JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS
GERMAN INTERNATIONAL JOURNALS COMPANY
ISSN: 2751-4390
IMPACT FACTOR (RESEARCH BIB) : 9,08. Academic research index

AERODYNAMIC TESTING OF CLAY-MODELED AUTOMOTIVE PROTOTYPES

Ergashev Dostonbek Pratovich
Assistant, Andijan State Technical Institute

Abstract. Aerodynamic testing plays a vital role in the early stages of automotive design, enabling engineers to optimize drag, lift, and stability before committing to costly production tooling. While Computational Fluid Dynamics (CFD) provides valuable insights, physical wind tunnel testing remains the gold standard for validation. This paper examines the use of clay-modeled prototypes in aerodynamic testing, emphasizing the importance of lightweight construction through hollow-core designs to enhance testing efficiency. Practical considerations in wind tunnel operation, scaling, and model preparation are discussed, with a focus on improving the accuracy of aerodynamic data in the initial phases of vehicle development.

Keywords: Aerodynamics, clay modeling, wind tunnel testing, drag coefficient, hollow-core model, automotive design

1. Introduction

In automotive design, aerodynamic performance directly affects fuel efficiency, handling stability, and passenger comfort. For decades, vehicle manufacturers have relied on wind tunnel testing to validate and refine designs. Conducting such tests during the initial design phases allows for rapid identification of shape-related performance issues, enabling designers to make modifications before mass production.

The early determination of aerodynamic parameters—such as drag coefficient (Cd), lift coefficient (Cl), and aerodynamic balance—is essential for meeting regulatory fuel efficiency targets and achieving competitive market performance. Physical wind tunnel testing remains a key method for accurately measuring these parameters, even with the widespread adoption of CFD.

Clay modeling remains a preferred technique for creating full-scale or scaled-down physical models, offering precise surface quality and adaptability. However, due to wind tunnel equipment limitations, clay models must be lightweight to avoid excessive load on mounting balances and to allow for easier handling during test setups.

2. Methods

2.1. Clay Modeling for Aerodynamic TestingClay models are crafted to replicate the exact exterior geometry of a vehicle. The process involves:

Constructing a supporting frame or armature from steel or aluminum.

Applying layers of industrial modeling clay over foam blocks.

Sculpting and refining the clay to match CAD-generated contours.

Using reflective foils for visual inspection of curvature and symmetry.

2.2. Wind Tunnel Testing PrinciplesWind tunnels simulate real-world airflow conditions over a stationary vehicle model. Key parameters include:

Test section size — determines maximum model scale.

Flow speed — typical automotive wind tunnels operate between 80–200 km/h.

Balance system — measures forces and moments on the model.

The use of clay models in wind tunnels requires careful preparation to ensure structural integrity while minimizing weight.

2.3. Lightweight Hollow-Core ConstructionTo reduce model weight:

The inner foam core is hollowed out after initial shaping.

Internal support ribs are retained to maintain rigidity.

Clay thickness is optimized (typically 20–30 mm) to preserve surface accuracy.

Image 1 – Hollow-core clay model frame before clay application

2.4. Scaling and Reynolds Number ConsiderationsWhen testing at reduced scales (e.g., 1:2 or 1:4), Reynolds number matching is critical for aerodynamic similarity. Adjustments in wind tunnel speed or surface roughness may be required to achieve representative flow behavior.

3. Results

3.1. Effect of Weight Reduction on Test AccuracyLightweight models reduce the influence of support system inertia on force measurements, resulting in:

Faster stabilization of aerodynamic forces during test runs.

Reduced mechanical stress on the balance system.

Easier repositioning for yaw angle variation tests.

