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Optimal Design for Robot Arm to Lift Electrical Cabinets with a Mass of 150 Kg

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Abstract: With the continuous development of industrial automation, the demand for industrial robots in the manufacturing sector is gradually increasing. Most types of robots are equipped with all driving resources on all stages to create completely automatic trajectories. In addition, many types of robot arms have one or more driving sources at the main joints, and the remaining joints will move according to the operator's control. This helps assist in moving the device according to the operator's trajectory. Therefore, optimizing the mass of the manipulator mechanism while still ensuring the durability of these types of manipulators is very necessary. The research object of this article is to optimize the design for the stages of the power arm lifting the electrical cabinet with a maximum weight of 150kg.
Keywords: Industrial automation, robots, design, optimizing, electrical cabinet

I. INTRODUCTION

Arm robot manipulators are widely used in industries ranging from welding, pick and place, assembly, packaging, labeling, ect. Trajectory planning and tracking is the basic design of an arm robot controller. The trajectory is established and determined to satisfy a certain criterion effectively and optimally. Optimizing the robot's trajectory is necessary to ensure good quality and energy-efficient products, and this optimization can be provided by appropriate modeling and design. The article [1] presents an evaluation study on the design and control of an arm robot controller for trajectory tracking by studying the modeling of the arm robot controller starting from kinematics and dynamics. learning and application of more advanced methods. The paper [2] presents a new motion controller to manipulate objects in 6D space with a two-arm robot controller. Current industrial systems typically consist of a single robotic arm controlled via a pendant. These systems cannot pick and place boxes of different sizes due to the limited specifications of the end-effector, which is very limiting. The study [3] presents the design and analysis of a six-degree-of-freedom (DOF) controller for welding, pick-and-place applications. The study developed the design of a robot using Solid Works and analyzed its motion, load capacity, and path tracing capabilities. However, robot design and analysis involves modeling its forward and reverse kinematics. The study modeled the forward and reverse kinetics using D-H parameters. The proposed model allows manipulator control to achieve any accessible position and direction in an unstructured environment. The research [4] presents a new way to find the optimal length and shape of two important links of a manipulator, in which the target length is as short as possible to reduce the mass and shape in the form of lines. The Bézier curve is chosen to avoid collisions. The chosen kinematic structure of the manipulator is fixed and based on the most typical structures of existing industrial robots, with six degrees of freedom. Two variables of the algorithm have been proposed; one method uses iterations to find a solution based on in-depth collision analysis, and the second method uses the PSO algorithm. The article [5] deals with the modeling and analysis of kinematics and kinematics for a robot arm consisting of two hydraulic cylinders that drive two rotating joints of the arm. The two cylinders and associated links of the robot form two locally closed kinematic chains that are added to the main robot mechanism. Therefore, the number of generalized coordinates of the mechanical system is increased, and the more complex mathematical model requires the construction of constraint equations for locally closed chains. Using the Lagrange formulation with the Lagrange Multiplier, the dynamical equations are first derived for all extended generalized coordinates. Then, a reduced form of the dynamic equations is generated by canceling the Multiplier. The article [6] presents a method for designing a position/sliding force controller for a robot control mechanism in limited working environment conditions. Compared with the traditional PID controller, the sliding controller has advantages such as high stability, high robustness, and ensures high interaction between the robot and the robot tracking the reference value regardless of uncertainty. protection of parameters. The stability of the position/force controller is proven using Lyapunov theory.

The lifting mechanism helps move equipment in the factory on a small scale, making it a very practical device to increase product movement speed while reducing direct labor and increasing worker safety. , with parts weighing from 25 kg to 500 kg, the use of this structure brings very high economic efficiency. These structures are currently being equipped in small and medium factories to Gradually replacing the daily work of workers, because the driving force of this structure is very little and the movement trajectory mainly relies on direct control from the worker, so the structure needs to be compact and lightweight. Flexibility and structural design and optimization according to lifting load is a very important issue of this structure. In this article, the author mentions the design and optimization of the structure for a 5-degree-of-freedom lifting mechanism combined with a clamp to assist in moving parts weighing less than 150 kg with ease. Moving radius is 1110 mm, maximum lifting height is 600 mm.

II. DYNAMIC DIAGRAM, DIMENSIONS OF CALCULATION OF DRIVING RESOURCES FOR STRUCTURES

II.A. Dynamic diagram and dimensions of the structure

The power steering mechanism has 5 degrees of freedom, of which 1 degree of freedom uses a hydraulic cylinder to drive, the other joints can move thanks to the operator's intervention.

