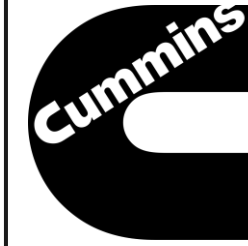


THREAD DETECTION SYSTEM

Proof of Concept

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PROBLEM STATEMENT

An industry partner's engine plant manufactures cylinder heads with hundreds of threaded holes, each required to meet strict depth and threading specifications. The facility relies on a manual inspection process using Go/No-Go gauges that takes 30-45 minutes per part, demands significant labor, and is vulnerable to human error from coolant residue, metal shavings, and inconsistent lighting. The objective is to design a reliable, automated system capable of detecting shallow or missing threads in blind holes during production reducing inspection time while maintaining or improving detection accuracy.

CUSTOMER BACKGROUND

An engine manufacturing facility faces ongoing challenges detecting thread defects in cylinder head holes during production. The most common defects are missing threads and holes drilled too shallow both causing assembly failures and reducing product reliability.

The current process depends entirely on manual gauging, requiring 15 - 45 minutes per part with meaningful risk of human error. Research confirms that 100% reliable manual inspection is statistically unachievable: variability between inspectors and operator fatigue compound in high-volume settings. Metal shavings, residual coolant, and inconsistent lighting inside the holes have caused previous automation attempts to fail, making this a persistent and costly manufacturing challenge.

REQUIREMENTS

#	Requirement	Target
1	Automated detection	No manual gauge needed
2	Single thread detection	≥1 threaded hole
3	Reliability	False +/- rate < 15%
4	Speed	5 min/part max.
5	Maneuverable	Movable across 2 axes

VACUUM CLEAN
10 sec

BORESCOPE IMAGE
5 sec

AI ANALYSIS
8 sec

PASS/FAIL DISPLAY
2 sec

25 sec / hole vs. 15 – 45 min manual inspection

EXPERIMENTATION AND CONCEPTS

VISION SYSTEM

Camera captures thread images analyzed by AI to detect defects. Provides consistent visualization but vulnerable to lighting variation inside deep blind holes.

LASER SYSTEM

Directs a laser beam into the hole to verify thread presence. Effective for external threads but unsuitable for blind holes due to coolant and debris interference.

CT / 3D SCANNER

Uses CT or structured-light scans to map thread profiles against CAD data. Highly accurate but prohibitively expensive and requires radiation safety infrastructure.

RGB-D CAMERA

Combines color imaging and depth sensing for a 3D hole profile. Cross-verifies visual and geometric data, though blind-hole geometry limits practical access.

FINAL DESIGN

The selected design uses a consumer-grade Milwaukee M12 borescope mounted on a custom aluminum extrusion frame with 3D-printed PLA holders. An operator places the cylinder head on the base plate and lowers a vacuum tube into the hole to clear coolant residue. After rotating the dual-tool assembly, the borescope captures thread images and transmits them to a compact computing unit. A custom AI vision model trained on hundreds of manually labeled images of properly threaded and defective holes across two iterative versions processes each image and displays a pass/fail result, along with a confidence score.



TESTING AND RESULTS

79%

Model V1 Accuracy
Binary pass/fail classification

85%

Model V2 Accuracy
Localized defect detection

89.3%

Final V3 Model Accuracy
Filtered Images in Pre-Processing

PROTOTYPE STATUS

Full aluminum frame stand completed. 3D-printed borescope holders fabricated and fitted. Borecope power confirmed. Vacuum system cleared liquid and debris in controlled tests.

AI DEVELOPMENT

Model V1 performs binary pass/fail classification. Model V2 uses localized detection identifying which regions within a hole are threaded vs. defective, giving operators clear rejection reasoning.

CURRENT CHALLENGES

Borecope lens focus difficulty near top of holes. Component delivery delays pushed formal data collection. Manual tool switching is being redesigned with a servo-driven rotating head.

NEXT STEPS

Improve AI model to >95.0% accuracy, integrate servo-driven vacuum-to-camera transition, and scale detection to support multi-hole inspection across an entire cylinder head.

POSSIBLE IMPROVEMENTS

With a higher resolution camera with adjustable focal length, a considerably higher accuracy could be achieved. A majority of the incorrect classifications are due to blurry images.