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# Planning and construction of the lifting and towing device of the autonomous mobile robot MiR 100 for the delivery of transport trolleys in intralogistics

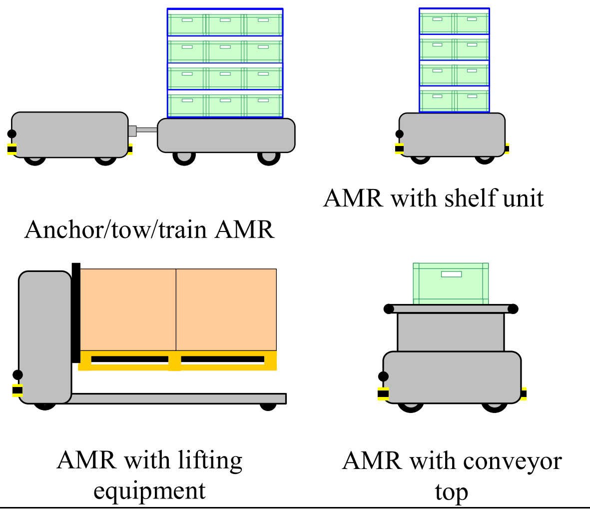
*Intralogistics is a very important area in warehousing and production for managing the flow of materials and informational flow. In recent years, automation and especially robotisation have had a major impact on throughput performance in intralogistics. Especially important is the transport of materials and products based on automated guided vehicles (AGVs) and autonomous mobile robots (AMRs) with different top modules, such as the lifting and towing device.*
*In this paper, planning and construction of the lifting and towing device of the autonomous mobile robot MiR 100 for the delivery of transport trolleys in intralogistics is presented. Using the engineering design methods, a new design of the lifting and towing device has been proposed and evaluated.*

***Keywords:** Intralogistics, Material Handling Systems, Automation nad Robotisation, Planning and Construction, Lifting and Towing Mechanism, Simulation and Animation.*

## 1. INTRODUCTION

Logistics is part of Supply Chain and represent very important activity on a global scale nowadays. The Council of Supply Chain Management Professionals (htt://www.cscmp.org/) has defined logistics as "… that part of Supply Chain Management that plans, implements, and controls the efficient, effective forward and reverse-flows, and the storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements."

The highest degree of automation and robotisation in logistics can be found in internal transport or so-called intralogistics for supplying workplaces with Automated Guided Vehicles (AGVs) and Autonomous Mobile Robots (AMRs); Figure 1.



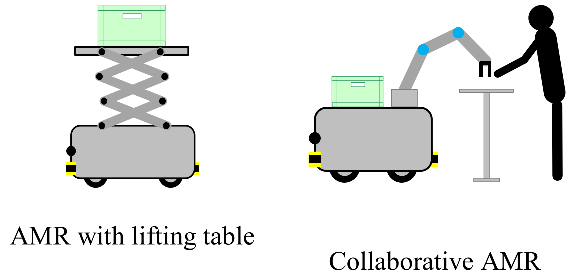




**Figure 1: Different types of AMR**

For transport of various loads within the intralogistics systems AGVs are used. Their route does not change, since they follow a fixed and pre-marked path. A few years ago, an advanced autonomous mobile robots (AMRs) began to appear on the market, which eliminate the disadvantages of classical AGVs. AMRs have a certain level of intelligence and can make their own decisions when they encounter new or unforeseen situations. With the help of sensors (LIDAR, camera, etc.), the AMR can detect the environment, and in case of obstacles detection, they find an alternative route and continue to deliver the cargo to the destination location. AMRs can automatically locate themselves in a production floor, make decisions, and in some cases even cooperatively operate in the form of swarm robots (Brambilla et al., 2013). AMRs are often used for localization in the SLAM (Simultaneous localization and mapping) method, which has been the subject of extensive research recently (De Ryck et al., 2020). Using SLAM algorithms, the AMR gradually builds a map of the area in which the AMR is located, and at the same time determines the current location on the map coordinates (Durrant-Whyte & Bailey, 2006) without a priori knowing the initial position. The autonomy of AMR's decisions, however, is enabled by the AMR's advanced management algorithms based on the use of

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machine learning (Sudhakara & Ganapathy, 2016) and artificial intelligence (Montiel-Ross et al., 2013), (De Geus et al., 2019). Both types of driverless vehicles (AGVs and AMRs) are equipped with safety systems that allow movement of these vehicles in working environments with operators. This represents the basics of collaborative automation and robotics in intralogistics.

