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Technical Note

# Experimental study of water drop impact on wood surfaces

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ABSTRACT

Experiments of water drop impact on wood surfaces were performed. The initial drop diameter was fixed at 2.4 mm ± 0.1 mm, while the drop impact Weber numbers were varied from 42 to 258. Three kinds of wood, such as Paulownia, Fraxinus mandshurica and Jatoba were considered, since they are combustible materials and popularly used for timber flooring, office furniture, etc. in China. In addition, they have different basic density, surface properties and water absorbability. The experimental results show that the critical impact Weber number of droplet splashing decreases as basic density of the wood increases. The spread factor is affected by wood surface properties and its basic density. It was also found that the water drop spreads along the direction of the grooves after it impacts on wood surface which phenomenon depends on pore grooves of wood surface..



## 1. Introduction

Liquid drop interaction with a surface has been studied for more than a century. The collision dynamics of the impinging drop may be vastly different between liquid and solid surfaces [1]. The fluid dynamical phenomena of liquid drop impact include spreading, receding, rebounding and splashing on solid surfaces [2,3]. However, many physical phenomena involved are still incompletely understood, including wetting of wood surfaces and fluid instabilities, etc. [2]. The problem will become even more complex if a rough wood surface comprising grooves or a charring wood surface is considered which usually happens to a fire case.

The collision dynamics of a water drop impinging upon liquid surfaces have been widely studied under various conditions [4–6]. Studies on drop collision with a solid surface, such as solid metallic surface, heated wax surface, solid and liquid coexist surface, textured surface, structured rough substrates with grooves, had also been widely performed [7–12]. However, most of the above researches just focused on metallic surface. There are few works considering the drop impact on wood surface. In fact, wood is one of the daily used combustible materials and wood fire is the main type of solid fires, especially in offices and historical buildings, etc. Water mist fire suppression technology has been regarded as a better substitute of conventional means for wood fire suppression. But the dynamical processes and the influence factors of water droplets impacting on wood surfaces are still not clear. Therefore, in order to deepen the knowledge on mechanism of wood fire suppression with water mist, the collision dynamics of a water drop impacting on wood surfaces with different properties has been studied in this work.

## 2. Experimental setup

The experimental apparatus includes a drop generator, a 1000 W iodine tungsten filament lamp, a Photorn FASTCAM high-speed video camera and a computer, etc. The Schematic diagram had been described in detail elsewhere [6]. Drops with initial diameter of 2.4 ± 0.1 mm were generated by the injection syringe. The drop was detached from the syringe by itself weight, so its impact velocity can be estimated by $V_0 = \sqrt{2gh}$ and controlled by varying the fall height which is less than 40 cm in this work [13].

The drop impacting process was recorded by the high-speed video camera at 2000 fps with 512 × 1024 pixels. The camera was coupled with a Nikon 200 mm micro-lens to obtain the required spatial resolution. A 1000 W iodine tungsten filament lamp was used for illumination. Wood surface roughness was measured by a TR240 surface roughness measuring instrument with accuracy of 0.001 μm. While wood surface microscope feature was imaged by a Sirion200 FESEM.

Three kinds of wood which have different basic densities and surface properties were considered. Fig. 1 shows their surface microscope features, while Table 1 gives the measured data of their basic density and average surface roughness.

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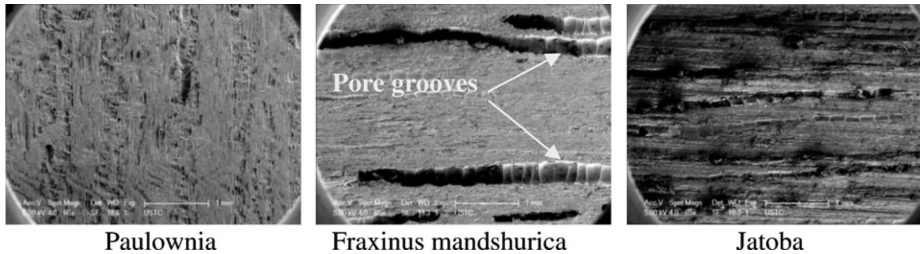


**Fig. 1.** FESEM image of three kinds of wood surfaces.

**Table 1**
Basic density and average surface roughness of the woods.

| Wood type | Basic density[a] (g/cm$^3$) | Average $R_a$ (μm) |
|---|---|---|
| Paulownia | 0.24 | 3.185 |
| Fraxinus mandshurica | 0.56 | 3.635 |
| Jatoba | 0.82 | 8.347 |

[a] Basic density of wood: the oven-dry mass of a wood sample divided by its green volume.

