

Multi-Component Thermal Analysis and Material Optimization of a V12 Engine Using SOLIDWORKS Simulation Environment

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ABSTRACT

A V12 engine is a multi-cylinder internal combustion configuration comprising twelve cylinders arranged in two banks, typically inclined at 60° to form a V-shaped geometry. This configuration ensures uniform firing intervals, inherent dynamic balance, and superior smoothness compared to lower-cylinder engines, making it highly suitable for luxury, high-performance, and heavy-duty applications. The present work focuses on the comprehensive digital development and evaluation of a V12 engine assembly using SOLIDWORKS. The complete engine model incorporates critical components including pistons, connecting rods, crankshaft, cylinder head, camshaft, valves, crankcase, lubrication system, and spark plugs, all designed with precise geometrical specifications. Following the modelling phase, advanced simulation tools are employed to investigate the thermal behaviour of key components under a high thermal load of 800 K. Thermal analysis is specifically conducted on the piston, crankshaft, camshaft, and valves to evaluate temperature distribution and heat dissipation characteristics under operating conditions. The simulation results provide detailed insights into thermal gradients and critical stress regions, enabling comparative assessment of component performance. Based on these findings, suitable materials are identified and selected to enhance thermal stability, durability, and overall engine efficiency. This integrated CAD-CAE approach demonstrates the effectiveness of simulation-driven design in optimizing engine components, reducing development time, and improving performance reliability in complex multi-cylinder engine system.

Keywords: Internal Combustion Engine, Engine Assembly, Transient Thermal Behavior, Deformation Analysis, Crankshaft Dynamics

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1. INTRODUCTION

The V12 engine stands as one of the most refined and high-performance configurations in the domain of internal combustion systems, recognized for its twelve-cylinder arrangement in a V-shaped layout that ensures exceptional balance, minimal vibration, and superior power delivery. This configuration is widely adopted in premium automobiles, motorsports engineering, and certain aviation applications due to its smooth operation and high power-to-weight efficiency. The intricate geometry and interdependence of multiple components make the V12 engine an

ideal candidate for advanced digital design and engineering analysis. Modern tools such as SOLIDWORKS enable engineers to construct highly detailed three-dimensional models of individual engine components, assemble them into a fully functional system, and simulate real-world operating conditions. Through integrated simulation capabilities, including finite element analysis, designers can assess structural integrity, thermal behavior, and dynamic performance, thereby improving design accuracy and reducing the need for costly physical prototyping. This virtual engineering approach significantly enhances the efficiency, reliability, and optimization of complex engine systems.

The evolution of internal combustion engines reflects a remarkable journey of technological advancement from bulky, noisy, and inefficient early prototypes to the compact, powerful, and reliable machines used today. Unlike external combustion systems, internal combustion engines generate mechanical work directly by burning fuel within the engine chamber, converting chemical energy into usable power. Since their development in the late nineteenth century, these engines have played a transformative role in shaping modern transportation and industrial applications. They have enabled the widespread adoption of automobiles, trucks, aircraft, and marine vessels, becoming a dominant power source due to their affordability, durability, and high efficiency. Over time, internal combustion engines have delivered a broad range of power outputs suitable for diverse applications, from small-scale devices to large industrial systems. Despite competition from electric motors, gas turbines, and steam engines, they continue to be widely utilized due to their robust performance and adaptability. Their enduring relevance underscores their critical contribution to global mobility and technological progress.

2. LITERATURE SURVEY

2.1 Fundamentals of Vehicle and Engine Technology

Light and Heavy Vehicle Technology by M. J. Nunney [1] provides a comprehensive foundation on automotive systems, including internal combustion engine configurations, operational principles, and performance characteristics. The work highlights the evolution of engine technologies and emphasizes the significance of multi-cylinder arrangements such as V-type engines for improved power delivery and smoothness.

2.2 Historical Development of V12 Engines

The V12 Engine by K. Ludvigsen [2] explores the historical evolution and engineering advancements of V12 engines. The study discusses their application in luxury and high-performance vehicles, emphasizing advantages such as reduced vibration, balanced operation, and high power output. Additionally, the technical evolution of the Jaguar V12 engine is detailed in [3], showcasing improvements in design, efficiency, and performance.

2.3 Performance Enhancement Techniques in IC Engines

Murali Krishna *et al.* [4] conducted an experimental study on improving diesel engine performance using water gas techniques. Their findings indicate enhanced combustion efficiency and reduced emissions, demonstrating the importance of innovative fuel strategies in modern engine systems.

2.4 Alternative Fuel and Hydrogen-Based V12 Engines

Kiesgen *et al.* [5] introduced the development of a 12-cylinder hydrogen-powered engine, marking a significant step toward sustainable propulsion systems. Similarly, Klütting *et al.* [6] focused on hydrogen powertrain development, emphasizing efficiency, reduced emissions, and environmental benefits. These studies highlight the potential of alternative fuels in future engine designs.

2.5 Advanced Engineering of Modern V12 Engines

Jägerbauer *et al.* [7] presented the design and development of BMW's 6.0-liter V12 engine, detailing innovations in combustion efficiency, structural design, and performance optimization.

The study demonstrates advancements in modern engine engineering for high-performance applications.

2.6 Simulation-Based Engine Analysis

A simulation model for cylinder pressure and performance analysis in spark-ignition engines is discussed in [8], emphasizing the importance of computational methods in understanding engine behavior and optimizing performance parameters.

3. PROPOSED SYSTEM

Solid Works is mechanical design automation software that takes advantage of the familiar Microsoft Windows graphical user interface.