The focus of our research study is on planning and construction of the lifting and towing device of the autonomous mobile robot MiR 100 for the delivery of transport trolleys in intralogistics (Lerher, 2022). For the planning and construction of the lifting and towing device of the autonomous mobile robot MiR 100, the following methods has been used as follows: engineering design methods, a method of non-structured interviews to obtain data from practice, a method of system and analytical modelling, statistical analysis, etc. Computer aided tools such as SolidWorks, PrePoMax and other tools has been used in our analysis.

## 2. DEVELOPMENT OF THE LIFTING AND TOWING DEVICE

The development of the lifting and towing device was done in such a way that we started from the overall dimensions of the MiR 100 mobile robot, with which we began dimensioning of individual components.

The basic 3D model of the MiR 100 robot was taken from the GrabCAD online library, as shown in Figure 2.

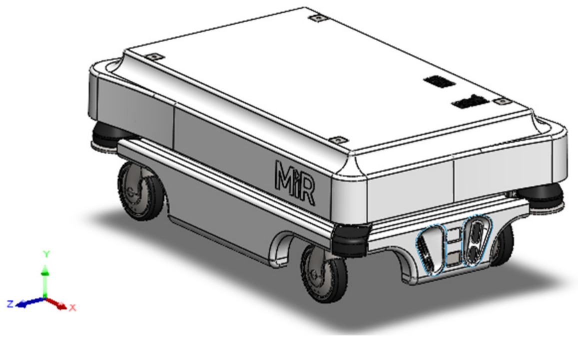

**Figure 2: AMR MiR 100**

Table 3.1 shows the materials and their properties that we used to make the lifting and towing device. The frame and arm of the lifting and towing device are made of the lightweight aluminium alloy AW 6060, which is commercially available. The material can also be welded and is used in practise. The so-called bearing element and the gripper are made of steel S460N, as this material is more resistant to plastic deformation due to the higher stress.

**Table 1. Material properties of the materials used**

| Material | AW 6060 | S460N |
|---|---|---|
| Density ($\rho$) | 2700 kg/m$^3$ | 7870 kg/m$^3$ |
| Elasticity modul ($E$) | 70000 MPa | 210000 MPa |
| Yield strength ($R_{p0,2}$) | 160 MPa | 460 MPa |

### 2.1 Dimensioning of individual parts of the lifting and towing device

The frame of the lifting and towing device was developed from a profile (30 mm x 30 mm x 3.2 mm) made of the lightweight aluminium alloy AW 6060. The individual Al beams were welded together to form a base frame of the lifting and towing device, as shown in Fig. 3.

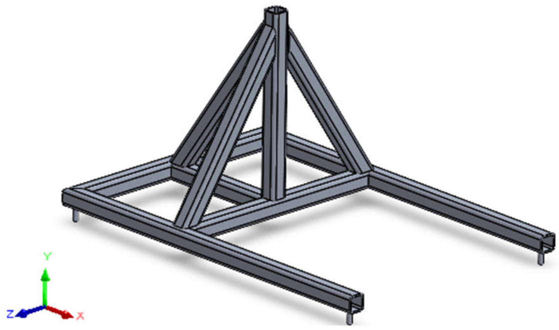

**Figure 3: The frame of the lifting and towing device**

A special mechanical part made of steel S460N, know as the bearing element, was designed to provide the connection between the arm and the frame of the lifting and towing device, as shown in Figure 4.

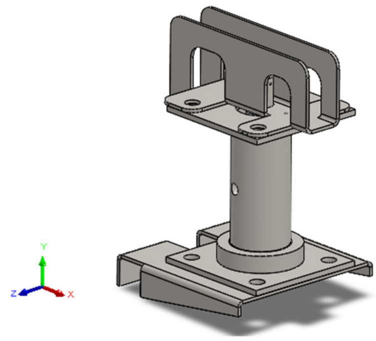

**Figure 4: The bearing element**

Next, in Figure 5, an arm of the lifting and towing device was developed from a profile (80 mm x 80 mm x 5 mm) made of the lightweight aluminium alloy AW 6060.

