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“A COMPREHENSIVE REVIEW OF CRANKSHAFT DESIGN OPTIMIZATION, MATERIAL SELECTION, AND STRUCTURAL PERFORMANCE ENHANCEMENT IN HEAVY-DUTY ENGINES”

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ABSTRACT

Crankshafts are critical components of heavy-duty internal combustion engines, responsible for converting the reciprocating motion of pistons into rotational motion while transmitting substantial mechanical loads. Their structural integrity and operational reliability directly influence engine performance, durability, and service life. Increasing demands for higher power output, reduced component weight, improved fuel efficiency, and extended operating life have intensified research into crankshaft design optimization and advanced material selection. This review paper presents a comprehensive assessment of existing research on crankshaft geometric optimization, material properties, structural analysis, and fatigue performance in heavy-duty automotive applications. Particular attention is given to the influence of crankpin diameter, journal dimensions, web thickness, fillet radius, and other geometric parameters on stress distribution, deformation, and fatigue resistance. The review also examines the comparative performance of commonly used crankshaft materials, including forged steel, alloy steel, and ductile cast iron, considering their strength, hardness, density, manufacturability, and fatigue characteristics. Computational techniques, particularly finite element analysis (FEA), are discussed for evaluating stress concentrations, deformation patterns, factor of safety, and fatigue life under representative engine loading conditions. Furthermore, the role of computer-aided design, parametric modelling, and numerical optimization techniques in achieving an effective balance between structural strength and weight reduction is explored. The review identifies key research challenges associated with realistic load modelling, material characterization, manufacturing-induced residual stresses, and experimental validation of numerical results. Finally, potential research directions are proposed for developing lightweight, durable, and structurally reliable crankshafts for heavy-duty engines. The findings of this review can provide a useful foundation for researchers and automotive engineers seeking to improve crankshaft design and performance through integrated geometric optimization and material selection.

Key Words: Crankshaft; Heavy-Duty Engine; Design Optimization; Material Selection; Finite Element Analysis; Fatigue Life; Structural Performance; Weight Reduction.

I. INTRODUCTION

The automotive industry has continuously focused on improving engine performance, mechanical reliability, fuel efficiency, and service life to meet the increasing demands of modern transportation and industrial applications. Heavy-duty engines are widely used in commercial vehicles, construction equipment, agricultural machinery, and other applications requiring high torque and sustained power output under demanding operating conditions. These engines are subjected to considerable mechanical and thermal loads, making the strength, durability, and reliability of their critical components essential for efficient operation. Among these components, the crankshaft plays a particularly

important role in determining engine performance and operational stability. A crankshaft is a fundamental mechanical component of an internal combustion engine that converts the reciprocating motion of the pistons into rotational motion through the connecting rods. During engine operation, the crankshaft experiences complex loading conditions arising from combustion pressure, reciprocating inertia forces, rotational effects, and vibrations. These loads produce bending and torsional stresses, which may lead to localized stress concentrations, excessive deformation, fatigue crack initiation, and eventual component failure. The crankshaft must therefore possess adequate mechanical strength, stiffness, fatigue resistance, and dimensional stability to withstand repeated loading throughout its service life. These requirements become particularly important in heavy-duty engines, where high torque, variable operating speeds, and prolonged operating periods can accelerate material degradation and fatigue damage.

The structural performance of a crankshaft is influenced by several factors, including its geometric configuration, material composition, manufacturing process, surface characteristics, and operating conditions. Important geometric parameters include crankpin diameter, main journal diameter, web thickness, crankshaft length, and fillet radius. These parameters affect the distribution of stresses and deformations within the component. In particular, abrupt geometric transitions and insufficient fillet radii may create localized stress concentrations that reduce fatigue strength. Consequently, suitable geometric modifications and dimensional optimization can improve load-bearing capacity and fatigue performance while maintaining acceptable manufacturing and packaging requirements. Material selection is another important consideration in crankshaft design. Conventional crankshafts are manufactured using forged steels, alloy steels, and ductile cast irons, depending on engine power requirements, production methods, cost constraints, and service conditions. Alloy steels offer favorable combinations of strength, toughness, and fatigue resistance, whereas ductile cast iron can provide good cast ability, vibration-damping characteristics, and potential manufacturing cost advantages. The selection of an appropriate material requires consideration of mechanical properties such as yield strength, ultimate tensile strength, hardness, elastic modulus, density, and fatigue resistance. A suitable material must provide adequate structural reliability without introducing unnecessary weight or production costs. Therefore, comparative material evaluation is essential for identifying an appropriate balance between mechanical performance, durability, and economic feasibility.

