

Structural and Thermal Analysis of A V6 Engine Cylinder Block: A Review

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Abstract— The cylinder block is the main structural component of an internal combustion engine. In a V6 engine it carries six cylinders arranged in two banks, supports the crankshaft and contains the coolant passages. During operation it is exposed to combustion pressure, thermal loads, vibration and mechanical forces, which produce stress, deformation and temperature variation in different regions of the block. Testing different block designs on physical prototypes is costly and time consuming, and Finite Element Analysis (FEA) is therefore widely used to predict structural and thermal behaviour before manufacturing. This review examines published research on thermal deformation of cylinder blocks, coupled thermal and mechanical analysis, FEA-based material comparison, residual stress in engine blocks and thermal management of multi-cylinder engines. The reviewed literature shows that temperature distribution, thermal loading and material properties strongly influence stress, deformation and dimensional stability. However, most studies treat structural and thermal behaviour separately, concentrate on single-cylinder, inline or diesel configurations, or compare materials only thermally. Integrated structural and thermal comparison of Aluminium Alloy and Grey Cast Iron for a V6 cylinder block under identical conditions is limited. Based on these findings, the proposed project develops a 3D CAD model of a V6 cylinder block and analyses it in ANSYS using static structural and steady-state thermal analysis.

Keywords: V6 engine; cylinder block; finite element analysis; ANSYS; thermal analysis; von Mises stress; Aluminium Alloy; Grey Cast Iron

I. INTRODUCTION

The V6 engine layout is widely used in passenger cars and light vehicles because it combines good power output and smooth running with compact packaging. Six cylinders are arranged in two inclined banks acting on a common crankshaft, which makes the engine shorter than an inline six-cylinder engine [7].

The cylinder block is the largest structural part of the engine. It carries the cylinders, contains the water jackets and oil passages, supports the crankshaft through the main bearing supports and provides mounting faces for the cylinder heads, oil pan and engine mounts. In service it is subjected to combustion pressure, thermal loads, vibration and mechanical forces. These conditions can cause stress concentration, deformation and temperature gradients, which affect

strength, bore distortion and finally engine reliability [1], [2].

Physical manufacturing and testing of alternative block designs is expensive. FEA divides the geometry into small elements and solves the governing equations numerically, which allows stress, deformation and temperature to be predicted at the design stage [8]. The present review supports an M.Tech CAD/CAM project on the design and analysis of a V6 engine cylinder block using FEA, in which a 3D model prepared in SolidWorks/CATIA is analysed in ANSYS for structural and thermal performance, and Aluminium Alloy is compared with Grey Cast Iron.

1. Scope And Relevance Of The Review

The review is focused on four connected areas: (1) thermal deformation and thermal loading of cylinder blocks, (2) coupled thermal–structural analysis of blocks

and cylinders, (3) material comparison by FEA, and (4) residual stress and thermal management of engine blocks. These areas directly support the proposed workflow of CAD modelling, structural analysis, thermal analysis and material comparison, and the review avoids unrelated topics such as combustion modelling or fatigue-life prediction.

II. LITERATURE REVIEW

1. Thermal Deformation And Coupled Analysis

Bao et al. [1] studied the thermal deformation of the cylinder bore of an aluminium alloy cylinder block of a diesel engine using a thermo-mechanical simulation and an orthogonal experiment method. The study showed that temperature distribution and material properties strongly affect cylinder distortion and dimensional stability. This is relevant to the present project because the thermal analysis will examine temperature distribution and thermal deformation near the cylinder walls.

Pan et al. [2] carried out a coupling analysis of the cylinder block of a two-stroke aviation piston engine, evaluating thermal and mechanical loads simultaneously. Thermal loading was found to be an important contributor to stress and deformation in the block, which supports analysing both structural and thermal behaviour of the V6 block rather than only one of them.

2. Material Comparison By Fea

Barua et al. [3] compared aluminium alloy, magnesium alloy, cast iron and stainless steel for an IC engine cylinder using FEA-based thermal analysis. Aluminium Alloy 6061 showed better heat-dissipation characteristics among the evaluated materials. The study is thermal only; the present work extends the comparison to include stress, deformation and factor of safety for Aluminium Alloy and Grey Cast Iron.

3. Residual Stress And Thermal Management

Alipooramirabad et al. [4] presented an overview of residual stress measurement in engine blocks. The review highlights the importance of thermal and manufacturing-induced residual stresses and discusses numerical and FEA approaches for stress prediction,

confirming FEA as an established tool for engine block stress assessment.