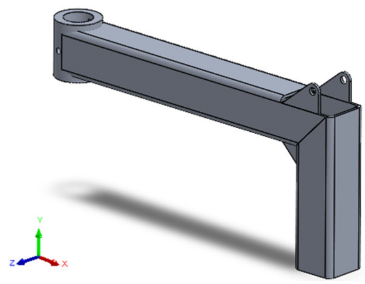

**Figure 5: The arm of the lifting and towing device**

In Figure 6 the gripper of the lifting and towing device was developed from a profile (40 mm x 40 mm x 4 mm) and the support plate made of steel S460N. The conical grippers on the support plate are made of synthetic rubber.

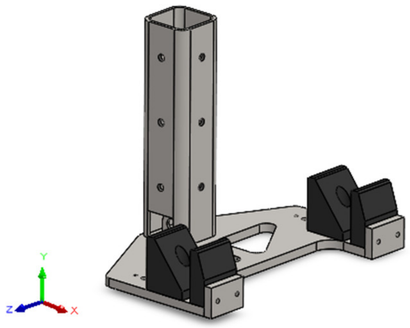

Figure 6: The gripper of the lifting and towing device

One of the basic assembly parts is the linear actuator, which is performing hoisting of the gripper in the vertical direction. We took the linear actuator from the GrabCAD online library and adapted it dimensionally to our case. It allows us to clamp the gripper with a maximum force of 1000 N per 200 mm of vertical movement. Figure 7 shows a linear actuator.

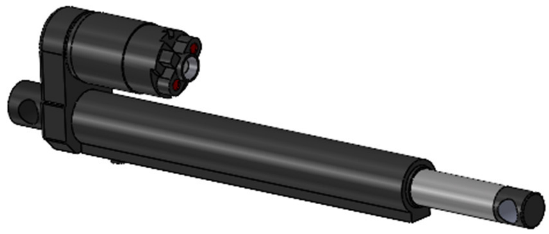

Figure 7: The linear actuator

Table 2 lists the masses of the individual parts of the final assembly of the lifting and towing device. The total mass must be increased to the additional masses for other standard mechanical parts.

Table 2. Masses of the individual parts of the lifting and towing device

| Assembly part | Mass |
| --- | --- |
| Frame | 3.0 kg |
| Upper bearing element | 0.6 kg |
| Lover bearing element | 0.5 kg |
| Housing of the bearing element | 1.1 kg |
| Arm | 3.9 kg |
| Gripper | 4.8 kg |
| Teflons | 0.3 kg |
| **Total mass** | **14.2 kg** |

## 3. NUMERICAL SIMULATION AND STRENGTH EVALUATION

Within the framework of computer simulations, we have calculated the strength of individual components of the lifting and towing device. The components are dimensioned to withstand the loads that occur when towing a 300 kg transport trolley. The calculation also takes into account the vertical force required to grip the trolley with a gripper with a maximum force of 1000 N.

In the following section, the linear-elastic analysis of the frame, the arm and the gripper of the lifting and towing device is presented. Results of numerical analyses based on the PrePoMax open-source software.

### 3.1 The frame of the lifting and towing device

The frame is a component dimensioned to withstand the loads at different positions of the arm of the lifting and towing device, as the arm can rotate and thus different loads are applied to the frame (see Figure 8).

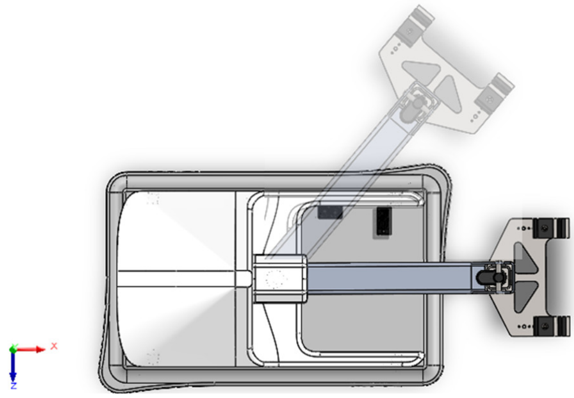

Figure 8: Example of rotating arm of the lifting and towing device

Based on the attachment of the basic frame on the MiR 100 mobile robot, two load cases when towing a 300 kg transport trolley could accour (Figure 9, 10).

