Redesigning the Cardinal

Public summary

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This Thesis covers an Industrial Design Engineering assignment provided by Universal Storage Containers. It explores the development of a new mechanism for the Cardinal mule, with it's primarily objective of assembling multiple Z-boxes at a storage container park. This required a lifting capability of 350 kg at a height of 2.6 meters.

The Z-box is a storage container designed by USC, which has a foldable and modular design. This means that the containers are delivered as flat sandwiches with the floor at the bottom and the floor on top, the walls folded between them. These containers are delivered in several models which have different storage sections within the container. Model 2 features two distinct compartments within the container, whereas Model 6 includes eight separate compartments. USC markets these containers to clients operating storage businesses, which function similarly to real estate ventures. Typically, clients place orders for substantial quantities of containers (exceeding twelve units), and these orders are subsequently transported and assembled by USC.

Twelve Z-box containers can be transported within a single 40-foot ISO container due to their folded design which saves a lot of costs. However, a disadvantage of this design is that the containers must be assembled at the on-site location. In this process a forklift is needed for removing the roof (350 kg) from the package, such that the building team can tilt the walls to a 90-degree angle. After this the forklift should relocate the roof on top of the assembly by lifting it 2.6 meters.

Unfortunately, renting a forklift incurs high costs and logistical challenges. Therefore the redesigned Cardinal mule, aims to replace the forklift, reducing cost and improving logistic flexibility. The research question that guides this thesis is: *"How can a Cardinal Mule be redesigned such that it can replace a forklift in the building process of a container park?"*

The Cardinal mule in Figure 1 is a specialized vehicle designed for load handling and transportation. These machines are typically compact and maneuverable, which makes them perfect for navigating tight spaces commonly found in construction sites, warehouses, and industrial environments. It is mostly used for moving heavy loads such as ISO containers, sheds and storage containers. The cardinal mule has a gasoline engine which powers the driving lifting mechanism. To move these large loads it uses two additional wheels which are attached at the bottom. In Figure 1a and b is shown how the Cardinal mule operates.

Figure 1a and b - (source: Cardinal Manufacturing LLC, (2024))

Unfortunately, this machine does not have the required lift capabilities of a forklift, it can only move loads by lifting approximately 0.5 meter of the ground with its hydraulics. Therefore the mini-crane concept was selected from three proposed designs and was subsequently further developed through four different subprojects; the Crane boom, Connection part, Lift mechanism and Stability fork. Each subproject is backed with additional research into safety regulations, supported with stability calculations, pin calculations and confirmed with a FEM analysis. The final design consists of a mini-crane connected on top of the Cardinal mule shown in Figure 3, in combination with a stability fork shown in Figure 4 to secure the stability of the machine during lift operations. The mini crane is powered by a hydraulic winch shown in Figure 2

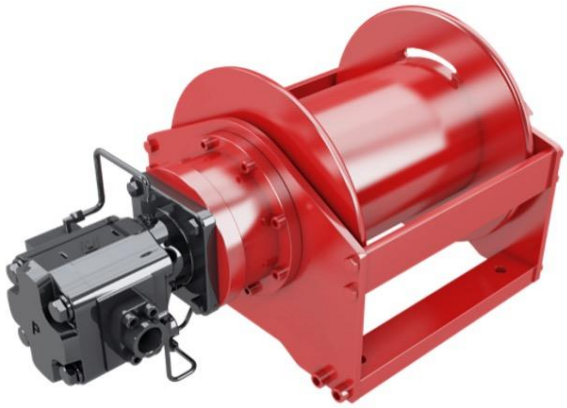

Figure 2 - NP08 Winch (Source: Dynamic Oil, (2024))

Figure 3 - Final design crane boom with connection part

Figure 4 - Final design Stability fork

To finalize this thesis a detailed cost evaluation is done which gives insight into the total cost of the cardinal, additional mechanism and other cost items. These are compared to the current cost of renting a forklift. Which resulted in a return on investment of 2.88 years. Furthermore the design is evaluated on its manufacturability and verified with the established requirements of the Analysis phase. This combination resulted in a new Cardinal mechanism capable of lifting a 350 kg roof to a minimum height of 2.6 meters as shown in Figure 5 and 6, while also being financially attractive.

Figure 5 - Redesigned Cardinal mule lifting the roof

Figure 6 - Redesigned Cardinal mule placing the roof