CFD Simulation of Wall Impingement of Tear Shape Viscoplastic Drops Utilizing OpenFOAM®

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Abstract:
The main objective of this study is to get insight into the dynamic behavior of viscoplastic drop in impingement process in which the Capillary number is greater than one. In numerical analysis, Volume Of Fluid (VOF) approach was used for capturing the liquid-gas interface. Two different drop shapes (spherical and tear shapes) were used to investigate the drop morphology in an impingement process. According to the results, the numerical results concerning the tear shape drop showed proper agreement with experimental reports (mean deviation of 16 %) in different impact velocities. The flow field was discussed during the impact process in terms of its effect on apparent viscosity and spreading length. Influence of contact angle, consistency, power law index, and surface tension variations on spreading parameter (ratio of contact diameter on the substrate to equivalent initial drop diameter) were investigated. Furthermore, three different rheological models (consisting of Herschel-Bulkley, Casson, and Robertson-Stiff) were employed to study the effects of rheological models on simulation outcomes.

Zusammenfassung:
Das Hauptziel dieser Arbeit ist, das Verständnis des dynamischen Verhaltens eines viskoplastischen Tropfens beim Aufprallprozess zu vertiefen, bei dem die Kapillarzahl größer als eins ist. Bei der numerischen Analyse wurde der „Volume of Fluid“-Ansatz angewandt, um die Flüssigkeit-Gas-Grenzfläche zu beschreiben. Zwei unterschiedliche Tropfenformen (sphärisch und Tränenform) wurden angewandt, um die Tropfenmorphologie beim Aufprallprozess zu untersuchen. Die numerischen Ergebnisse hinsichtlich der Tränenform zeigten eine gute Übereinstimmung mit experimentellen Daten (mittlere Abweichung von 16 %) bei unterschiedlichen Aufprallgeschwindigkeiten. Das Strömungsfeld bei dem Aufprallprozess wurde im Zusammenhang mit der scheinbaren Viskosität und der Ausbreitungslänge diskutiert. Der Einfluss des Kontaktwinkels, der Konsistenz, des Potenzgesetzexponenten und der Oberflächenspannung auf den Ausbreitungsparameter (Verhältnis des Kontaktdurchmessers auf dem Substrat zu dem äquivalenten Anfangsdurchmesser des Tropfens) wurde untersucht. Darüber hinaus wurden drei unterschiedliche rheologische Modelle (Herschel-Bulkley, Casson und Robertson-Stiff) angewandt, um den Einfluss der rheologischen Modelle auf die Simulationsergebnisse zu erfassen.

Résumé:
Le principal objectif de cette étude est d’avoir une idée du comportement dynamique d’une goutte viscoélastique durant un contact dans lequel le nombre capillaire est plus grand que un. Dans l’analyse numérique, l’approche du volume de fluide (VOF) a été utilisée afin de capturer l’interface gaz-liquide. Deux formes de goutte différentes (formes sphérique et de larme) ont été utilisées afin d’étudier la forme de la goutte durant le contact. D’après les résultats, les données numériques pour la goutte en forme de larme sont en assez bon accord (déviation moyenne de 16%) avec les résultats expérimentaux reportés pour différentes vitesses d’impact. Le champ de vitesse durant l’impact a été discuté en termes d’effets sur la viscosité apparente et la longueur d’étalement. L’influence de l’angle de contact, de la consistance, de l’indice rhéo-amincissant et des variations de la tension de surface sur le paramètre d’étalement (ratio entre le diamètre de contact sur la surface et le diamètre équivalent initial de la goutte) a été étudiée. De plus, trois modèles rhéologiques différents (Herschel-Bulkley, Casson et Robertson-Stiff) ont été employés afin d’étudier les effets des modèles rhéologiques sur les résultats de simulation.

Key words: wall impingement, viscoplastic fluids, computational Fluid dynamics (CFD), drop Shape, openFOAM®

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