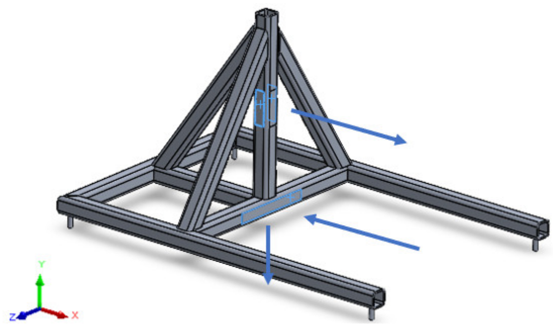

Figure 9: Load case 1

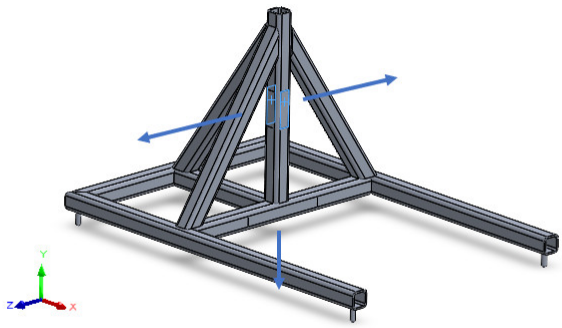

Figure 10: Load case 2

Figures 11 and 12 show von Mises stress values for both load cases 1 and 2. As can be seen, the stresses are relatively low throughout the frame, even though the loads were assumed to be relatively higher. Because of the small stresses, relatively small displacements also occur, as can be seen in Figures 13 and 14.

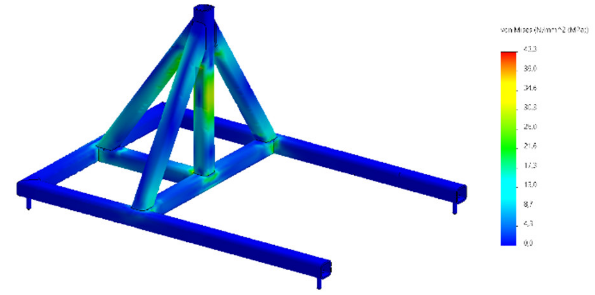

**Figure 11: Von Mises stress values for load case 1**

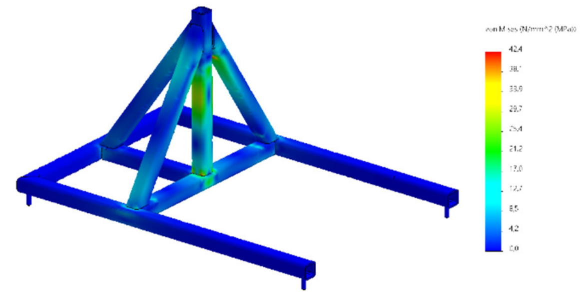

**Figure 12: Von Mises stress values for load case 2**

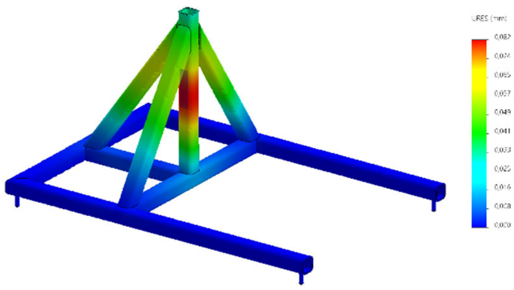

**Figure 13: Displacement for load case 1**

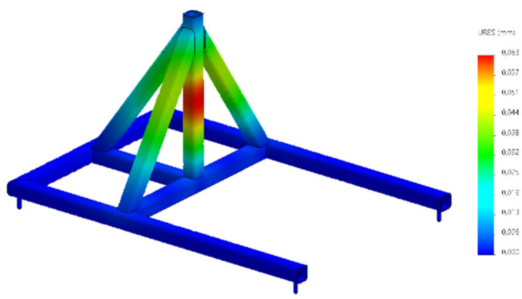

**Figure 14: Displacement for load case 2**

### 3.2 The arm of the lifting and towing device

The arm is only subjected to the vertical load caused by the vertical force required to grip the trolley with a gripper, which is 1000 N maximum (Figure 15).

