Topology Optimization of Door Catcher using SolidWorks

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Abstract

Topology Optimization uses mathematical approach to analyse the design and provide an optimal material configuration. This exact approach provides optimal material distribution while striking a delicate balance between strength and functionality. This research offers a strategic approach to door catcher design, using SolidWorks for detailed modelling and simulation. This designed door catcher blends a striker and body neatly into its frame. The continuously shifting components improve door functionality. The stress analysis in this work makes significant use of SolidWorks simulations to identify the most effective distribution of Nylon 6/6 material. This method improves efficiency while meeting high strength requirements. The study examines the fundamental characteristics of Nylon 6/6 as well as additive manufacturing technologies. The findings change the design environment for important elements like door catchers, which contributes to the ongoing discussion regarding Additive Manufacturing and its revolutionary influence in a wide range of applications.

Keywords: Door Catcher, Topology Optimization, SolidWorks, Additive Manufacturing

1. Introduction

Prior to the widespread adoption of additive manufacturing (AM), industries relied on traditional production processes. CNC machining, injection moulding and subtractive manufacturing were all popular techniques for shaping or removing material to manufacture components. Then additive manufacturing (AM) has fundamentally altered traditional production techniques, particularly with the invent of 3D printing technology. This technology seeks to replace conventional techniques and is actively revolutionising the commercial engineering sector, particularly for polymer manufacture. Additive manufacturing (AM), when combined with new material technology, is essential to economic competitiveness [1]. Several industries, including the automotive, aerospace, and healthcare sectors, use AM. It offers several advantages, including reduced waste output, low volume production and design freedom [2].

Manufacturers find the economic advantages of using various additive manufacturing (AM) technologies into their production processes. Fused deposition modelling (FDM) has emerged as the most common 3D printing technology for thermoplastic materials because of its speed, ease of utilisation and value for money [3,4]. In past Nylon was limited to textiles, but today, due to its high strength, there are more applications, including for the manufacture of mechanical parts. Filament material parameters have a significant impact on mechanical, metallurgical and physical qualities, as well as surface quality. Several research have focused on analysing the effects of process parameters on input response and identifying optimal settings for the FDM method for Nylon [5].

Topology optimisation is a structural optimisation approach that optimises material distribution within a specified design space for given loads and boundary conditions while meeting the product's performance objectives. The majority of topological optimisation procedures are carried out by combined use of Computer Aided Design (CAD) concept, Finite Element Analysis (FEA) concept, and distinct optimisation algorithms in consideration of diverse production techniques. Topology optimisation when explored to its full potential by considering additive manufacturing is a strong design method to save time, material and energy that are not economically possible with any other manufacturing process. Topology optimisation combined with additive manufacturing processes can minimise product weight. Lightweight design brings key advantages in product development, including minimised material, processing and use of energy [6].

A door catcher, also known as the "knuckle catcher," prevents unintentional opening of doors and maintains the door in a closed position. They operate by simply being pushed into position. They come with a wide variety of options including different holding forces, materials and finishes.

In this case study, a Door Catcher is designed using SolidWorks and Topology Optimization is used to reduce the weight and determine the most efficient material distribution.

2. Material

Nylon 6/6 has many uses in engineering because of its exceptional mechanical properties. Nylon 6/6 is a great choice for applications such as a click joint. Its durability in a range of applications is guaranteed by its excellent resistance to chemicals and wear. In the consumer goods sector and automotive engineering, Nylon 6/6 is a lightweight, versatile material that offers a well-balanced combination of strength and flexibility [7].

Table 2.1: Material Properties

Material used	Nylon 6/6
Elastic Modulus	1000 MPa
Poisson’s Ratio	0.3
Shear Modulus	2930 MPa
Mass Density	1150 kg/m^3
Tensile Strength	73 MPa
Yield Strength	60 MPa
Thermal Conductivity	0.245 W/m-K
Specific Heat	1500 J/Kg.K

3. Process

Fused Deposition Modelling (FDM) is an additive manufacturing process where a thermoplastic filaments such as Nylon is extruded through a nozzle that melts and deposits the material on the build platform gradually and systematically[8,9]. Moreover a 3D printer plays a pivotal role in determining the quality and precision of the prints. We selected Prusa Mini as the FDM Printer which distinguishes itself with a commendable 180x180x180 mm build volume. The Prusa Mini helps the creation of excellent prints by carefully placing each layer. This accuracy becomes vital when dealing with advanced materials like Nylon, which we have selected as the material for FDM printing. Due to its well-known rigidity and durability, nylon is a great choice for applications requiring robust components.

