International Journal of Analytical, Experimental and Finite Element Analysis
Vol. 7, Issue. 4, Dec 2020, pp 91 - 100
https://doi.org/10.26706/ijaefea.4.7.20200807

An Evaluation on Computer Aided Design, Analysis and Mechanical Properties of Hatch Cover Opening Hooks

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Abstract— **Warehouses inside the ship are of great importance in maritime transport. Due to the adverse weather conditions in maritime transport, hatch covers must be manufactured appropriately and installed on ships. In this study, Computer Aided Design (CAD), manufacture, analysis, and mechanical properties of hatch cover opening hooks used to close stock type warehouse lids in maritime transport were examined. In literature studies, the mechanical properties of St-37, St-52, St-44, St-70, AISI 4140, Weldox 700, Hardox 600 steels, and Aluminum 6061 materials used as hook materials were examined. In the studies, it is seen that curved crane hooks and the same materials are preferred in these hooks. It was concluded that it would be appropriate to use St-37 from structural steels, AISI 4140 steel from tempered steels and high strength Weldox 700 steels as hook material. There is a need for the design and manufacture of special hooks for cranes made to open and close the hatch covers. Hook design - analysis by Finite Element Method (FEM) should be done and stress values should be examined. Accretion stress points should be determined by this FEM and a reliable manufacturing should be done. In addition, optimum conditions will be achieved by designing and manufacturing hooks with economical, long life and high mechanical properties.**

Keywords— *Hatch cover, Hooks, CAD, FEM, Mechanical Properties*

I. INTRODUCTION

In World Trade, the ability to transport manufactured and manufactured goods from the point of production to markets without damage, as soon as possible and cheaply has been a determinant of competitiveness among transport types. In this context, maritime transport took the first place among transport types with a share of 90% [1]. Transportation is one of the most important elements of foreign trade. When we look at the profitability rates among the types of transport, we see that maritime transport is 14 times cheaper than by airline, 7 times by road and 3.5 times cheaper than by railway [2]. For this reason, most of the cargo in World Trade is transported by seaway. These ships have warehouse sections in the transport section. On ships, dry cargo is carried in compartments located in the hull and called warehouses. Each compartment is covered with covers to protect it from effects such as sea water, rain, solar heat and to create usable areas on the deck [1, 2]. Hatch covers are used to cover the cargo in the hatch/cargo area and to protect the cargo from air, sea conditions [3]. Hatch covers are made of various materials to protect them from the adverse effects of air and sea water. It also closes the hatch opening, making the area waterproof [1-4]. The first hatch covers were made using wooden materials [5]. These hatch

Research Article – Peer Reviewed
Published online – 19 Dec 2020

Cite this article – Ömer ŞENGÜL, Menderes KAM, "An evaluation on computer aided design, analysis and mechanical properties of hatch cover opening hooks", *International Journal of Analytical, Experimental and Finite Element Analysis*, RAME Publishers, vol. 7, issue 4, pp. 91-100, 2020.
https://doi.org/10.26706/ijaefea.4.7.20200807

covers made of wood could not withstand weather conditions last long [1-5]. In some studies, hatch covers have also been manufactured with composite materials that are not affected by lightness and weather conditions, but these hatch covers have also not been preferred because they are not very durable [1,3,5]. Today, hatch covers are made the various types of steel and cast iron [6]. Hatch covers are widely used today and have been studied by many researchers [1-6]. Stacking hatch vovers are known as the most common [1]. There are specially designed cranes to mount these hatch covers to the hatch sections on freighters. The biggest problem with these cranes is the synchronization problem of the crane and the hatch cover when installing the hatch covers. In order to solve this synchronization problem, the design and manufacture of specially designed hooks should be done [1-6 , 7]. In addition, optimum conditions will be achieved by designing and manufacturing hooks [6,7] with more economical [1-5], long life [5], and high mechanical properties [5, 6]. Therefore, in this field in the literature studies, and especially current studies have been extensively examined.

A. Hatch Covers

Hatch covers are used to close warehouses located on ships to carry cargo through ships [1, 2]. It is placed to make the hatchway for waterproof, to protect the load placed in the warehouse from all weather conditions, as well as to strengthen the structure in the openings of the hatchway. Warehouse covers are made of wood, composite, and steel materials according to the material they are made of [1, 2]. Currently, hatch covers made of steel materials are widely manufactured [5].

a. Folding Type Hatch Covers

This type of hatch covers protects the warehouse load from harsh weather conditions. They also allow cargo to be stacked on deck, as in container ships [7]. Folding type hatch covers are used on handy size and handy max bulk carriers, where maximizing hatch sizes relative to the ship's beam is particularly important [8]. Reliable and proven folding hatch cover technology enables efficient and safe shipping. This is especially important on remote ports where maintenance services may not be available in a short time. Figure 1 shows folding type hatch covers.

