**BILKENT UNIVERSITY**

**DEPARTMENT OF MECHANICAL ENGINEERING**

**ME 482 Mechanical Engineering Design II**

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**Assignment 6-Final Report**

# Optimization of a Dishwasher Hinge

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**Summary**

This project aimed to optimize the hinge mechanism design for Arçelik's dishwasher doors, adhering to the specified design criteria and standards. The existing hinge mechanism had a crucial limitation: while facilitating door movement, it lacked the required stability to keep the doors open at various angles between 0 and 90 degrees. The project spanned from September 2022 to May 2023, during which a new pulley design was developed while preserving the integrity of other components. The project encompassed essential phases, including needs assessment, concept selection, preliminary and detailed design, progress reporting, and presentations. This report presents the final design, which involved the creation of a unified double-pulley using 3D printing (SLA technology). Rigorous physical tests were conducted by integrating the double-pulley into a standard dishwasher. In the near future, a comprehensive evaluation will be conducted to assess the prospective performance of the unified double-pulley in its ability to support dishwasher doors with a weight capacity of up to 15.2 kg. This assessment aims to determine the pulley's efficacy in effectively sustaining the doors at intermediate angles spanning from 0 to 90 degrees while in an open position. This optimized hinge mechanism design offers promising potential for enhancing the functionality and stability of Arçelik's dishwasher doors, meeting the desired design objectives and surpassing the previous limitations.

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## 1. Problem Definition

In the context of dishwasher functionality, the proper operation of various components and structures is crucial. Among these components, the dishwasher door plays a pivotal role in facilitating the washing cycle. To ensure effective cycle execution, the door must fulfill the tasks of opening and closing the dishwasher while remaining stable at different angles to facilitate dish loading and unloading.

Central to the functionality of the dishwasher door is the hinge mechanism, which establishes the connection between the door and the dishwasher chassis. Comprising four main components, namely a spring, pulleys, a rope, and hinge arms, the mechanism enables the mechanical movement of the door. Starting from the chassis frame, the spring is affixed to the back wall, followed by the pulleys and ultimately the hinge arms. Acting as a connector, the rope is attached to both the spring and the hinge arm, passing through the pulleys.

A critical requirement for a well-functioning hinge mechanism in modern dishwashers is its ability to remain stable at any given point, particularly at intermediate angles between 0 and 90 degrees. While the optimized hinge mechanism employed in this project fulfills the necessary mechanical requirements for opening and closing the dishwasher door, it falls short of meeting the stability criterion and fails to stay open at intermediate angles. Thus, the primary objective of this project was to optimize the hinge mechanism provided by Arçelik, ensuring its stability within the 0 to 90-degree range, while adhering to Arçelik's specific safety requirements and design constraints.

An essential challenge in the optimization process was to minimize the number of alterations. Therefore, efforts were made to maintain the number, nature, orientation, and dimensions of the components as close as possible to the original design. Additionally, the optimized design aimed to prioritize cost-effectiveness, efficiency, durability, and originality of the mechanism.

To address concerns surrounding the design and optimization process, parameters and design criteria were established. These facilitated comparative analysis and continuous improvement throughout the project. Evaluation criteria primarily encompassed adaptability, safety, cost, material selection, and simplicity. Component design took into account Arçelik's requirements and constraints regarding testing, warehousing, logistics, and safety standards.

In essence, safety considerations revolved around the development of a mechanism capable of adequately supporting a dishwasher door weighing 15.2 kg. The mechanism needed to maintain stability at intermediate angles while carrying the door, thereby preventing abrupt door falls, minimizing noise generated by the mechanism, and avoiding malfunctions during the door sealing process, among other vital considerations.

## 1.1. Requirements and Constraints

The optimization process for the existing hinge mechanism is guided by a set of requirements and constraints established by the project group and industry supervisors at Arçelik. These requirements and constraints can be categorized as follows:

### 1.1.1. Operational and Functional Requirements

The primary and foremost criterion is that the dishwasher door must be capable of opening to a maximum angle of 90 degrees and closing completely at a minimum angle of 0 degrees. The hinge mechanism must ensure the door's stability at any desired angle within the range of 0 to 90 degrees. Furthermore, the hinge mechanism should have the ability to support loads ranging from 5 kg to 15.2 kg, considering the varying mass of dishwasher doors based on the dishwasher model and whether it is a built-in model.

