Stainless steel flame wick design with green and safety concerns

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Abstract

Sustainable products become increasingly important for the company in addressing eco-performance to satisfy global environmental regulations. Wick module using stainless steel was designed to fulfill Green and Safety regulations. A specific wick and its rolled from a metallic meshed body provided active capillary phenomenon. The temperature at the tip of the cord can reach 900 degrees Celsius, so the fuel in the stainless steel wick can burn. Only carbon dioxide and water vapor are produced during the combustion process. Due to the lower viscosity coefficient of water, there is a relatively small increase in the liquid level over time. We chose liquid biofuel as the test object. When the metal roll was placed vertically, we found that there was a significant increase in fluid level.

Keywords: Flame wick, Safety , Stainless steel, Capillary

1. Introduction

Burning is a dangerous event. A faulty power pole near Melbourne sparked the Kilmore East fire. The flames quickly spread to most surrounded areas. Assisted by steep slopes and strong winds, this fire spread to nearby suburbs, including Kinglake where 38 people died. The inefficient alarm system highlights the role of smart grids in case of a bushfire. An early warning and evacuation system was proposed [1] to extinguish the fire, especially in easy burning wild and remote areas.

Flame can use for heating or watching. In any case, product safety is the most critical design consideration. The non-traditional wick achieved by design with stainless steel mesh. The specific folding and routing of those meshes not only extend the lifetime of the wick but also reduces the possibility of safety issues. Some backgrounds behind this design discuss here.

1.1. The flame

Combustion is a chemical process in which a substance reacts with oxygen to produce heat. Light provided during combustion either as a flame or as a glow. A flash is the visible gaseous part of a fire. It caused by a highly exothermic reaction taking place within a thin zone. There are three zones in a candle flame. In the outer region, complete combustion of the fuel takes place, and the color of the flame is blue. In the middle zone, partial combustion of the fuel takes place, and the color of the flame is yellow. It is the moderately hot part of the fire. In the inner zone, there are unburnt vapors of the fuel. The color is grey or black and is the least hot part.

1.2. Effects of incomplete combustion

If there is a shortage of air (oxygen), incomplete combustion of hydrocarbon takes place. Incomplete combustion releases less energy than complete combustion; it produces carbon monoxide (Fig. 1).

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Occupational Safety and Health Agency (OSHA) regulated burning of fuels contributes significantly to air pollution risks to human health. The toxic emissions such as carbon monoxide (CO), Sulphur Oxides (SOx) and Nitrogen Oxide (NOx) caused human health complications [1]. The affinity of carbon monoxide for hemoglobin is 200 times greater than for oxygen. In the oxygen-hemoglobin dissociation curve, oxygen-carrying capacity is markedly diminished when carboxyhemoglobin values reach 40% to 50%, makes the oxygen which is bound to hemoglobin less available for delivery to tissues [2]. Hyperbaric oxygen treatment has been evaluated in multiple trials to manage neurologic sequelae of carbon monoxide exposure.

When the combustion reaches steady-state efficiency, one can measure its critical parameters to determine the required service and installation adjustments. In the traditional modification, we adjusted fuel-pressure to produce less than 200 ppm or 400 ppm. The burner and fuel-air mixture should be maintained within a safe and efficient range [2]. But this process is time-consuming. That is the main reason we developed flame wick material to fulfill those safety concerns.

1.3. Previous wick design

Pure Cotton alcohol lamp uses typically 20cm cotton wicks which often utilized in the chemical laboratory. The alcohol lamps use glass-stoppered and employ a cork surmounted by a metal disc and wick support. The most common improper operations of alcohol lamps are (1) failure to provide for pressure equalization and (2) use of large wick. The combustion changes surrounding temperature and atmospheric pressure. Sometimes the pressure force the alcohol goes up and out of the wick. While removing the ground-glass stopper, and lighting the lamp, will ignite the excess alcohol and creating a fire hazard. A hole drilled through the cap act as the vent to maintain an equal pressure of fuel reservoir could reduce this risk [2].

