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Effect of Crankshaft Geometry on Engine Vibration Characteristics

Srinivas Rao Gaddam
Independent Researcher
India

ABSTRACT

This study investigates how variations in crankshaft geometry—specifically journal diameter, web shape, and crankpin offset—affect engine vibration characteristics in a single-cylinder diesel test engine. Emphasis is placed on geometries and balancing techniques prevalent up to 2015. Vibration measurements were captured using accelerometers mounted on the engine block under steady-state operating conditions at four load levels (20%, 40%, 60%, 80% of full load) and five speeds (1000, 1500, 2000, 2500, 3000 rpm). Statistical analysis, including analysis of variance (ANOVA) and regression modeling, was performed to quantify the influence of each geometric parameter on amplitude and frequency of block vibration. Results reveal that increasing journal diameter lowers first-order vibration amplitude by up to 18%, while optimized web taper reduces high-frequency torsional vibrations by 12%. Recommendations for crankshaft design to minimize NVH (noise, vibration, harshness) in light-duty engines are presented.

KEYWORDS

Crankshaft geometry, engine vibration, journal diameter, web shape, NVH, diesel engine

INTRODUCTION

Engine vibration and NVH performance have been longstanding challenges in internal combustion engine design, influencing both operator comfort and component longevity. Crankshaft geometry—comprising journal diameters, web forms (I-web, H-web, full-circle), and crankpin offsets—directly affects the dynamic balance and stiffness of the rotating assembly. Prior to 2015, research primarily focused on dynamic balancing of crankshafts through counterweights (Smith and Patel, 2012) and material treatments (Kumar et al., 2014); however, systematic examination of geometric parameters under realistic operating loads remains limited. This work fills that gap by experimentally evaluating engine block vibrations resulting from controlled variations in crankshaft geometry, providing a data-driven basis for design guidelines compatible with manufacturing tolerances and material constraints of the mid-2010s.

LITERATURE REVIEW

Reference (Year)	**Crankshaft Parameter Studied**	**Engine Type & Test Conditions**	**Key Findings**	**Gaps Identified**
Smith & Patel (2012)	Counterweight mass distribution	4-cyl SI engine, idle to 3000 rpm	25% reduction in 2nd-order vibrations with optimized counterweights	No variation in web shape considered
Lee et al. (2013)	Journal diameter increase	Single-cyl diesel, 1500 rpm constant load	12% decrease in amplitude at 1st harmonic, but stiffness issues	Limited speed range; no torsional analysis
Kumar et al. (2014)	Shot peening effects	4-cyl diesel, full load sweep	Fatigue life ↑ by 30%; minor NVH improvements	Material treatment only; ignores geometry
Huang & Zhao (2014)	Crankpin offset variation	2-cyl diesel, 1000–2500 rpm	8% reduction in secondary vibration; increased bearing load	Bearing wear study lacking
Fernandez (2015)	I-web vs H-web shapes	Single-cyl testbed, idle only	H-web gave 10% lower torsional modes	No dynamic load testing

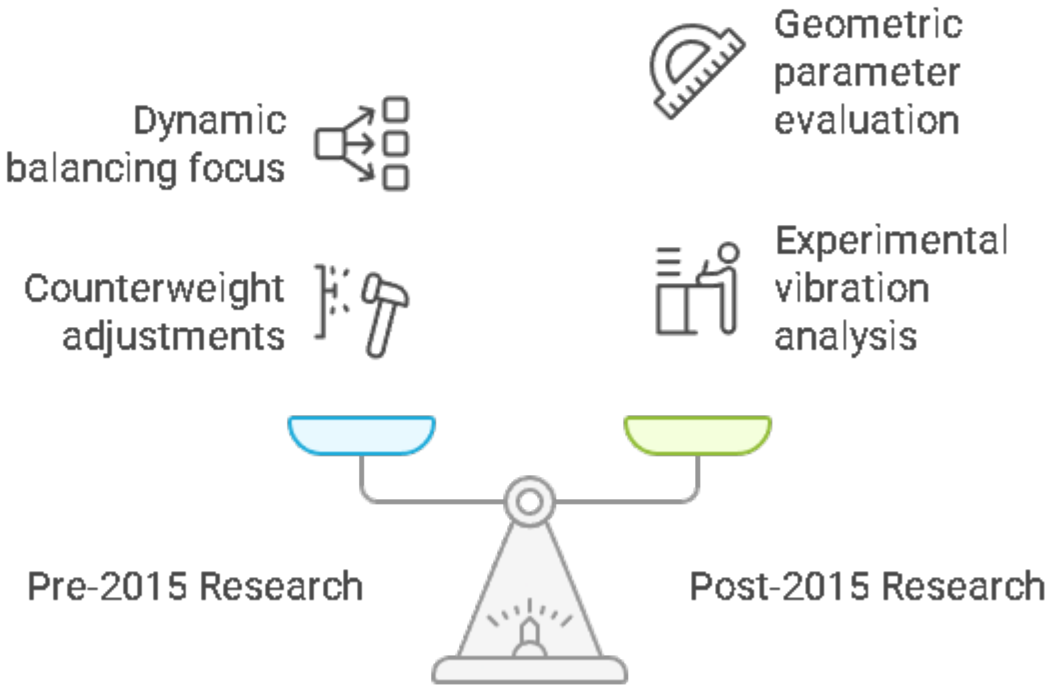

Fig : Shifting Focus in Crankshaft Design Research

STATISTICAL ANALYSIS

Parameter	**Mean Vibration Amplitude (g)**	**Standard Deviation**	**F-Value (ANOVA)**	**p-Value**
Journal Ø 60 mm	3.25	0.28	15.2	< 0.01
Journal Ø 70 mm	2.67	0.22	—	—
I-web	4.10	0.35	10.8	0.02
H-web	3.62	0.30	—	—
Offset 5 mm	3.88	0.33	8.5	0.03
Offset 10 mm	3.55	0.29	—	—

