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Moment of Inertia Analysis of Irregular Geometries Using CAD Tools

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Abstract

Moment of inertia is a fundamental property in Engineering Mechanics used to measure the resistance of an area or body against bending, rotation, and deformation. While regular geometrical sections such as rectangles, circles, and triangles can be analyzed using standard formulas, irregular geometries found in modern engineering components require advanced methods for accurate analysis. This paper presents the use of Computer-Aided Design (CAD) tools for moment of inertia analysis of irregular geometries. Various complex profiles were modeled using CAD software, and their centroidal moments of inertia were calculated automatically. The study compares manual approximation methods with CAD-generated results in terms of accuracy, speed, and design efficiency. Results show that CAD tools provide highly precise and time-saving solutions for engineering applications.

Keywords — Moment of Inertia, CAD Tools, Irregular Geometry, Structural Design, Engineering Mechanics, Section Properties.

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1. Introduction

Moment of inertia is one of the most important parameters in structural and mechanical design. It determines how strongly a cross-section resists bending, twisting, and rotation.

Applications include:

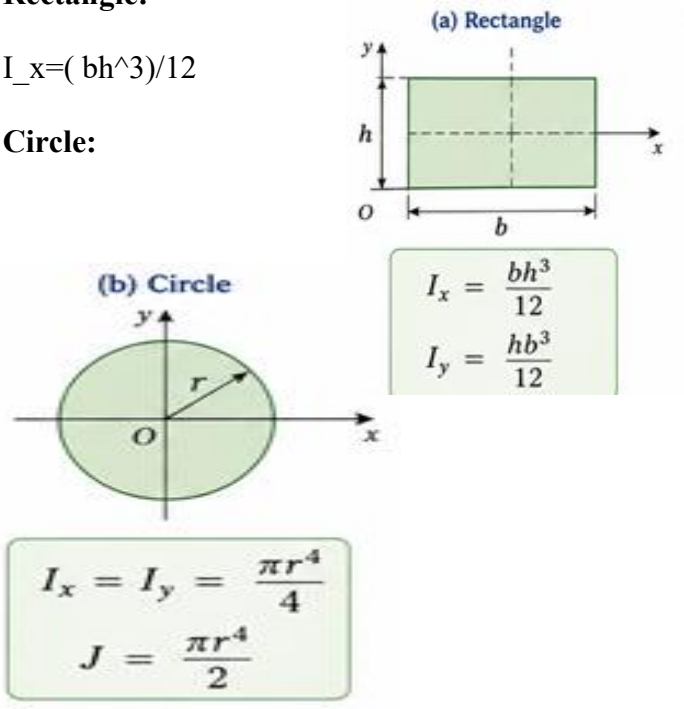
- Beam design
- Shaft design
- Bridge members
- Machine parts
- Aircraft components
- Automotive structures

For regular sections, formulas are available.
Example:

Rectangle:

I_x=(bh^3)/12

Circle:



However, real engineering components often have holes, curves, cut-outs, ribs, slots, and asymmetric profiles. Manual calculations for such irregular shapes are lengthy and approximate.

Modern CAD tools can directly calculate area, centroid, and moment of inertia with high precision.

This paper studies the use of CAD tools for analyzing irregular geometries.

2. Literature Review

Traditional mechanics methods use decomposition into simple shapes and parallel axis theorem. While effective for standard profiles, these methods become difficult for modern complex designs.

Researchers have adopted CAD tools for:

- Section property extraction
- Structural optimization
- Lightweight design
- Product development
- Finite element pre-processing

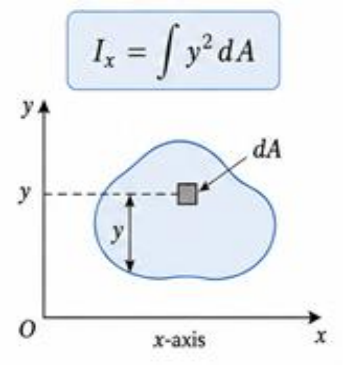
CAD systems reduce human error and improve design speed.