### 1.1.2. Dimensional Requirements

The hinge mechanism must fit within the designated space allocated in the lower back part of the dishwasher's chassis. While there may be slight variations among models, a standard dishwasher typically has dimensions of 60x60x85 cm and a volume of approximately 0.30 $m^3$. Although there are no specific constraints regarding individual components, maintaining the original dimensions of the current system is preferable.

### 1.1.3. Safety Requirements

The hinge mechanism should be capable of enduring 50,000 cycles, as specified by Arçelik for all their dishwasher models. Additionally, the mechanism must adhere to specific codes and standards outlined within the project. Given the washing cycle's exposure to high temperatures and a humid environment, the mechanism should remain fully functional at temperatures up to 110 degrees Celsius and exhibit resistance to humidity.

### 1.1.4. Material Requirements

While the optimization process entails specific material constraints, an analysis was conducted on the existing materials of the components, considering their properties, cost, and safety aspects. Design-for-assembly principles were also taken into account to ensure ease of production and accessibility.

### 1.1.5. Cost Requirements

The project was assigned a budget of 10,000 Turkish liras. After necessary deductions, the net budget available for the project amounts to approximately 7,080 Turkish liras.

### 1.1.6. Time Constraints

The project is estimated to be completed within a timeframe of 36 weeks. A Gantt chart is utilized to provide a detailed timeline outlining the project's milestones. The initial half of the project was executed between September 2022 and December 2022, followed by the second half spanning from January 2023 to May 2023.

## 2. Concept Selection

Throughout the project, three different pulley designs were created and evaluated. At the end of the first phase, the pulley design used in the Detailed Design report (D1), the pulley design used in the Progress Report at the beginning of the second phase (D2), and finally, the pulley design used in the Final Report (D3) are shown in Figure 1. The evaluation process utilized checklists provided in the appendix (See Appendices A to E).

The criteria for evaluation are as follows:

- Adaptability
- Simplicity
- Cost
- Material
- Safety

Due to D1's poor performance in adaptability, material, and simplicity criteria, it was eliminated. The D2 design was eliminated due to material criteria and also failed during the conducted tests.

After evaluating and testing the D1 and D2 designs, they were eliminated, and the D3 design, which met all project criteria and requirements, was selected. Despite being less cost-effective compared to D1 and D2, the D3 design was deemed suitable as the final design due to its optimal fulfillment of all requirements.The modification made to the system was limited to the pulley assembly, resulting in costs being primarily associated with the production of the pulley component. As a result, the project is characterized by its low-cost nature. Furthermore, the system demonstrates high compatibility as only the pulley assembly was altered, making it suitable for integration into Arçelik's existing system.
The Design Matrix, which assesses all design concepts, is presented in Table 2.1.

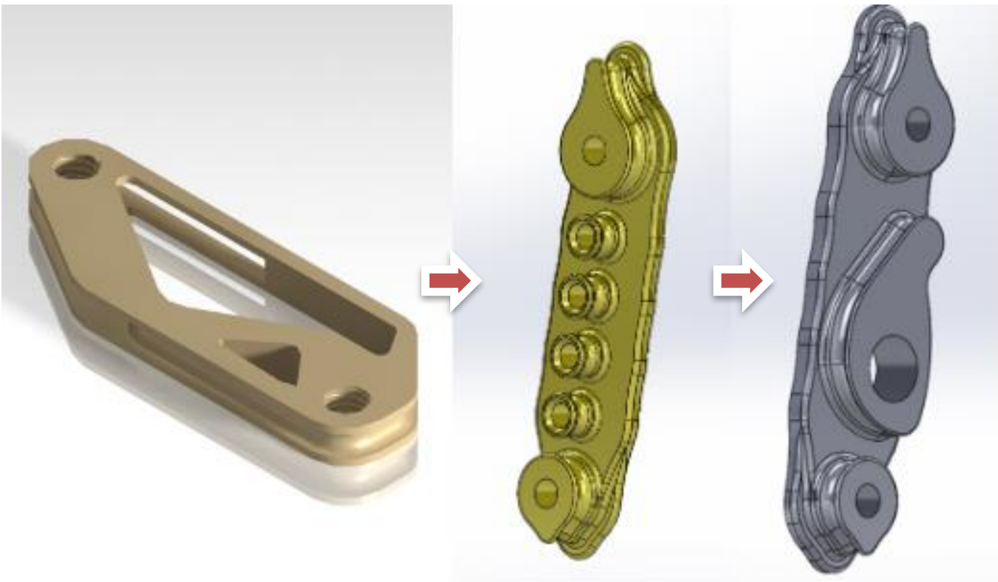


Figure 1: Pulley Design Concepts from left to right in the chronological order: Detailed Design, Progress Design, Final Design of the Pulleys

