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Comparative Strength Analysis of Circular and Rectangular Plates with Different Automotive Plastic Materials

Rahul Deore[1], Ganesh Badiger[2], Prashant Kharwante[3], Dr. R. R. Arakerimath[4]

[1,2]Student, JSPM's Rajarshi Shahu College of Engineering, Tathawade, Pune, Maharashtra
[3]Student, Department of Technology, Savitribai Phule Pune University, Pune, Maharashtra
[4]Professor, Department of Mechanical Engineering, JSPM's Rajarshi Shahu College of Engineering, Tathawade, Pune, Maharashtra

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ABSTRACT: Development in Design for Manufacturing and Assembly in recent years has led to demand for intricate and complex products for assembly. Plastics are widely used materials in automotive applications and are processed using various manufacturing techniques to produce the end product. The most used manufacturing method is Injection moulding to create intricate shapes. Injection dies used in this process bear heavy load for injecting the plastics for hot injection moulding as well as cold injection moulding. This paper shall focus on study of comparative strength analysis of circular and rectangular plates with block with different plastic materials. Increase the service life of circular and rectangular plates with block. Two plates were design with base as rectangular plate and circular plate and were analysed for materials Polypropylene (PP) and Polycarbonate (PC). Block were design and analysed for materials Polypropylene (PP) and Polycarbonate (PC). Finite element analysis (FEA) was carried out for both circular plate and rectangular plate base designs using materials Polypropylene (PP) and Polycarbonate (PC) for forces of 10N, 30N and 50N on the force points of the base of plate to determine the stress, deformation and Factor of Safety (FOS). The circular base erosion pressure plate had a higher Factor of Safety (FOS) and lower Stress concentration at failure areas compared to rectangular base plate and hence resulted being a better design for enhancing the service life. The deformation of circular base plate was lower compared to rectangular base which is useful for manufacturing parts with less error margin.

KEYWORDS: Finite element analysis, Injection moulding, Polypropylene, Polycarbonate.

I. INTRODUCTION

Circular plates and rectangular plates with block are manufactured by a hot injection mounding process with different materials like polypropylene (PP) and polycarbonate (PC). Polypropylene (PP) belongs to crystalline and Polycarbonate (PC) belongs to amorphous. Crystalline and amorphous belong to the thermo-plastic categories.

Four blocks were placed on a circular plate and a rectangular plate. Blocks are placed in a transverse and longitudinal direction towards each other. Force applied on block top face, block top face having some area. Circular plate and rectangular plate plates on fixtures and blocks are placed on the top of the face of the circular plate and rectangular plate and then force applied on the top face due to the applied force block get deform.•

Objective of this research is Design uses plastic material polypropylene and polycarbonate. Von Mises stress needs to be reduced to enhance service life.Finding an optimum shape to reduce the volume of material used for permissible stress and deflection limits.Finding the optimum thickness of parts.

Scope of this research is Development of plates for lower stress and deformation. Minimizing deflection due to forces. Optimising the volume to stress ratio to the minimum value for the six-sigma design methodology.Development circular and rectangular plate for plastic material like polypropylene and polycarbonate.

Development block for plastic material like polypropylene and polycarbonate.

P. S. Gujar et al. [1] aim of this study was deflection of a thin circular plate, a decrease with increased thickness, because shear force deformation is not considered. Bending stress in radial and circumferential direction are equal when uniform distributed load on circular plate. Bending stress in radial and circumferential direction increases with decreased thickness. Modeling and analysis on circular plate in ANSYS for 4 nodes and 181 shells.

M.L.Pavan Kishore et al. [2] this study is stress analysis of plate with parameters like holes, material, load to calculate stress distribution in the plate. Stress distribution and deflection on the near the hole area of the plate. For the different materials, different stress distribution and deflection on the whole area of the plate. Kirchhoff plate theory uses finite element analysis (FEA) static deflection for rectangular plates.