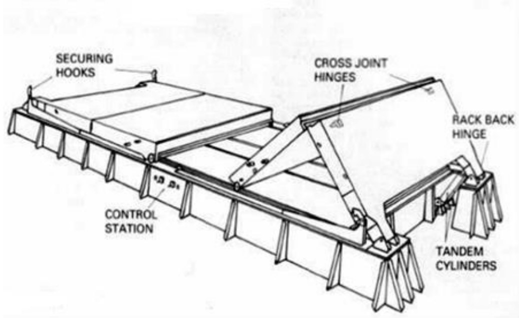


Figure 1. Folding Type Hatch Covers [8].

b. Rolling Type Hatch Covers

These types of hatch covers are covers consisting of two wings that open to the port and starboard direction of the ship, with the wheels sliding smoothly on a rail. It is often used on large bulk carriers [9]. Figure 2 shows rolling type hatch covers.

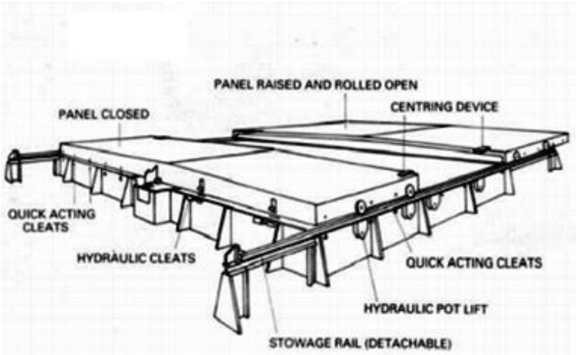


Figure 2. Rolling Type Hatch Covers [9].

c. Stacking Hatch Covers

This type of hatch covers is found on cargo and general cargo ships manufactured by small single hatch casting. The operating mechanism is to lift with hydraulic pistons located in the hatch mouth and stack the covers on top of each other [1-9, 10]. Figure 3 shows stacking hatch covers.

Figure 3. Stacking Hatch Covers [1-10].

d. Lift Away Hatch Covers

Opening and closing of this type of hatch is completely done with the help of cranes [11]. It is a simple hatch cover [12]. Figure 4 shows the lift away type hatch covers.

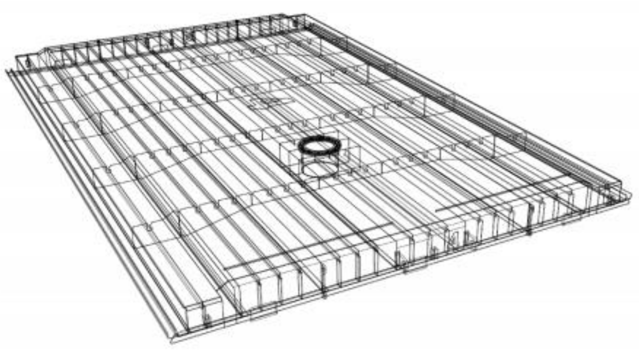


Figure 4. Lift Away Hatch Covers [11]

II. Hook Design, Manufacturing And Analysis

The most important machine element of lifting machines is hooks. Hooks get names according to the function performed. Attention is paid to its functions when designing hooks [13]. The design, manufacture and analysis of hooks are carried out by various methods. The aim of this study is to design specially designed hooks for hatch cover gantry.

A. Hook Design

There are many design programs when designing hooks. Currently, hooks are usually designed using SOLIDWORKS and CATIA design software [13]. In studies [14], the C hook design was made to carry heavy loads attached to the crane hooks and to balance the crane hooks [15]. The design of the model was made by the CATIA program.

Figure 5 shows the C hook type design. This type of hooks is designed for the most economical and safe lifting of coils. In Figure 6, they are simple built hooks used for cranes. This type of hooks is a model used to lift industrial heavy loads. Also, this type of hooks is a kind of hook that is mounted on the crane with wire ropes.

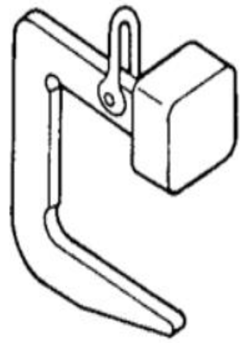


Figure 5. Balanced C-hook Lifter [14]

Figure 6. Design of Lifting Hook [16]

In Figure 7, the designed crane hook is used to lift the load with the help of a chain or pods. This hook type has extremely sensitive components and it is subject to very rapid breakage during lifting [17]. This type of hook is also modelled by CATIA design software.

