Life Span Improvement of Ejector Unit Using Topology Optimization

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***Abstract*: Stretch blow molding machine is used for the manufacturing of PET bottles. The purpose of the Ejector Unit of the Stretch Blow Molding Machine is to pick and eject out the manufactured PET bottles by executing a frequent semicircular cyclic motion of its Rotating Arm. This frequent cyclic motion of the rotating arm creates a large impact load on the shock absorbers of the Ejector unit and causing them to fail in a span of 6 months.**

The paper attempts to improve the life span of Ejector unit. This is done by reducing the impact load taken up by the shock absorbers, through decreasing the mass of the rotating part by Topology Optimization performed through ANSYS 18.1. The CAD Model of Ejector unit is designed using Solidworks 2018 and the modeled parts of Rotating Arm of the Ejector unit is made to undergo topology optimization by the software supported Optimality Criterion methods. After that their optimal shapes (optimal material distribution) for given loads and boundary conditions are obtained.

***Index Terms*: Ejector Unit, ANSYS 18.1, Topology Optimization, Stress Analysis**

I. INTRODUCTION

Ejector Unit (fig 1) functions to eject out the manufactured PET bottles from the Stretch Blow Molding Machine. Ejector unit works by executing a semicircular motion of the rotating arm with the help of a Pneumatic Rotary Actuator. Thus, manufactured PET bottles are collected from one side and are ejected out into the conveyor unit at the other side. Therefore, it’s necessary to stop the rotating arm (fig 2) at the end of each and every 180° motion for picking and ejecting out the manufactured PET bottles. This sudden and continuous stopping creates a large impact load on the Shock Absorbers of Ejector Unit and causes them to fail rapidly after installation. In present scenario replacing the shock absorber model can’t be done since it effects the design of the Ejector unit model and its functionality. Thus, it’s necessary to improve the life span of the Ejector unit by decreasing the failure rate of shock absorbers by reducing the impact load taken up by the shock absorbers. This failure rate reduction is done by performing Topology Optimization on Ejector unit components, in order to reduce the mass of the rotating components without affecting the stiffness of parts and also without effecting the performance parameters. Thus, by the reduction of mass, there will be a large reduction in the impact load and stress development taken by the Shock Absorbers during the picking and ejecting out operations of bottles.

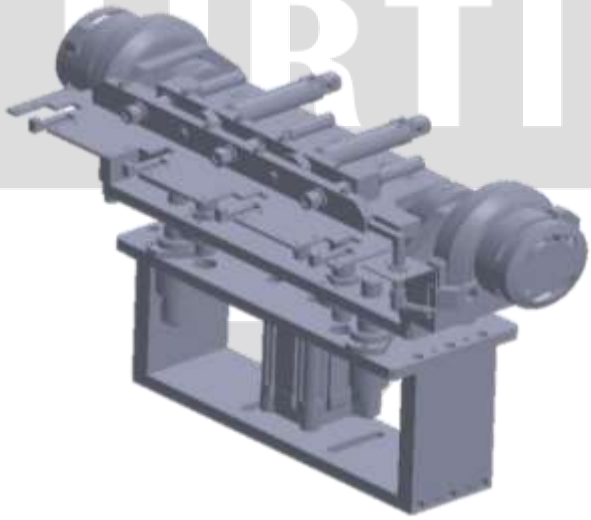


Fig 1: Ejector Unit of Stretch Blow Molding Machine

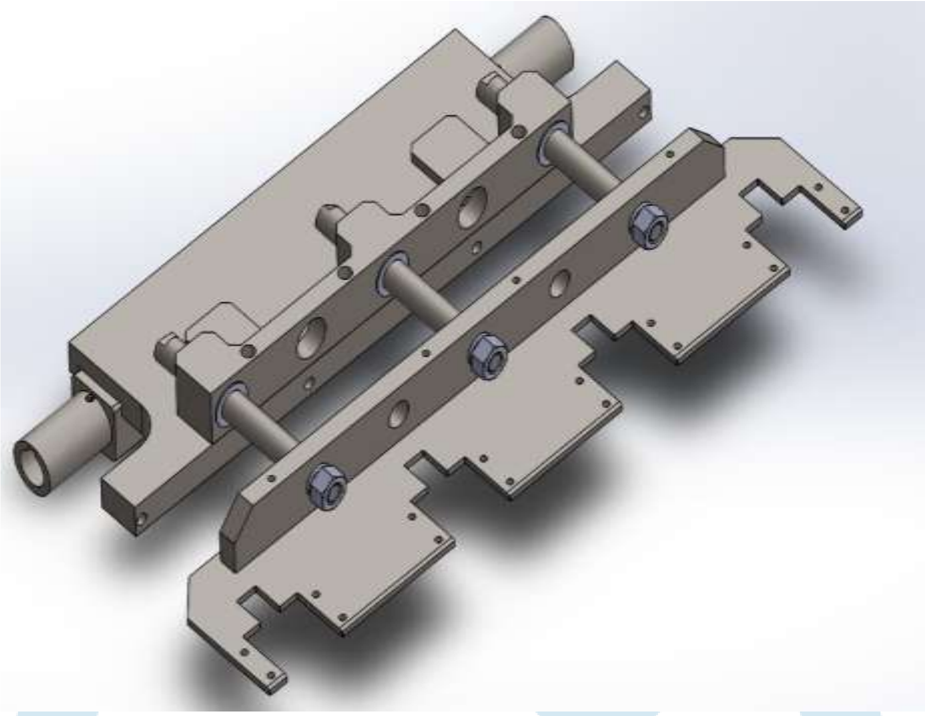


Fig 2: Rotating Arm of Ejector Unit

II. TOPOLOGY OPTIMIZATION

Topology optimization is a useful tool for a designer which generates the optimal shape of a mechanical part. The optimized shape is generated within a predefined design space based on a given set of loads, boundary conditions and constraints with the goal of obtaining maximum efficiency and performance of system in terms of reduced mass or volume of part by retaining the desired mechanical properties and also without affecting the design purpose. The topology optimization deals with the optimal distribution of material within the structure by maximizing the static stiffness. This can also be stated as the problem of minimization of compliance of the structure. Compliance is a form of work done on the structure by the applied load. Lesser compliance means lesser work is done by the load on the structure, which results in less energy storage in the structure which in turn, means that the structure is stiffer. Optimization can basically be categorized into three types namely: (a) Topography (b) shape and (c) topology (layout). And here we basically focuses on the topology optimization.