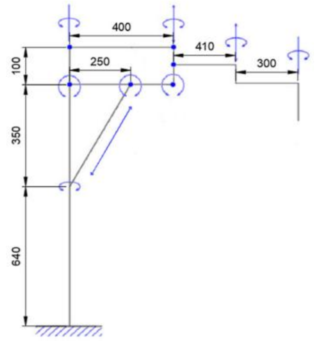

Figure 1 Dynamic diagram and dimensions of the structure

II. B. Calculate hydraulic cylinders

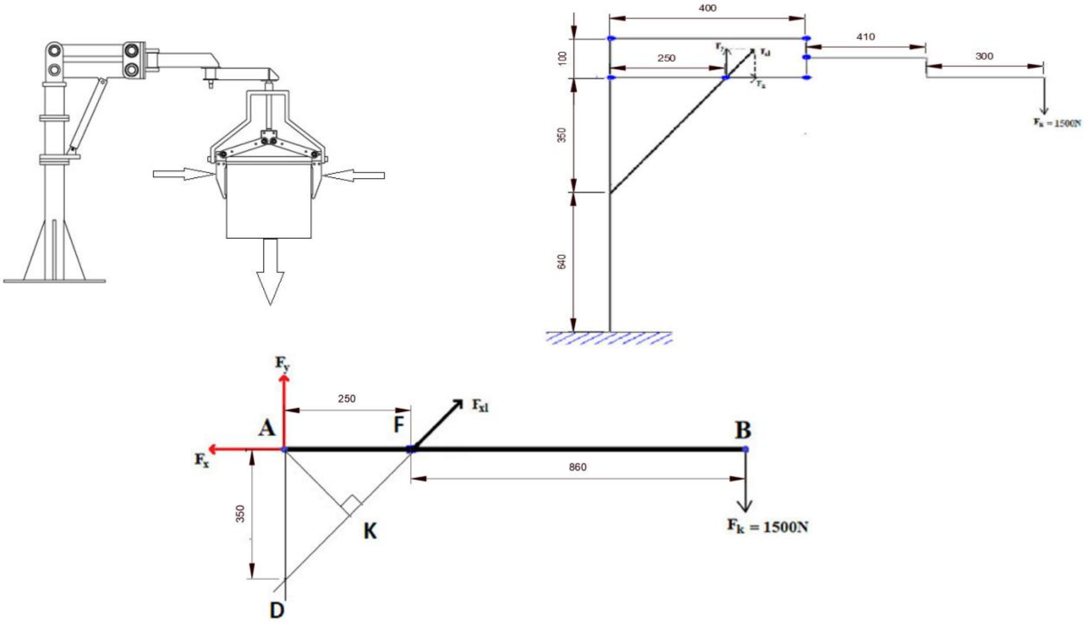

Figure 2 Force-bearing diagram of the structure and link separation diagram

Calculate the force required for the cylinder:

$$\text{Tan } \widehat{AFD} = \frac{350}{250} \Rightarrow \widehat{AFD} = 54^0 \quad (1)$$

$$\text{Sin } \widehat{AFD} = \frac{AK}{AF} \Rightarrow AK = 202.25 \text{ mm} \quad (2)$$

According to the balanced equation:

$$M_A = F_{xl} \times 202.25 - F_k \times (860 + 250) = 0 \Rightarrow F_{xl} \approx 8232 \text{ N} \quad (3)$$

Calculate the diameter D of the cylinder:

$$F\,(N) = 3.14 \times D \times D \times \frac{p}{40} = 8232N \text{ (with p = 140bar)} \Rightarrow D \approx 27 \text{ mm} \quad (4)$$

