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RESEARCH ARTICLE

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A study on hydroentangling waterjets and their impact forces

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Abstract We study the possibility of obtaining an intense fluctuating force during the steady-state operation of a waterjet. In this paper, characteristics of waterjets in the so-called first wind-induced breakup regime are briefly explained and the impaction between such waterjets and a smooth flat plate is discussed. We consider these waterjets to consist of three different regions: (1) a continuous portion, (2) a discrete portion (a stream of drops) and (3) a spray region. Using fluid dynamics simulation we obtain an impulsive impact force for the discrete portion of these waterjets. The peak of this impulsive impact force is found to be 3.5–4 times greater than that of the continuous portion. We validate our simulations by conducting an experiment for a stream of large low-speed drops. The impact force of these drops is in good agreement with that of simulation.

List of symbols

a_0	radius of drop (m)
c	speed of sound in water, 1,500 m s^{-1}
C_d	discharge coefficient
d_j	waterjet diameter (m)
d_0	nozzle capillary diameter (m)
D	drop diameter (m)
f	frequency (s^{-1})
F_{imp}	impact force (m)
h	film thickness (m)
H^*	dimensionless film thickness
p	manifold pressure (Pa)
r	radius (m)
Re	Reynolds number
U	drop or jet velocity (m s^{-1})
We	Weber number
Z	Ohnesorge number

Greek letters

λ	wavelength (m)
μ	viscosity (Pa s)
ν	kinematic viscosity (m^2 s^{-1})
θ	contact angle
ρ	density (kg m^{-3})
σ	surface tension (N m^{-1})

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1 Introduction

Collimated high-speed liquid jets have found variety of industrial applications. Such streams are frequently used in transferring energy from a reservoir onto a target with minimum dispersion. These applications extend from jet cutting/cleaning to nonwoven fabric manufacturing. In this paper we describe a nonwoven manufacturing process called hydroentangling as an example for studying waterjets and their impact force. However, we do not limit the generality of this work by focusing strictly on hydroentangling technique.

Nonwovens, by definition, are engineered assemblies of natural or man-made fibers bonded together in the form of sheets, webs, or bats (Butler 1999). Nonwoven fabrics are becoming increasingly more sophisticated and continue to find new applications in many sectors. Nonwovens are currently used in air and liquid filtration, automobiles and airplanes, cosmetics and hygiene products, surgical gowns, and acoustics, amongst many others. Nonwoven manufacturing processes are high speed and low cost as opposed to their traditional