Table 2.1: Design Matrix for the Pulley Concepts

| | | **Design 1 (Detailed Design)** | | **Design 2 (Progress Design)** | | **Design 3 (Final Design)** | |
|---|---|---|---|---|---|---|---|
| Criteria | % | Rating | Rating (%) | Rating | Rating (%) | Rating | Rating (%) |
| Adaptability | 20 | 1 | 0.2 | 4 | 0.8 | 5 | 1 |
| Simplicity | 20 | 2 | 0.4 | 3 | 0.6 | 3 | 0.6 |
| Cost | 30 | 5 | 1.5 | 3 | 0.9 | 2 | 0.6 |
| Material | 10 | 2 | 0.2 | 2 | 0.2 | 5 | 1 |
| Safety | 20 | 3 | 0.6 | 4 | 0.8 | 5 | 1 |
| Total Score | | 2.9 | | 3.3 | | 4.2 | |
| Rank | | 3 | | 2 | | 1 | |
| Elimination | | Yes | | Yes | | No | |

## 3. Codes and Standards

In the design and manufacturing process, adherence to various standards has been crucial. Here is an overview of the applied standards.

### 3.1. Dimensional Standards

#### 3.1.1. DIN-7168 m Tolerances

The DIN-7168 m tolerances have been utilized for angular and linear dimensions in technical drawings and part design, ensuring accurate dimensional specifications [1].

### 3.2. Safety Standards

To assess the suitability of manufactured parts for domestic use, multiple safety standards have been employed, covering fire resistance, shock resistance, and material selection.

#### 3.2.1. ISO 12100:2010: General Safety Standards for Machinery Design

ISO 12100:2010 provides a comprehensive framework for ensuring machinery design safety, including risk evaluation, hazard identification, and risk reduction strategies [2].

#### 3.2.2. ISO 19353: Fire Resistance Standards

ISO 19353 establishes criteria for assessing the fire resistance of materials and components, mitigating fire-related risks [3].

#### 3.2.3 ISO 834-1: Fire Resistance Standards

ISO 834-1 focuses on evaluating the fire resistance of structural elements, preserving structural integrity and stability during fire conditions [3].

#### 3.2.4 2006/95/EC: Low Voltage Standards

The Low Voltage Directive (2006/95/EC) sets safety regulations for electrical equipment operating within defined voltage limits, ensuring compliance and minimizing risks [4].

### 3.3. Additive Manufacturing Standards

ISO/ASTM 52900:2021 governs the production phase, facilitating successful additive manufacturing within the CAD/CAM environment [5].
According to ISO/ASTM 52900:2021, parts' positioning and coordinates are determined for additive manufacturing, assessing material compatibility and

feasibility. The standard aids in evaluating part complexity and attachment point suitability, allowing for necessary design adjustments [5].

## 4. Design

### 4.1. Working Principle

The modeling process began after receiving details of the current system to determine the required compensation. A free body diagram was used to analyze the hinge arm, aiming to minimize the moment on its base for preventing door rotation. Due to the complexity of modeling inertial losses and the need to account for other moving components, a moment near zero was targeted instead of precisely zero.

In the existing system, the spring reaction was insufficient to compensate for the door weight, necessitating an additional force on the same side of the pivot. Constraints regarding the door's mass, shape, and length, as well as the fixed dimensions of the hinge arm, couldn't be modified within the project scope.

Increasing the spring constant excessively to compensate for the moment had potential drawbacks, such as increased risk of spring failure and potential impact on customer comfort. Modifying the system to address this disparity would likely require users to exert more force to open the door.

To address these uncertainties and considerations, a functional prototype will be acquired for comprehensive testing. Based on the feedback received, design adjustments will be made to ensure ongoing improvement.

The initial prototype and its improved version were designed with consideration to the friction experienced by the pulley assembly, resulting from the normal force exerted by the rope tension. In the first prototype, this was accomplished by routing the rope through a series of smaller pulleys in a wrapping and snaking manner. By utilizing the **Capstan Equation* and considering the total swept angle of the rope, along with the coefficient of friction of the material, we were able to determine the magnitude of the generated force.

