ABSTRAK

Nama : FIRMANSAH

Program Studi : Magister Teknik Mesin

Judul : ANALISIS STATIS DAN VALIDASI EXPERIMENTAL CONTAINERIZED FIRE PUMP STATION

Pemanfaatan kontainer ISO 40 ft High Cube sebagai *containerized fire pump station* memberikan keunggulan modularitas, namun modifikasi bukaan ventilasi dan akses berpotensi mengubah jalur aliran beban dan menurunkan kekakuan struktur. Dalam konteks operasi proteksi kebakaran, desain harus memenuhi kebutuhan ventilasi dan akses ruang pompa sesuai NFPA 20, sementara secara struktural tetap mempertimbangkan filosofi ketahanan kontainer berdasarkan ISO 1496-1 untuk kondisi *lifting* dan *stacking*.

Penelitian ini mengkaji unit kontainer ISO 40 ft High Cube yang dimodifikasi menjadi fire pump station dengan bukaan *intake/exhaust louver*, pintu ganda yang lebar, rangka pengaku di sekeliling bukaan, serta baseframe internal. Metodologi menggabungkan *finite element analysis* (FEA) solid 3D elastis linier dan uji statik di workshop untuk validasi kekakuan global. Load case meliputi LC2 (*dynamic lifting* ψL 1,2g), LC3 (*static workshop/operasi pondasi*), dan LC4 (*dynamic stacking* ψstack 2 tier 1,8g). Studi konvergensi mesh menetapkan mesh acuan h= 20 mm.

Validasi LC3 dilakukan melalui perbandingan defleksi inkremental $\Delta\delta$ antara FEA dan uji statik workshop pada titik ukur T1-T6, dengan $MAPE_{global}$ (T1-T4) sebesar 10,01% yang menunjukkan kesesuaian kekakuan global. Pada mesh acuan, diperoleh LC3: $\sigma_{vm,max}$= 161,56 MPa, δ_{max}= 2,69 mm, $SF_{design,min}$= 1,55; LC2: $\sigma_{vm,max}$= 236,71 MPa, δ_{max}= 3,40 mm, $SF_{design,min}$= 1,14; dan LC4 (2 tier 1,8g): $\sigma_{vm,max}$= 296,21 MPa, δ_{max}= 2,86 mm, $SF_{design,min}$= 1,16. Hotspot tegangan bersifat lokal dan pada beberapa area terindikasi *spot stress/singularity*, sehingga interpretasi kelayakan difokuskan pada respons global dan tegangan nominal elemen rangka utama di sekitar jalur beban.

Secara keseluruhan, hasil menegaskan bahwa integrasi kebutuhan NFPA 20 dan evaluasi struktural berbasis ISO 1496-1 dapat dilakukan secara kuantitatif melalui FEA tervalidasi, serta menghasilkan dasar rekomendasi batas operasional pada kondisi *lifting* dan *stacking*.

Kata kunci:
Container fire pump station; NFPA 20; finite element analysis; validasi; stacking

ABSTRACT

Name : FIRMANSAH

Degree Program : Master Mechanical Engineering

Title : STATIC ANALYSIS AND EXPERIMENTAL VALIDATIO OF CONTAINERIZED FIRE PUMP STATION

Using an ISO 40ft High Cube container as a containerized fire pump station provides modular deployment advantages; however, large ventilation and access openings may alter load paths and reduce structural stiffness. In fire-protection service, the design must satisfy pump room ventilation and access requirements in accordance with NFPA 20, while structurally remaining consistent with the ISO 1496-1 strength philosophy for lifting and stacking conditions.

This study investigates a modified ISO 40ft High Cube container featuring intake/exhaust louvers, a wide double door, reinforcement frames around the openings, and an internal baseframe. The methodology combines a linear-elastic 3D solid finite element analysis (FEA) and a full-scale static workshop test to validate global stiffness. The evaluated load cases include LC2 (dynamic lifting ψL 1,2g), LC3 (static workshop/ foundation operation), dan LC4 (dynamic stacking ψstack 2 tier 1,8g). A mesh convergence study established a reference mesh with a maximum element size of h= 20 mm.

LC3 validation was performed by comparing incremental deflection $\Delta\delta$ between FEA and the workshop test at measurement points T1-T6. The resulting MAPEglobal (T1-T4) of 10.01% indicates adequate agreement in global stiffness. For the reference mesh, the results are: LC3: σvm,max= 161.56 MPa, δmax= 2.69 mm, SFdesign,min= 1.55; LC2: σvm,max= 236.71 MPa, δmax= 3.40 mm, SFdesign,min= 1.14; and LC4 (2 tiers, ψstack = 1.8): σvm,max= 296.21 MPa, δmax= 2.86 mm, SFdesign,min= 1.16. Stress hot spots are localized and show indications of spot stress/singularity in some areas; therefore, structural interpretation focuses on global response and nominal stress levels in the main framing elements along the primary load paths.

Overall, the results confirm that integrating NFPA 20 requirements with ISO 1496-1-based structural assessment can be carried out quantitatively using a validated FEA model, providing a defensible basis for operational limits under lifting and stacking conditions.

Keywords:
Containerized fire pump station; NFPA 20; FEA; validation; stacking