In recent years, computer-aided design (CAD), finite element analysis (FEA), and numerical optimization techniques have become important tools for investigating and improving crankshaft performance. CAD-based modelling allows the development and modification of crankshaft geometry, while FEA facilitates the evaluation of stress distribution, deformation, and critical regions under specified loading and boundary conditions. Fatigue analysis can further support the estimation of component life under cyclic loading. By integrating these techniques, researchers can investigate the influence of geometric and material parameters before manufacturing physical prototypes. However, the reliability of numerical predictions depends on the accuracy of the applied loads, material properties, mesh quality, contact conditions, and boundary constraints. Experimental validation remains important for confirming analytical and computational findings. Design optimization of heavy-duty crankshafts involves achieving an appropriate balance between structural strength, fatigue resistance, weight, manufacturability, and cost. Increasing component dimensions may improve strength in certain regions but can also increase mass, inertia, and manufacturing requirements. Conversely, excessive material removal may reduce stiffness and fatigue resistance, particularly around highly stressed fillets and journal transitions. An effective optimization strategy must therefore identify critical design parameters and evaluate their combined influence on the overall structural response. The integration of geometric optimization with suitable material selection offers a promising approach for improving crankshaft reliability while avoiding unnecessary material usage.

Although numerous investigations have examined crankshaft stress analysis, material comparison, fatigue behaviour, and design modification, these research areas are often evaluated separately or under different operating assumptions. A consolidated understanding of the relationships among geometric parameters, material properties, stress concentrations, fatigue life, and weight reduction is therefore valuable. Particular attention is required when applying findings from general automotive crankshafts to heavy-duty engine applications, where loading conditions, duty cycles, and durability requirements may differ considerably. This review paper aims to critically examine existing research on crankshaft design optimization, material selection, and structural performance enhancement in heavy-duty engines. The review focuses on the influence of geometric parameters on stress distribution and deformation, the comparative characteristics of commonly used crankshaft materials, and the application of CAD, FEA, fatigue assessment, and numerical optimization techniques. It also discusses the limitations of existing analytical and computational approaches, identifies

research gaps, and outlines potential directions for future investigations. The review is intended to provide a technical foundation for developing optimized crankshaft designs that achieve improved structural reliability, fatigue performance, and weight efficiency under demanding engine operating conditions.

II. PROBLEM IDENTIFICATION

The crankshaft is one of the most highly loaded components of a heavy-duty internal combustion engine and plays a critical role in transmitting power from the pistons to the drivetrain. During engine operation, it is subjected to repeated bending and torsional loads, inertial forces, and fluctuating combustion pressures. These operating conditions can generate localized stress concentrations, excessive deformation, and fatigue damage, potentially resulting in crack initiation and premature component failure. Therefore, improving crankshaft structural performance while maintaining appropriate weight, dimensional accuracy, and manufacturing feasibility remains an important engineering challenge. One of the major problems in conventional crankshaft design is the difficulty of achieving an optimum balance between mechanical strength and component weight. Increasing journal diameters, web thickness, or other structural dimensions may improve load-bearing capacity but can also increase mass, rotational inertia, material consumption, and manufacturing costs. Conversely, excessive reduction in dimensions may compromise stiffness, fatigue resistance, and operational reliability. The identification of suitable geometric parameters and their optimal combinations is therefore necessary to improve structural performance without introducing unnecessary material.

Material selection presents another significant challenge in crankshaft development. Forged steel, alloy steel, and ductile cast iron possess different mechanical, fatigue, manufacturing, and economic characteristics. Although high-strength alloy steels may offer favourable mechanical properties, their overall suitability depends on the specific loading conditions, heat treatment, manufacturing process, and service requirements. Similarly, the use of alternative materials cannot be justified solely by their density or strength; their fatigue resistance, toughness, machinability, and long-term reliability must also be considered. A systematic comparative assessment of candidate materials is consequently required to identify suitable combinations of strength, durability, and weight efficiency.