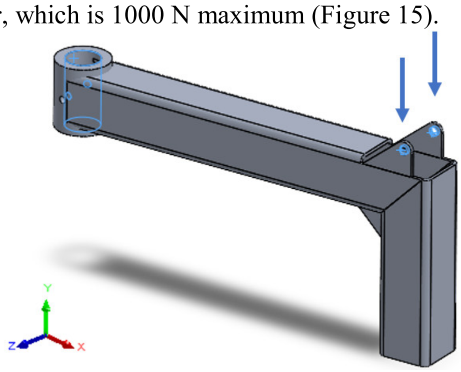

**Figure 15: Position of the vertical force on the arm**

Figure 16 shows von Mises stress values on the arm of the lifting and towing device. The stresses are relatively low with the amount to 47.9 MPa at their maximum.

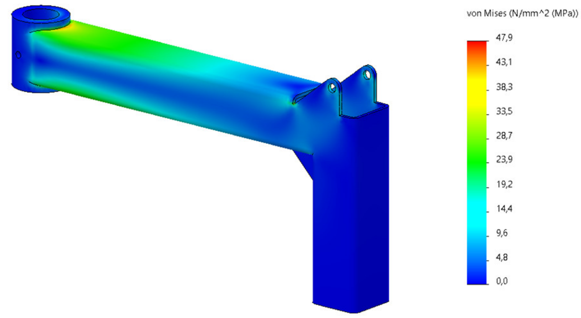


**Figure 16: Von Mises stress values for the load case of the arm**

In Figure 17 we can see the displacement on the arm of the lifting and towing device with a maximum displacements of 0.49 mm.

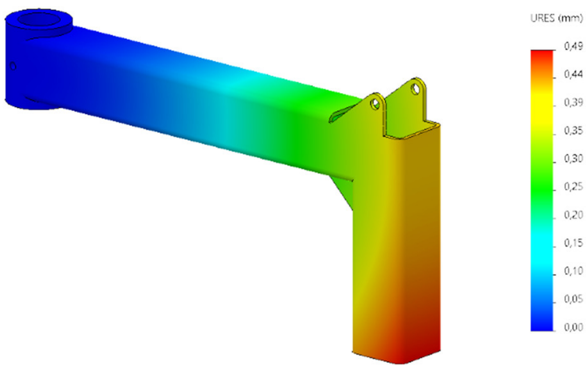


**Figure 17: Displacement for the load case of the arm**

### 3.3 The gripper of the lifting and towing device

The gripper of the lifting and towing device is providing a vertical force required to grip the transport trolley with a maximum force of 1000 N (Figure 18).

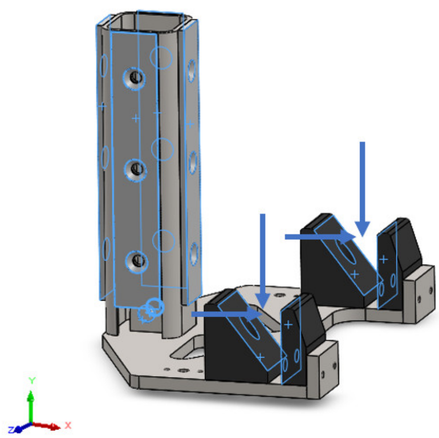

**Figure 18: Position of the vertical force on the gripper**

Figure 19 shows von Mises stress values on the gripper of the lifting and towing device. The stresses of 260 MPa at their maximum do not exceed the yield stress for the selected material S460N.