⇒ Choose 40 – Hydraulic Cylinder (p = 140 bar, D = 40) from SUMAC

III. MAIN STAGES OF LIFTING STRUCTURE

Figure 3 shows the main stages of the structure

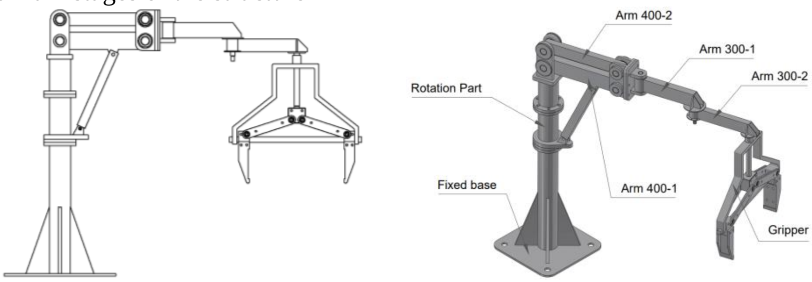

Figure 3 The main stages of the lifting structure

IV. OPTIMIZE THE STRUCTURE OF THE STAPLES OF THE LIFTING STRUCTURE

IV.A. Optimization problem

With commonly used structures of lifting and lowering assist structures, they are often not optimized in terms of the entire structure to ensure uniform durability conditions to reduce body weight as well as save materials when mass produced. To optimize this problem, we will place the force at the clamping tip of the lifting mechanism, considering the most dangerous position of the mechanism is when the links are fully extended as shown in Figure 4.

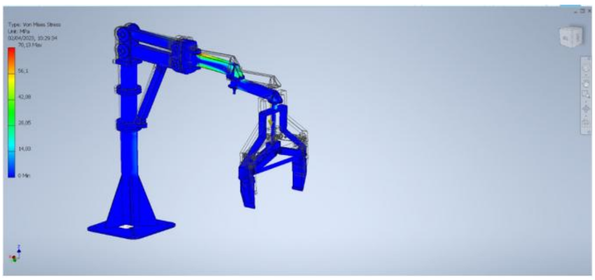

Figure 4 The most dangerous position of the mechanism is when the links are fully extended

IV.B. Optimize the lever arm 300-2

Drawing of the 300-2 lever arm before optimizing the material is steel with a mass of 3.257kg shown in Figure 5. The maximum stress before optimization is 37.55 MPa

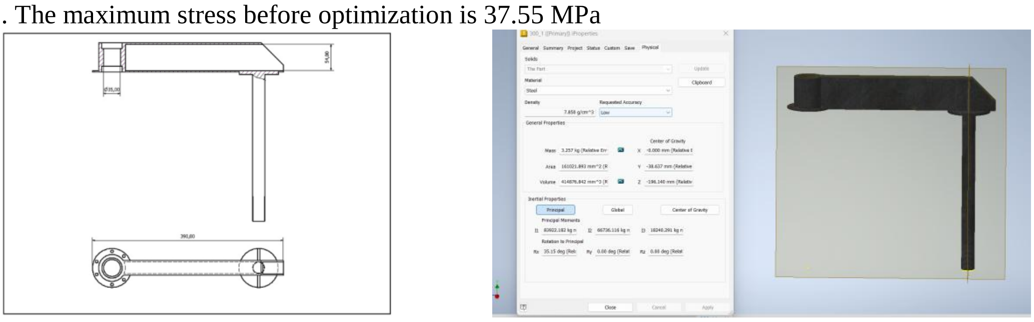

Figure 5. The drawing of the 300-2 lever arm before optimizing

Lever arm 300-2 after optimization:

+ Raise the wall thickness of the part, the distance between the top and bottom surfaces is 51 mm, 4 mm smaller than the original distance. Lift a distance of 89 mm in length.

+ Reduce the thickness of the remaining parts.

+ Increase inner diameter from 33mm to 40mm, optimal weight is 2.791kg

+ The optimal post-stress is 37.71 MPa, almost unchanged, and the mass has been reduced by 0.5 kg.

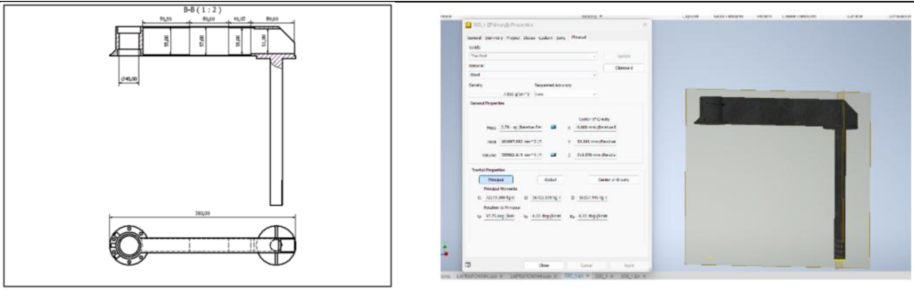

Figure 6 The drawing of the 300-2 lever arm after optimizing

IV.C. Optimize the lever arm 300-1

Drawing of the 300-1 lever arm before optimizing the material is steel with a mass of 2.954kg shown in Figure 7. The maximum stress before optimization is 70.69 MPa