The topological optimization can be categorized into two approaches. The first approach is the assumed micro structure approach which tries to find out the micro structural parameters (e.g. size and orientation of holes) of each designed element in a finite element model. The second approach assumes no microstructure, but rather heuristically designs the material properties (Young's modulus, density etc.) of each element directly to find optimal material distributions. Unlike traditional optimization, topological optimization does not require design variables (that is, independent variables to be optimized). In this, the structural problem, (material properties, FE loads etc.) and the objective function (the function to be optimized), the state variables (the constrained dependent variables) are required to be defined from among a set of predefined criteria (for example mass constraint).

III. METHODOLOGY

CAD model of the Ejector Unit is designed with the help of Solidworks 2018 software. Each part of the Ejector unit is separately designed and are assembled with the help of Solidworks 2018. Designed parts are made to undergo stress analysis with the help of ANSYS 18.1 software. In ANSYS each part of the Rotating Arm including the Bottle Holder, Guide Rod, Guide Rod Holder and Central Rod are made to undergo Static Stress Analysis based on the individual loading conditions of the parts. Later on Topology Optimization is performed on the Stress analyzed parts using the mass constraint. Then the parts are redesigned based on the Topology Optimization result using Solidworks 2018. And then the redesigned parts are again assembled and masses are calculated using the Evaluate option of Solidworks. Then the new assembly of Topology Optimized Parts are Stress analyzed to prove that it will withstand the previous loading conditions without any failure

3.1) Components of the Rotating Arm of Ejector Unit

a) Bottle Holder

Bottle holder grab the bottles from the time of picking to the time of ejection of the manufactured PET bottles from the Stretch Blow Molding machine to the conveyor unit for packaging.

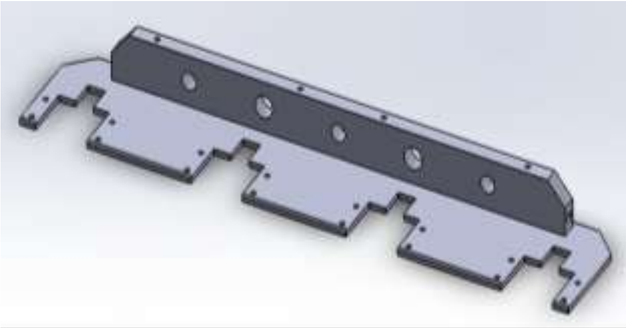


Fig 3: Bottle Holder

b) Guide Rod

Guide Rod guides the piston of pneumatic actuators during extraction and contraction of bottle holder at the time of picking and ejecting of PET bottles. They also reduces the load given to the piston of Pneumatic Actuator by the Bottle Holder during its working cycles.

Fig 4: Guide Rod

c) Guide Rod Holder

Guide rod holder holds both the guide rod and pneumatic actuators for the purpose of extraction and retraction of the Bottle Holder part.

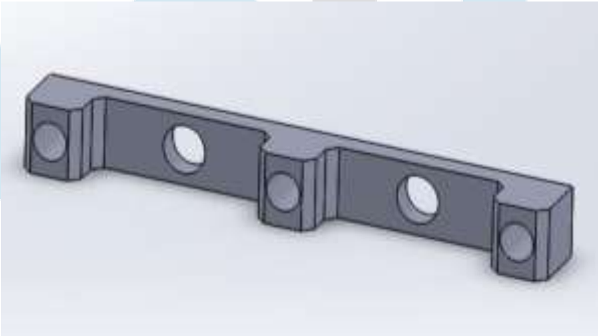


Fig 5: Guide Rod Holder

d) Central rod

Central rod acts as the axis of rotation for the Rotating Arm. It's the central rod which holds every component of the Rotating arm so as to execute the semicircular rotational motion provided by the Rotary Actuator.

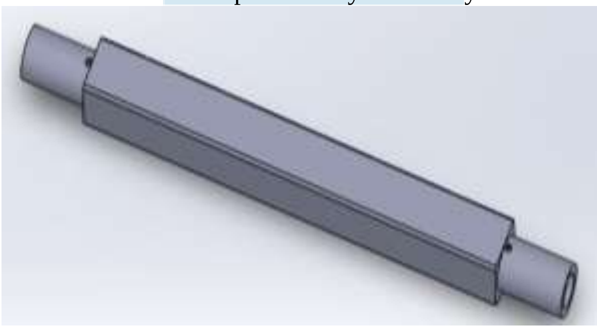


Fig 6: Central Rod

3.2) Stress Analysis of the Components of Rotating Arm

Stress Analysis of the Rotating Arm parts was performed in Static Structural workbench of ANSYS 18.1. The stress analysis done on each component is different from each other because of the unique boundary conditions (fixed support, load acting, etc..) of each part. In the previous model, EN 8 were used as the material for the manufacturing of Ejector unit components. But in the topology optimized model Aluminium 6063 T6 Alloy is used instead of EN 8 for mass reduction. And here the Stress analysis of each component is done on parts made of Aluminium alloy and based on this result topology optimization of the 4 main parts are performed.

