle that shall govern every engineering project and by which the designer must always be suspicious of the results obtained by a single methodology, being a good principle and practice to always confirm results by means alternative to those used in the first place, especially if major personnel or property damage is probable of resulting from failure of the designed equipment.[10] Lim Buan Teck analyzed stress loading on the drum subjected to multilayer of rope and improved design of an anchor handling and towing winch. He studied the relation between multilayering and generated stress on drum, therefore determine the critical thickness to balance the manufacturing cost and safety of operation. Two experiments were conducted on the prototype to simulate the actual loading on drum under shaft. The experimental result proved that generated hoop stress depends largely on the loading conditions. As the wounding continue to load on another

layer of rope on the wounded layer of rope, the inner wounded rope will experience lesser pulling force from the load. The inner layer of rope acts to be part of or additional thickness to the cylinder, and therefore, the hoop stress generated is much lower. [11] Joey McKee proposed the design, construction and evaluation of hydraulic powered power take off or PTO winch for M37 cargo truck, produced by the United States in 1952. He replaced the factory mechanical drive system with the complete hydraulic system. This winch is rated at 7500 lbs. receives its input power via a driveshaft connected to the transmission power take off gearbox capable of bidirectional operation. When the winch is operated the PTO hydraulic pump is engaged providing hydraulic pressure controlled by a 4 way valve delivering flow to a hydraulic motor. The hydraulic motor turns a small driveshaft directly coupled to the back of the factory winch. Author concluded that the size of the hydraulic pump in this system is larger than necessary to run the one hydraulic motor. The largest problem with outfitting a vehicle with a hydraulic system is acquiring enough room to fit the various components while retaining functionality and ease of maintenance. [12]

III. CONCLUSION

Winches are available in different types based on drive system. They are driven by using hydraulic system, pneumatic system, electrical system and mechanical system. So depending on the drive source they are named as hydraulic winches, pneumatic winches, electrical winches and mechanical winches. They are used in various field of engineering application such as, in portable water well machineries, marine environment, boat or ship, oil rig, vehicle recovery etc. The above literature review presents various areas of improvements in the design of winch system, which helps to improve its performance. Analyses of winch components are carried out to find the causes of poor performance and corrective solution is implemented for better performance of the overall system. Here improvements are made to minimize the cost factor and maintenance cost there by making the system compact, which meets the winching requirement of particular system. Proper safety is the important consideration in the design of winch system. Authors provide the prevention through design approach to prevent the injuries during winching operation and to perform the safe operation. Thus developed design of winches can be used to pull heavy load in every field of engineering application. ACKNOWLEDGMENT First, I would like to thank my advisors and guides Prof. Ashtekar Jaydeep (Asst. Prof. at VACOE Ahmednagar) and Mr. Kulkarni Mangesh (Scientist, VRDE Ahmednagar) who provided extensive guidance in many times of need and sharing of knowledge. I would like to express my deep sense of gratitude to Mr. Ghogare Vikas (Scientist, VRDE Ahmednagar) and Prof. Kharad Bharat (M.E. Coordinator, VACOE Ahmednagar) for their valuable encouragement and support. I would like to thank my parents for their motivation and supports.

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