It is an easy-to-learn tool which makes it possible for mechanical designers to quickly sketch ideas, experiment with features and dimensions, and produce models and detailed drawings.

A Solid Works model consists of parts, assemblies, and drawings. Typically, it begins with a sketch, create a base feature, and then some more features to the model. (One can also begin with an imported surface or solid geometry). Associativity between parts, assemblies, and drawings assures that changes made to one view are automatically made to all other views.



Fig 2. 3D Finite Element Representation in SOLIDWORKS

Orthographic views are two-dimensional views of three-dimensional objects. Orthographic views are created by projecting a view of an object onto a plane which is usually positioned so that it is parallel to one of the planes of the object. Orthographic projection is common method of representing three-dimensional objects, usually by three two-dimensional drawings in each of which the object is viewed along parallel lines that are perpendicular to the plane of the drawing. For example, an orthographic projection of a house typically consists of a top view, or plan, and a front view and one side view (front and side elevations).

Front view of an object shows the width and height dimensions. Frontal plane of projection is the plane onto which the Front View (FV) of the multi-view drawing is projected. Top view of an object shows the width and depth dimensions. Horizontal plane of projection is the plane onto which the Top View of the multi-view drawing is projected. Top view is always positioned and aligned with the front view.

The right-side view is the standard side view used. The right-side view of an object shows the depth and the height dimensions. The right-side view is projected onto the profile plane of projection, which is a plane that is parallel to the right side of the object. Side view is always positioned to the side.

4. RESULTS ANALYSIS

Fig 3 illustrates the finite element analysis (FEA) results of a crankshaft, highlighting the distribution of von Mises stress under applied loading conditions. The color contour ranges from blue (low stress) to red (high stress), indicating that most regions of the crankshaft experience minimal stress, while comparatively higher stress concentrations are observed near the crank

journals and fillet regions. This analysis helps identify critical areas prone to failure and supports design optimization for improved strength, durability, and performance of the crankshaft under operational conditions.

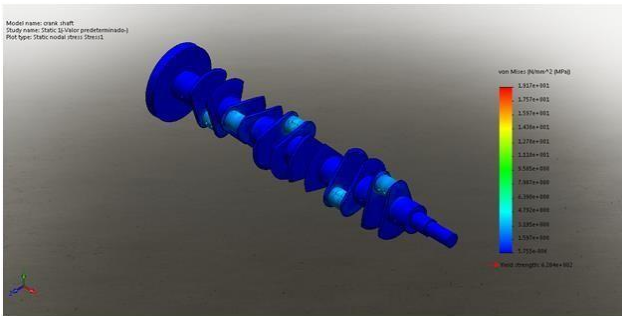


Fig 3. Von Mises Stress Distribution Analysis of Crankshaft Using FEA

Fig 4 presents the material properties assigned to the crankshaft model for simulation purposes, defined as cast alloy steel with linear elastic isotropic behavior. Key mechanical parameters such as yield strength, tensile strength, elastic modulus, and Poisson’s ratio are specified along with physical properties including mass density, shear modulus, and thermal expansion coefficient. These properties are essential inputs for accurate finite element analysis, enabling reliable evaluation of stress distribution, deformation, and thermal response of the crankshaft under operating conditions

Model Reference	Properties	Components
	Name: Cast Alloy Steel Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 241.275 N/mm^2 Tensile strength: 448.082 N/mm^2 Elastic modulus: 190000 N/mm^2 Poisson's ratio: 0.26 Mass density: 7300 g/cm^3 Shear modulus: 78000 N/mm^2 Thermal expansion coefficient: 1.5e-005 /Kelvin	SolidBody 1(Fillet2)(crank shaft)

Fig 4. Material Property Definition of Cast Alloy Steel for Crankshaft Simulation

Table 1. Comparative Stress and Deformation Analysis of Crankshaft Materials under Applied Load

material	load	Stress(mpa)	Deformation(mm)
Allo y steel	1000	12.21	0.0003
1023 steel	1000	12.20	0.00032

Table 1 presents a comparative evaluation of crankshaft performance using two different materials—Alloy Steel and 1023 Steel—under an identical load of 1000 N. The results indicate that both materials exhibit nearly similar stress values, with Alloy Steel showing 12.21 MPa and 1023 Steel showing 12.20 MPa, suggesting comparable strength characteristics under the given loading condition. However, a slight variation is observed in deformation, where Alloy Steel demonstrates marginally lower deformation (0.0003 mm) compared to 1023 Steel (0.00032 mm). This indicates that Alloy Steel provides slightly better rigidity and resistance to

deformation, making it a more suitable choice for improved structural stability in crankshaft applications.

5. CONCLUSION

The research successfully demonstrates the design, modeling, and simulation-based evaluation of a V12 engine assembly using advanced CAD and CAE tools. All major components, including the piston, connecting rod, crankshaft, camshaft, valves, and cylinder head, were accurately developed and assembled, ensuring proper geometric and functional integration. Thermal and structural analyses were carried out under high loading conditions, providing detailed insights into temperature distribution, stress concentration, and deformation behavior of critical components. The results revealed that stress levels remained within permissible limits, while thermal analysis helped identify regions subjected to higher heat exposure, guiding effective material selection. A comparative study of materials further indicated that alloy steel offers slightly better rigidity and performance compared to conventional steel, making it more suitable for crankshaft applications. The study highlights the effectiveness of simulation-driven design in optimizing engine components, minimizing potential failures, and improving performance without the need for physical prototyping. This approach not only reduces development time and cost but also enhances reliability, making it highly valuable for modern automotive engineering and high-performance engine design.

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