WALL-SLIP EFFECTS ON FLOW RESTART IN A PLUGGED WAXY CRUDE OIL PIPELINE

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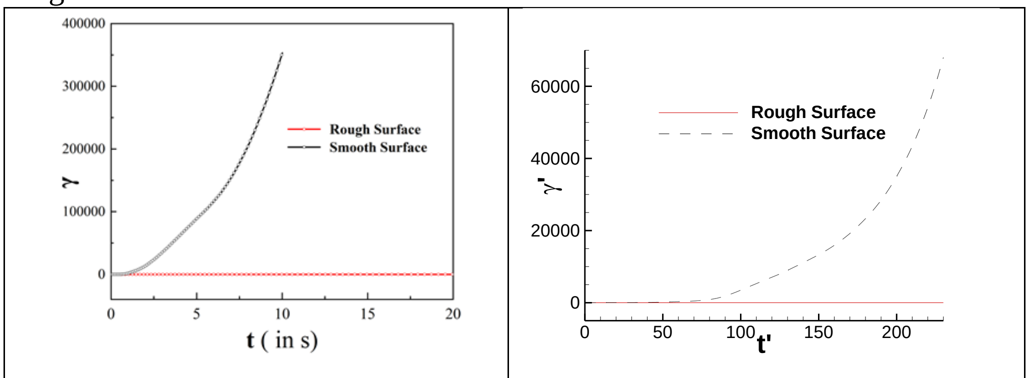
ABSTRACT

The gel degradation mechanism during flow restart operation in a waxy crude oil pipeline can be favorably explained through “indirect structural degradation-based rheological model”[1]. The waxy crude oil at subsea condition undergo gel degradation following irreversible thixotropy when a pressurized fluid is induced at the inlet of the pipeline. The sequence of gel degradation involves initial elastic deformation followed by creep, shear stress localization, strain consolidation, gel failure at wall-fluid interface (for homogeneous type pristine gel), gel compression and viscosity reduction. The waxy crude oil at subsea is a structured elasto-viscoplastic fluid, and at fully deformed condition it becomes Newtonian[2]. In several cases, the flow restart shows wall-slip as a major cause of gel failure at the wall-fluid interface[3]. Our experiments and numerical simulations suggest that the gel deformation is high for a wall-slip induced scenario (Fig. 1). This is opposite to the intuition that wall-slip creates lesser gel deformation in respect to no-slip scenario. Thus, there is an improved accuracy in the estimate for pressure requirements in flow restart operation. The no-slip and wall-slip scenario are mimicked through rough and smooth plates in rheometric experiments. Numerical simulations are done using in-house FORTRAN-based code following finite-volume-methodology[2]. The bulk flow is explained by elasto-viscoplastic rheology[4] and the complexities at the wall-fluid interface is defined by a static-based slip model where the slip-velocity follows a power-law of shearing stress at the wall[5]. It is to be noted that the fluid in this study is considered as weakly compressible.

The simulations in our study can capture the flow intricacies even at the smallest timescale where one can see initial compressive pressure wave propagation, gel degradation, and steady-state flow. The results from the simulations reveal the significance of wall-slip at the initial pressure propagation stage (Fig. 2). Once a sustained flow starts occurring at the outlet, the pronounced effect of wall-slip alleviates in competition to the deformation caused through bulk flow. This is furthermore ascertained by the analysis of transient flow, deformation and shear stress variations at locations in the vicinity of the wall of the pipeline. The article captures the slip-stick mechanism for the scenario where the wall-slip possessing yielding behavior (i.e. the scenario where the wall-slip occurs at a stress (τ) higher than the critical stress for wall-slip (τ_c)at the wall-fluid interface). A series of numerical comparisons are done to distinguish the

gel degradation mechanism for no-slip and wall-slip scenario for various cases of aspect ratio α, and gel degradation constant k.



(a) (b)

Figure 1: Comparison of strain evolution showing flow and no-flow scenario for smooth surfaces (signifying wall-slip) and rough surfaces (signifying no-slip) using (a) experimental (for parallel plate configuration in Anton Paar MCR 301 rheometer) and (b) numerical simulations (at a location near the inner wall of a pipeline).

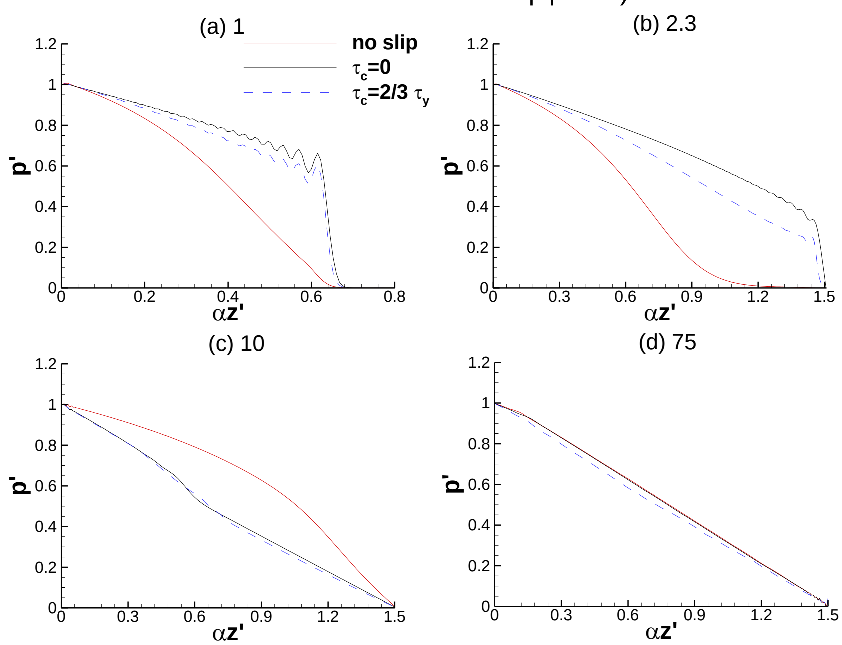


Figure 2: Comparison for the time evolution of axial pressure profile at initial gel viscosity of 100 Pa s, induced pressure P = 40 kPa with the cases for no-slip, shear-thinning slip (τ_c = 0) and conditional slip scenario (τ_c = 2/3 τ_y) at time instants t' = (a) 1, (b) 2.3, (c) 5, and (d) 75.

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