**The Capstan equation relates tension in a rope on a cylinder to the applied force and angle of wrap, aiding in the analysis of rope and cable systems.*

The previous design was modified due to several reasons. After testing and calculations, it was determined that the previous design experienced more friction and was prone to breakage. Here are the specific reasons for the design change:

1. Friction: The previous design resulted in higher friction levels than initially anticipated. This friction generated excessive heat, causing wear and potential damage to the pulley system. To mitigate this issue, the new design was optimized to minimize friction and reduce heat buildup.

2. Breakage: The previous design, which utilized the strength resin material, proved to be susceptible to breaking under certain conditions. When subjected to the 50,000 cycle tests, the resin could not withstand the forces and eventually failed. The maximum temperature resistance of the strength resin is 80 degrees Celsius, but the temperatures reached during the 50,000 cycle tests ranged from 90 to 110 degrees Celsius. To address this weakness, a more durable material, Mold resin, was selected for the new design. Mold resin has a higher temperature resistance (up to 280 degrees Celsius) and is less prone to breakage [6].

By making these design changes, the goal was to improve the overall performance and durability of the pulley system, ensuring that it could withstand the intended usage and reduce the likelihood of damage due to friction or breakage.

As shown in Figure 2, the final design consists of three pulleys: upper, middle and lower pulleys. An additional pulley of the same mechanism was positioned symmetrically (on both sides of the door). The shapes of the pulleys are different from each other and also not uniform.

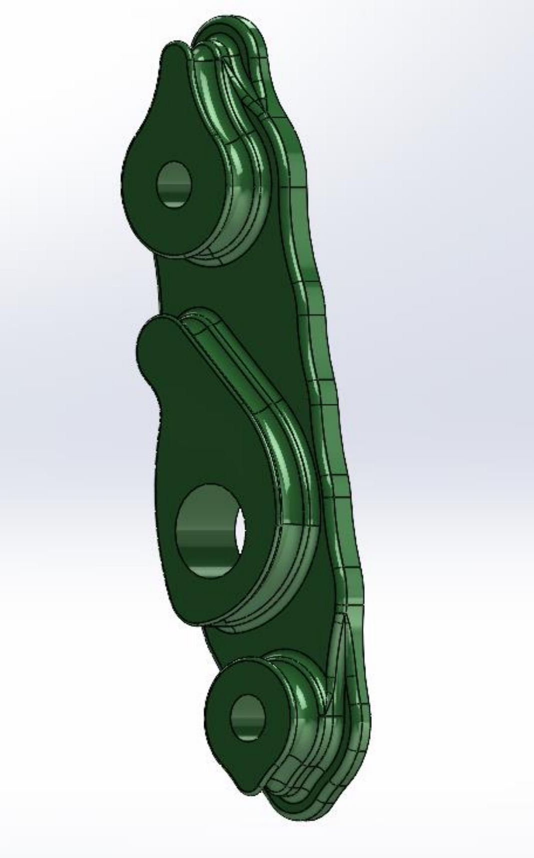


Figure 2: Final Pulley Design

A service hole was opened in the middle pulley. The upper and lower pulleys have one threaded hole each. The rope comes from the hinge and wraps around these three pulleys, connecting to the spring. The design was optimized to minimize friction-induced heat, wear, and damage, while also ensuring the ability to support the door. A new round and uniformly sized service hole was created in the center of the pulley system with a tolerance of +-0.01mm. This service hole was suggested by Arçelik to allow for intervention in the machine. This design optimized the path and contact of the rope on the pulley. Also, the dimensions of the threaded holes were increased by 0.15mm with a tolerance of +-0.01mm (See Appendix F for technical drawings).

The thickness of the bottom layer where the pulleys are placed was increased by approximately 1mm. This was done to enhance its resistance to bending and vibration.

The rope passes through the front face of the middle pulley while the back where the rope does not pass are left as walls. This is to provide support to the back of the pulley where the most normal force is applied. It also contributes to the overall durability of the pulley system.

The positions of the pulleys were intentionally chosen. There is a gap between the middle and bottom pulleys, as the rope requires a ventilation gap while sliding (see

Figure 2). Without this gap, prolonged friction during long-term use (50,000 cycles test) could cause wear or irreversible damage to the pulley. The main reason for this is that the surface of the pulley in friction reaches temperatures of 90-110 degrees Celsius during the 50,000 cycle tests.

The rope should pass through the pulleys with as little zigzag as possible, and the pulley design takes this into consideration. The more the rope bends, the higher the tension, leading to increased temperature and potential damage (see Appendix G). The final design optimizes these factors. The purpose of such a design is to transmit the rope through the hinge without bending it out of alignment (see Appendix H).

