A Novel No-Scrub Window Cleaner for Skyscrapers

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Executive Summary

Skyscrapers window cleaners are top of the list for the most dangerous jobs in the world. Cleaners often work hundreds of feet in the air with simple protection equipment, risking their lives to wipe windows manually. Because of the high risk and scale of the work, window cleaning is an expensive service provided only through specialized companies. Given that high-rise window cleaning is dangerous and labor intensive, this design proposal provides a novel cleaning solution which is fast-acting and requires minimal labor operation. It utilizes powerful surfactants that lift off dirt, bugs, and water spots easily without a scrub. Workers can easily apply the product at the top of the building via a foam cannon and finish off with a quick rinse. Because of the generality of this product, it can be easily modified to clean various smooth surfaces, namely solar panels, aircrafts, and cruise ships, broadening revenue streams and increasing product impact.

Background

As skyscrapers with glass curtain walls become a prominent architectural trend, the issue of keeping the exterior clean naturally arose. Current methods of cleaning are labor intensive and dangerous. The most common cleaning method is to send workers down the sides of the building from the roof on a platform. Equipped with cleaning tools such as sponge, T-bar wand, squeegee, spare blades, and bucket, the worker would laboriously clean and dry each panel of glass by hand. Workers often need to repeat this multiple times to cover the entire perimeter of a building.

This proposal describes a brand new cleaning solution that is fast-acting and requires minimal human operation. Most commercial glass cleaners expect the consumers to spray on the cleaning solution, scrub the surface with a sponge, rinse with water, and remove excess water with a squeegee. Such a process becomes costly and labor intensive when applied to tall buildings. Even on a small scale, the product may be applied to cleaning household windows to eliminate potential injuries related to climbing up ladders. Possible combinations of ingredients that can achieve such cleaning power will be discussed. Future usage scenarios, safety considerations, and product limitations will also be addressed.

Unlike above mentioned window cleaners, this scrub-free glass cleaner contains surfactants that can lift most dirt and grime from the surface and guide them off through a simple rinse. In addition, workers can apply this product from the building top via a foam cannon. A frothy foam layer will flow down slowly, taking any dirt and grim with it, eliminating the need for a person to scrub the glass floor by floor. In addition, the product will also leave behind a clear hydrophobic coating that will eliminate water residue on the surface and does not require manual drying.

Because of the hydrophobic layer, the glass will stay clean longer, requiring less frequent cleaning.

Although the concept of a no-scrub cleaner is nothing new, it had never been applied to large scale buildings. Most commercial window cleaners do not have enough cleaning power and thus require manual scrubbing. Additionally, the product can be technically challenging to formulate. The applied foam must cover the whole surface from the top to the bottom and retain its cleaning power. This might be easier imagined than done.

Technology

Overview

The major containment of glass surfaces are dust particles. Dust is the general term for small particles made of various materials, with diameter ranging from 1 to 100 µm. Dust particles are held to the glass via electrostatic attraction that is much stronger than the downward force of gravity. The electrostatic force arises because the dust particles have had a few electrons knocked off while floating around as it has been buffeted by drafts and knocked into objects. This will give it a slight positive charge. Glass is hydrophilic and prone to having water marks left behind by rain. Dust particles on the surface contain minerals such as calcium carbonates and other things. Rain is slightly acidic and can collect dust and dissolve the minerals when landing and gliding on the dusty surface. Water spots develop on surfaces when water evaporates and the leftover minerals accumulate, making a dull patch on the surface. Another major containment are bugs and small insects smashing into the glass and sticking to it.

In order to succeed, the product should first be sprayed onto the outer glass surface of the building via a high pressure foam cannon. The product then sticks onto the glass surface, forming a frothy foam layer. The moisture in the foam will first hydrate caked on dirt. Powerful surfactants will cut through the dirt and bugs, and then safely guide them off the surface through a thorough rinse. Product is also designed to leave behind a hydrophobic coating on the glass, allowing rinsing water to flow down. The product solution is a homogeneous mixture of various cleaning agents in water based solvent.