4. Design

A door catchers is a component used to hold doors in a specific position or to restrict them from swinging open or closed unintentionally. It basically has two components.

1. Body
2. Striker

4.1 Body

The part Body is attached to the frame of the door. It has a mouth shaped structure which expands and contracts when the striker hits the tip. The bolt size provided for the Body is M4.

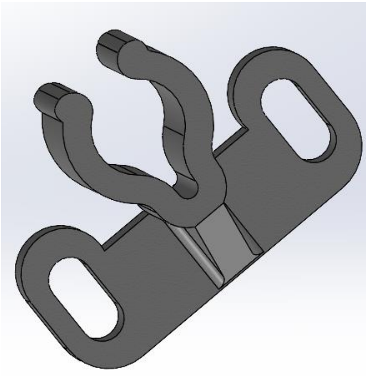

Fig 4.1: Body

4.2 Striker

The part Striker is attached to the door. It has a cylindrical shaped structure which strikes the mouth of the Body to form a lock. The bolt size provided for the Striker is M4.

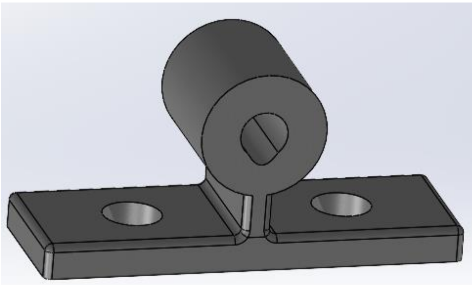

Fig 4.2: Striker

The Body and the Striker when in the locked position has dimension of 29.10 X 30 X 12.98 mm.

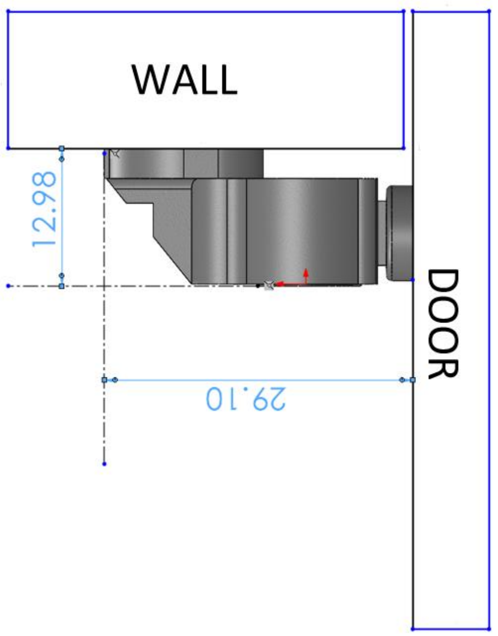

Fig 4.3: Application Reference

5. Finite Element Analysis

We considered the non-linear analysis for this case. The maximum push-in and pull-out force required is to be determined. Two different cases are considered for this analysis.

1. Push-in Force case
2. Pull-out Force case

5.1 Push-in Force Case

An assembly of the striker and the body of the door catcher is created in Solidworks for analysis. The material properties of Nylon 6/6 is defined for the parts of the door catcher and also three mate conditions were defined for the assembly.

- The horizontal plane of the striker and the body was made coincident.
- The vertical plane of the striker and the body was made coincident.
- The tip of the body and cylindrical face of the striker were made tangent.

A non linear study was created with the following settings.

- Local interactions were defined for outer cylindrical surface of the striker and inner cylindrical surface of the body.
- The bottom part of the body which is to be attached to the door is made fixed geometry.
- The thin edges of the striker were restricted for roller/slider fixture.
- A range of force values (2 N - 31 N) were applied on the top of the striker.
- Fine mesh density was applied for the assembly.

The following result was obtained for the above set of conditions.

- The maximum Von Mises Stresses resulted was 53.1 N/mm^2.
- The Maximum push-in force obtained was 31 N.

