Design, Fabrication and Performance of Anti-splashing Surface

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1. Abstract

In the last few years, we have seen how much damage has been done to the world due to the spread of the virus called Corona. Such microorganisms adhere to surfaces like glue and spread from one surface to another when exposed to external forces. In general, the rate of splashing seems to depend on the speed of the fluid, but many other external parameters are involved. These microorganisms are more likely to be found in medical surgery room sinks, household kitchen sinks or bathroom surfaces and urinals, and juice industry containers. Our goal is to fabricate an anti-splash surface coating that prevent those microbial agents from spread, has high performance and can be used on a variety of surfaces.

2. Short description of the Research Problem

Over the last decade there is a huge amount of research going on for anti-splashing surface. When a liquid drop impacted on a solid surface with an internal energy, the drops produce some internal droplets that flying away from the impact. This behavior is generally known as splashing and its product as splash. There are many small particles that human eyes cannot observed. This small particle can be harmful virus or bacteria or any kinds of detrimental micro agent. They stick to the surface and will stay if there is no external force applied. When a droplet falls on the surface it creates splash and those pernicious micro agents spread out. Thus, they will stick to another surface and will spread in massive amount. Therefore, anti-splashing surface is necessary to reduce the spreading and splashing.

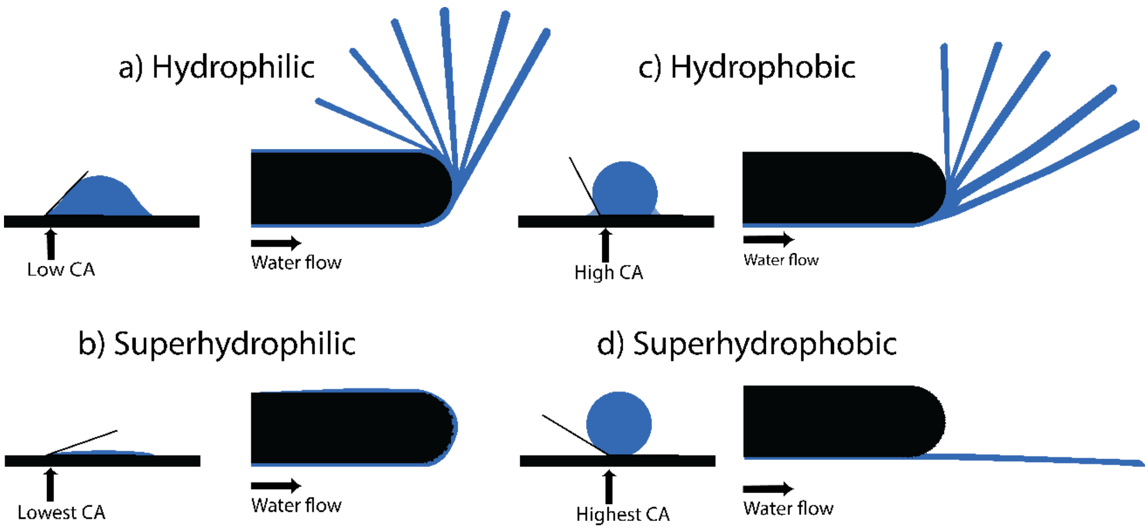


Fig 1: Types of surfaces in terms of splashing

To reduce the flying droplets spreads and overflow, it introduces anti-splashing surface. In terms of spreading of liquid, there are mainly 4 types of surfaces:

1. Hydrophilic surface
2. Super hydrophilic surface
3. Hydrophobic surface
4. Super hydrophobic surface

It is very important to know the liquid solid interaction to the surface in every part of technology. Because it will help to reduce the damage of the device. In recent year, in wearable and mobile phone industry started launching water proof devices, there must be heavy research of surface. In case semiconductor manufacturing droplet splash can shows a huge impact.

Besides technology and devices, many industries are using anti splashing surface to reduce contamination when packaging. this surface play's vital role in medical sector also with household area. After surgery hospital personnel must need to wash the equipment that uses for the operation and contamination happens with flying drops. Some more includes:

- Juice factory. (For maintain the self-life of the produce)
- Urinals and toiletries (to reduce splashing and spreading of liquid)
- Surgery basin in medical
- Washing basin inside kitchen
- Flooring tiles etc.

