Emulsion-based Lubricant Replenishment Strategies for Lubricant-Impregnated Slippery Surfaces under Flow

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Lubricant-Impregnated Slippery Surfaces (LubISS) constitute of textured/porous substrates infiltrated with a chemically compatible lubricant [1]. The action of capillary forces establishes an immobilized liquid surface which keeps the lubricant in place within the texture.
As a consequence, they are liquid-repellent and non-sticking surfaces. Droplets immiscible with the lubricant slide off these surfaces very easily. A formidable challenge which needs to be addressed is the problem of lubricant depletion [2, 3]. Evaporation of the lubricant, cloaking, drainage due to gravity or flow conditions causes progressive loss of lubricant which in turn destroys the functionality of the coating [4, 5]. In this work, a proof of concept for a novel approach to the formation of LubISS is introduced. We rely on the flow of emulsions through a closed water-filled flow cell containing a regular and uniform micropillar array. We observe that oil droplets transported through the channel readily attach to the tops and walls of the micropillars. Subsequently, the droplets grow in size due to the coalescence with other arriving oil droplets. Eventually, the growing droplets spread onto the bottom substrate and hence gradually fill the channel, leading to the formation of a LubISS. The influences and effects of the texture and geometry of the solid substrate, the surface chemistry, the flow conditions, the oil viscosity, the chemical nature and the filling mechanism are investigated by Laser Scanning Confocal microscopy (LSCM) and advanced image processing. Central to the successful filling of a structure is the addition of a positively charged surfactant at a concentration within the range of the point of charge reversal in order to compensate for the negative charges present on the oil droplets preventing droplet coalescence. This approach can in principle facilitate a strategy for active lubricant replenishment preventing the detrimental depletion of lubricant since starting with the empty micropillar array represents the worst-case scenario of a porous structure completely depleted of lubricant.

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