a) Bottle Holder

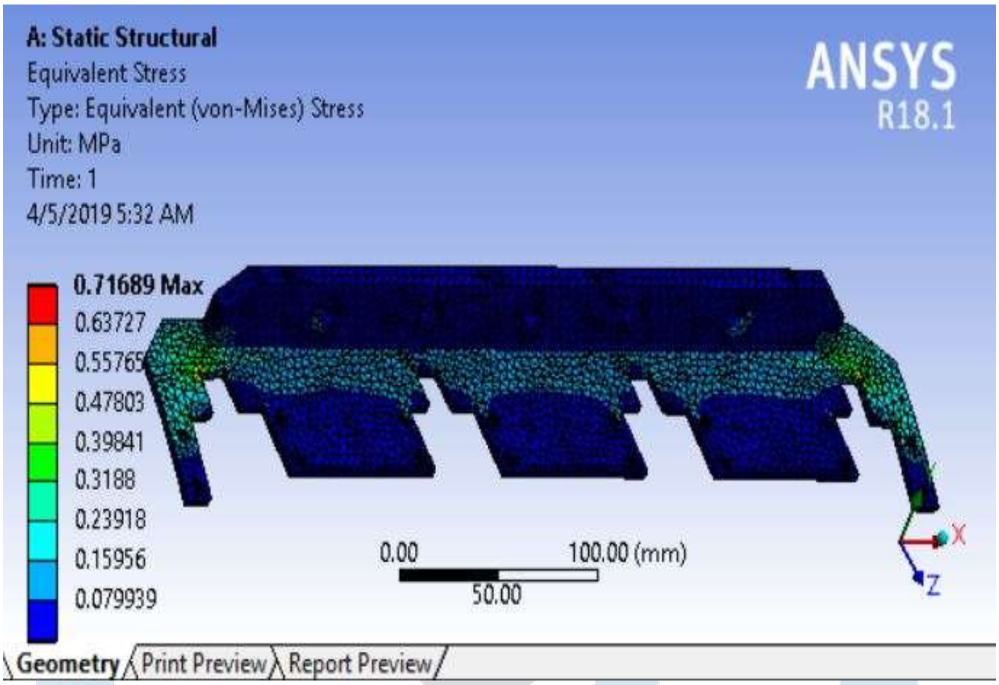


Fig 7: Stress Analysis of Bottle Holder

b) Guide Rod

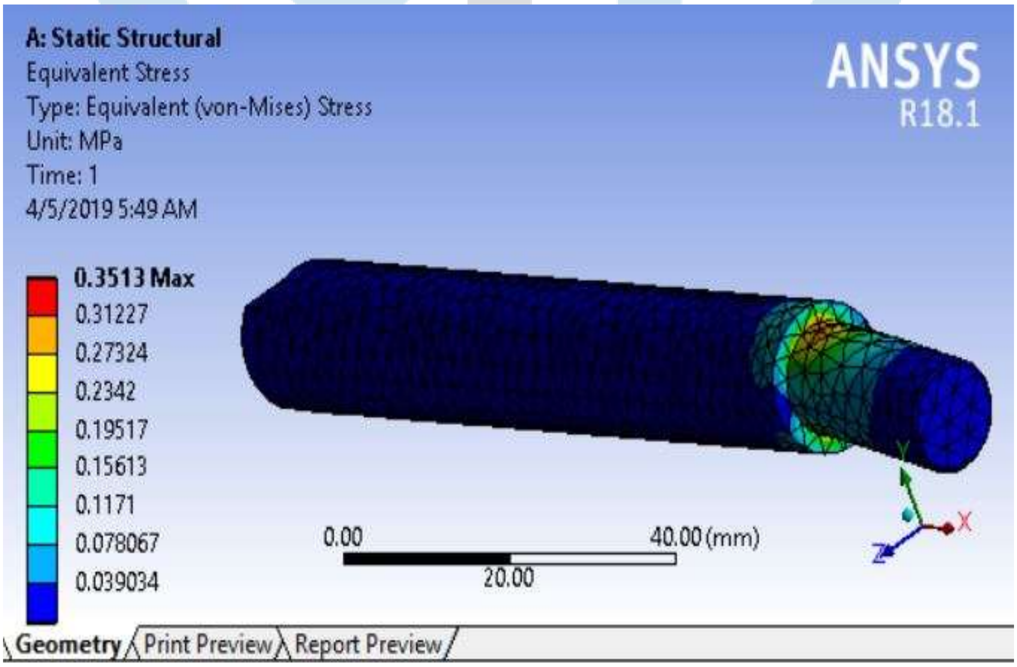


Fig 8: Stress Analysis of Guide Rod

c) Guide Rod Holder

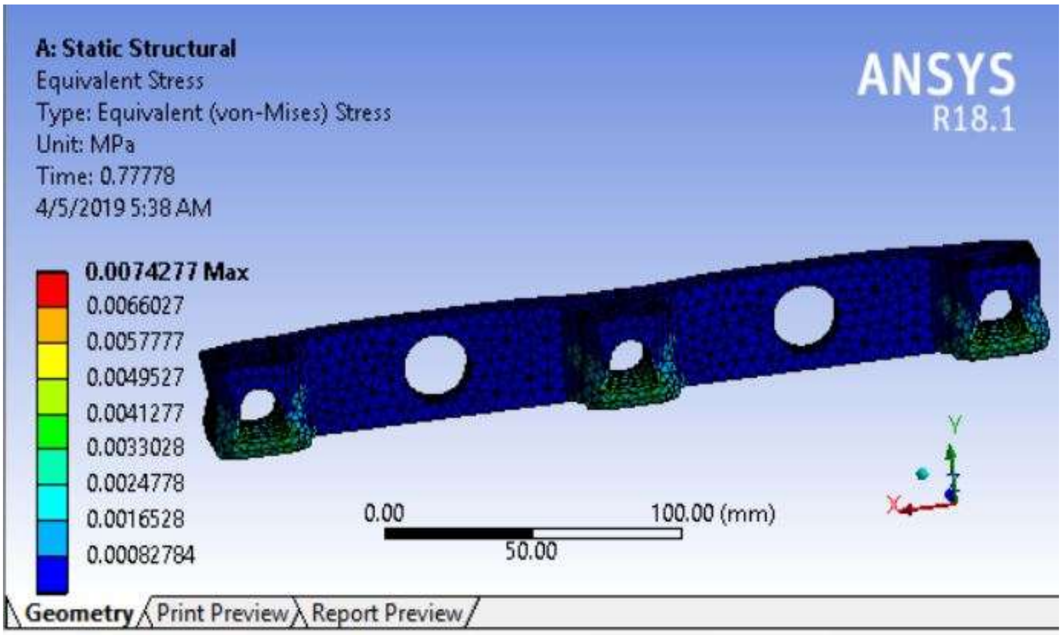


Fig 9: Stress Analysis of Guide Rod Holder

d) Central Rod

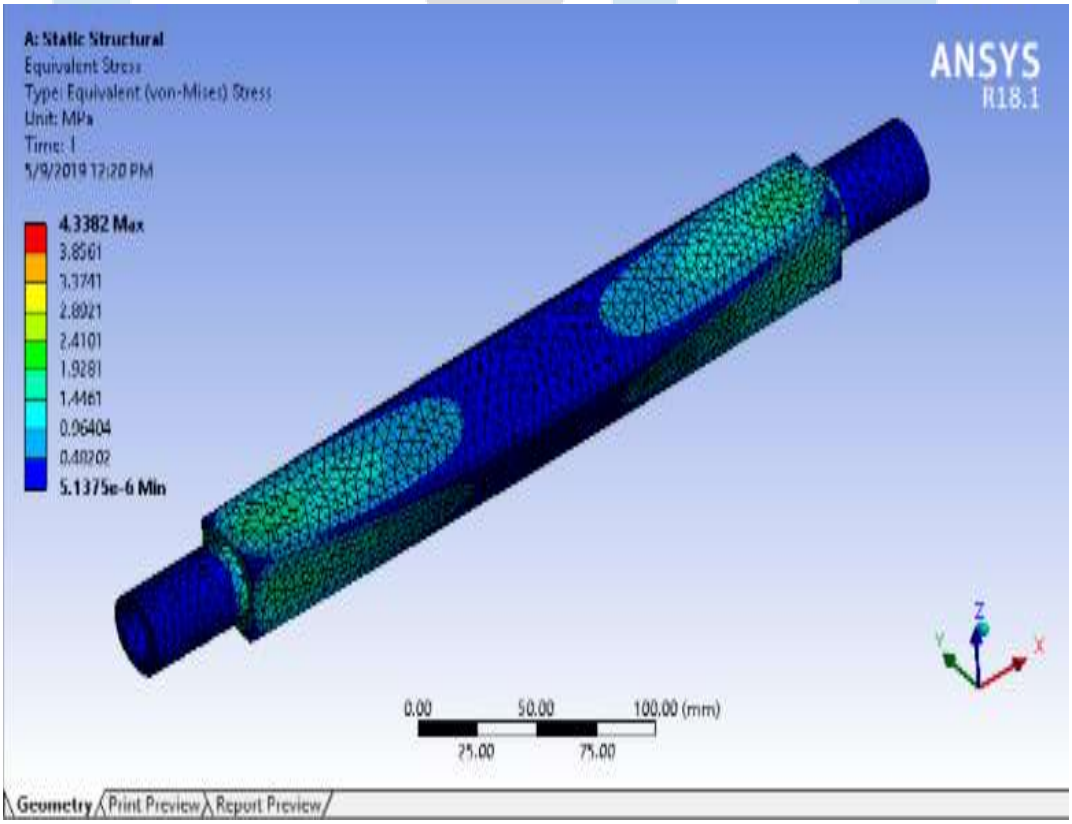


Fig 10: Stress Analysis of Central Rod

3.3) Topology Optimization of Ejector Unit Parts