Furthermore, the complex geometry of a crankshaft includes crankpins, main journals, connecting webs, and fillet transitions, where stress distributions may vary considerably under operating loads. Traditional design calculations may not adequately capture the local effects of geometric discontinuities and complex loading conditions. Although finite element analysis provides an effective means of evaluating stress, deformation, and potential critical regions, the accuracy of its predictions depends on appropriate material models, realistic boundary conditions, representative loading, and adequate mesh refinement. The relationship between geometric modifications, material properties, and fatigue performance therefore requires careful investigation. Another important issue is the limited integration of geometric optimization and material selection in a unified design approach. Evaluating these factors independently may lead to designs that perform well in one aspect but remain suboptimal in others. For example, a geometry that reduces mass may increase local stress, while a stronger material may increase cost without providing a proportional improvement in fatigue life. An integrated assessment is needed to determine how dimensional modifications and material characteristics jointly influence the factor of safety, deformation, fatigue behaviour, and overall component weight. Based on these challenges, the principal research problem is to establish how appropriate geometric modifications and material selection can improve the structural performance and fatigue reliability of heavy-duty engine crankshafts while controlling weight and maintaining practical manufacturing requirements. A systematic review of existing research is necessary to identify established methods, compare reported findings, recognize methodological limitations, and determine research gaps that can guide future crankshaft design and optimization studies.

III. RESEARCH OBJECTIVE

The primary objective of this review paper is to examine existing research on crankshaft design optimization, material selection, and structural performance enhancement for heavy-duty engines. The specific objectives are as follows:

1. To review existing crankshaft design methodologies and identify the major geometric parameters influencing structural strength, stiffness, and operational reliability.

2. To evaluate the influence of crankpin diameter, main journal dimensions, web thickness, and fillet radius on stress distribution, deformation, and stress concentration.
3. To compare the mechanical and physical properties of commonly used crankshaft materials, including forged steel, alloy steel, and ductile cast iron, with respect to strength, fatigue resistance, density, and manufacturability.
4. To examine the application of computer-aided design (CAD) and finite element analysis (FEA) for evaluating crankshaft stress, deformation, factor of safety, and fatigue performance under representative engine loading conditions.
5. To review geometric design optimization and material selection techniques aimed at reducing crankshaft weight while maintaining adequate structural strength and fatigue reliability.
6. To investigate the relationship between material properties, geometric modifications, and crankshaft failure mechanisms, particularly fatigue crack initiation and propagation under cyclic loading.

IV. LITERATURE REVIEW

The design and optimization of crankshafts have been extensively investigated to improve structural strength, fatigue life, and weight efficiency in internal combustion engines. Crankshaft performance is influenced by geometric parameters, material properties, engine loading, and manufacturing processes. Finite element analysis (FEA) has become an important tool for evaluating stress distribution, deformation, and fatigue behaviour, while geometric optimization and material substitution are increasingly used to improve mechanical performance.

Rawat and Agrawal (2026) investigated stress distribution and fatigue life prediction of crankshafts under cyclic loading using finite element analysis. The crankshaft was modelled using CATIA V5, while structural and fatigue simulations were performed in ANSYS Workbench. The study examined the effects of crankpin oilway configuration and material selection on stress concentration and fatigue performance. Three materials, namely QT 7000, AISI 4130, and Ti-6Al-4V, were compared under specified bending and torsional loads. The results indicated that the presence of oilways influenced stress concentration and fatigue behaviour, while Ti-6Al-4V exhibited a higher fatigue safety factor than the other investigated materials. The study highlights the importance of combining geometric assessment, fatigue analysis, and material selection to improve crankshaft performance.

Yadav and Dwivedi (2026) presented a comprehensive review of crankshaft optimization and fatigue-life enhancement, focusing on material selection, geometric modifications, and finite element analysis. The study examined the influence of fillet radius, stress concentration, residual stresses, and cyclic loading on crankshaft durability. Various improvement techniques, including fillet rolling, surface treatments, shot peening, induction hardening, and alternative material selection, were discussed. The authors emphasized that crankshaft fatigue performance depends on the combined effects of geometry, material characteristics, manufacturing processes, and operating loads. Their review supports the development of integrated optimization strategies for improving crankshaft strength and service life.