The crane hook designed in Figure 8, it is a machine element designed for lifting very heavy loads on large cranes [18].

Figure 7. Crane hook model [17]

The typical crane hook was shown in Figure 9. It is a type used for general industrial purposes. It is designed by SOLIDWORKS software [19].

A special trapezoidal cross section crane hook model was shown in Figure 10 [20]. It is modelled on the CATIA software program.

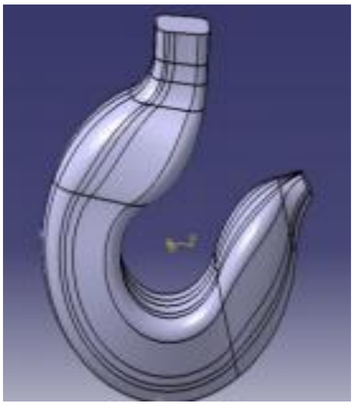


Figure 8. 3D Model of Trapezoidal Section [18]

Figure 9. Crane Hooks [19]

Figure 10. Special Crane Hook [20]

In Figure 11, a special wire rope winch hook design is modelled by CATIA design software [20]. Figure 12 shows the crane hook modelled by Catia design software [21]. In Figure 13, the design of the hook for decorative purposes was made by SOLIDWORKS design software.

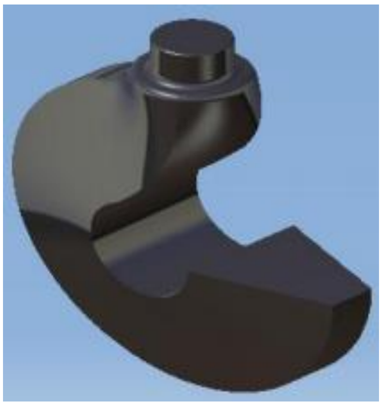


Figure 11. Crane Hook Having Trapezoidal Section [20]

Figure 12. Special Hook Crane [21]

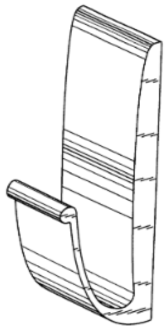


Figure 13. Decorative Hook Design [18-21]

B. Materials Used in Hook Manufacturing

Many materials are used in the manufacture of hooks. St-37, St-52, St-44, St-70, AISI 4140, Weldox 700, Hardox 600 steels, and Aluminum 6061 for the manufacture of different types of hooks examined in the literature, the mechanical properties of the materials are given in Table 1. According to these data, AISI 4140, Weldox 700, and

Hardox 600 steels stand out for their high strength. Due to the low elongation value of Hardox 600 steel, it is believed that it can break more easily against impact and is not suitable for use, especially in dynamic loading.

TABLE 1

MECHANICAL PROPERTIES OF THE MATERIALS

Material	Tensile Strength (MPa)	Yield Strength (MPa)	Strain Failure (%)	Hardness (HB)
St-37 Steel	340-470	215	25	125
St-44 Steel	430-580	255	21	143
St-52 Steel	490-630	355	21	180
St-70 Steel	670-830	345	10	210
Alüminim 6061	55-124	103-228	26	65
AISI 4140 Steel	900-1100	750	12	190
Weldox 700 Steel	780-930	700	14	240-310
Hardox 600 Steel	2000	1650	7	570-640

St-37 structural steel is used in the manufacture of many machine elements today. In recent studies [23], it is widely used in simple overlay bonding connections. This material is suitable for use in cold drawing operations by re-processing after hot production [24]. Both the welded joints of this material and the removable fasteners are made with the appropriate joining process. Due to such features, new studies [25] have shown that the frequency of use in the construction sector has increased.

St-52 structural steel is widely used in industrial structures, building construction, bridge construction, shipbuilding, and offshore breakwaters [26]. It is mainly used in the construction industry and in applications requiring high strength. In recent studies [27], in products made of composite material with St-52 steel and layered with this new composite material, the inner part of the steel with very high strength and the outer part of the production was made with this composite material. In current literature studies, St-52 steel has been used in layered productions by making composite with laminated [28].

St-44 structural steel is widely used in the construction industry and in the construction of high strength hot drawn industrial profiles. In recent studies, they have made a composite with mild steels and subjected this composite material to heat treatment after tempering, placing this composite material between the two steels to extend the life of the material under dynamic loading conditions [29].