A two-way coupled CFD, combustion and FEA study of a 6-cylinder heavy-duty diesel engine [5] identified high-temperature zones and showed that improved coolant-flow paths reduced critical engine-block temperatures and enhanced thermal management. This indicates that critical thermal zones can be located numerically and used to guide design changes.

4. Finite Element Thermal Modelling And Validation

Belchev et al. [6] developed a SolidWorks-based model of an automotive engine cylinder head with finite-element meshing and thermal boundary conditions, and compared the numerical temperature results with experimental measurements for validation. The work supports the CAD-to-FEA workflow adopted in this project and shows that such thermal models can be validated against measurements.

5. Additional Relevant Studies

Shen et al. [15] used transient finite-element thermal modelling to study how alumina ceramic coatings influence temperature distributions in aluminium engine cylinders. Their work shows that coatings can alter heat transfer because of differences in thermal conductivity. For the present project, this supports treating material properties and thermal boundary conditions as key inputs and documenting any simplifications made in the model.

Bao et al. [1] modelled thermo-mechanical cylinder-bore deformation and validated the simulation using temperature-field measurements. A separate study of aluminium engine blocks with cast-in grey-iron liners modelled distortion during casting and machining, showing that manufacturing history can contribute to residual stress and liner out-of-roundness [12]. These studies highlight the importance of distinguishing operating-load stresses from manufacturing-induced residual stresses.

Kummitha and Reddy [9] and Subbiah et al. [20], Rupesh et al. [21], and Tiwari et al. [22] examined thermal behaviour of engine cylinders/blocks with different materials. Although these studies focus on finned

geometries rather than a complete V6 block, they demonstrate that material thermal conductivity and geometry affect heat dissipation. Their findings are useful background, but their results should not be transferred directly to a water-jacketed V6 cylinder block.

Arsah et al. [19] investigated lightweight aluminium cylinder-block design using finite-element stress analysis. Their work is relevant to the trade-off between mass reduction and structural performance, particularly when comparing aluminium alloys with cast-iron alternatives. Material selection should therefore consider stress, stiffness, density and thermal behaviour rather than heat transfer alone.

A numerical and experimental investigation of an engine block under mechanical and thermal loads reported that thermal loading had a major influence on

block deformation. The study compared finite-element modal results with experimental modal analysis and evaluated stress and strain under operating loads [18]. This supports careful definition of boundary conditions and validation wherever experimental data are available.

Fontanesi and Giacomini [17] presented a coupled computational fluid dynamics, conjugate heat-transfer and finite-element methodology for a V6 diesel-engine cylinder head and cooling jacket. Their study links coolant-flow behaviour with thermal loading and structural performance, making it particularly relevant to V6-specific thermal assessment. It also indicates that cooling-jacket geometry and operating conditions can influence local temperature and stress distributions.

6. Summary Of Reviewed Studies

Ref.	Research focus	Key finding / relevance
[1]	Thermal deformation of cylinder bore	Temperature distribution and material properties strongly affect bore distortion. Supports thermal deformation study.
[2]	Cylinder block coupling analysis	Thermal loading contributes significantly to stress and deformation. Supports combined structural and thermal analysis.
[3]	Cylinder materials	Aluminium Alloy 6061 gave better heat dissipation among four materials. Supports material comparison.
[4]	Residual stress in engine blocks	Thermal and manufacturing residual stresses are important; FEA used for prediction. Supports FEA for block stress.
[5]	Thermal management of 6-cylinder engine	Improved coolant flow reduced critical block temperatures. Supports identifying critical thermal zones.
[6]	Cylinder head thermal model	Numerical temperatures compared with measurements. Supports CAD-to-FEA workflow.

7. Critical Analysis Of Literature

The reviewed studies establish that temperature distribution, thermal loading and material properties influence stress, deformation and dimensional stability of cylinder blocks, and that FEA is a reliable tool for predicting them. However, the studies are limited in three ways. First, structural and thermal behaviour are often evaluated separately. Second, most work concerns single-cylinder, inline, aviation or diesel configurations rather than a V6 block. Third, material comparison is mostly thermal and does not report stress, deformation and factor of safety together under identical geometry, loading and meshing. These observations are consistent with coupled V6-engine thermal analysis [17], engine-block thermo-mechanical

investigation [18], and cylinder-bore deformation studies [1], [12].