## 3. Results and discussion

### 3.1. Effects of surface texturing and roughness on deformation of drop impact

The wettability of the liquid is quantified by the contact angle which can be described by Young's equation [14]. However, Young's equation is valid when there is no adsorbed liquid film on the solid surface. For a rough horizontal surface, the contact angle is lower than that for smooth surface, and it makes the rougher surface more wettable [10].

Fig. 2 gives the time-elapsed images showing the deformation of a water drop impact upon wood surfaces with $We = 42$. A jet is obviously formed at the surface of Paulownia and Jatoba, and the height of jet formed at Jatoba surface is higher than that at Paulownia surface. The drop spreading on Fraxinus mandshurica surface is quite different from the other ones due to the big pore grooves which may interrupt outward spreading and energy transfer. With $We = 42$, there is no splash on any of these wood surfaces. With $We = 129$, water drop broke up and splashed multi-satellite droplets on Jatoba surface. As shown in Fig. 3, with $We = 258$, no matter how much the surface roughness is, prompt splash occurs at the beginning of water drop impact. In addition, some liquid lines that like long strips of fingers were shot around the impacting drop on Paulownia surface. These indicate that the prompt splash may be not only affected by surface roughness, but affected by surface texture and basic density, although Xu et al. stated that, the corona splash dominates at small surface roughness and the prompt splash dominates at large surface roughness [15].

### 3.2. Effects of wood basic density on critical impact Weber number

If define droplet splash as the impact drop breaks up and splashes multi-droplets, so the critical impact Weber number of

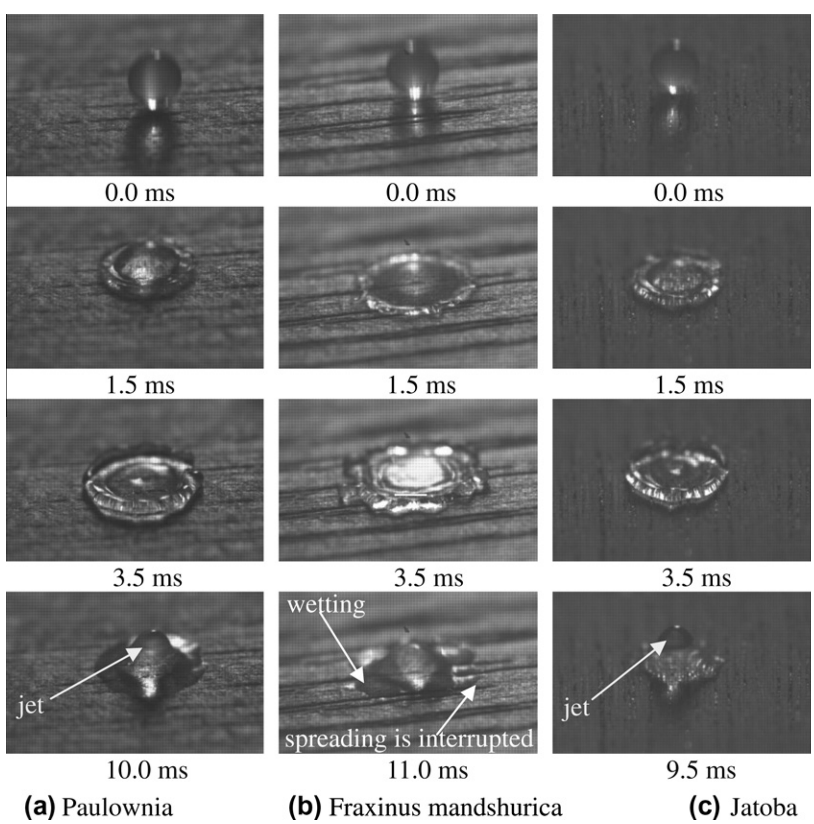


**Fig. 2.** Time-elapsed images of water drop impact upon different wood surfaces ($We = 42$).