Our goal in this research is to incorporate both fluid dynamics numerical software simulation data and using image processing algorithm to real-time slow-motion camera data and compare the performance of anti-splashing surface.

3. Rationale of the proposed research

Few points why we think this project will be beneficial:

- In medical sector, hospital personnel's needs to wash their hands and uses equipment in washing basin after surgery. There must be some micro agents gathered around basin surface and will fly with the splash of liquid. If the surface anti splashing parameter is less than will fly long distance and would be contact with the washed equipment and make that equipment unusable. Those microbial agents expand rapidly. If that equipment uses in another surgery, it is possible that those harmful agents will go inside and expand. Same goes for the household kitchen washing basin. So, if there is an anti-splashing coating in basin, it can reduce the splash of liquid.

- Inside urinals, there are a huge amount of microbial agent gathered around the surface. Again, a coating of anti-splashing surface can help to reduce splash.
- In liquid/juice industry, self-life is an important term. Overflow and spreading of liquids occur when packaging them. At the meantime, some micro-organism can enter in packaging stage and reduce the self-life of the product.
- In recent, Artificial intelligence can develop surface pattern automatically it will be a huge step for anti-splashing surface industry.

4. Aims and objectives of the research

Our main goals of the research are:

- To study the formation and splash effect of a water droplet on a pillar
- To design different geometric pattern surface and compare their splashing through simulation.
- To differentiate our pattern design with artificial intelligence powered design
- To check the flexibility of the anti-splash surface and compare the surface with natural surface structure.
- To evaluate the splashing with high-speed camera
- To fabricate a coating type anti-splash structure that can glued in any surface.

5. Literature review and theoretical framework

The study of the effect of liquid and solid surfaces can broadly be witnessed in nature and these are indeed very pertinent in both medical and industrial benefits including spray ink-jet printing, liquid atomization and cleaning, pesticide deposition & spraying, liquid fuel combustion, triboelectricity generation, coating manufacture, electrostatic painting, spray cooling, forensic research, semiconductor manufacturing and so forth [1-5]. Among the countless number of solid surfaces, all are mainly focused on the hydrophobic and hydrophilic surfaces. With micrometer scale roughness of surface reduces water repellency and energy of the droplet. Again, reduction of splashing on surfaces has the effect on prevention of human disease, plant disease, hygiene and safety.

Majority of the existing researches is established based on photographic images captured by high resolution cameras. To find the splash control of the liquid with geometric targets Gabriel Juarez *et al.* [6] proposed practical difference of the dynamics of the impact process affected and influenced by the target cross-sectional geometry. They used polydimethylsiloxane pillar which width are millimeter in scale and water-glycerin color additive droplet. They showed that lamella expansion of droplet is equal to the pillar edge number. For the number of pillar edges is less than 8 it results regular splashing and more than that it turns to irregular splashing [6].

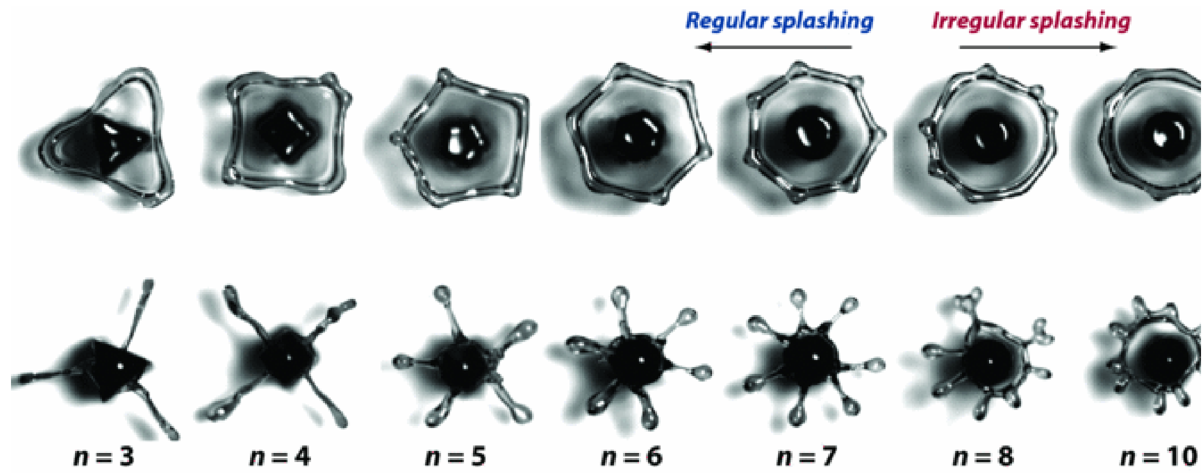
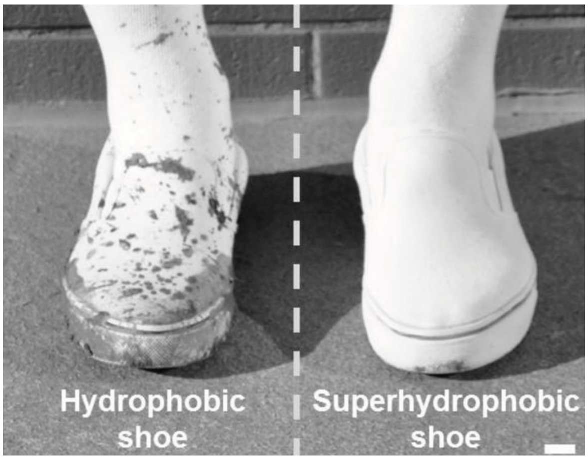


