APEM journal

Advances in Production Engineering & Management
Volume 21 | Number 2 | June 2026 | pp 268–275
https://doi.org/10.14743/apem2026.2.573

ISSN 1854-6250
Journal home: apem-journal.org
Original scientific paper

Premature failure analysis of a high-strength hot-dip galvanized 42CrMo4 steel bolt

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A B S T R A C T

This study investigates the premature failure of a high-strength hot-dip galvanized 42CrMo4 steel bolt of property class 10.9 used in a spatial steel structure. The aim was to identify the most likely failure mechanism and provide a basis for preventing similar failures. The investigation included visual and macrographic examination, optical emission spectroscopy, light optical microscopy (LOM), zinc-coating thickness evaluation, and Vickers hardness testing (HV1). The fracture occurred at the head-to-shank junction. The steel exhibited a tempered martensitic microstructure with banding, while the zinc coating was 82-155 μm thick and showed local damage and cracking. Hardness values ranged from 330 to 401 HV1, with several measurements exceeding 350 HV1. All measured alloying elements except carbon were within the nominal composition ranges for 42CrMo4 steel. Considering the fracture morphology, elevated local hardness, coating condition, and short time to failure, hydrogen embrittlement was identified as the most likely failure mechanism. These findings illustrate the value of combining fracture-surface observations, metallography, coating assessment, and hardness measurements in the failure analysis of high-strength galvanized fasteners. From a practical perspective, the results may support more informed selection, inspection, and quality control of high-strength fasteners, thereby helping to reduce the risk of similar premature failures.

A R T I C L E I N F O

Keywords:
Failure analysis;
High-strength bolt;
Hydrogen embrittlement;
Hot-dip galvanizing;
42CrMo4 steel;
Head-to-shank junction;
Optical microscopy;
Vickers hardness

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Article history:
Received 11 June 2026
Revised 29 June 2026
Accepted 5 July 2026

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