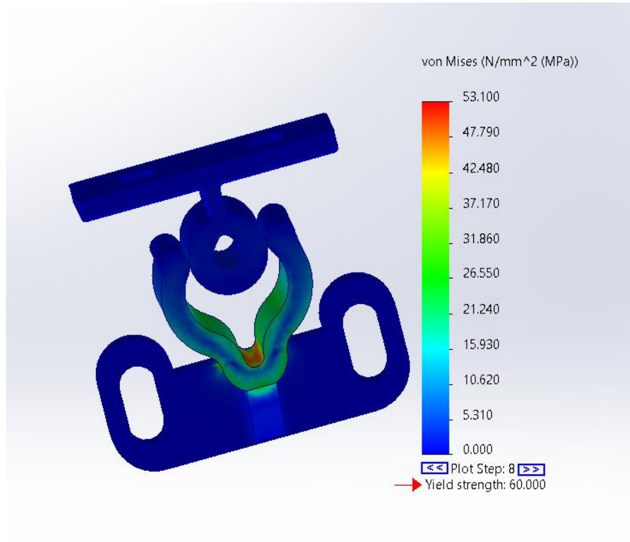

Fig 5.1: Von Mises Stress for Push-in Force case

The displacement required to push-in the striker is 10mm. Several iterations were done based on the force as input starting from 2N. When a force of 31.3 N was applied the striker displaced 6.682 mm and from then on the striker is pushed in by the body due to strain energy in the body.

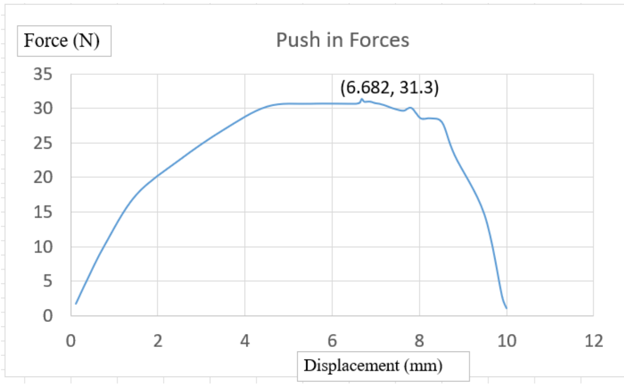

Fig 5.2: Force Displacement Curve of Push-in Forces

5.2 Pull-out Force Case

The three mate conditions defined for the assembly were

- The horizontal plane of the striker and the body was made coincident.
- The vertical plane of the striker and the body was made coincident.
- The inner cylindrical surface of the body and cylindrical face of the striker were made coincident.

A non linear study was created with the following settings.

- Local interactions were defined for outer cylindrical surface of the striker and inner cylindrical surface of the body.
- The bottom part of the body which is to be attached to the door is made fixed geometry.
- The thin edges of the striker were restricted for roller/slider fixture.
- A range of force values (31 N -36.95N) were applied on the top of the striker.
- Fine mesh density was applied for the assembly.

The following result was obtained for the above set of conditions.

- The maximum Von Mises Stresses resulted was 42.997 N/mm^2.
- The Maximum pull-out force obtained was 37 N.
- The obtained Von Mises Stress is within the Yield Strength limit.

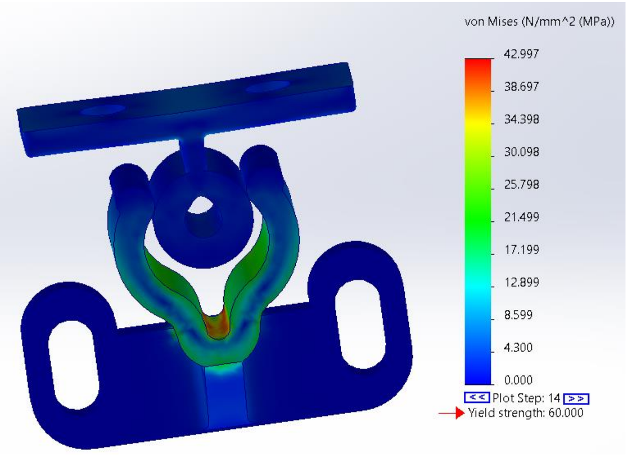

Fig 5.3: Von Mises Stress for Pull-out Force Case

To determine the pull-out force, a series of iterations were done based on the force as input starting from 31N. When a force of 37 N was applied the striker displaced 4.98 mm and then the striker is pulled out by the body due to the strain energy.