Results also depend on the quality of the model, the mesh and the boundary conditions. A useful block analysis therefore needs a representative 3D geometry, a mesh refined in critical regions and realistic loads, and the numerical results should be interpreted with engineering judgement and, where possible, validated against published data. Published validation work demonstrates the value of comparing numerical results with experimental measurements where possible [1], [18].

III. RESEARCH GAP

- Most existing studies evaluate structural stress or thermal behaviour separately; integrated structural

and thermal comparison for a V6 cylinder block is limited.

- Available studies concentrate on single-cylinder, inline or conventional diesel-engine configurations; simplified FEA studies focused on a V6 block structure are comparatively limited.
- Detailed comparison of Grey Cast Iron and Aluminium Alloy under identical geometry, loading, meshing and thermal boundary conditions is limited.

1. Problem Statement

A V6 engine cylinder block is exposed to high combustion pressure and temperature during operation. These loads may cause excessive stress, deformation and thermal expansion, which can affect the strength and reliability of the engine.

Manufacturing and testing different cylinder-block

designs is costly and time consuming. Therefore, a 3D V6 cylinder-block model is required to be developed and its structural and thermal behaviour analysed using FEA before physical manufacturing.

2. Objectives

- To Design A 3d Model Of A V6 Engine Cylinder Block.
- To perform static structural analysis and determine von Mises stress and total deformation.
- To perform thermal analysis and study the temperature distribution.
- To compare Aluminium Alloy and Grey Cast Iron.
- To recommend a suitable material based on the simulation results.

Proposed Methodology

Stage	Activity	Description
1	3D CAD Modelling	Create the V6 cylinder block (60° bank angle, six bores, water jackets, main bearing supports, mounting points, ribs) in SolidWorks/CATIA.
2	Geometry Preparation	Clean up the geometry and remove small features that do not affect the results.
3	Material Selection	Assign Aluminium Alloy and Grey Cast Iron in turn.
4	Import into ANSYS	Import the model into ANSYS Workbench.
5	Meshing	Mesh the block with refinement near bores and bearing supports; check mesh quality and independence.
6	Boundary Conditions and Loads	Apply gas pressure and supports for the structural case; temperature and convection for the thermal case.
7	Static Structural Analysis	Obtain von Mises stress, equivalent strain, total deformation and factor of safety.
8	Thermal Analysis	Obtain temperature distribution, total heat flux and thermal deformation.
9	Result Evaluation	Evaluate stress, deformation and temperature and locate critical regions.
10	Material Comparison and Optimization	Compare the two materials; optionally compare original and lightweight designs.
11	Conclusion	Recommend a suitable material.

IV. PROPOSED EVALUATION PARAMETERS

- Von Mises stress – maximum and minimum values and their locations.
- Total deformation and equivalent strain – regions of maximum deformation.
- Factor of safety – ratio of material strength to maximum equivalent stress.

- Temperature distribution – maximum temperature and critical zones near the cylinder walls.
- Total heat flux and thermal deformation.
- Comparison of Aluminium Alloy and Grey Cast Iron on all of the above parameters.
- Expected Outcomes
- A complete 3D V6 cylinder-block model.
- Maximum and minimum stress values and regions of maximum deformation.

- Temperature distribution across the block and critical thermal zones near the cylinder walls.
- A comparison of Aluminium Alloy and Grey Cast Iron and a recommended material.

V. DISCUSSION

The literature suggests that the value of FEA for a cylinder block lies in locating critical regions early and in comparing design and material options under the same conditions. The two materials are expected to behave differently: Aluminium Alloy has higher thermal conductivity and lower density, while Grey Cast Iron has higher stiffness. The proposed integrated structural and thermal analysis will show how these properties affect stress, deformation, temperature and factor of safety in a V6 geometry.

The present project is positioned as a CAD/CAM and CAE simulation study rather than a new combustion or fatigue-life methodology. Its contribution is a V6-specific, integrated and material-comparative analysis under identical boundary conditions.

VI. CONCLUSION

Published research confirms that thermal loading and material properties strongly influence stress, deformation and dimensional stability in engine blocks, and that FEA is an established means of predicting them. The gaps identified are the limited integrated structural and thermal analysis of V6 blocks and the limited material comparison under identical conditions. The proposed project addresses them through a CAD-to-FEA workflow in ANSYS, with the expected outcome of a validated understanding of critical regions and a recommended material for the V6 cylinder block.

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