Abhimanyu kumar et al (2025) examined a fractured crankshaft from a six-cylinder diesel engine used in a wheel loader. The investigation combined chemical composition analysis, micro structural examination, mechanical testing, scanning electron microscopy, and finite element analysis to identify the causes of failure. The results associated reduced fatigue resistance with lower-than-expected molybdenum content, low hardness, and manganese sulphide inclusions. Stress analysis also identified the crankpin fillet as a critical region corresponding to crack initiation. The study demonstrates that crankshaft reliability depends not only on nominal material strength and geometry but also on chemical composition, microstructure, hardness, and manufacturing quality.

Uday man et al (2025) investigated the fatigue performance of a commercial crankshaft and a modified lightweight design. Harmonic response analysis was used to evaluate stress distribution, and numerical fatigue predictions were compared with experimental fatigue-test results. The study reported approximately 10% mass reduction without a considerable reduction in bending and torsional fatigue strength. The relative errors in fatigue-strength estimation were reported as approximately 2% for the original crankshaft and 7% for the lightweight model. The findings demonstrate the potential of numerical simulation and experimental validation for achieving weight reduction while maintaining adequate fatigue performance.

Yadav and Gupta (2024) reviewed crankshaft design, loading conditions, fatigue behaviour, and performance improvement techniques for internal combustion engines. Their study discussed the bending and torsional loads acting on crankshafts and the role of cyclic stresses in fatigue failure. The review emphasized the importance of identifying critical stress regions and applying appropriate design strategies to improve durability. The authors highlighted finite element analysis, material selection, and fatigue assessment as important methods for evaluating crankshaft reliability. This review provides a foundation for understanding the major factors affecting crankshaft structural performance and the need for systematic design optimization.

Girish Gokhle et al (2024) evaluated the structural response of crankshafts manufactured from different materials using finite element analysis. Static structural simulations were performed under specified loading and boundary conditions to compare von Mises stress and deformation. The study considered alternative materials, including cast iron and titanium alloy, to examine their suitability for crankshaft applications. The reported results indicated favourable strength and deformation characteristics for Ti-6Al-4V in the investigated configuration. The study demonstrates the usefulness of comparative material analysis for understanding structural performance, although fatigue behaviour, cost, manufacturability, and practical heavy-duty operating requirements must also be considered.

Shahane and Pawar (2023) investigated crankshaft optimization using finite element analysis to improve structural performance and reduce component weight. A three-dimensional crankshaft model was developed and subjected to structural and dynamic evaluation under specified operating conditions. The researchers examined modifications to the existing geometry while maintaining compatibility with the engine assembly. Their study reported a weight reduction of approximately 4.37% in the optimized design compared with the original configuration. The findings indicate that geometric modification can reduce material usage while maintaining the dimensional and functional requirements of an existing engine design.

Degefe et al. (2023) studied the optimization and finite element analysis of a single-cylinder engine crankshaft to improve fatigue life. The investigation involved computer-aided modelling, structural analysis, and fatigue assessment using ANSYS. The study examined the effect of design modification on stress distribution and the fatigue performance of the crankshaft. The findings demonstrated the value of integrating CAD modelling and numerical simulation to identify critical regions and evaluate alternative configurations. This work provides a useful basis for further investigations into crankshaft geometry optimization and fatigue-life improvement.

Dhokale et al. (2022) investigated crankshaft optimization with the objective of reducing component weight and manufacturing cost. The study involved finite element and stress analysis to identify critical regions under engine operating loads. Analytical dynamic calculations were verified using ANSYS simulations, after which geometric, material, and manufacturing alternatives were evaluated. The researchers considered manufacturing feasibility and design constraints during the optimization process. Their work highlights the importance of evaluating stress distribution and practical production requirements when developing lightweight crankshaft designs.