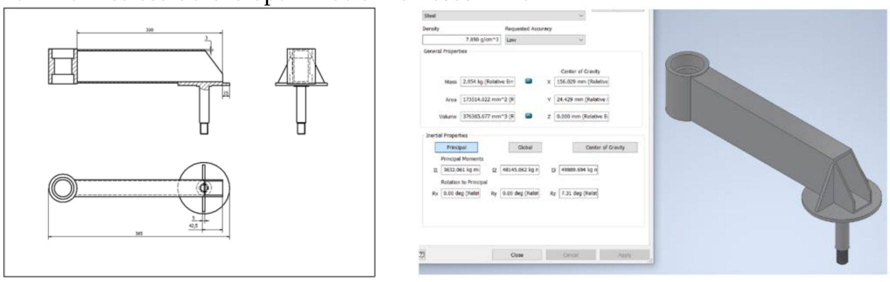

Figure 7 The drawing of the 300-1 lever arm before optimizing

After optimization: Dimensions of the lever arm 300-1 and weight 2.390kg shown in Figure 8. The maximum generated stress is 73.37 MPa.

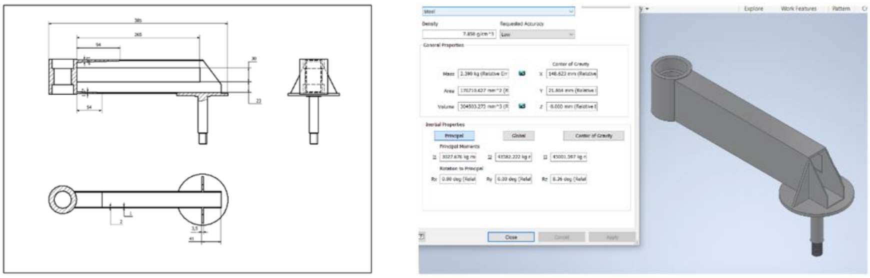

Figure 8 The drawing of the 300-1 lever arm after optimizing

IV.D. Optimize the lever arm 400-1

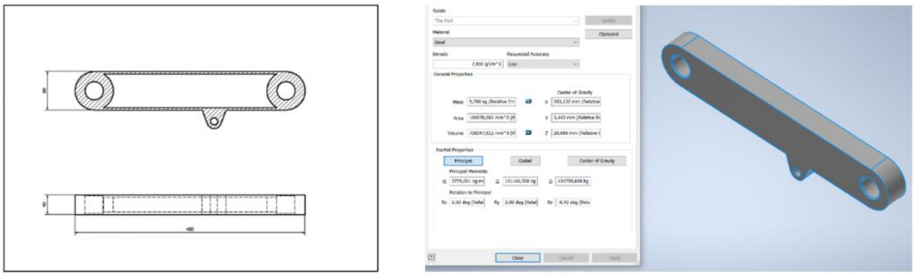

Figure 9 The drawing of the 400-1 lever arm before optimizing

Drawing of the 400-1 lever arm before optimizing the material is steel with a mass of 5.798 kg shown in Figure 9. The maximum stress before optimization is 21.2 MPa

After optimization: Dimensions of the lever arm 400-1 and weight 2.555kgshown in Figure 10. The maximum generated stress is 33.53 MPa

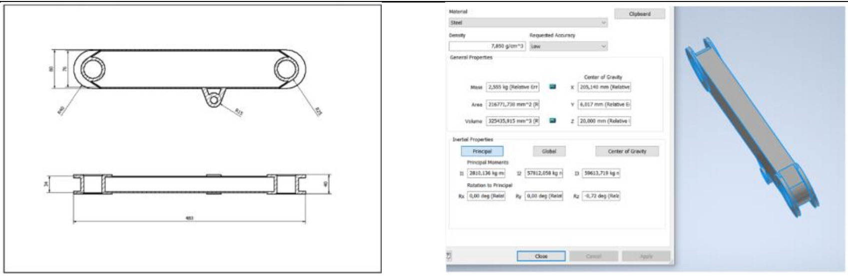

Figure 10 The drawing of the 400-1 lever arm after optimizing

IV.E. Optimize the lever arm 400-2

Drawing of the 400-2 lever arm before optimizing the material is steel with a mass of 2.265 kg shown in Figure 11. The maximum stress before optimization is 24.68 MPa