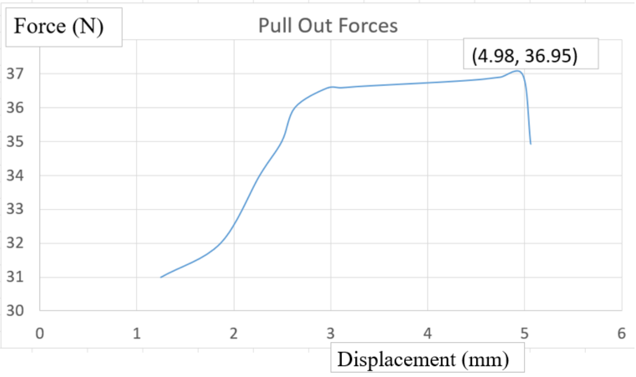

Fig 5.4: Force Displacement Curve of Pull-out Forces

6. Topology Optimization

The Topology Optimization study was conducted on the body and the striker separately.

6.1 Body

A topology study was conducted on the designed model of the body with material properties of Nylon 6/6.

- The bottom part of the body was made fixed.
- Screw force of 20 N was applied on both the sides of the body.
- A force of 40 N was applied at the mouth of the body.
- The goal was set to best stiffness to weight ratio.
- The mass constraint was set to 40% and Factor of Safety as 1.25.
- The inner cylindrical surface of the body was added to preserved region.
- Fine mesh density was applied for the assembly.

After generating the mesh, the study was conducted. The result of the topology study of the body is given below.

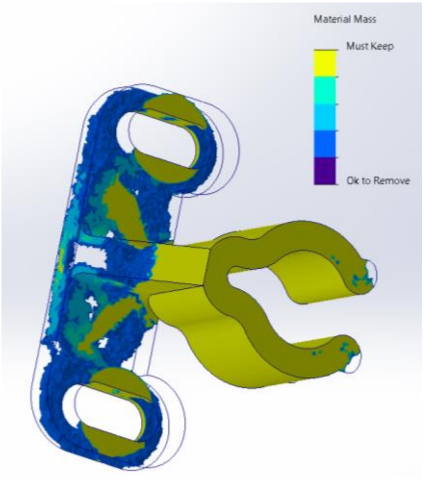

Fig 6.1: Topology result of Body

6.2 Striker

A topology study was conducted on the designed model of the striker with material properties of Nylon 6/6.

- A fixed constraint was placed at the bottom part of the striker.
- Screw force of 20 N was applied on both the sides of the striker.
- A force of 40 N was applied at the outer cylindrical surface of the striker.
- The goal was set to best stiffness to weight ratio.
- The mass constraint was set to 40% and Factor of Safety as 1.25.
- The outer and inner cylindrical surface of the striker was added to preserved region.
- Fine mesh density was applied for the assembly.

After generating the mesh, the study was conducted. The result of the topology study of the striker is given below.

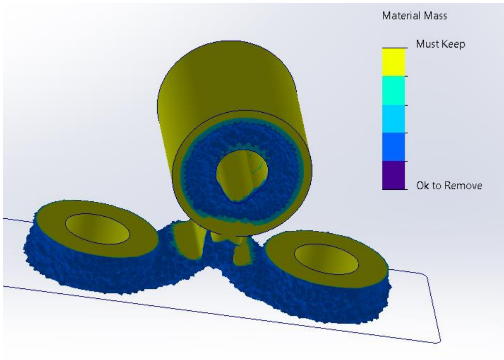

Fig 6.2: Topology result of the Striker

7. Results and Discussion

The results from the Topology optimization study of the body and the striker indicate that there are some ok to be removed areas where stress concentration is below the limit condition. The material mass plot of the body and the striker was generated from the obtained topology results.

