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Structural Strength Evaluation and CFD Analysis of Turbulent Flow Characteristics in an 11 Inch Nominal Size 5000 PSI Tubing Hanger
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ABSTRACT

In this energy transition era, oil and gas remain one of the primary non-renewable energy sources that continue to play an important role in supporting global energy demand. Consequently, the reliability of equipment used in the oil and gas industry remains essential for sustaining production operations. A tubing hanger is one of the critical components in the wellhead system that supports the tubing string, provides a flow path, and maintains pressure integrity during oil and gas production. This study aims to design an 11-inch nominal size tubing hanger with a 5000 psi working pressure in accordance with API 6A, evaluate its structural strength analytically, and investigate its turbulent flow characteristics using Computational Fluid Dynamics (CFD).

The tubing hanger was designed based on customer specifications and API 6A requirements using AISI 4130 low-alloy steel. The structural strength evaluation was conducted using analytical methods. Subsequently, CFD simulations were performed in ANSYS Fluent using a two-dimensional axisymmetric model with the k–ω SST turbulence model. The simulations were carried out for three different fluid conditions, namely oil, an oil–water mixture, and gas, under various mass flow rates and different working pressure conditions for the gas phase.

The structural analysis results indicate that all evaluated design parameters satisfy the applicable acceptance criteria, demonstrating that the proposed tubing hanger is capable of safely operating under a 5000 psi working pressure. The CFD results show that increasing the mass flow rate leads to higher pressure drop, flow velocity, and turbulent kinetic energy for all investigated fluid conditions. Compared with the oil and oil–water mixture, the gas phase exhibits greater pressure losses, higher flow velocities, and stronger turbulence intensity due to its lower density and compressibility. Furthermore, the first sudden contraction within the tubing hanger geometry was identified as the most critical hydraulic region, as it consistently produced the greatest pressure loss, the highest flow acceleration, and the strongest turbulence generation.

Keywords: tubing hanger, API 6A, Computational Fluid Dynamics, structural strength, turbulent flow, pressure drop.

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INTISARI

Pada era transisi energi kini, minyak dan gas merupakan sumber energi tak terbarukan yang masih menjadi komoditas utama bagi kelangsungan umat manusia. Kebutuhan peralatan pada industri migas tetap menjadi fokus utama dalam menunjang keberlangsungan produksi. *Tubing hanger* merupakan salah satu komponen utama pada sistem *wellhead* yang berfungsi menopang rangkaian tubing, menyediakan jalur aliran fluida produksi, serta menjaga integritas tekanan selama operasi produksi minyak dan gas. Penelitian ini bertujuan untuk merancang *tubing hanger* berukuran nominal 11 inci dengan tekanan kerja 5000 psi sesuai standar API 6A, mengevaluasi kekuatan strukturalnya secara analitis, serta menganalisis karakteristik aliran turbulen menggunakan *Computational Fluid Dynamics*.

Perancangan dilakukan berdasarkan spesifikasi dari *customer* dan persyaratan API 6A dengan menggunakan material AISI 4130. Lalu, evaluasi kekuatan struktur dilakukan menggunakan metode analitik. Selanjutnya, analisis CFD dilakukan menggunakan ANSYS Fluent pada model dua dimensi *axisymmetric* dengan model turbulensi k-ω SST. Simulasi dilakukan pada tiga kondisi fluida, yaitu minyak, campuran minyak-air, dan gas dengan variasi laju aliran massa serta variasi tekanan kerja untuk fase gas.

Hasil analisis menunjukkan bahwa seluruh parameter kekuatan struktural memenuhi kriteria penerimaan berdasarkan standar yang berlaku, sehingga desain *tubing hanger* dinyatakan mampu beroperasi secara aman pada tekanan kerja 5000 psi. Hasil CFD menunjukkan bahwa peningkatan laju aliran massa menyebabkan peningkatan *pressure drop*, kecepatan aliran, *dan turbulent kinetic energy* pada seluruh kondisi fluida. Dibandingkan dengan minyak dan campuran minyak-air, fase gas menghasilkan *pressure drop*, kecepatan aliran, dan intensitas turbulensi yang lebih tinggi akibat densitas yang lebih rendah dan sifat kompresibel. Selain itu, kontraksi mendadak pertama pada geometri tubing hanger teridentifikasi sebagai daerah paling kritis karena menghasilkan kehilangan tekanan terbesar, percepatan aliran tertinggi, dan pembangkitan turbulensi paling kuat.

Kata kunci: *tubing hanger*, API 6A, *Computational Fluid Dynamics*, kekuatan struktural, aliran turbulen, *pressure drop*.