Pavan Kishore Mamaduri et al. [3] aim of this study is the material effect on stress of a rectangular plate with holes and without holes. Calculate stress distribution and deflection on a rectangular plate having holes shaped like rectangle, square, elliptical, circular etc., two different materials are used for calculating stress distribution and deflection on rectangular plates with holes and without holes.

Enem, J. I et al. [4] aim of this study is a large deflection analysis of thin rectangular isotropic plate under a uniform distributed load. By using the Ritz method to calculate large deflection and stress on a thin isotropic rectangular plate. Large deflection decreases with aspect ratio increases. Bending stress applied on a plate only considers other deformation. The middle of the plate is neglected.

Pengpeng Xu et al. [5] aim of this study is the effect of static loads on circular plates. Decomposing the total deflection into static deflection and dynamic deflection. By using Helmholtz–Duffing equations to find out whether forces are not affected by dynamic deflection but affected by static deflection.

Devaraj E. et al. [6] aim of this study is that maximum stress will be the corner axis of sides on both sides when a static load is applied to a single hole. If there are two or three holes in the plate, maximum stress is released. Holes one, two and three with respective diameters of 6mm, 8mm, and 10mm. stress and deformation on the plate under the contact force applied. High stress concentration will be near holes and less stress concentration will be away from holes.

Aashutosh Kumar. et al. [7] aim of this study is dynamic nature of plate to study of dynamic analysis. Plate ratio of high strength to weight. Plate dynamic load over the span. Structure strength increase by adding stiffeners on plates. Analysis of rectangular plates with stiffeners form basic structure of plate then analysis of basic structure of plates. Addition of stiffeners in plates, increased yield strength better result.

Wei Han. et al. [8] aim of this study is a circular thin plate clamped with a frictionless contact elastic sphere. Predict the relation between contact force and relative force. Analysis of a thin circular plate and elastic sphere contact stress and surface displacement. Deflection of thin circular plate and elastic sphere is more.

M. G. Sobamowo. et al [9] aim of this study is dynamic of circular plate in contact with fluid and resting. Radial and circumferential stress are determined. Increased elastic foundation, increased nature frequency and mode shapes due to radial and circumferential stress are determined.

Al-Shammari et al [10] aim of this study is a circular hole at the center crack forms from a circumference of a rectangular plate. Holes and cracks in the rectangular plate change the structure of natural frequency and mode shape. Factors affected are on rectangular plate, like plate geometry, hole radius, crack length, crack number and boundary conditions. The natural frequency is increased with increasing hole diameter and decreased with increasing circumferential crack diameter.

Material for this research is Polymers are broadly classified into two categories, namely: Thermoplastic, Thermoset and elastomers. Thermoplastics can be recycled, reshaped, and used even after a diminishing life cycle. Thermosets at the end of their life cycle cannot be recovered or recycled. Thermoplastics can be further classified into two sub-parts – Crystalline and Amorphous. Crystalline materials have the particles linearly arranged, whereas amorphous has a random arrangement. Polypropylene is a crystalline material, and Polycarbonate materials belong to an amorphous category.

Material properties of polypropylene (PP)

Table 1. General properties.

Sr. No.	Properties	SI Units
1	Density	0.9 g/cm^3
2	Shrinkage Factor	1%
3	Notched Izod	40 J/m
4	HDT at 1.82 MPa	70 ^{0}C
5	Tensile Strength	30 MPa
6	Compressive	10 MPa

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	Strength	
7	Ultimate Tensile Strength	70 MPa

Material properties of polycarbonate (PC)

Table 2. General properties.