Topology Optimization of the parts is performed in the Topology Optimization Workbench of ANSYS 18.1 based on the result of stress development obtained from the static structural workbench of ANSYS 18.1. Along with this 50% mass removal option was also performed for the removal of unwanted and less stress developed material without reducing the strength of parts for performing its required function without any failure.

a) Bottle Holder

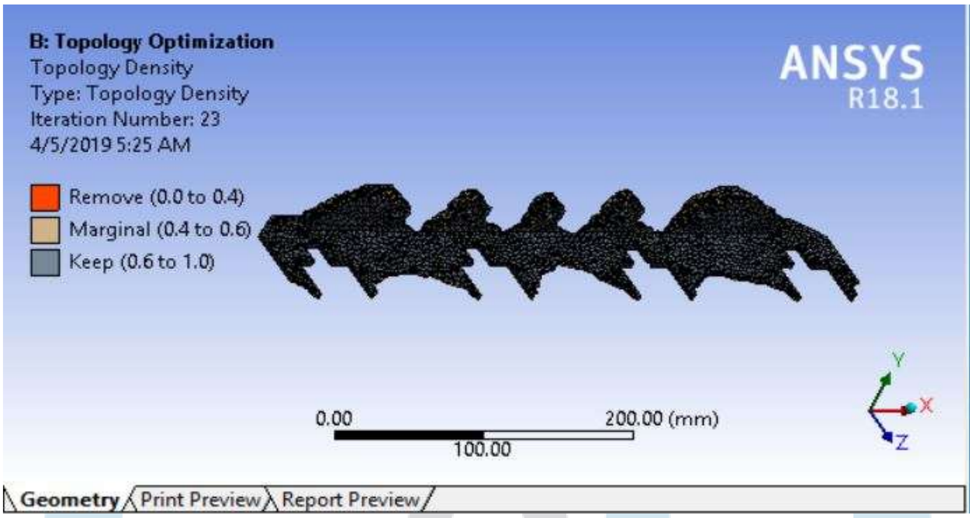
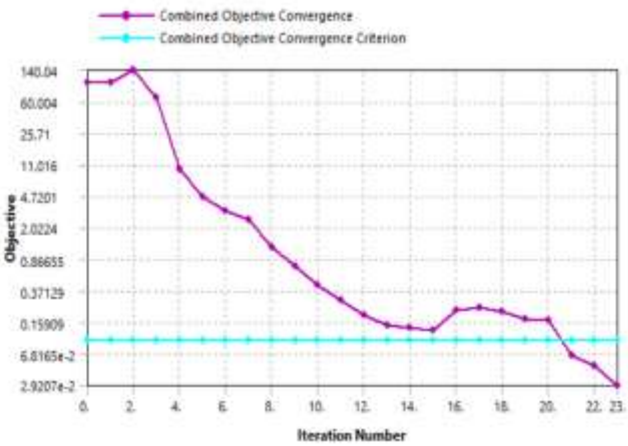
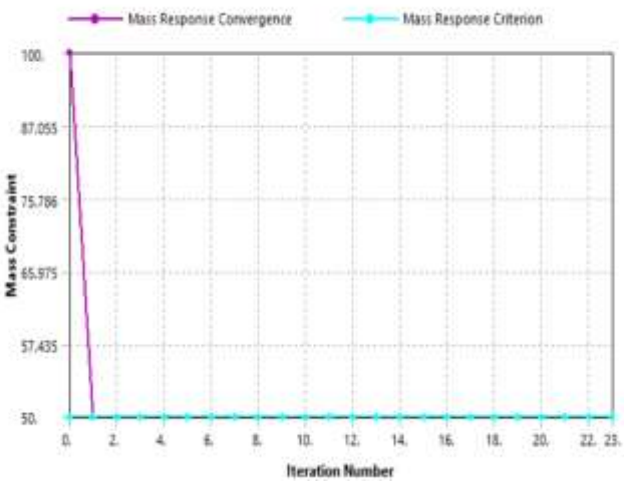


