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Perancangan Adjustable Pipe Rotator Untuk Proses Surface Coating Pipa Hidrolik
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

ABSTRACT

The surface coating process of 80 mm diameter and 6-meter long hydraulic pipes in the heavy equipment industry is currently performed manually using brushes, with the workpiece placed on a static notched rack on the floor. This method makes rotating the heavy pipe difficult, carries a high risk of scratching the wet paint surface, and creates non-value-added activities such as waiting for touch-dry paint and grinding dried paint residue, leading to an operational cycle time of up to 120 minutes per batch. Furthermore, the stooped working posture increases the risk of Musculoskeletal Disorders (MSDs) for operators. This research aims to design an ergonomic Adjustable Pipe Rotator, analyze its structural strength, and estimate the reduction in coating lead time. The tool design was carried out using Computer-Aided Design (CAD) software, with SS400 structural steel as the primary constituent material and a working height adjustment of 932 mm based on standing elbow height anthropometry. The structural feasibility evaluation was analyzed through linear static simulation based on the Finite Element Method (FEM) using Computer-Aided Engineering (CAE) software. The static loading simulation results (supporting 3 pipes simultaneously weighing 166.5 kg under a 1,633 N load) indicate that the rotator structure is safe and highly rigid. The maximum equivalent stress (Von Mises stress) occurring in the structure is 185.16 MPa, remaining below the yield strength limit of the SS400 steel material (245 MPa). The maximum total deformation is recorded at 0.8062 mm, which strictly meets the maximum allowable deflection tolerance limit of 2.0 mm. Furthermore, the minimum safety factor value is at 1.46, convincingly exceeding the required minimum static safety limit of 1.25. Operationally, the implementation of this Adjustable Pipe Rotator design is estimated to be able to reduce the total coating time from 120 minutes to 75 minutes per cycle. This represents a 37,5% increase in operational time efficiency.

Keywords: *finite element method, pipe rotator, surface coating, tool design*

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INTISARI

Proses pelapisan permukaan (*surface coating*) komponen pipa hidrolik berdiameter 80 mm dan panjang 6 meter di industri alat berat saat ini masih dilakukan secara manual menggunakan kuas dengan meletakkan benda kerja di atas dudukan statis bergerigi pada lantai. Metode ini menyebabkan proses pemutaran pipa yang berat menjadi sulit dilakukan, berisiko tinggi menggores lapisan cat yang masih basah, serta menimbulkan pemborosan waktu tunggu cat kering sentuh (*touch dry*) dan pembersihan lelehan cat hingga mencapai *lead time* 120 menit per siklusnya. Selain itu, postur kerja membungkuk dan jongkok memicu risiko kelelahan fisik serta gangguan *Musculoskeletal Disorders* (MSDs) pada operator. Penelitian ini bertujuan untuk merancang alat bantu *Adjustable Pipe Rotator* yang ergonomis, menganalisis kekuatan strukturnya, serta mengestimasi peningkatan efisiensi waktu operasional pengecatan. Perancangan alat dilakukan menggunakan perangkat lunak *Computer-Aided Design* (CAD) dengan material penyusun utama baja struktural SS400 dan penyesuaian tinggi kerja 932 mm berdasarkan antropometri tinggi siku berdiri. Evaluasi kelayakan struktur dianalisis melalui simulasi statis linier berbasis *Finite Element Method* (FEM) pada perangkat lunak *Computer-Aided Engineering* (CAE). Hasil simulasi pembebanan statis sebesar 1.633 N (menopang 3 batang pipa simultan seberat 166,5 kg) menunjukkan bahwa struktur *rotator* dinyatakan aman dan kaku. Nilai tegangan ekuivalen maksimum (*Von Mises stress*) yang terjadi pada struktur adalah sebesar 185,16 MPa, berada di bawah batas tegangan luluh material baja SS400 (245 MPa). Deformasi total maksimum tercatat sebesar 0,8062 mm, yang masih memenuhi batas toleransi kelurusan penumpuan sebesar 2,0 mm. Selain itu, nilai rasio keamanan (*safety factor*) minimum berada di angka 1,46, melampaui batas aman minimum pembebanan statis yang disyaratkan sebesar 1,25. Secara operasional, pengimplementasian *Adjustable Pipe Rotator* ini mampu memangkas total waktu pengecatan dari 120 menit menjadi 75 menit per siklusnya, yang merepresentasikan peningkatan efisiensi waktu operasional sebesar 37.5%.

Kata kunci: finite element method, pipe rotator, surface coating, perancangan alat