Fig 2: Lamella expansion for different edges of pillar pattern [6]

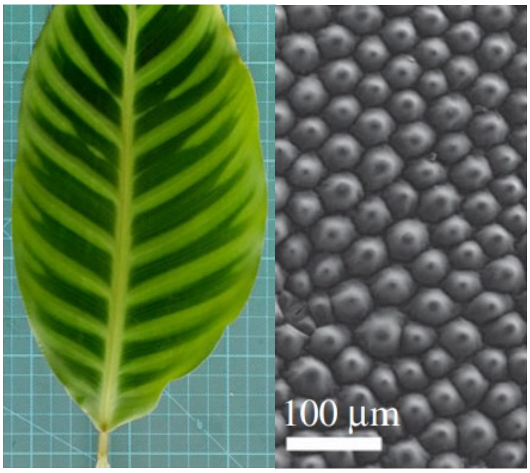
Koch and Grichinik [7] explored with different natural self-cleaning plant leaf surface structure. This type of leaves keeps them free from dirt and pathogens. They show the conical shape micro scale hierarchical surface pattern of calathea zebrina leaf, a natural superhydrophobic surface. This micro scale conical shape increases the contact angle of leaf-drops and keeps free from dirt [7].

Zhichao Dong *at el.* [8] Designed hydrophobic and superhydrophobic foot sole and differentiate their splashing phenomena. The contact angle of the water drops increases with the structured pattern changes from micro to nano scale. They showed that micro and nano structured superhydrophobic pattern sole significantly suppresses the overflow of muddy water [8].

Again, splashing of a drops also depends on how soft or hard the solid structure is. Softer the surface, lesser the splash. Chistopher J. Howland et al. [9] showed the difference of splashing varying the surface. After impacting droplet into acrylic surface which has young's modulus of 3GPa produced irregular splashing and more flying drops. But with the less young's modulus (<100kPa) softer surface, the loss of energy rate is more, hence the splash is less. [9]



a) Footwear sole on muddy water [8]



b) Calathea zebrina leaf and Its surface SEM Image [7]

Results from earlier studies demonstrate a strong and consistent association between a superhydrophobic material with anti-splash phenomena. A considerable amount of literature has been published saying the shape of the droplet spreads the least or the shape of the droplets changes slightly. This aspect influence splash to occur less by maintaining a certain range of contact angle with the surface. A fabrication of two different superhydrophobic surfaces with open air pockets superhydrophobic ZnO (SH-ZnO) and sealed air pockets superhydrophobic anodic aluminum oxide (SH-AAO) was introduced Wuseok Kim *et al.* [10]. With a high-speed camera the effect of pore structure on the anti-splashing properties of superhydrophobic surfaces were investigated.

Previous published studies are limited to photographic illustration and fabrication of the droplet impacting on the surface. The existing literatures on anti-splashing surface lacks clarity regarding smaller ranges and ideal values. Where in our work we will do a quantitative analysis using CFD simulation for different material properties in micrometer and millimeter ranges.