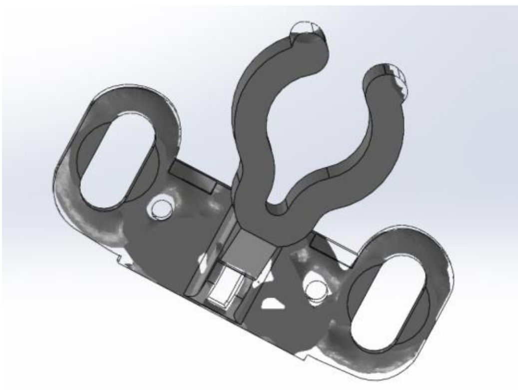

Fig 7.1: Material mass plot of Body

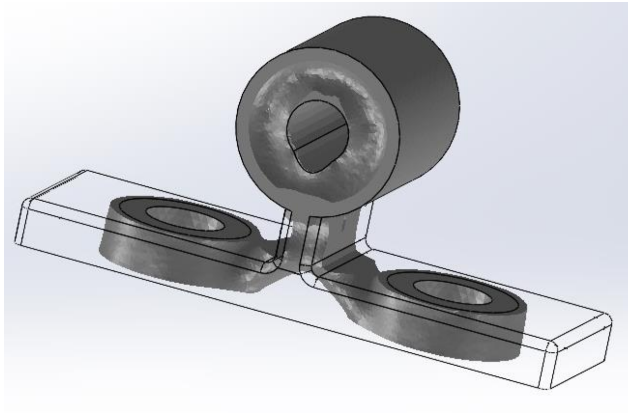

Fig 7.2: Material mass plot of Striker

The result obtained from Solidworks is not aesthetically pleasing and the geometry is rough. The model also contains overhanging areas which leads to use of more support structures. This can lead to material wastage, more time for printing and post-processing. So it is important to remodel the part [6]. The final design is prepared by closely following topology optimization and reducing overhanging areas which is less than 45°.

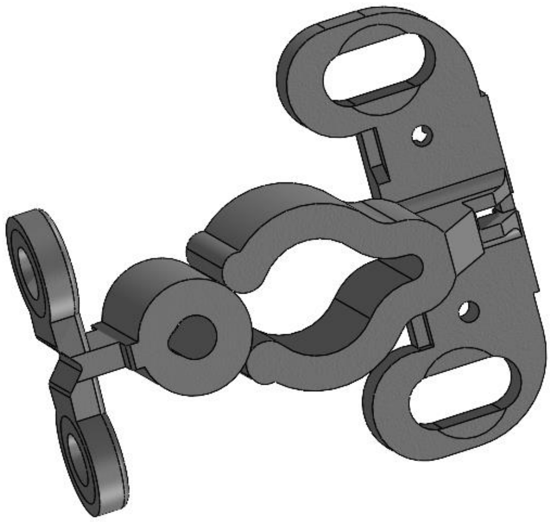

Fig 7.3: Final design of Door Catcher

The newly designed model should meet the same design requirements and withstand mechanical loads. Inorder to verify it the model was subjected to analysis. The von Mises stress obtained for Push-in force case is 54.934 N/mm^2 and that for Push-out force case is 49.380 N/mm^2 which is below the yield strength of the material. The initial weight of the door catcher was 3.94 g and after optimization weight reduced to 3.32 g (16% reduction).

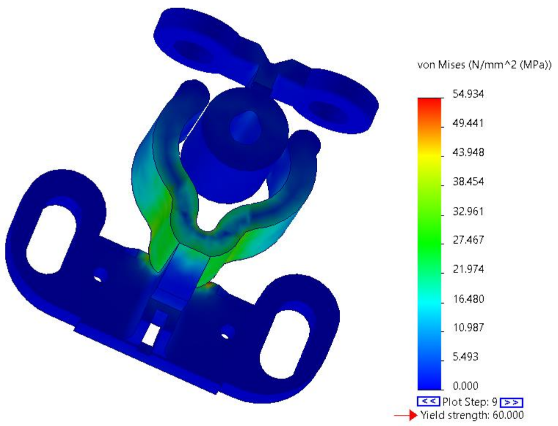

Fig 7.4: Von Mises Stress for Push-in Force case

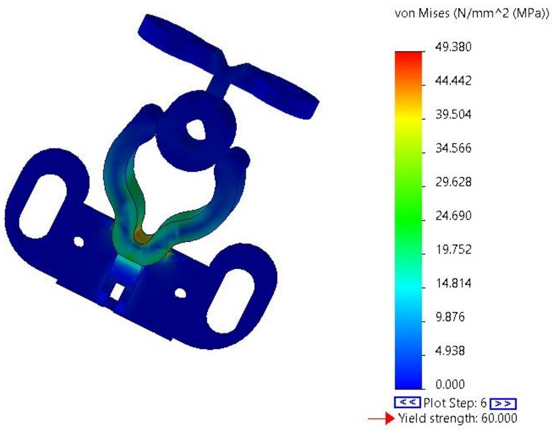

Fig 7.5: Von Mises Stress for Pull-out Force case

8. Conclusion

From the study it is concluded that Topology optimization can be employed to reduce the weight of components without compromising the force requirements. An optimized model of door catcher was designed with the help of Solidworks. The final design satisfies the yielding condition and the results from topology optimization brought in an overall weight reduction of 16%.

9. Acknowledgements

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10. References

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