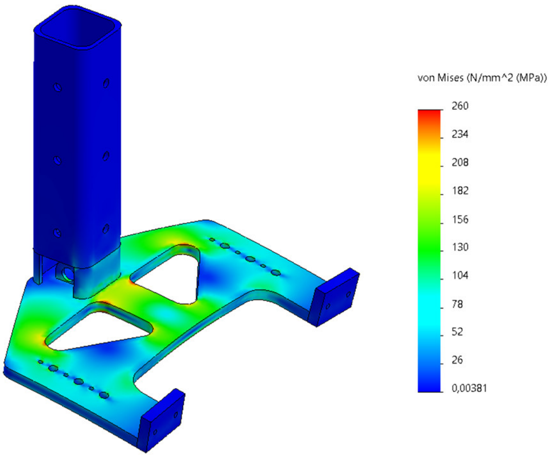


**Figure 19: Von Mises stress values for the load case of the gripper**

In Figure 20 we can see the displacement on the gripper of the lifting and towing device with a maximum displacements of 2.70 mm.

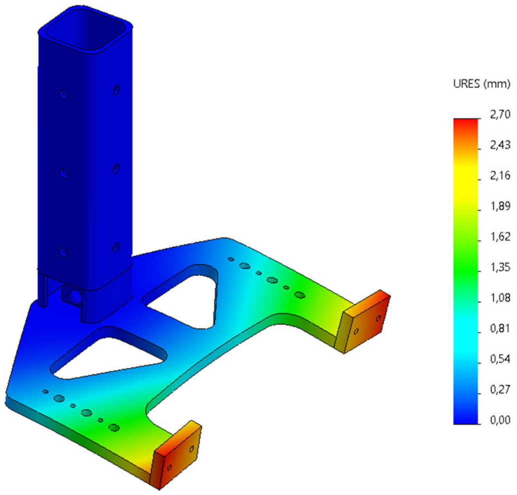


**Figure 20: Displacement for the load case of the gripper**

## 4. LIFTING AND TOWING DEVICE ATTACHED ON THE AUTONOMOUS MOBILE ROBOT MIR 100

Based on the developmen and numerical analysis the final design of the lifting and towing device in presented on the following figures 21, 22 and 23.

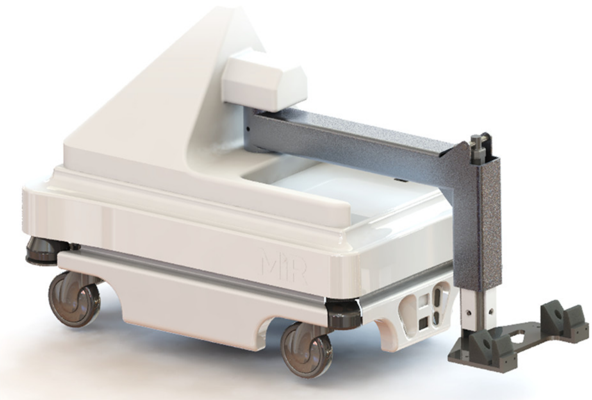

**Figure 21: Render of the lifting and towing device on MiR 100**

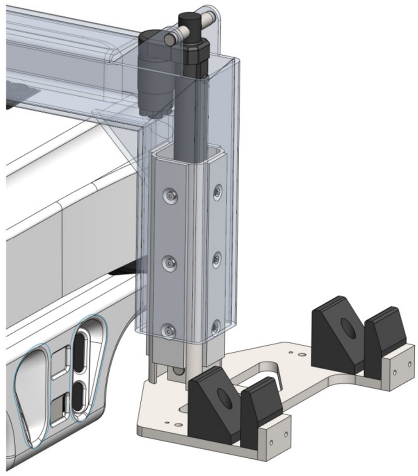

**Figure 22: Detail of the gripper attached to the linear actuator**

**Figure 22: Towing a transport trolley with the proposed lifting and towing device attachmed on MiR 100**

## 5. CONCLUSION

The aim of this paper is to present planning and design of the lifting and towing device of the autonomous mobile robot MiR 100 for the delivery of transport trolleys in intralogistics.

For the development of the proposed lifting and towing device, the engineering design methods were used to obtain the most efficient design of the lifting and towing device on a mobile robot MiR 100.

All the main mechanical parts of the lifting and towing device were designed using SolidWorks commercial software and PrePoMax open-source software for structure analyses.

This study can be extended as follows: (i) simulation of the feasibility analysis of the proposed lifting and towing device and (ii) cost analysis for the prototype construction of the proposed lifting and towing device.

**ACKNOWLEGEMENTS**

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