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Spreading of a non-Newtonian liquid drop over a homogeneous rough surface

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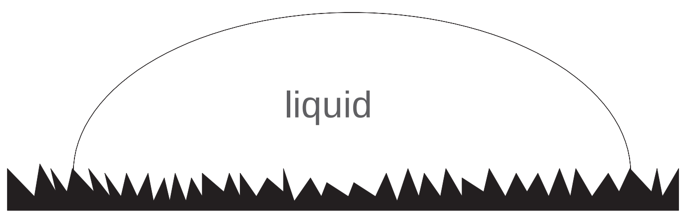
HIGHLIGHTS

- A non-Newtonian liquid drop spreads faster over rough surface than smooth surface.
- Dilatant liquid spreads faster than pseudo plastic liquid on a rough surface.
- Surface roughness provides enhance spreading in case of complete wetting.

GRAPHICAL ABSTRACT



Spreading over a homogeneous rough surface

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ABSTRACT

The spreading of a non-Newtonian liquid drop over a homogeneous rough surface is theoretically analyzed in the case of complete wetting. Using the energy approach, a relation is derived among the surface roughness, spreading rate of the drop and the contact angle. It is shown that non-Newtonian liquid drop spreads faster over rough surface than smooth surface. Further, it is observed that a shear thickening liquid ($n > 1$) spreads with faster speed than a shear thinning liquid ($n < 1$) over a rough surface.

1. Introduction

Spreading phenomena are ubiquitous in nature and numerous industrial applications. It is part of many industrial processes like ink-jet printing, painting, spray coating etc. Better understanding of spreading mechanism helps us to design and control the industrial process effectively. Although, spreading process itself is a very complex phenomenon since it is related to many factors like inertial, capillary, gravitational forces, wettability, porosity, surface roughness etc. Fortunately, the problem of liquid spreading over a surface can be formulated mathematically in terms of nonlinear partial differential equation of higher order with appropriate boundary conditions.

Due to numerous industrial applications, spreading process/mechanism has drawn attention of many researchers such as Marmur [1], Cazabat [2], Léger and Silberzan [3], Ehrhard [4], Seaver and Berg [5], Bahr et al. [6] and others to study its various physical aspects. Earlier studies are limited to understand the spreading behaviour of Newtonian liquid over a surface. Voinov [7] first theoretically analyzed the spreading of drop. Whereas, Tanner [8] has established a relationship between the bottom radius of the drop with time. Later, many theoretical and experimental works (Hocking [9,10], Starov [11], Chen [12] and others) have been carried out on drop spreading by applying different approaches under different physical circumstances. In general, spreading process is categorized into two types *i.e.* high speed impact spreading and low-speed spreading. In fact, first one is known as inertia dominated (forced) spreading and the second one is called surface force dominated (capillary) spreading. During the process, some amount

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