Sr. No.	Properties	SI Units
1	Density	1.2 g/cm^3
2	Shrinkage Factor	1.1 %
3	Notched Izod	70 J/m
4	HDT at 1.82 MPa	90 ^{0}C
5	Tensile Strength	50 MPa
6	Compressive Strength	20 MPa
7	Ultimate Tensile Strength	90 MPa

II. DESIGN CALCULATION

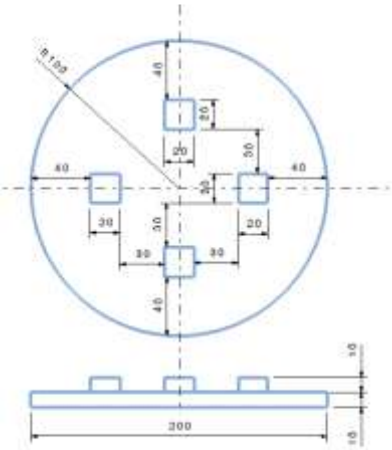

Figure No.1 2D View of Circular Plate

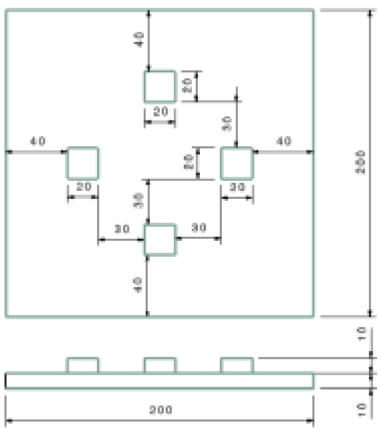

Figure No.22D View of Rectangular Plate

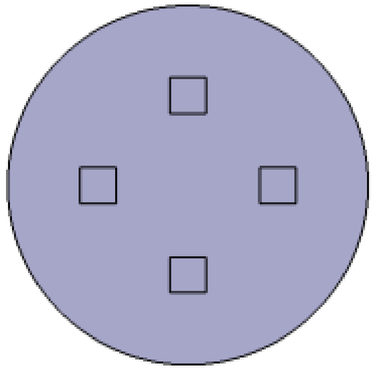

Figure No.33D View of Circular Plate

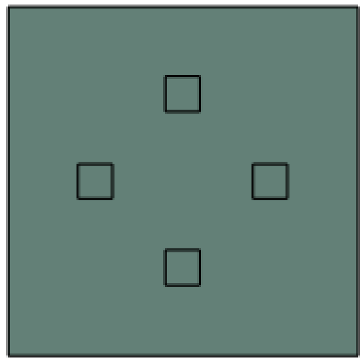

Figure No.43D View of Rectangular Plate

Calculation for 10N both circular plate and rectangular plate

$$\text{Pressure (Pi)} = \frac{\text{Compressive Force (Fc)}}{\text{Area (A)}}$$

$$\text{Projected Area (A)} = \text{Base x Width}$$

$$\text{Projected Area (A)} = 0.02 \text{ x } 0.02$$

$$A = 0.004 \text{ m}$$

$$Pi = \frac{10}{0.0004}$$

$$Pi = 25000 \text{ Pa or } 0.025 \text{ MPa}$$

$$\text{Total Pressure (TPi)}$$

$$= \text{Number of Block x Pressure (Pi)}$$

$$TPi = 4 \text{ x } 25000$$

$$TPi = 100000 \text{ Pa or } TPi = 0.1 \text{ MPa}$$

Calculation for 30N both circular plate and rectangular plate

$$\text{Pressure (Pi)} = \frac{\text{Compressive Force (Fc)}}{\text{Area (A)}}$$

$$Pi = \frac{30}{0.0004}$$

$$Pi = 75000 \text{ Pa or } 0.075 \text{ MPa}$$

$$\text{Total Pressure (TPi)}$$

$$= \text{Number of Block x Pressure (Pi)}$$

$$TPi = 4 \text{ x } 75000$$

$$TPi = 300000 \text{ Pa or } TPi = 0.3 \text{ MPa}$$

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Calculation for 50N both circular plate and rectangular plate