The product is originally a water-like and shear thinning liquid, able to be sprayed out through the nuzzle of the foam cannon. By going through a pressurized foaming nozzle, it foams up to hydrate caked on dirt, suspend the mineral and dust particles, and dissolve dead bugs on the glass surfaces of the building. The product foam must have a relative yield stress, characteristic of frothy and consistent foam. The product must have a suitable viscosity to ensure an adequate flowing speed on the surface at the normal temperature (-10 to 50 °C) and atmospheric pressure driven by gravity only. The product foam with low viscosity will run off easily and thus cannot provide enough time for the active ingredients to work. On the other hand, high viscosity might cause difficulty to flow down. The product must remain shelf stable until use. The product contains mainly sodium hypochlorite and other powerful surfactants. It will also have a mechanism that allows it to leave behind the hydrophobic coating layer.

Chemical Formulation

To achieve the technical specifications discussed above, the product uses water as a solvent, with various surfactants, acidic components, hydrophobic coating agents, and foam stabilizers. Because loose dust particles are often positively charged, negatively charged surfactants are preferred. Anionic surfactants have negatively charged hydrophilic ends, which will lift and suspend the dust particles in micelles. The micelles, suspending dusts are then rinsed away with ease. Some popular anionic surfactants include sodium laureth sulfate (SLES), sodium xylene sulfonate, both are popular ingredients and relatively inexpensive. SLES is an effective foaming agent to create frothy foams that will adhere to the glass surface. Sodium xylene sulfonate increases the ability of water to dissolve other molecules, thus helping remove dirt. Another useful surfactant is lauryldimethylamine oxide (LDAO), a foam builder and stabilizer, viscosity enhancers, and is effective in killing common bacteria. Water spots contain caked on dust and various minerals. Since most minerals are basic. Having an acidic component such as citric acid will effectively neutralize and dissolve the minerals off the glass surface. The water in the foam will also act to moisten the dried dust clump, loosening it up to be suspended by anionic surfactant micelles. Bugs and insects are mainly protein and can be dissolved using strong acid, such as citric acid, or antimicrobial agents, such as bleach (sodium hypochlorite). Sodium hypochlorite is also a popular ingredient used for surface purification and odor removal on a large scale. So, it functions both to dissolve bugs and eliminate odor. Lastly, the product needs to leave a hydrophobic coating of polydimethylsiloxane (PDMS). PDMS is an inexpensive hydrophobic polymer that can be coated on solid surfaces to make them water-resistant. The product will come in liquid form and the level of frothiness of the foam depends on the foam cannon and percentage of surfactants in the formula. Hydrofluorocarbon 152a may also be added as an aerosol propellant, a foam expansion agent, used as an all-purpose surface cleaner. In order to keep the solution stable when stored for an extended period of time with no phase separation, some stabilizing agents may be added. Salt is used to lower the freezing point and prevent volatilization while operating under extreme climates.

Ingredient List:

Water, Sodium Laureth Sulfate (SLES), Sodium Xylene Sulfonate, Lauryldimethylamine Oxide (LDAO), Sodium Hypochlorite, Citric Acid, Salt, Polydimethylsiloxane (PDMS), Hydrofluorocarbon 152a.

Product must be odorless. Although it does not matter the color of the product, the proposed product is originally a colorless liquid that does not dye or contaminate any surface when cleaning. It also does not contain fragrance since it will be used in large open areas, having a scent provides zero benefits.. This product is non-toxic to ensure public safety. It is also formulated using mild ingredients to avoid any chemical burn during accidental contact with skin. The product also does not emit toxic fumes. The ingredients used in this product must be non carcinogenic and irritable to ensure public health. The product should be eco-friendly since it is used outdoors and will be washed down to the draining system and evaporate to the air. Avoid contact with eyes, skin and clothing. Wear gloves when in use.