### 4.2. Advantages of the Final Design Considering Existing Solutions

The existing lid system of Arçelik experiences issues between 0 and 90 degrees due to a lack of sufficient pulling force to balance the door. Consequently, Arçelik sought a new system capable of providing an adequate pulling force or friction force to compensate for the door's weight using springs, pulleys, and hinges.

In Arçelik's current system, a rope stretched between two pulleys generates the pulling force (friction force) necessary to maintain balance and stability of the door. However, the insufficient friction force between the rope and the pulleys prevents the door from achieving balance at all angles. In contrast, our system incorporates an enhanced pulley system and rope combination, which significantly increases the friction force and ensures that the door remains balanced at any angle.

A comparison between the new and old systems reveals a proportional increase in the pulling force applied to the door, attributed to the enlarged contact surface between the rope and the pulleys. The primary objective of the project has been successfully accomplished.

## 5. Prototype

### 5.1. Test Results

It was confirmed that the pulley integrated well with the dishwasher; however, the threaded holes experienced tight fitting. Additionally, once the system started operating, the middle pulleys of the prototype from the previous design could not withstand the applied normal force and broke as shown in Figure 3. The remaining upper and lower pulleys were able to withstand tension, ensuring that the door remained in position at all angles with door masses of 5 and 13 kilograms. However, when the door mass was increased to 15.2 kilograms, it could only be held steady up to 45 degrees.

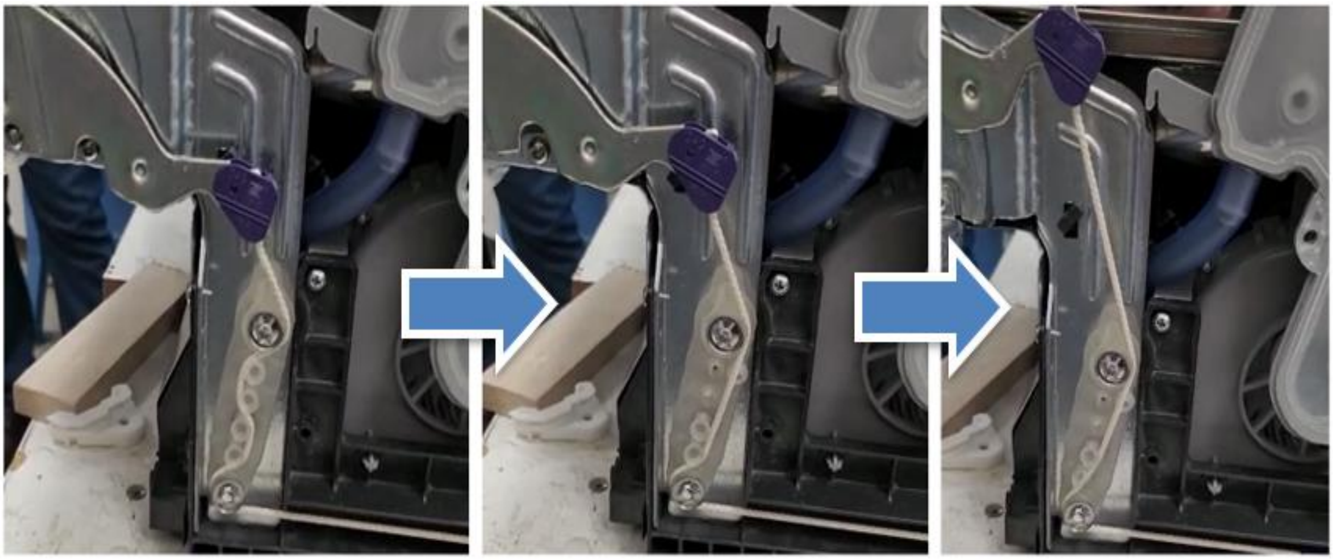


Figure 3: Test Results of the Prototype

Figure 4: Test Environment

### 5.2. Test Results Discussion

It was unexpected that there would be such a high level of friction during the test. Furthermore, it was anticipated that the ability to hold the door at every angle would be limited, but it was realized that the problem actually stemmed from the strength of the material used. Another surprising aspect was that concerns were raised about potential noise generated by the prototype during friction, yet it was observed that no noise was produced. This was primarily attributed to the flexible nature of the material utilized.