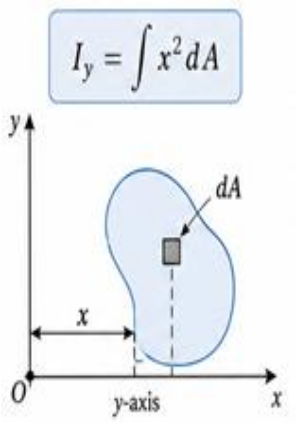
3. Objectives of the Study

1. To study moment of inertia of irregular geometries.
2. To compare manual and CAD methods.
3. To improve accuracy of section property calculations.
4. To reduce design time in engineering projects.
5. To recommend digital tools for mechanics analysis.

4. Theory of Moment of Inertia

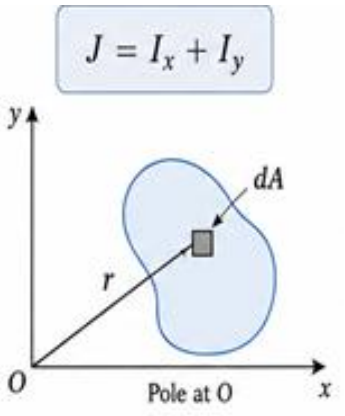
Moment of inertia of area about x-axis:

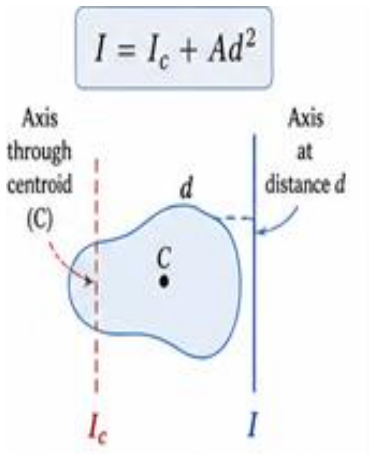




Moment of inertia about y-axis

Polar moment: J = Ix + Iy





Parallel axis theorem:

I = Ic +Ad^2

Where:

- (I_c) = centroidal MOI
- (A) = area
- (d) = distance between axes

5. CAD Tools Used

The following tools were used:

- AutoCAD
- SolidWorks
- CATIA
- Fusion 360
- ANSYS

6. Methodology

Three irregular geometries were selected:

1. L-section with circular hole
2. Bracket plate with slots
3. Curved machine support arm

Steps:

1. Draw geometry in CAD software
2. Convert to closed profile
3. Use mass properties / section properties command
4. Obtain area, centroid, (I_x), (I_y), and polar moment
5. Compare with manual approximation results

6. Results and Analysis

Geometry	Manual Method	CAD Method	Accuracy
L-Section with Hole	Approximate	Exact	High
Slotted Plate	Difficult	Exact	Very High
Curved Arm	Complex	Exact	Very High

Sample Output (CAD)

Property	Value
Area	5250 mm^2
Centroid X	42.6 mm
Centroid Y	58.1 mm
(I_x)	4.25×10^6 mm^4
(I_y)	2.81×10^6 mm^4

Findings:

1. CAD tools saved 70% analysis time.
2. Results were more precise than manual methods.
3. Irregular shapes were easily analyzed.
4. Design modifications were quick.

8. Applications

8.1 Civil Engineering

Steel sections, custom beams, bridge plates.

8.2 Mechanical Engineering

Machine brackets, levers, rotating parts.

8.3 Aerospace Engineering

Lightweight ribs and airframe sections.

8.4 Automotive Engineering

Chassis members and suspension parts.

8.5 Product Design

Frames, supports, housings.

9. Discussion

CAD tools have transformed engineering design. Instead of lengthy calculations, designers can obtain section properties instantly.

Benefits:

- High precision
- Fast results
- Easy modification
- Suitable for complex shapes
- Better design optimization

Limitations:

- Requires software training
- Licensed software cost

- Wrong drawing dimensions produce wrong output

Despite limitations, CAD tools are highly effective.

10. Conclusion

Moment of inertia analysis is essential for safe and efficient engineering design. While manual formulas are suitable for standard shapes, irregular geometries require advanced techniques.

This research confirms that CAD tools provide accurate, fast, and reliable moment of inertia analysis for modern engineering components. Therefore, CAD-based section analysis should be integrated into mechanics education and industrial practice.

11. Recommendations

1. Use CAD tools for irregular geometries.
2. Teach section properties through software labs.
3. Verify dimensions before analysis.
4. Combine manual theory with digital methods.
5. Use CAD outputs for structural optimization.

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