$$\text{Pressure (Pi)} = \frac{\text{Compressive Force (Fc)}}{\text{Area (A)}}$$

$$\text{Pi} = \frac{50}{0.0004}$$

$$\text{Pi} = 125000 \text{ Pa or } 0.125 \text{ MPa}$$

$$\text{Total Pressure (TPi)}$$

$$= \text{Number of Block x Pressure (Pi)}$$

$$\text{TPi} = 4 \text{ x } 125000$$

$$\text{TPi} = 500000 \text{ Pa or TPi} = 0.5 \text{ MPa}$$

Static Analysis The model was meshed using hexahedral elements for a circular plate and a rectangular plate. The circular plate and rectangular plate were meshed using an element size of 0.8 mm to cover the critical geometries for calculating the stresses impending upon deflection. Static Structural analysis is performed on the circular plate and rectangular plate model. The model was selected based on the required solution and the conditions in application. The model was meshed using hexahedral elements with a variable element size for components.

Table 3. Nodes and Elements Details

Sr. No.	Plate	Nodes	Elements
1	Circular	11796	6784
2	Rectangular	14793	8525

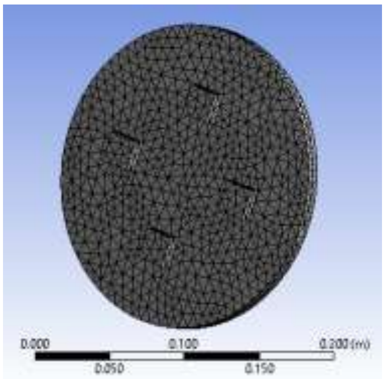

Figure No.5Mesh Model of Circular Plate

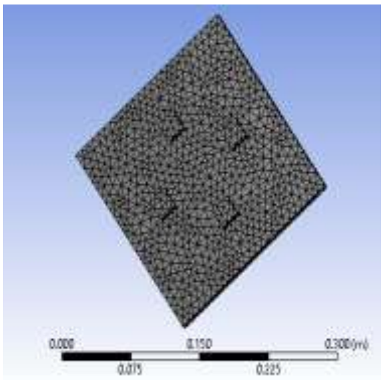

Figure No.6Mesh Model of Rectangular Plate

Circular Plate Deformation and Stress

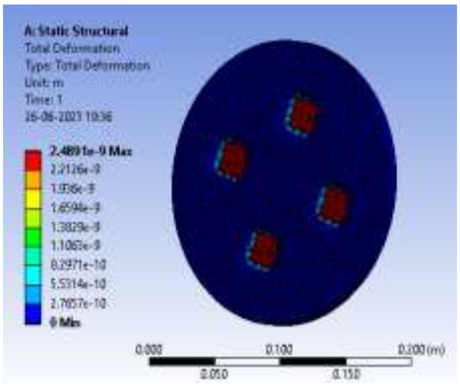

Figure No.7 Deformation of Circular Plate

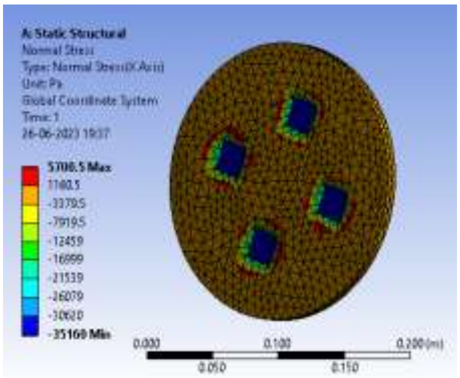

Figure No.8 Stress of Circular Plate

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Rectangular Plate Deformation and Stress