The ongoing work on this project is being carried out in a methodical and controlled manner, ensuring meticulous progress. The advancements and outcomes of the project will be communicated to the evaluators of ME 482 in a timely fashion.

## 6. Conclusions and Discussions

In summary, the primary aim of this project was to optimize the hinge mechanism design for Arçelik's dishwasher doors, specifically targeting the stability limitation at intermediate angles within the 0 to 90-degree range. By successfully developing a new pulley design, the project effectively enhanced both the functionality and stability of the dishwasher doors.

Thorough testing and evaluation of the final design, incorporating a unified double-pulley manufactured through 3D printing (SLA technology), demonstrated significant potential in meeting the desired design objectives and surpassing the previous limitations. Consequently, the optimized hinge mechanism design adequately fulfilled the operational and functional requirements of opening and closing the dishwasher door, ensuring stability at various angles within the designated range.

The project's success can be attributed to multiple contributing factors, encompassing a comprehensive needs assessment, meticulous concept selection, and detailed design phases. Following a systematic approach, the project team maintained regular progress reporting and presentations, fostering effective communication and collaboration.

However, the project encountered challenges and limitations along the way. Notably, the initial design experienced higher-than-expected friction levels, resulting in wear and potential damage to the pulley system. Additionally, the material employed proved susceptible to breakage under specific conditions, emphasizing the necessity for a more durable alternative. Overcoming these obstacles involved design modifications such as friction reduction, the selection of a temperature-resistant material, and optimization of the pulley system's path and contact with the rope.

Reflecting on the project, several areas emerge as potential areas for improvement. The initial pulley designs (D1 and D2) did not meet the project criteria and were consequently eliminated. A more comprehensive evaluation and testing during the concept selection phase could have yielded time and resource savings. Furthermore, conducting further analysis and simulations could have better anticipated challenges pertaining to friction and material strength.

Furthermore, this project is not intended for misuse against society with malicious intent, and to prevent such misuse, all production stages have been documented in collaboration with the project team. Additionally, the project poses no harm to the user, as all tests have been conducted with due regard to safety conditions to ensure non-harmful effects. In terms of self-assessment, the project team demonstrated exemplary problem-solving skills, adaptability, and unwavering dedication towards achieving the project objectives. Effective collaboration and communication throughout the project facilitated continuous improvement and decision-making. Nevertheless, greater emphasis on risk assessment and mitigation strategies could have better prepared the team for unforeseen challenges.

Overall, the optimized hinge mechanism design for Arçelik's dishwasher doors exhibits substantial potential in enhancing both the functionality and stability of the doors. While the project achieved its goals, certain refinements and adjustments could have been implemented. The team's self-assessment highlights a commendable level of teamwork and dedication, with opportunities for further enhancement in areas such as risk management. The project's outcomes provide valuable insights for future optimization projects and contribute to the ongoing improvement of Arçelik's dishwasher door mechanism.

## 7. References

[1] "Din 7168-general dimension tolerances," [Online]. Available: http://www.ironfoundry.com/din7168.html. [Accessed 22 October 2022].

[2] "ISO 12100:2010," ISO, 9 March 2022. [Online]. Available: https://www.iso.org/standard/51528.html. [Accessed 22 October 2022].

[3] "INTERNATIONAL STANDARD ISO 19353 Safety of machinery — Fire prevention," ISO, 2019.

[4] "2006/95/EC Düşük Voltaj Yönergesi Hakkında Bilgi Alın," BSI, [Online]. Available: https://www.bsigroup.com/tr-TR/Hizmetlerimiz/Urun-Belgelendirme-Test-Hizmetleri/cebelgesi/ab-yonergeleri-ce-belgesi/Dusuk-Voltaj-Yonergesi/. [Accessed 22 October 2022].

[5] "ISO/ASTM 52900:2021(EN), additive manufacturing general principles," ISO, [Online]. Available: https://www.iso.org/obp/ui/#!iso:std:74514:en. [Accessed 22 October 2022].

[6] “3D Baskı Malzemeleri - 3D3 Teknoloji Profesyonel 3D Baskı Hizmeti,” *3D3 Teknoloji*. https://3d3teknoloji.com/3d-baski-malzemeleri/ [Accessed 24 May, 2023].