Fig 11: Topology Optimized view of Bottle Holder





Object Name	*Topology Density*
State	Solved
Scope	
Scoping Method	Optimization Region
Optimization Region	Optimization Region
Definition	
Type	Topology Density
By	Iteration
Iteration	Last
Retained Threshold	0.5
Exclusions Participation	Yes
Suppressed	No
Results	
Minimum	1.e-003
Maximum	1.
Original Volume	2.6878e+005 mm³
Final Volume	1.4723e+005 mm³
Percent Volume of Original	54.777
Original Mass	0.74451 kg
Final Mass	0.40782 kg
Percent Mass of Original	54.777
Visibility	
Show Optimized Region	Retained Region
Information	
Iteration Number	23

b) Guide Rod

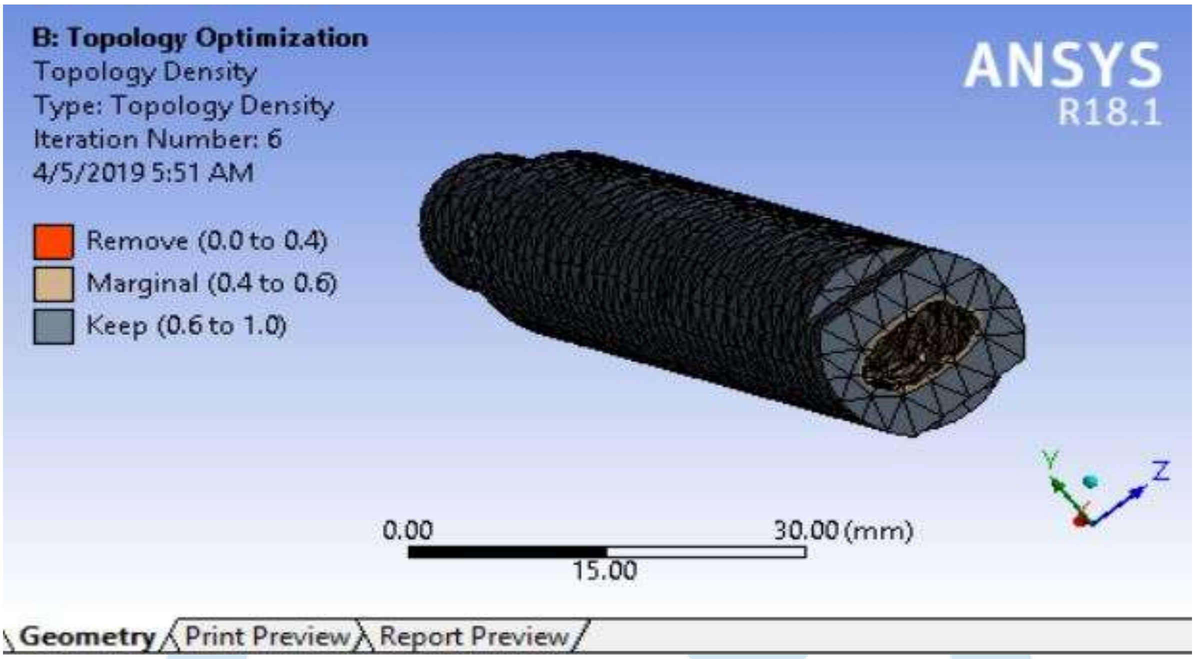
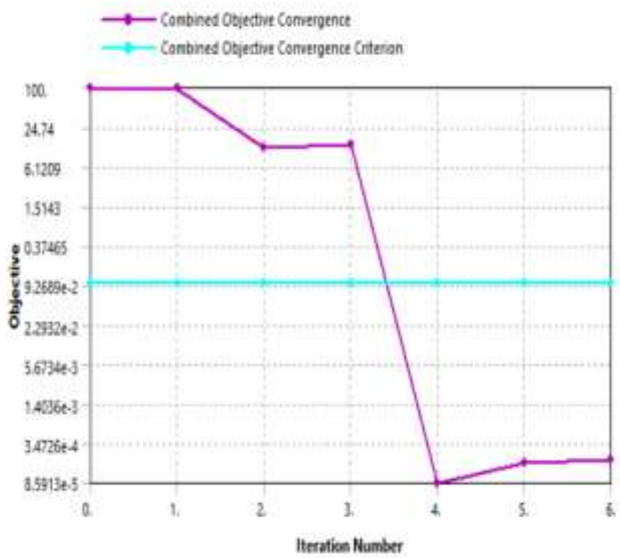
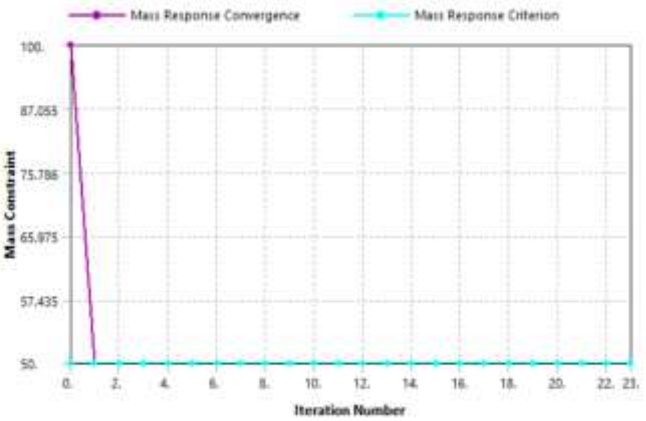


Fig 14: Topology Optimized view of Guide Rod



Object Name	*Topology Density*
State	Solved
Scope	
Scoping Method	Optimization Region
Optimization Region	Optimization Region
Definition	
Type	Topology Density
By	Iteration
Iteration	Last
Retained Threshold	0.5
Exclusions Participation	Yes
Suppressed	No
Results	
Minimum	1.e-003
Maximum	1.
Original Volume	4.1259e+005 mm³
Final Volume	2.4706e+005 mm³
Percent Volume of Original	59.879
Original Mass	1.1429 kg
Final Mass	0.68434 kg
Percent Mass of Original	59.879
Visibility	
Show Optimized Region	Retained Region
Information	
Iteration Number	23