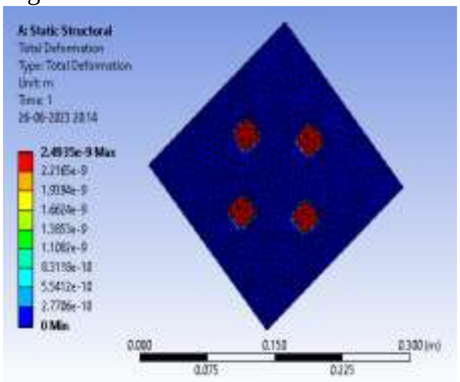

Figure No.9Deformation of Rectangular Plate

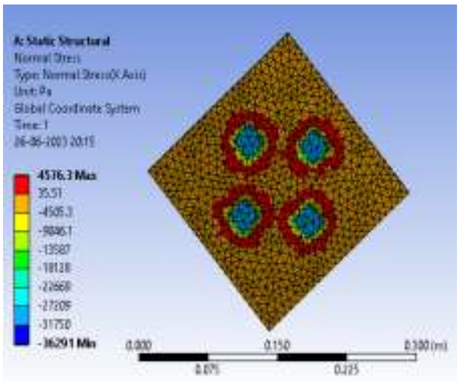

Figure No.10Stress of Rectangular Plate

III. RESULTS AND DISCUSSION

A comparison of a circular and rectangular plate with polypropylene and polycarbonate material with different loads like 10N, 30N and 50N. The result output is deformation and stress of the circular and rectangular plate with polypropylene and polycarbonate.

Table 4. Deformation and Stress for circular and rectangular with polypropylene and polycarbonate material with various loads

Sr. No.	Types of Plates	Load (N)	Deformation (m)	Stress (Pa)
1	Circular (PP)	10	4.9783E-10	1140.1
2		30	1.4930E-09	3420.3
3		50	2.4891E-09	5700.5
4	Circular (PC)	10	4.9801E-10	411.46
5		30	1.4940E-09	1234.4
6		50	2.4900E-09	2057.3
7	Rectangular (PP)	10	4.9871E-10	915.26
8		30	1.4961E-09	2745.8
9		50	2.4935E-09	4576.3
10	Rectangular (PC)	10	4.9781E-10	1010.2
11		30	1.4934E-09	3030.6
12		50	2.4891E-09	5050.9

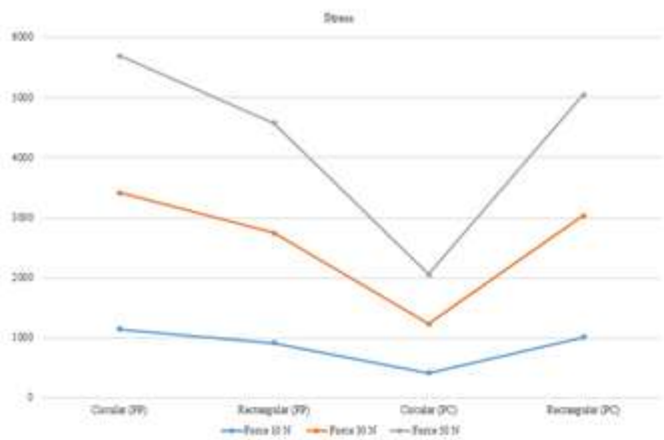

Figure No.11Stress (Pascal) circular and rectangular plate with polypropylene and polycarbonate material

IV. CONCLUSION

From the study of comparative strength analysis of circular and rectangular plates with block with different plastic materials

The circular plate with polycarbonate material has the lowest stress and it is 411.46 Pascal and a rectangular plate with polypropylene material has the lowest stress and is 915.26 Pascal for applied forces.

Circular plate with polycarbonate material has the highest stress and it is 2057.3 Pascal and a rectangular plate with polycarbonate material has the highest stress and is 5050.9 Pascal for applied forces.

The circular plate with polycarbonate material has the lowest deformation, it is 4.9801E-10 Meter and a rectangular plate with polypropylene material has the lowest deformation, which is 4.9871E-10 meters for applied forces.

The circular plate with polypropylene material has the highest deformation, 1.4930E-09 Meter, and a rectangular plate with polycarbonate material has the highest deformation and is 1.4934E-09 meters for applied forces.

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