# 8. Appendix

## Appendix-A: Safety Checklist

Table 8. 1: Safety Checklist 1

| EVALUATION | POINTS |
|---|---|
| Complies with all of the standards | 3 |
| Complies with some of the standards | 2 |
| Complies with no standards | 1 |

Table 8. 2: Safety Checklist 2

| EVALUATION | POINTS |
|---|---|
| Can carry the load | 2 |
| Load with reinforcements | 1 |
| Cannot carry the load | 0 |

**Appendix-B: Adaptability Checklist**

Table 8. 3: Adaptability Checklist

| EVALUATION | POINTS |
|---|---|
| Requires no components to change | 5 |
| Requires 1 component to change | 4 |
| Requires 2 components to change | 3 |
| Requires 3 components to change | 2 |
| Requires all components to change | 1 |

**Appendix-C: Material Checklist**

Table 8. 4: Material Checklist

| EVALUATION | POINTS |
|---|---|
| Are the components made of this material readily available for third-party repairment? | YES (1 POINT) |
| Is the material environmentally friendly? | YES (1 POINT) |
| Is the material resistant to humidity and high temperatures? | YES (1 POINT) |
| Is the material resistant to corrosion, and abrasion? | YES (1 POINT) |
| Is the material resistant to fatigue (life-cycle)? | YES (1 POINT) |

## Appendix-D: Cost Evaluations

Table 8. 5: Cost Checklist

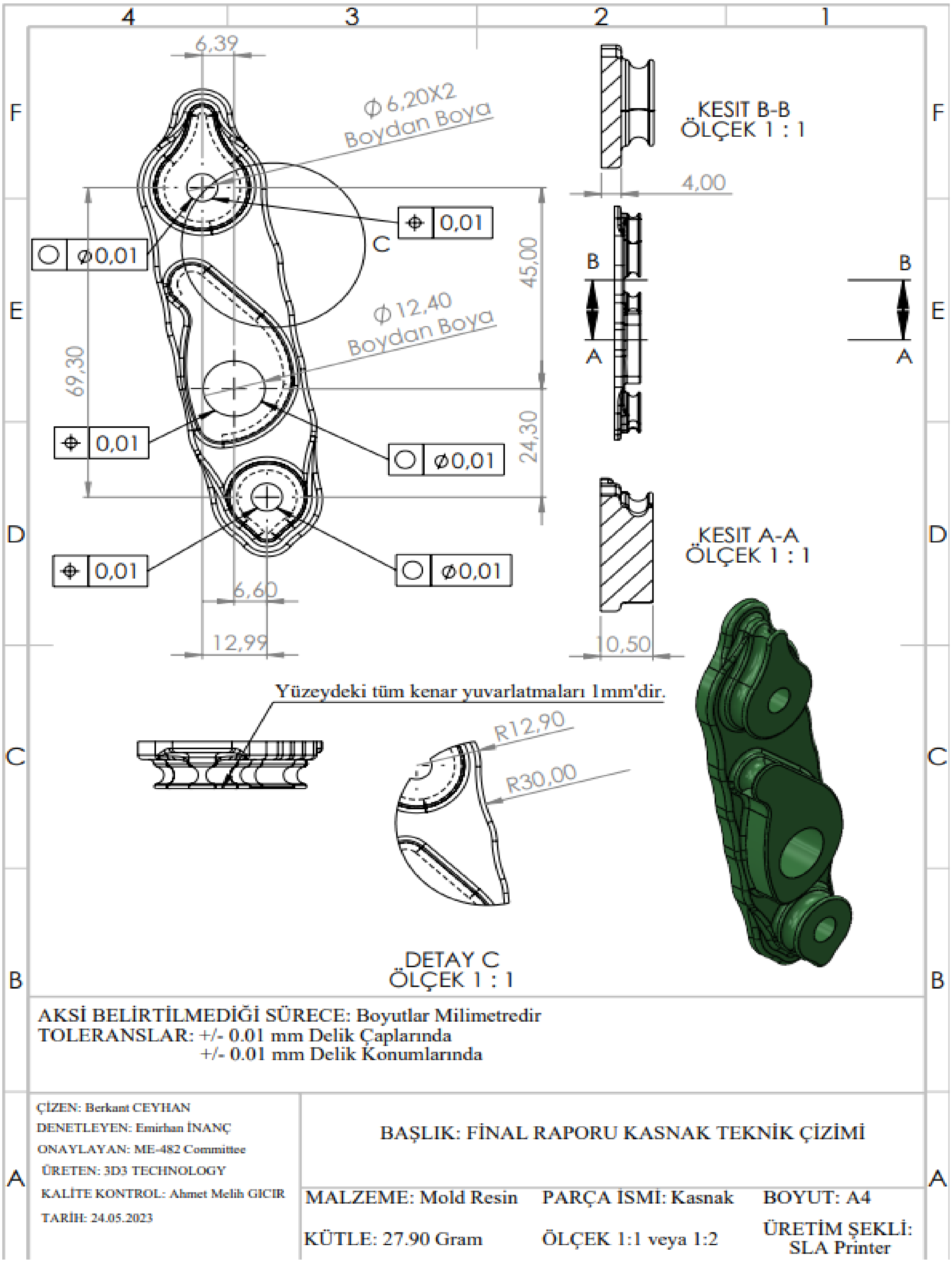
| TOTAL COST | POINTS |
|---|---|
| x < 100 TL | 5 |
| 100 TL < x < 200TL | 4 |
| 200 TL < x < 300 TL | 3 |
| 300 TL < x < 400 TL | 2 |