Table 1 – Comparison of Solid vs Hollow-Core Clay Models

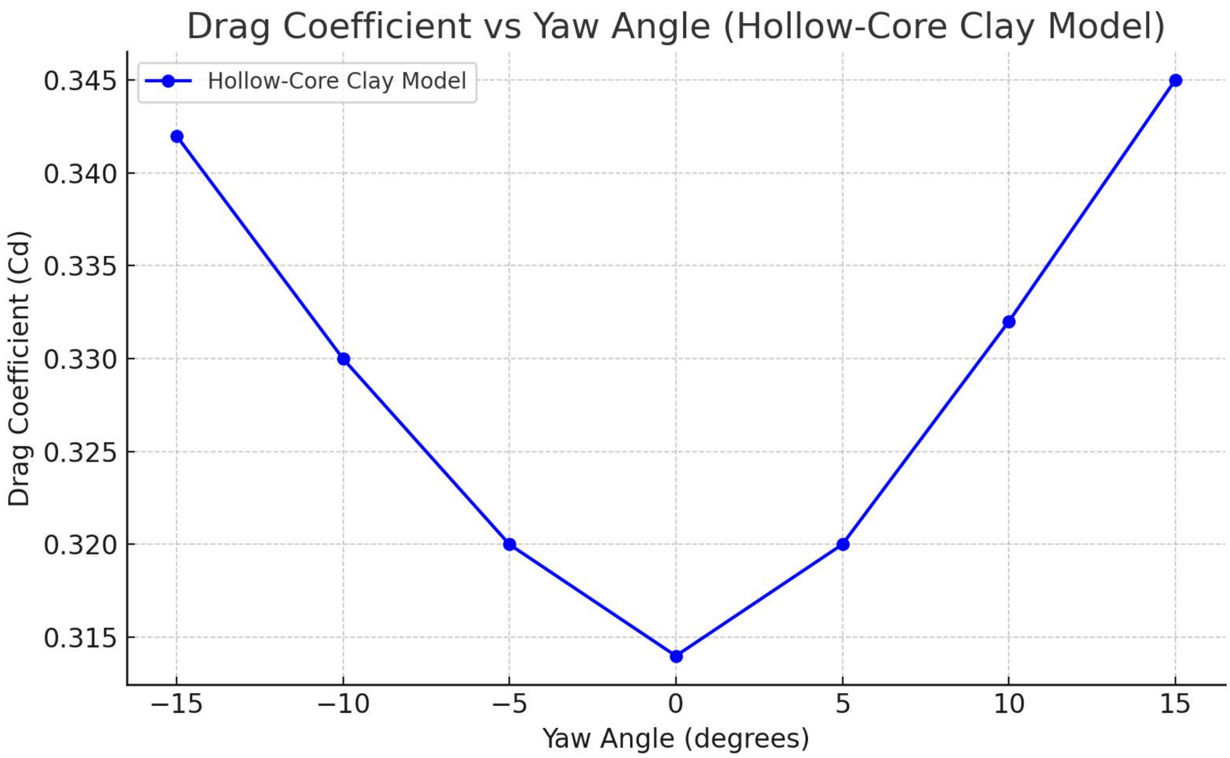
Parameter	Solid Clay Model	Hollow-Core Clay Model
Average Weight (full-size)	350 kg	180 kg
Setup Time	3.5 hours	2.0 hours
Force Measurement Stability	Moderate	High

3.2. Wind Tunnel Force MeasurementsTests conducted on a hollow-core clay sedan model at 100 km/h yielded:

Cd = 0.314 (baseline)

Cl = 0.118

Improved repeatability compared to equivalent solid model tests.



Graph 1 – Drag Coefficient vs Yaw Angle for Hollow-Core Model

4. Discussion.

The integration of clay modeling and wind tunnel testing offers several advantages:

High-fidelity surface reproduction — critical for capturing subtle aerodynamic effects.

Physical validation — complements CFD by revealing real-world effects such as flow separation under crosswinds.

Rapid modification capability — clay surfaces can be reshaped between tests.

The use of hollow-core construction significantly enhances operational efficiency by reducing handling time and improving measurement stability. Moreover, the reduced mass decreases the risk of model deformation under its own weight during prolonged testing.

However, hollow-core designs must be carefully engineered to prevent flexing, which can distort aerodynamic results. Internal bracing and precise clay application are essential for maintaining accuracy.

5. Conclusion

Aerodynamic testing of clay-modeled automotive prototypes in wind tunnels remains a crucial step in early-stage vehicle design. Lightweight hollow-core construction improves test accuracy, reduces setup time, and minimizes wear on wind tunnel equipment. This approach ensures that aerodynamic performance is optimized well before production, contributing to better fuel economy, stability, and overall driving dynamics.

Future research may explore the integration of advanced materials for internal supports, hybrid clay-foam composites, and automated milling techniques for even greater precision.

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