St-70 structural steel is widely used in applications requiring rivets, special bolts, wedges, and good strength. In recent studies [30], it was welded using electric arc protected electrodes and heat treatment was applied after this welding [30, 31].

Aluminum 6061 with good corrosion resistance, it is widely used in defense industry, aircraft industry, shipbuilding industry [31]. There are also application areas such as thermoform vacuum molds, low pressure blow molds, automotive material, aircraft parts, camera lenses, marine equipment, bicycle cases, brake pistons, hydraulic pistons. It has also been used in the manufacture of hooks that do not require much strength [32]. In addition, the wear behavior of cutting tools was also studied [33].

AISI 4140 steel is a material known in industry as tempered steels, used in shafts, gears, and machine parts operating under high stresses with high tensile strength. In the literature studies, dynamic behaviors, vibrations, surface roughness, and mechanical properties (hardness, tensile strength, and breaking strength) of different heat and cryogenic treated tempered steels were examined [34-37].

Weldox 700 is also high in high strength, light weight, wear resistance, and corrosion resistance. They are widely used in the defense industry. In recent studies [38-40], it has been used in armor construction and the interaction of armor and bullets has been studied experimentally.

Hardox 600 is steel with a much higher hardness formed by dressing metal layers of ordinary steel. Although it is generally used in the construction and mining sector, it has recently been used in many areas. In the studies, the weldability properties of these materials were examined [40].

C. Finite Element Method (FEM)

The finite element method (FEM) is a numerical method commonly used today for precise solving of complex engineering problems [39-41]. FEM is used in many engineering fields. Stress values and numerical solutions of hooks under static and dynamic loads are commonly performed today with ABAQUS and ANSYS analysis programs. For deriving reduced models for geometrically nonlinear structures nearly twenty years in a sequential, predetermined displacements of a finite element static and dynamic applications in the finite element method has been used [42]. In Figure 14-15-16-17-18, studies on some FEM were examined.

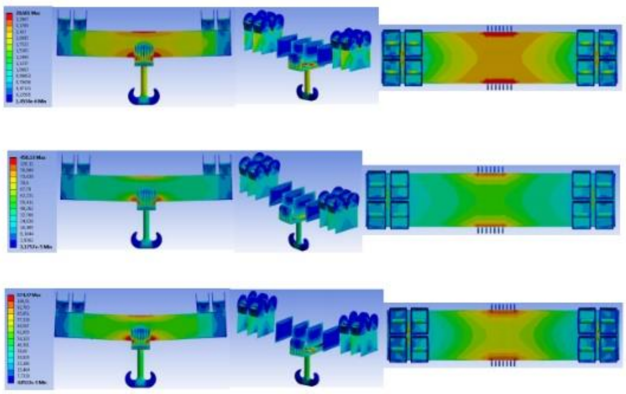


Figure 14. Analysis with Numerical Method of Gantry Crane Hook [43]

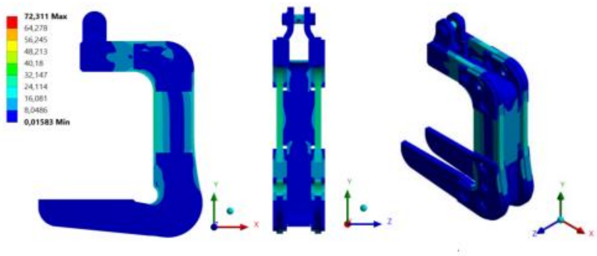


Figure 15. Strength Analysis of C-Hook for Hoad using the Finite Element Method [15]

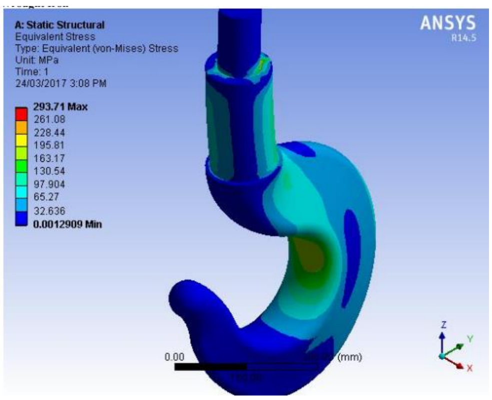
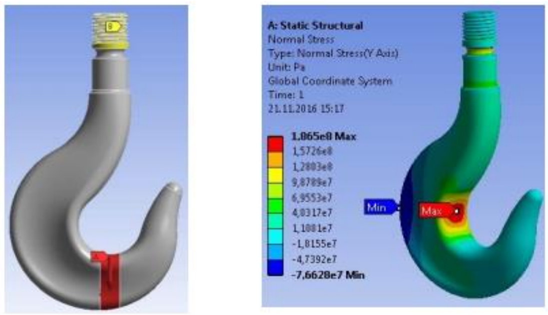