6. Research methodology

We are designing a surface with a specific geometrical formation which ensures the least splash of water on the surface. The development of the geometry will be done using CAD software at the very beginning of this work. Afterwards, the work will be developed based on computational fluid dynamics simulations and results. The basic procedure of this research is stated below-

a) Specification of system parameters:

A droplet falling on a surface requires an ideal diameter, pressure, surface tension, and viscosity values, as well as the surface, which needs a material, roughness, and young's modulus to be mentioned.

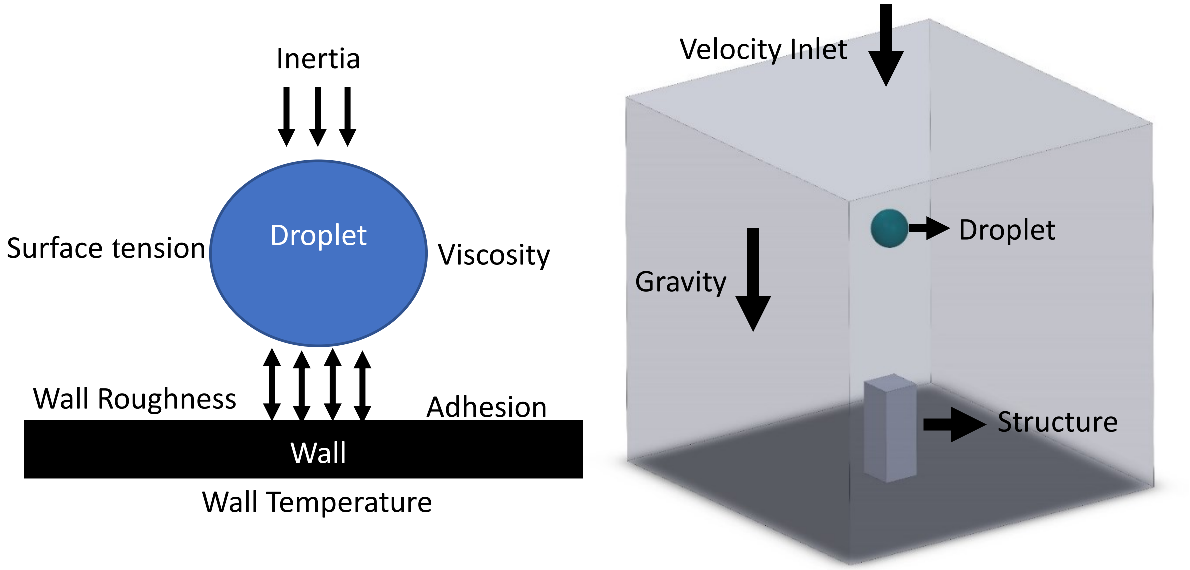


Fig 3: System parameters of droplet impingement

b) Developing Geometrical model:

To design a system, modelling a design need to be developed using any CAD software. The model will consist of small pillars on a solid surface. The specifications of each dimension of the geometry are significant for further calculations.

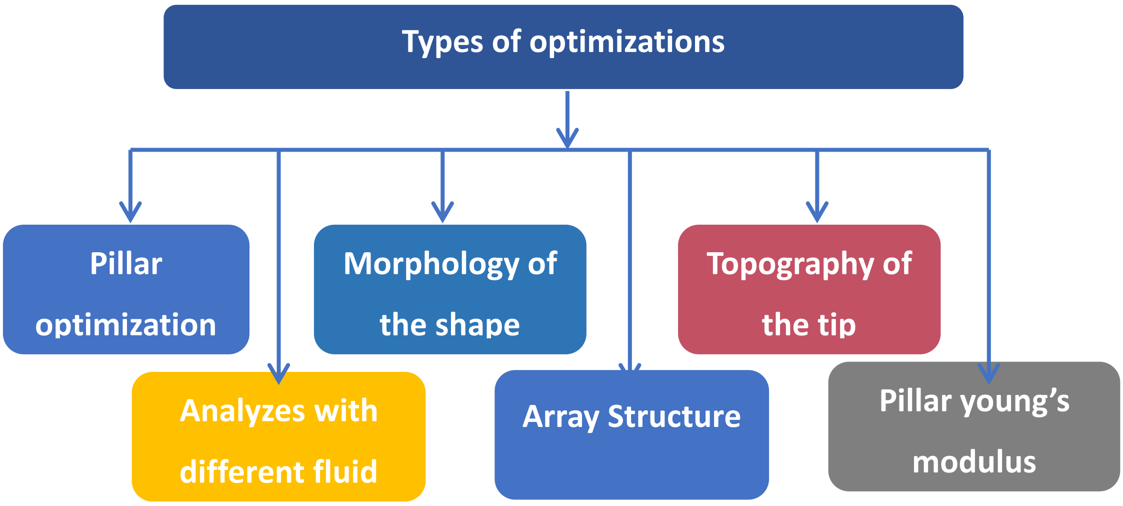


Fig 5: Optimization model

c) Simulation and Result study: -

With a desired or demo design, simulations need to be performed. The result of the simulation will decide further optimization of other parameters.