## Appendix-E: Simplicity Evaluations

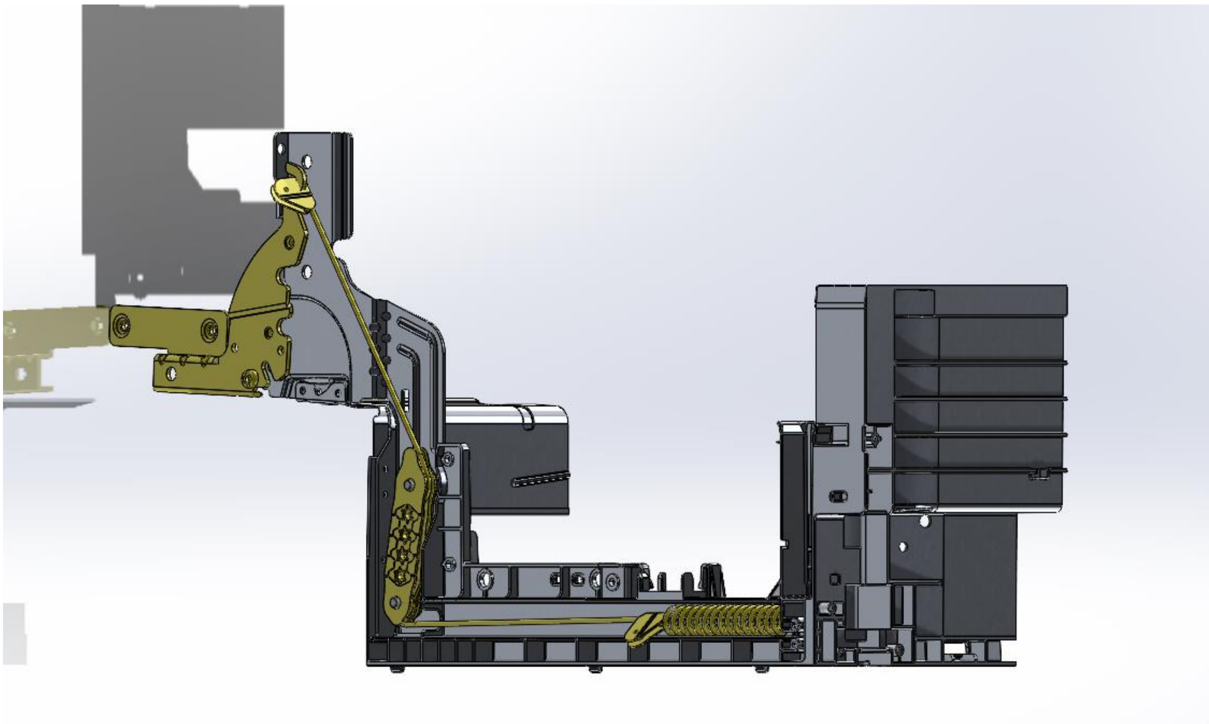
Table 8. 5: Simplicity Checklist

| EVALUATION | POINTS |
|---|---|
| Would the orientation of the system change (weight, order of the components, dimensional changes)? | NO (1 POINT) |
| Does the system contain components of different nature (mechanical, electromechanical, thermal, fluid, software)? | NO (1 POINT) |
| Is the system composed of different pieces (including the structural support elements)? | NO (1 POINT) |

**Appendix F: Technical Drawing of the Final Design**



## Appendix G: The Assembly of the Progress Design (D2)



## Appendix H: The Assembly of the Final Design (D3)