c) Guide Rod Holder

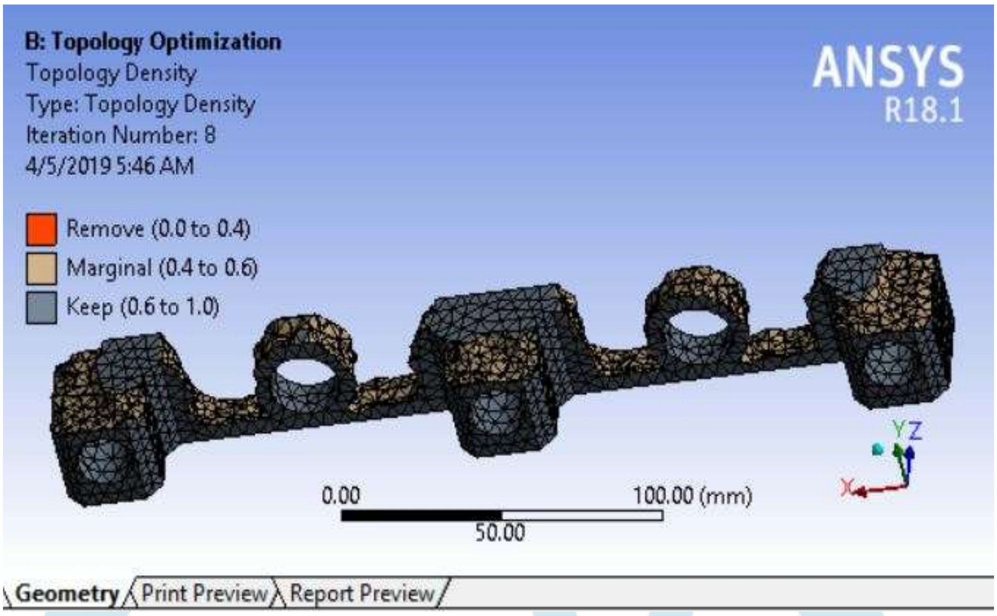
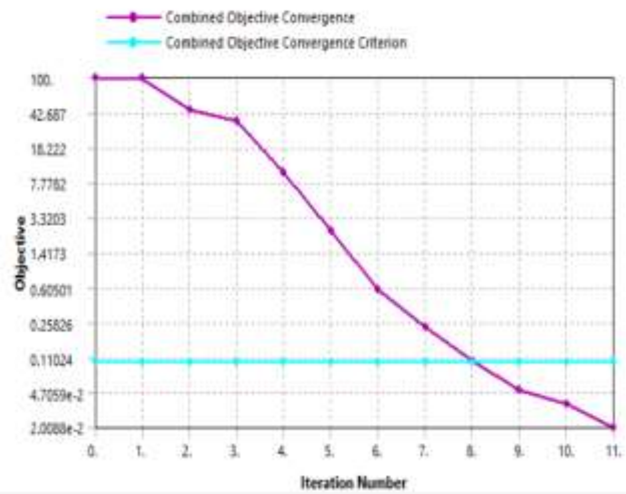
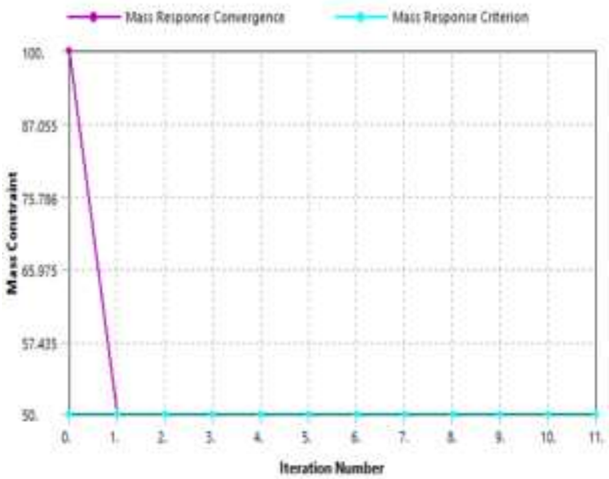


Fig 17: Topology Optimized view of Guide Rod Holder





Object Name	*Topology Density*
State	Solved
Scope	
Scoping Method	Optimization Region
Optimization Region	Optimization Region
Definition	
Type	Topology Density
By	Iteration
Iteration	Last
Retained Threshold	0.5
Exclusions Participation	Yes
Suppressed	No
Results	
Minimum	1.e-003
Maximum	1.
Original Volume	1.399e+005 mm^3
Final Volume	97853 mm^3
Percent Volume of Original	69.943
Original Mass	0.38754 kg
Final Mass	0.27105 kg
Percent Mass of Original	69.943
Visibility	
Show Optimized Region	Retained Region
Information	
Iteration Number	11

d) Central Rod

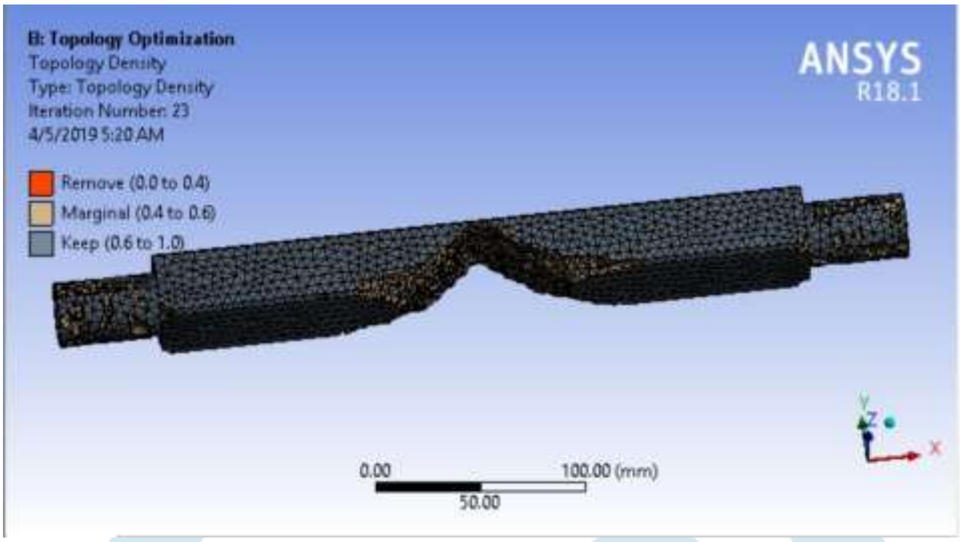
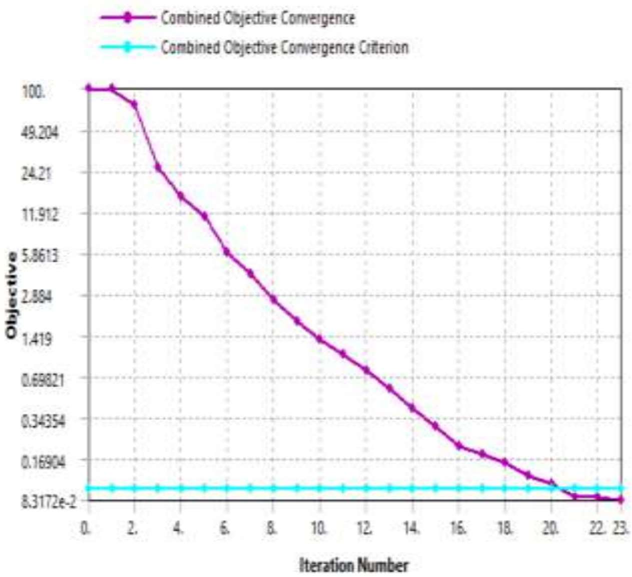
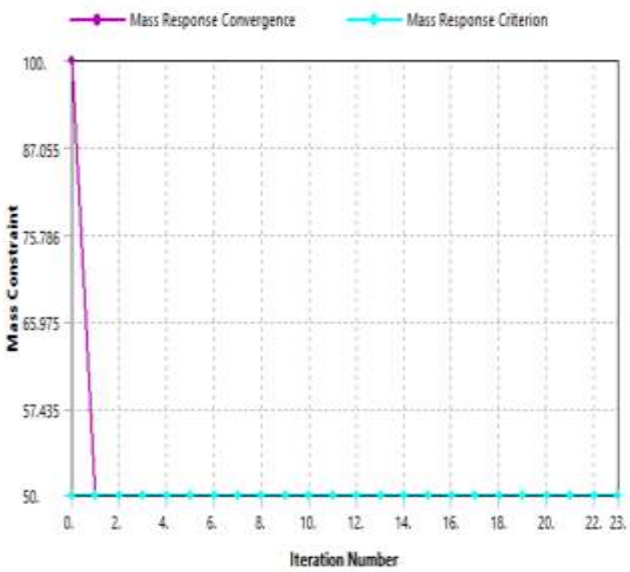