Gupta, Mahesh, and Dinesh Kumar (2021) investigated the design and analysis of crankshafts using different materials, with particular emphasis on the fatigue performance of forged steel and ductile cast iron. Dynamic simulations were performed for crankshafts associated with similar four-cylinder, four-stroke engines, and finite element analysis was used to determine stress magnitudes at critical locations. Engine pressure-volume data and engine specifications were used to establish loading conditions. The researchers also considered geometric modification, fillet rolling, and microalloyed steel as approaches for improving fatigue strength and reducing cost. The study demonstrates the importance of integrating material selection, geometric modification, manufacturing feasibility, and fatigue assessment in crankshaft design optimization.

ulut et al. (2021) investigated the fatigue life and stress distribution of a single-cylinder diesel engine crankshaft under varying forces and rotational speeds. The crankshaft, manufactured from C45 steel, was analysed using ANSYS Workbench to evaluate stress, deformation, fatigue life, and factor of safety at critical locations. Experimental low-cycle fatigue tests were also performed to validate the numerical findings. The results identified sharp corners near the flywheel side as critical regions requiring careful design consideration. The study demonstrates the importance of combining numerical simulation with experimental validation to improve crankshaft durability and identify potential

fatigue failure locations.

Karthick et al. (2020) investigated the modelling and structural analysis of an engine crankshaft using EN8 steel and forged steel. A three-dimensional crankshaft model was developed using SolidWorks and analysed using ANSYS under specified loading and boundary conditions. The study compared stress distribution and total deformation for the two materials to evaluate their suitability for crankshaft manufacturing. The investigation also considered the potential for weight and production-cost reduction. The findings highlight the importance of comparative material evaluation and finite element analysis in developing crankshafts with improved structural performance and manufacturing efficiency.

Song et al. (2020) examined the applicability of different critical-distance models for predicting high-cycle fatigue strength in mechanical components, including crankshafts. The research compared theoretical approaches for estimating fatigue limits in components containing geometric discontinuities and stress concentrations. Experimental verification and the influence of model-parameter errors were considered in assessing prediction accuracy. The study highlighted the importance of selecting appropriate fatigue assessment methods when evaluating components subjected to cyclic loading. These findings are relevant to crankshaft design because localized stresses near fillets and other geometric transitions can significantly influence fatigue life and structural reliability.

Ali, Rehman, and Khan (2020) investigated crankshaft fatigue life using stress-based and strain-based analytical approaches. The study evaluated fatigue performance by considering nominal stress, stress concentration, loading conditions, component size, surface finish, and reliability factors. The predicted fatigue behaviour obtained from the two approaches was compared to understand their suitability for estimating component life under cyclic loading. The investigation emphasized that fatigue prediction requires more than a simple comparison of maximum stress with material strength. The study provides a useful foundation for selecting appropriate fatigue assessment methods during crankshaft design optimization and durability evaluation.

V. CONCLUSION

The present review examines the major research developments in crankshaft design optimization, material selection, and structural performance enhancement for heavy-duty engines. The reviewed literature indicates that crankshaft performance is strongly influenced by geometric configuration, material properties, engine loading conditions, manufacturing processes, and fatigue behaviour. Since crankshafts operate under repeated bending and torsional loads, appropriate design and material selection are essential for ensuring structural integrity, operational reliability, and extended service life. The literature demonstrates that finite element analysis (FEA) is an effective technique for evaluating stress distribution, total deformation, critical stress regions, and factor of safety under specified operating conditions. Geometric parameters such as crankpin diameter, main journal diameter, web thickness, and fillet radius significantly influence the structural response of crankshafts. Suitable modifications to these parameters can reduce stress concentrations and improve load-bearing capacity. However, excessive dimensional reduction may compromise stiffness and fatigue resistance, making systematic design optimization necessary. Material selection is equally important in achieving improved crankshaft performance. Forged steel, alloy steel, and ductile cast iron offer different combinations of strength, toughness, fatigue resistance, density, manufacturability, and cost. The reviewed studies indicate that no single material is universally optimal for all engine applications. Material suitability must be evaluated according to the specific loading conditions, required fatigue life, manufacturing processes, and economic constraints. Furthermore, fatigue assessment and experimental validation are necessary to establish the reliability of numerical predictions and confirm the effectiveness of proposed design modifications. An important finding from the review is that geometric optimization and material selection should be considered together rather than as independent design activities. An integrated approach can help achieve an appropriate balance between structural strength, fatigue life, component weight, and manufacturing feasibility. CAD modelling, FEA, and numerical optimization provide useful tools for investigating alternative configurations and identifying potential improvements before physical manufacturing and testing. Despite significant progress, further research is required to improve the integration of realistic engine loading, material-specific fatigue properties, manufacturing-induced residual stresses, and experimental validation into crankshaft optimization procedures. Multi-objective optimization that considers stress, deformation, fatigue life, weight, and cost simultaneously represents a promising direction for future investigations. In conclusion, the systematic