Fig. 1. Cork surmounted by a metal disc and wick support

The brass feed-through on the left is paired with a woven glass fiber wick (Fig. 1); this fitting replaces a cork. The woven-cotton wick paired with a formed glass feed-through support to be fitted through a cork. A vent hole is not generally necessary when using these wick supports, as they fit loosely in the opening of the reservoir. Conventional wicks are typically made out of braided cotton or fiberglass, and liquid fuel or melted wax is drawn up to reach the flame by capillary action. After ignition, fuel vaporizes and combusts on the tip of the cord that exposes to flash, the tip of the cotton wick will be carbonized and burnt out gradually due to high temperature on the top of the flame. Thus, cord made of consumable material must be adjusted and trimmed to maintain combustion.

Flame scale varies as the height of wick changes. It is dangerous for users to keep a stable flame. Moreover, cords produce a fire that oxygen reacts with vaporized fuel by diffusion. The rate of diffusion limits the combustion speed. If there is not sufficient oxygen for the reaction-diffusion flames produced by the wick, tend to produce incomplete combustion and more soot particles.

U.S. Patent No. 2012/0202160 [3] utilized a ribbon style wick made of porous material. A reusable burner includes a canister carrying fuel such as diethylene glycol with a burner assembly. The woven wick structure containing a plurality of threads in side by side extends down into the fuel. The shape of the wick material before shaping for use in the candle is in the roll form. The capillary flow determined by pore size and the viscosity of the fuel. When the wick is in the way of a thin ribbon, it has fewer pores on cross-section. The weaker capillary flow results in a smaller flame.

2. Parameters Experiments

2.1. Material and structure choose

Stainless steel flame wick was selected from various routine designs to improve safety concerns. The capillary phenomenon is the ability of a liquid to flow in narrow spaces in opposition to gravity. If the diameter of the tube is sufficiently small, then the combination of surface tension and adhesive forces dominate. The thinner the space in which the liquid can travel, the further up it goes. In fuel selection, based on eco-performance, we choose transparency “biofuel liquid” [4]. The capillary phenomenon presents much easier because the biofuel's viscosity is low. This property allows the fuel transport from the lower fuel tank to the upper ignition area [5]. When fuel is filled into the body below the wick, the wick can volatilize fuel for combustion.

The cord placed in the holding space and the two jaws can hold the wick so that the wick's head end located in the burning area [6]. The user can adjust the clamping gap by compressing the clamper to control the size of the combustion flame. The use of metal mesh wick also removes the disadvantage of waste and burn out of cotton thread core.

In [7], an investigation systematically identify the parameters affecting the evaporation from and boiling within, thin capillary wicking structures. The experimental studies examined under steady-state conditions at atmospheric pressure with a range of volumetric porosities and mesh sizes. The investigation described the wicking fabrication process and experimental test facility and focused on the effects of the capillary wick thickness [7]. The upper corner of each channel provides capillary effects to facilitate transport of the liquid. A thinner wick can altogether make possible the fabrication of thin vapour chambers [8]. The impacts of wick thickness and wick porosity on the heat transfer coefficient [9] were also investigated (Fig. 2).

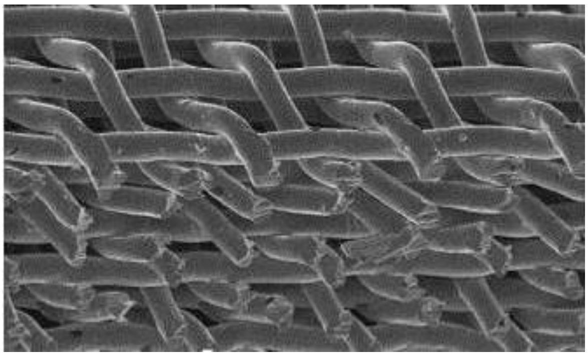

Fig. 2. Mesh structure and wick porosity [9], with evaporation resistances of 2 ×100 mesh at various heat fluxes.

We first place water droplets on the metal mesh. Since the metal mesh is quite fine, the water droplets will appear flat and adhere to the surface. The fine structure causes the surface tension to dominate the shape of the droplet. When you press water droplets on the metal net, a liquid film formed on the surface (Fig. 3). While you touch the backside of the net, the droplet quickly pass through the mesh and move downwards. Touching destroyed the surface tension (metal mesh is in close contact), so the liquid transferred through these adjacent grids.