Fig 20: Topology Optimized view of Central Rod





Object Name	*Topology Density*
State	Solved
Scope	
Scoping Method	Optimization Region
Optimization Region	Optimization Region
Definition	
Type	Topology Density
By	Iteration
Iteration	Last
Retained Threshold	0.5
Exclusions Participation	Yes
Suppressed	No
Results	
Minimum	1.e-003
Maximum	1.
Original Volume	4.1259e+005 mm³
Final Volume	2.4706e+005 mm³
Percent Volume of Original	59.879
Original Mass	1.1429 kg
Final Mass	0.68434 kg
Percent Mass of Original	59.879
Visibility	
Show Optimized Region	Retained Region
Information	
Iteration Number	23

3.3) Redesigned Rotating Arm Parts

Based upon the result of the Topology optimization obtained from ANSYS. The parts were redesigned using SOLIDWORKS 2018.

a) Bottle Holder

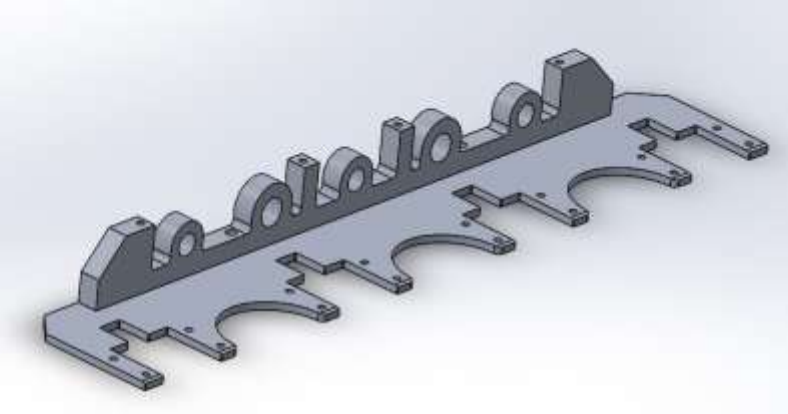


Fig 23: Topology Optimized Bottle Holder

b) Guide Rod

Fig 24: Topology Optimized Guide Rod

c) Guide Rod Holder

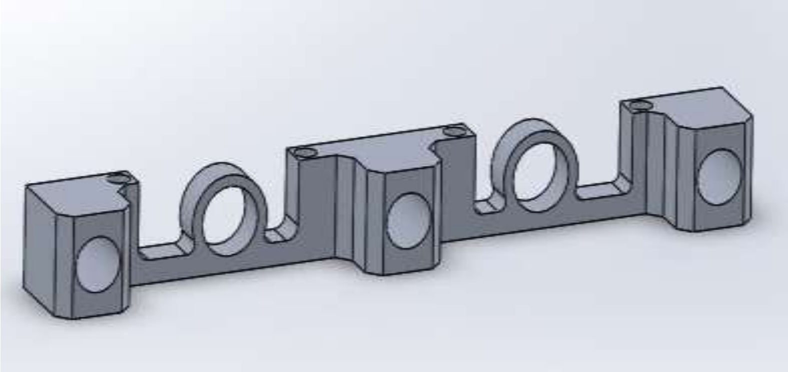


Fig 25: Topology Optimized Bottle Holder

d) Central Rod

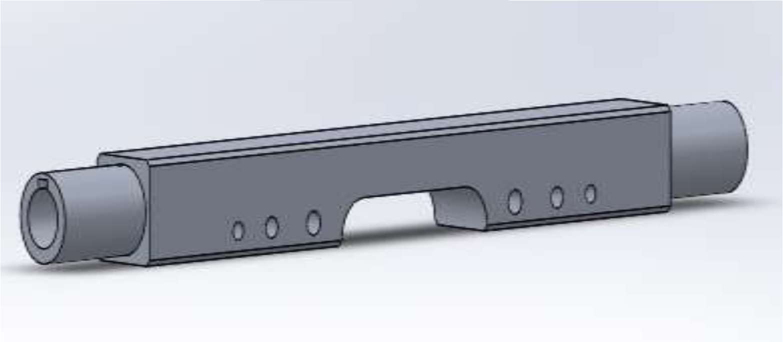
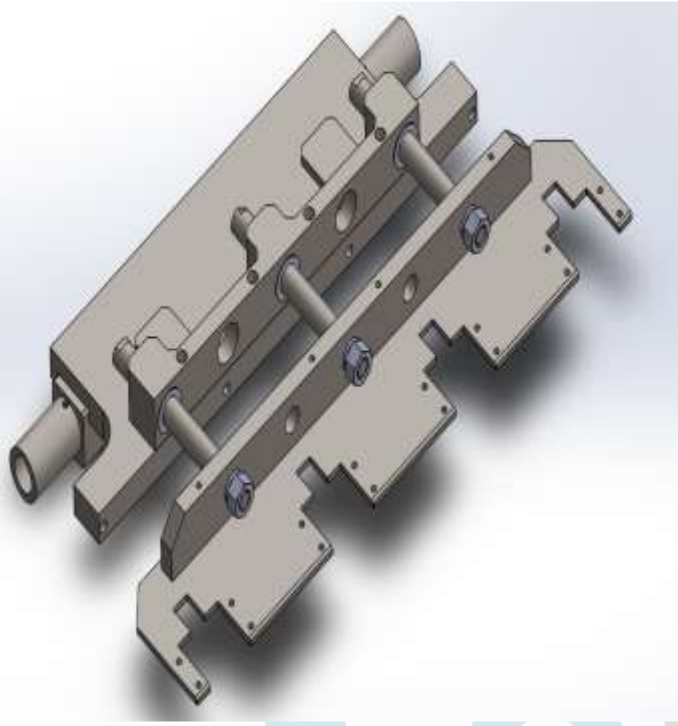