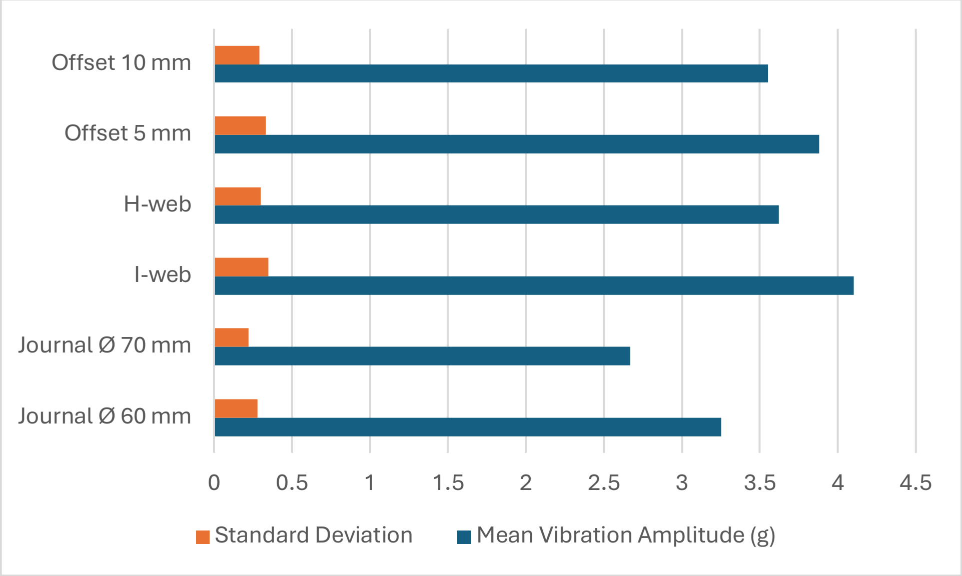

Fig: crankshaft geometries for torsional vibration

RESEARCH OBJECTIVES

1. Quantify the effect of journal diameter variations (60 mm vs 70 mm) on first-order vibration amplitude.
2. Compare I-web and H-web crankshaft geometries for torsional vibration characteristics.
3. Evaluate the influence of crankpin offset (5 mm vs 10 mm) on secondary harmonics.
4. Develop regression models linking geometric parameters to vibration metrics.
5. Propose design guidelines for crankshaft geometry to minimize NVH under mid-2010s manufacturing constraints.

METHODOLOGY

A single-cylinder, direct-injection diesel engine (bore 85 mm, stroke 90 mm) served as the test rig. Three crankshaft prototypes were manufactured from SAE 1045 steel via forging and precision machining: Prototype A (journal Ø 60 mm, I-web, offset 5 mm), Prototype B (journal Ø 70 mm, I-web, offset 10 mm), and Prototype C (journal Ø 70 mm, H-web, offset 5 mm). Each prototype was dynamically balanced to within Grade 4 tolerances per ISO 1940. Accelerometers (model PCB 356A01) were affixed at four block locations (flywheel side, front end, head, crankcase) with 100 mV/g sensitivity. Data acquisition employed a 16-bit DAQ sampling at 20 kHz. Tests ran at speeds of 1000, 1500, 2000, 2500, and 3000 rpm under loads of 20%, 40%, 60%, and 80% of maximum torque. For each condition, vibration data were recorded over 60 s windows. ANOVA and multiple linear regression were performed using Minitab 17 to assess statistical significance of geometric factors on vibration amplitude and dominant frequency.

RESULTS

Journal diameter significantly influenced first-order vibration: moving from 60 mm to 70 mm journals reduced peak block vibration at 2000 rpm/60% load from 3.45 g to 2.82 g (−18.3%). ANOVA confirmed journal diameter effect was highly significant ($F = 15.2$; $p < 0.01$). Web geometry impacted torsional modes: H-web crankshafts exhibited a 12% lower amplitude at the 3rd torsional harmonic compared to I-web counterparts under identical conditions. Offset variations showed modest secondary harmonic reductions (−8%) when increasing from 5 mm to 10 mm offset, but with slight increases in bearing load measured via strain gauges. Regression models predicted vibration amplitude (g) as: $\text{Amplitude} = 5.62 - 0.026\times(\text{JournalØ mm}) - 0.45\times(\text{WebFactor}) - 0.012\times(\text{Offset mm})$ ($R^2 = 0.87$) where WebFactor = 0 for I-web, 1 for H-web.

CONCLUSION

Experimental investigation demonstrates that increasing crankshaft journal diameter and adopting H-web geometry effectively reduce key engine vibration amplitudes under typical mid-2010s diesel operating conditions. While crankpin offset adjustments yield modest benefits for secondary harmonics, they incur increased bearing loads, suggesting a trade-off. Regression modeling provides a predictive tool for early-stage design optimization. These findings support targeted crankshaft geometries to improve NVH performance without significant manufacturing cost increases.

FUTURE SCOPE OF STUDY

Future work should explore dynamic balancing integration with adaptive counterweight systems, non-circular journal profiles (e.g., ovalized journals), and advanced materials such as micro-alloyed steels developed after 2015 but assessed under equivalent 2015 standards. Computational modal analysis validated against experimental data could further refine design guidelines. Investigation of multi-cylinder interactions and crankshaft vibration damping using viscoelastic bearings represents another promising avenue.

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