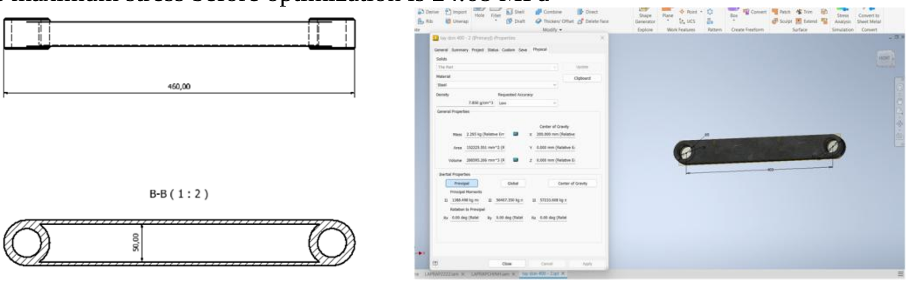

Figure 11 The drawing of the 400-2 lever arm before optimizing

After optimization: Reduce the thickness of the inner wall of the part, create a taper at the top and bottom to reinforce important locations. Dimensions of the lever arm 400-2 and weight 1.717 kg shown in Figure 12. The maximum generated stress is 27.04 MPa.

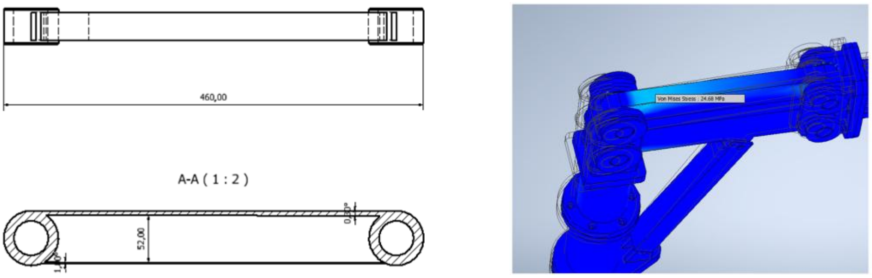

Figure 12 The drawing of the 400-2 lever arm after optimizing

IV.F. Optimize the rotation part

Drawing of the rotation part before optimizing the material is steel with a mass of 10.215 kg shown in Figure 13. The maximum stress before optimization is 4.66 MPa

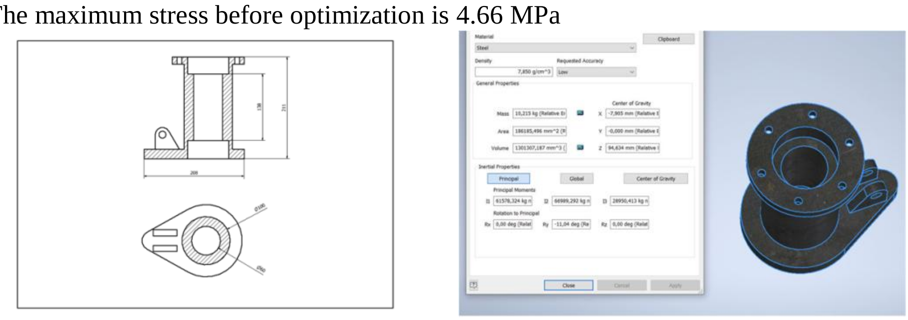

Figure 13 The drawing of the rotation part before optimizing

After optimization: Dimensions of the rotation part and weight 6.130 kg shown in Figure 14. The maximum generated stress is 29.62 MPa.

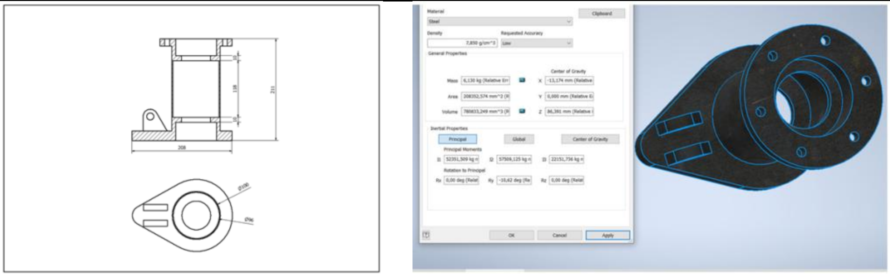

Figure 14 The drawing of the rotation part after optimizing

V. CONCLUSION

This article mainly deals with the principle of a type of robot structure that helps lift goods using a driving force, analyzes the structure of the stages and optimizes the mass of the stages while still Ensures durability when lifting objects weighing less than or equal to 150kg. After optimization, the results of the article can be applied to significantly reduce the mass of the manipulator, helping to reduce the impact force to move the structure, and the flexibility of the structure will increase.

VI. ACKNOWLEDGEMENTS

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