Physical Requirements

Physical characteristics of the ideal flow behavior can be imagined. The sprayed foam layer must flow down at about 0.03 m/s in order to cover a 10 floor building in less than 20 min. Based on the flow behavior, the product should soften dirt and debris in less than 5 min so any remaining foam can be rinsed off. Having a short desired cleaning time also prevents the product foam from drying out. The foam should also have a relatively high yield stress in order to stay in tact as an approximately 1 cm layer on the exterior of buildings. For buildings that are taller than twenty stories, high speed wind might blow foam away. To combat this issue, bench scale experiments should be conducted to discover an ideal yield stress, and layer thickness. Ideally thinner the layer, while still providing powerful clean, is desirable due to the zero velocity at the boundary layer. To achieve physical characteristics requires the following rheological specifications. Yield strength values should be the same as water in the cannon. Yield strength values should be 0.01–0.07 MPa for the 0.09 g/cm^3 foam. Viscosity values should be the same as water in the cannon. Viscosity values should be 1000-2000 MPa for the foam.

Because this specific application is for high rise buildings. The product must be able to operate at atmospheric pressure and sometimes extreme temperatures (-10 to 65 °C). Depending on the climate of the location, summer heat and radiation from the sun can heat up the exterior of the building up to 65 °C. The cleaning foam layer must remain stable under extreme conditions without evaporating quickly and experience no changes in yield stress or flow behavior. Additionally the liquid cleaning solution must endure high shear rates (inside the cannon) and experience high pressure change during the spray of foam cannon, then the frothy foam should have low shear rates (at the surfaces of the buildings).

Other

Because this product shares many similarities with commercial glass cleaning or foam cleaning products, manufacturers are already equipped for large scale production. Similar to other cleaning products, The product should be stored in a container that is tightly closed in a cool, dry area. It should not be stored below 0 °C or above 37°C. It should not be stored in direct sunlight.

Success Criteria

Below are few success criterias while formulating the product.

1. After mixing all the ingredients, the solution is odorless and stable.
2. The solution has a low viscosity so that it can be easily sprayed.
3. Yield stress of the sprayed foam should follow the parameters listed in the technology section.
4. Cleaning foam is not volatile during cleaning time.
5. Although having a good amount of yield stress, the foam is able to flow a good amount of distance under gravity alone.
6. The product provides enough cleaning power to not require scrubbing.
7. The product leaves behind a hydrophobic layer, which is tested with a rinse.

First step would be to increase the concentration of hyper surfactants of an existing foaming cleanser formulation. The amount of time required to lift up dirt at various concentrations of hyper surfactants is tested and analyzed to optimize concentration. While searching for the ideal functional formulation, viscosity and stability of the liquid solution should be measured. After the liquid solution is transformed into foam, its yield stress, stability and cleaning power is quantified. As the foam is destabilized and rinsed away, the hydrophobicity of the surface needs to be tested. On the bench scale, a big panel of glass is used to mimic a building exterior. Before the experiment, artificially create dead bugs, water stains, and dust particles. After applying the foam, the flowing speed will need to be measured. The foam should not dry during the cleaning process, which takes about 30 mins. The PDMS coating layer thickness and consistency is also measured. After rinsing, the testing object should be clean and no water residual remains on the surface. To compete with existing surface cleaners, comparison tests with powerful existing commercial cleaners will be performed and analyzed.

Final Discussion

The proposed product has immense potential for adaptation for other applications. Automation is key for development, and this product partially automates a labor-intensive sector. Because the efficiency of solar panels drastically decreases when dust and other debris are collected, it requires frequent washing. However, it is a challenge for many families to regularly clean something on top of the roof. On a commercial scale, solar panels and the mirror for concentrated solar power can also benefit from the ease of cleaning with this product. Other applications include cleaning of cars, aircrafts, and cruise ships, by adjusting the cleaning surface from glass to other smooth surfaces.