Figure 16. Analysis of Special Crane Hook [44]



(a) (b)

Figure17. (a) Boundary Conditions (b) Stress Contour on Lifting Hook [45]

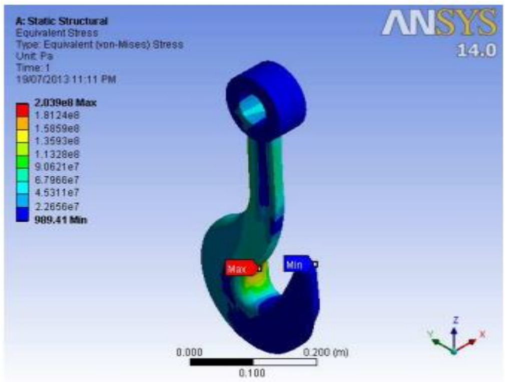


Figure 18. Trapezoidal cross section crane Hook [46]

A study conducted in Figure 14 [43], 2x400-ton crane hook was examined. In this study, static and dynamic loads of the hook during the movement of the crane were determined. The resulting stress values were compared with the values obtained from analytical calculations. These values overlap with each other.

In the study conducted in Figure 15 [15], the fatigue analysis of the material and the life calculations of the hook were performed by finite element method under dynamic loading conditions in this special hook, which was designed with a special type of C-hook.

In the study conducted in Figure 16 [44], gray casting was processed in high-strength low-alloy steels under different loading conditions using structural steel material data. Stress values formed under these different static and dynamic loads and where stresses accumulate were studied by the finite element method.

In Figure 17, the study [45], a lifting hook with a lifting capacity of 50 kN under static loading conditions in the stress values and critical points of the different materials were determined by FEM. The stress values of these critical points have been compared with the theory of curved beams.

In the study conducted in Figure 18 [46], the voltage distributions of the crane hook were examined. The results for measuring the stress value with Winkler-Bock theory have been compared with the FEM.

The FEM will guide the determination of errors that will occur without the production of a design.

III. Production Methods

There are many production methods of hooks, which are diverse. Simple hooks are produced by forging in mold or free [47, 48]. With the forging process, we can especially give examples of crankshafts, hand tools, bolt heads, gears, wheels, connecting rods, hooks [49]. By forging, the mechanical properties of the workpiece are increased. In addition, forging is done by using the physical state change of the material. Simple built escapes are produced by closed die forging processes [50]. Simple hooks manufactured with aluminum material are manufactured by hot pressing method [51]. The manufacture of rope hooks by the combined molding method is also in the works [52]. This combined molding method prevents time loss in production based on classic methods and saves cost by mass production [53]. In addition, hook production is carried out by casting method [54].

IV. Conclusion

In this study, CAD, manufacture, analysis, and mechanical properties of hatch cover crane hooks used to close hatch cover in maritime transport were examined. In this context, the strength of structures is an important indicator for their ability to carry loads. From a safety point of view, it is important to reduce the failures of hooks and determine where this failure is caused. The stress values that occur on the hooks and the critical stress points that accumulate in some parts of the hook should be determined and improvements should be made here. In the literature studies, it has been concluded that curved crane hooks and these hooks always use the same materials. It was concluded that the design and manufacture of special hooks for cranes manufactured to open and close the hatch covers specially designed to close the hatch cover of cargo and cargo transport ships were not carried out. It is also thought that classical hooks may not perform this task correctly. Therefore, more thorough research should be done. In this context, there is a need for the design and manufacture of special hooks for cranes made to open and close the hatch covers. Hook design and analysis by FEM should be done and stress values should be examined, and accretion stress points should be determined by FEM and a reliable manufacturing should be done. Alternative production methods for the production methods of llama type hooks have not been included in the literature studies. It has been concluded that production can also be done with plasma, laser cutting method and machining methods in llama type hooks. It was concluded that it would be appropriate to use St-37 from structural steels, AISI 4140 steel from reclamation steels and high strength Weldox 700 Steels as hook material.

As a result, optimum conditions will be achieved by designing and manufacturing hooks with economical, long lasting and high mechanical properties.

Acknowledgement

We would like to thank the Düzce University Scientific Research Projects Unit for their contribution to the project coded 2020.22.01.1124.

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