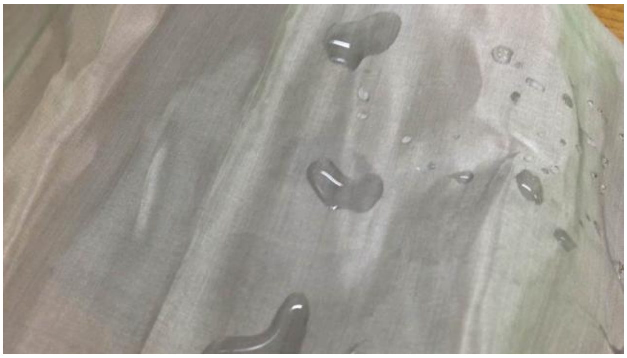

Fig. 3. Stainless steel in the tiny mesh

2.2. Water/diameter change

To observe the effect of surface tension on the metal mesh, we selected a metal mesh with a size of 10 cm and a width of 15 cm and wound the metal mesh into columns of different diameters. Therefore, when the diameter of the roll is large, the mesh is loose. When the diameter decreases, the gap between the mesh layers becomes tight. First, we place the roll column vertically into the water and recording the height of the water in the mesh roll at different times. There was a gradual increase in the liquid level over time (Fig. 4), but due to the lower viscosity coefficient of water, the elongation is relatively small.

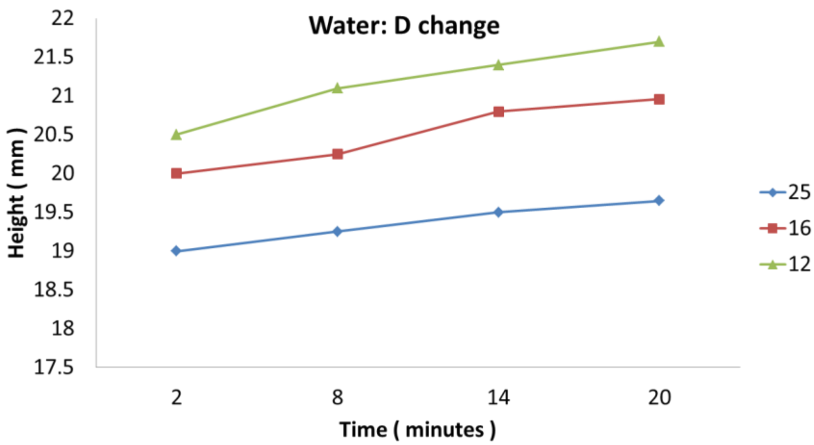

Fig. 4. Liquid height vs. time

2.3. Fuel / diameter 12mm

Second, we chose biofuel as the test liquid. We found that there was a significant increase in liquid level (then in water). Careful observation of the contact surface of the fuel with the metal mesh, the shape of the contact surface is slightly recessed downwards, which shows that the adhesion is lower than that of water (Fig. 5). The woven wick and cotton wicks are multilayer structures. The capillary phenomenon exists in this complex, curvature and 3D structure. Stainless mesh has its stiffness, deformation limit, and thread core content. A specific rolled from should provide effective capillary action (Fig. 6).

Fig. 5. Measurement setup of liquid biofuel

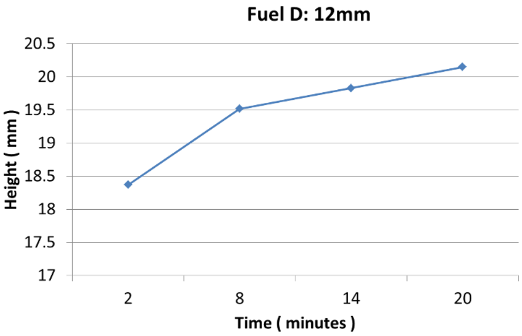

Fig. 6. Liquid fuel height vs. time of capillary phenomenon

3. Proposed Wick Structure

A wick configured from a single metallic meshed wick material continuously includes a spiral section with loops, folded section, helical section. With a second length extending from the fold to the spiral part, and a wrapped section with a shape including spiral and folded sections (Figure 7). The metallic meshed wick is curled about the imaginary axis to include the at least one loop in which the wick material is folded [10, 11]. The second length extending to the spiral part in which the meshed wick is wrapped to include the contour around the spiral and folded sections.