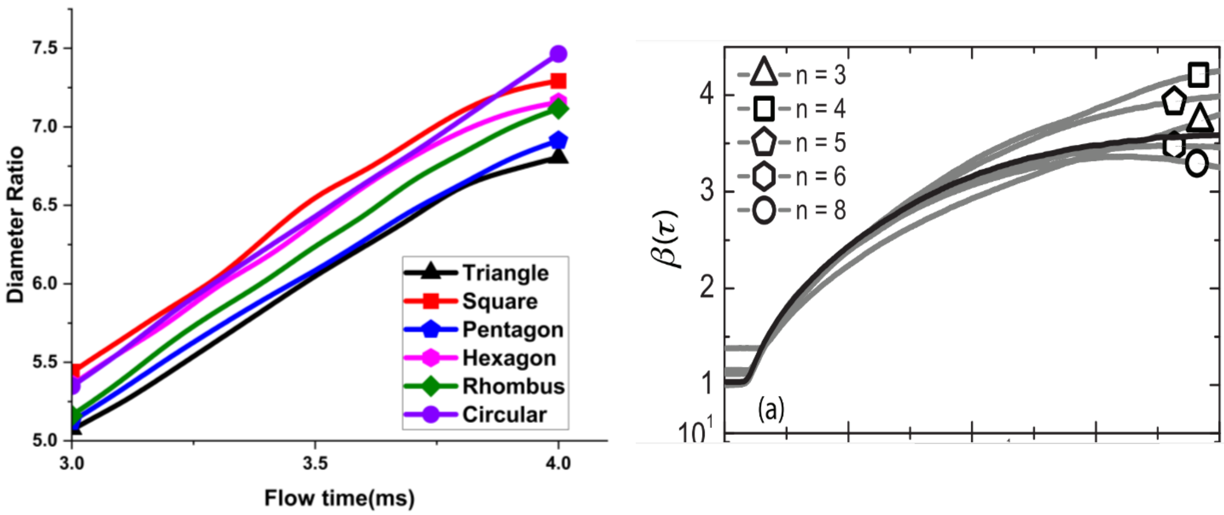


Fig 4: Validation with published data

d) Optimization of the parameters: -

The analyzed results of the previous process will help to determine which criterion affects most. A generalized thought of optimization of pillar diameter, the cross-section of various pillar shapes, velocity and direction of the water droplet, various structural design arrangements, young's modulus, stress, and strain of the surface material needs to be optimized to establish the final model.

e) Implementation of the model: -

Any simulations that have been established expect to be implemented practically to prove their actual value in the present world. Our system design can be created using any mold and a 3D printer. As the range of the design will be on a smaller scale, it is possible to develop it with an advanced 3D printing device.

7. Expected outcome and contribution of the research

The economic benefit of this product is enormous. The work can assure spreading diseases, correct estimation of product life. It can accurately validate the shelf life of a product. The surface design we are proposing can be used to protect water corrosive materials. The industries producing liquid products, e.g., juice and beverages, will greatly benefit.

The research aims to increase the anti-splashing probability on material by creating a specific geometrical shape. It emphasizes on reduction of bacterial infection through fluids that can be a reason for spreading any physical disease, and lessen the loss of efficiency and life of any liquid product.

8. Time frame with activity plan

Month-->	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Continuous review of current research	■	■	■	■														
Setup required tools and tech				■	■													
Pillar optimization					■													
Morphology of the pillar						■	■											
Topography of the tip							■	■										
Array Structure									■	■								
Droplet with different velocity										■	■							
Analyzes with different fluid										■	■							
Multiple array Structure												■	■					
Fabrication of the model												■	■	■				
Experimental performance Analysis													■	■	■	■		
Documentation																■	■	■

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