Fig 26: Topology Optimized Central Rod

IV. RESULT

Mass Comparison

Previous CAD Model of Ejector Unit



Mass properties of FINAL PART IN ASTM A36
Configuration: Default
Coordinate system: -- default --

Mass = 11881.29 grams

Volume = 1522712.07 cubic millimeters

Surface area = 351246.23 square millimeters

Center of mass: (millimeters)
X = 168.51
Y = 222.00
Z = 303.07

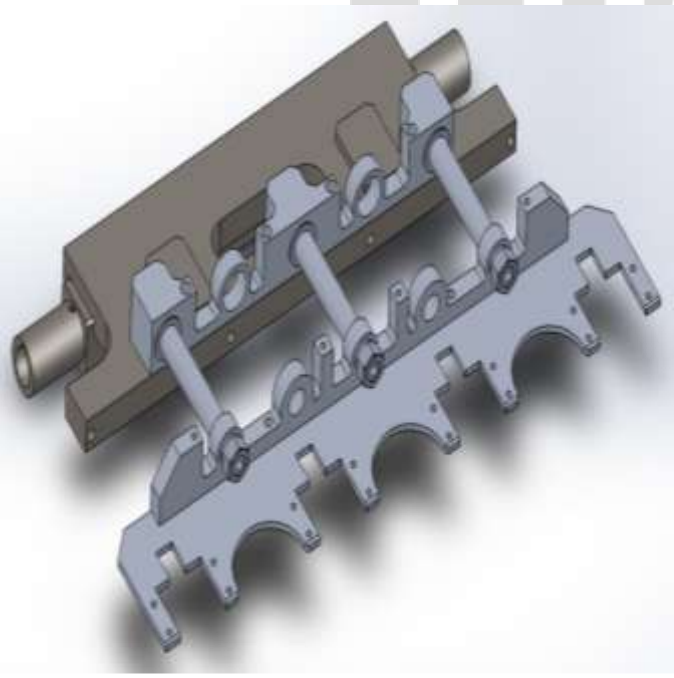
Principal axes of inertia and principal moments of inertia: (grams * square millim
Taken at the center of mass.
Ix = (0.00, 0.00, 1.00) Px = 47530661.87
Iy = (0.98, 0.18, 0.00) Py = 125676258.80
Iz = (-0.18, 0.98, 0.00) Pz = 168553772.04

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 127120169.39 Lxy = 7734851.64 Lxz = 55454.18
Lyx = 7734851.64 Lyy = 167109822.82 Lyz = -5749.35
Lzx = 55454.18 Lzy = -5749.35 Lzz = 47530700.5

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.
Ixx = 1803973852.55 Ixy = 452194460.24 Ixz = 606816556.
Iyx = 452194460.24 Iyy = 1595764066.63 Iyz = 799380047.
Izx = 606816556.48 Izy = 799380047.19 Izz = 970450164.

Fig 27: Previous CAD Model of Rotating Arm

Optimized Model of Ejector Unit



Mass properties of FINAL PART IN ALUMINIUM ALLOY 6063 T6
Configuration: Default
Coordinate system: -- default --

Mass = 8339.23 grams

Volume = 1299228.24 cubic millimeters

Surface area = 338714.30 square millimeters

Center of mass: (millimeters)
X = 155.84
Y = 229.80
Z = 272.42

Principal axes of inertia and principal moments of inertia: (grams * square millim
Taken at the center of mass.
Ix = (1.00, 0.00, 0.00) Px = 23183679.21
Iy = (0.00, 0.17, -0.99) Py = 92777993.10
Iz = (0.00, 0.99, 0.17) Pz = 113547069.30

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 23183711.75 Lxy = -33814.60 Lxz = 35955.70
Lyx = -33814.60 Lyy = 112971702.15 Lyz = -3408613.1
Lzx = 35955.70 Lzy = -3408613.14 Lzz = 93353327.7

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.
Ixx = 1082473541.88 Ixy = 298619005.13 Ixz = 354077799.
Iyx = 298619005.13 Iyy = 934398504.66 Iyz = 518662294.
Izx = 354077799.52 Izy = 518662294.78 Izz = 736278554.

Fig 28: Topology Optimized CAD Model of Ejector Unit

- In this Section, Topology Optimized model of the Ejector Unit was obtained, through the process of Topology Optimization performed using ANSYS 18.1.
- Before performing Topology Optimization on the individual components of Rotating Arm, the stress analysis result of the respective components like Bottle Holder, Guide Rod, Guide Rod Holder and Center Rod where taken into account from the Static Structural Workbench of Ansys.
- Based on this Stress development, maximization of the static stiffness has been considered using the Ansys software as a part of Topology Optimization. This can also be stated as the problem of minimization of compliance of the structure. Since compliance is a form of work done on the structure by the applied load. Lesser compliance means lesser work is done by the load on the structure, which results in lesser energy storage in the structure which in turn, means that the structure is stiffer.
- The model of each part of Ejector Unit which was obtained from the Topology Optimization workbench with decreased mass was redesigned in SOLIDWORKS 2018.
- It is confirmed that the parts will surely withstand the previous loading conditions. Since the topology Optimization was performed based on the stress development result of previous boundary conditions and also to have less compliance or to have maximum stiffness. The optimized parts will now only produce a small value of impact loading due to the reduction in the mass of the Rotating Arm of Ejector Unit.

V. Inference

In this paper, we mainly focused on improving the life span of the Ejector Unit of Stretch Blow Molding Machine. The main aim was to perform Topology Optimization of Ejector Unit so as to reduce the mass of Ejector Unit parts. Thus there will be a reduced value of impact load and stress development on the Shock absorber by the newly designed topology optimized model, thereby leading to an increased life span of Ejector Unit. The topologies obtained by satisfying the compliance domain and mass constraints, allow us for a better and faster identification of the final three dimensional structure.

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