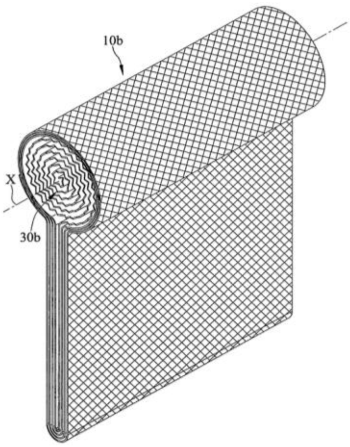

Fig. 7. Perspective view of a wick [10, 11]

4. Evaluations

4.1. Prototype and measurement

In this measurement, we evaluated the combustion flame. The 1:1 scale prototype model was built based on material and dimension in our design (Fig. 8). The engineer put the fuel into the storage space in the lower fuel container. The metal mesh extended from the top to the bottom of the fuel storage area. We use ignition device on mesh roll to start burning and found that the metal mesh can show a stable flame. When the wind blows, the flash can still be stable combustion.

The evaluation indicated that the grid structure and the liquid fuel could be steadily transmitted upward through the capillary action. Besides, we tested the carbon monoxide concentration during combustion, and we found that the proportion of carbon monoxide was low. This means that the metal grid was able to support complete combustion. While the oxygen content of the surrounding reduced to 17.4%, the flame automatically extinguished; at this moment only a small amount of CO accumulated in the enclosed space.

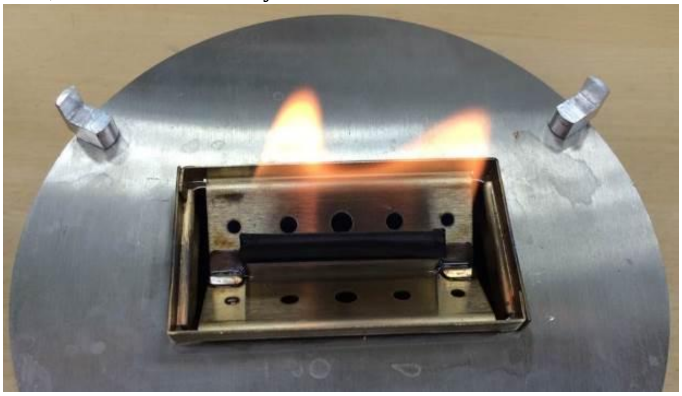

Fig. 8. Stable flame height with stainless steel wick

4.2. Discussion

Wicks in flame devices are used to maintain the flame scale or to evaporate non-combustible fuel. The oxygen combines with the fuel by diffusion. The wick uses the heat of the flame itself to vaporize its fuel and allows the oxygen diffuses into the flash from the surrounding air. The novel stainless steel wick design substantially improves the combustion efficiency and increase flame scale without compromising the combustion efficiency. The high thermal conductivity of the stainless steel mesh pre-heats the fuel which enables better oxidation. In many cases, stainless steel wick induced complete combustion.

The high porosity also enables the diffusion more effectively. We adjusted the wick's pores number, density, and surface area to exposure surrounding air. When flame scale increases, stronger convection is also created to carry the hot combustion products away. The mesh is non-consumable to high temperature in a semi-open chamber. As a result, it increases the surface area consequently provide better fuel evaporation and achieve complete combustion.

5. Conclusions

A new stainless steel flame wick was proposed and evaluated. A metallic wick configured from a single metallic meshed wick material continuously included a spiral section was recommended. By proper folding, the detail sections include loop, fold, extending part, and wrapped sections. The evaluations demonstrated stably burn. The temperature at the tip of the wick reached 900 degrees Celsius, so the fuel in the wick could approach completely burn. When the oxygen content reduced in a confined space, the flame will automatically extinguish. Only a small amount of CO accumulated in the enclosed space (far below the human hazard standard). The specific folding and routing of those meshes not only extended the lifetime of the wick but also reduced the possibility of carbon monoxide produced.

Conflict of Interest

The authors declare no conflict of interest.

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