

INTISARI

Penentuan lokasi *flash point* pada sumur produksi panas bumi merupakan faktor penting dalam evaluasi kinerja aliran karena berkaitan langsung dengan perubahan rezim aliran, distribusi tekanan, dan profil suhu. Keberadaan gas non-kondensabel, khususnya CO₂ terlarut, memengaruhi sifat termodinamika fluida dan meningkatkan tekanan jenuh campuran, sehingga posisi *flash point* dapat bergeser secara signifikan. Oleh karena itu, diperlukan pemodelan numerik yang andal untuk mengkaji pengaruh variasi konsentrasi CO₂ terhadap karakteristik aliran sepanjang sumur.

Analisis dilakukan menggunakan metode numerik Euler–Cauchy eksplisit dengan pendekatan diskretisasi kedalaman untuk menghitung gradien tekanan dan suhu secara bertahap. Interaksi termodinamika campuran CO₂–H₂O dimodelkan melalui tekanan parsial CO₂ dan tekanan jenuh campuran, sementara sifat fluida diperbarui secara progresif sepanjang lintasan aliran. Simulasi diterapkan pada lima variasi fraksi massa CO₂, yaitu 0,00%; 0,25%; 0,50%; 0,75%; dan 1,00%.

Hasil menunjukkan bahwa semakin besar konsentrasi CO₂, lokasi *flash point* bergeser ke kedalaman yang lebih dalam. Pada fluida tanpa CO₂ (0,00%), *flash point* terjadi pada kedalaman 1134,75 m (P = 46,85 bar; T = 259,89°C). Pada 0,25% CO₂, *flash point* berada pada 1174,75 m (P = 52,71 bar; T = 259,91°C). Pada 0,50% CO₂, kedalaman *flash point* menjadi 1233,88 m (P = 58,58 bar; T = 259,93°C). Pada 0,75% CO₂, *flash point* terjadi pada 1312,25 m (P = 64,46 bar; T = 259,95°C), sedangkan pada 1,00% CO₂, *flash point* berada pada 1409,50 m (P = 70,34 bar; T = 259,97°C). Hasil ini menunjukkan bahwa keberadaan CO₂ meningkatkan tekanan jenuh campuran, sehingga *flashing* terjadi pada tekanan yang lebih tinggi dan kedalaman yang lebih besar. Ditemukan adanya zona transisi dua fase setelah *flash point* pada fluida yang dipengaruhi CO₂. Secara keseluruhan, metode Euler–Cauchy eksplisit terbukti efektif untuk memprediksi *flash point* pada sumur *geothermal* dan memberikan gambaran yang jelas mengenai pengaruh CO₂ terhadap perubahan profil aliran, khususnya pada zona transisi pasca-*flashing*.

Kata kunci : panas bumi, sumur produksi, *flash point*, CO₂ terlarut, dua fase, metode Euler–Cauchy.

ABSTRACT

Determining the *flash point* location in geothermal production wells is a critical factor in evaluating flow performance, as it is directly associated with flow regime transitions, pressure distribution, and temperature profiles. The presence of non-condensable gases, particularly dissolved CO₂, affects the thermodynamic properties of the fluid and increases the saturation pressure of the mixture, leading to a potentially significant shift in the *flash point* location. Therefore, a reliable numerical modeling approach is required to investigate the influence of varying CO₂ concentrations on flow characteristics along the wellbore.

The analysis was performed using an explicit Euler–Cauchy numerical method with depth-wise discretization to incrementally calculate pressure and temperature gradients. The thermodynamic interaction of the CO₂–H₂O mixture was modeled through CO₂ partial pressure and mixture saturation pressure, while fluid properties were progressively updated along the flow path. Simulations were conducted for five dissolved CO₂ mass fractions, namely 0.00%, 0.25%, 0.50%, 0.75%, and 1.00%.

The results shown that increasing CO₂ concentration shifted the *flash point* to greater depths. For CO₂-free fluid (0.00%), the *flash point* occurred at a depth of 1134.75 m (P = 46.85 bar; T = 259.91 °C). At 0.25% CO₂, the *flash point* was located at 1174.75 m (P = 52.71 bar; T = 259.91 °C). For 0.50% CO₂, the *flash point* depth increased to 1233.88 m (P = 58.58 bar; T = 259.93 °C). At 0.75% CO₂, the *flash point* occurred at 1312.25 m (P = 64.46 bar; T = 259.95 °C), while at 1.00% CO₂, it was located at 1409.5 m (P = 70.34 bar; T = 259.97 °C). These results indicated that the presence of CO₂ elevates the saturation pressure of the mixture, causing flashing to occur at higher pressures and greater depths. In addition, a two-phase transition zone was identified downstream of the *flash point* in CO₂-influenced fluids. Overall, the explicit Euler–Cauchy method was shown to be effective in predicting the *flash point* in geothermal wells and in providing clear insights into the influence of CO₂ on flow profile variations, particularly within the post-flashing transition zone.

Keywords: geothermal wellbore, flash point, dissolved CO₂, two-phase, Euler–Cauchy method.