integration of geometric design optimization, comparative material evaluation, and structural and fatigue analysis can support the development of lightweight, durable, and reliable crankshafts for heavy-duty engines. The findings of this review provide a foundation for future research aimed at improving crankshaft performance while maintaining the strength, durability, and operational reliability required in demanding automotive applications.

REFERENCES

- [1] P. Rawat, A. P. Agrawal, and S. Ali, "Investigation of stresses and fatigue life prediction of crankshafts under cyclic loading using FEM approach," *Applied Research*, vol. 5, no. 2, Art. no. e70088, 2026, doi: 10.1002/appl.70088.
- [2] X. Yang, J. Lei, Y. Bi, M. Yu, and Y. Yi, "Torsional fatigue failure study and lightweight design of hybrid engine crankshaft based on multidimensional analysis and experimental-simulation synergy," *Engineering Failure Analysis*, vol. 182, Art. no. 110145, 2025, doi: 10.1016/j.engfailanal.2025.110145.
- [3] D. Yadav and V. Dwivedi, "Optimization and fatigue life enhancement of crankshafts in internal combustion engines: A comprehensive review of material, geometry, and finite element analysis," *Research and Development in Machine Design*, vol. 8, no. 2, pp. 25–40, 2025, doi: 10.5281/zenodo.15909647.
- [4] D. Yadav and V. Dwivedi, "Finite element-based geometry optimization to enhance fatigue life of a single-cylinder engine crankshaft," *Recent Innovations in Material Engineering*, vol. 1, no. 2, pp. 13–25, 2025.
- [5] J. Yadav and T. K. Gupta, "Crankshaft design and fatigue analysis for enhanced internal combustion engine performance: A review," *Journal of Advancements in Material Engineering*, vol. 9, no. 2, 2024.
- [6] M. Bulut, O. Cihan, and İ. Temizer, "Fatigue life and stress analysis of the crankshaft of a single cylinder diesel engine under variable forces and speeds," *Materials Testing*, vol. 63, no. 8, pp. 770–777, 2024, doi: 10.1515/mt-2020-0122.
- [7] L. Karthick, N. Mallireddy, J. Yogaraja, S. Sivakumar, and A. Sasikumar, "Modelling and analysis of an EN8 crankshaft material in comparison with forged steel crankshaft," *Materials Today: Proceedings*, vol. 47, pp. 6168–6172, 2023, doi: 10.1016/j.matpr.2021.05.079.
- [8] S. Song, C. Wu, M. Wan, and F. Zhao, "Evaluation of the applicability of different critical distance models in component high cycle fatigue research: Both experimental verification and parameter error influence analysis," *Engineering Failure Analysis*, vol. 119, Art. no. 105014, 2022, doi: 10.1016/j.engfailanal.2022.105014.
- [9] V. C. Shahane and R. S. Pawar, "Optimization of the crankshaft using finite element analysis approach," *Automotive and Engine Technology*, vol. 2, pp. 1–23, 2021, doi: 10.1007/s41104-016-0014-0.
- [10] M. Degefe, P. Paramasivam, T. Dabasa, and S. Venkatesh Kumar, "Optimization and finite element analysis of single cylinder engine crankshaft for improving fatigue life," *American Journal of Mechanical and Materials Engineering*, vol. 1, no. 3, pp. 58–68, 2020, doi: 10.11648/j.ajmme.20170103.11.
- [11] S. B. Dhokale, S. K. Gadekar, A. B. Ekar, and N. M. Kodarkar, "Optimization of crankshaft for weight reduction," *International Journal of Research*, vol. 3, no. 6, 2020.
- [12] P. Horváth and J. Égert, "Stress analysis and weight reduction of a one-cylinder engine crankshaft," *Acta Technica Jaurinensis*, vol. 8, no. 3, pp. 201–217, 2020, doi: 10.14513/actatechjaur.v8.n3.377.