Variable Diameter Umbrella

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Abstract
The umbrella market contains a vast array of designs, but all of these designs can be broken down into one of two categories. New umbrella designs are targeted towards either; 1. improving durability and function, or 2. making the umbrella more portable and easy to carry. Designing for portability often limits the strength and size of the umbrella, so most umbrella’s on the market end up either being larger and often more durable, or smaller and more portable. Various umbrella sizes are currently on the market and each one serves a unique purpose, but no one umbrella encompasses all functions of the various sizes. The umbrella will have a canopy that will be adjustable in size to encompass all umbrella uses, thereby increasing its functionality.

The scope of this project is to develop a multi-functional umbrella capable of adjusting to different canopy sizes. The umbrella will deploy in a similar fashion to current umbrella designs. Once deployed the umbrella utilizes telescopic ribs to expand to nearly double its original diameter.

Using a CAD model, the structure of the umbrella and canopy expanding mechanism were functionally validated. To produce a working prototype, a solution for canopy material storage must be reached and the design must be optimized based on force calculations.
The Need for Project

The umbrella market is a vast array of designs that target a single function. Most umbrella designs are purposed to serve a specific use and as a result users often end up owning more than one umbrella. Various umbrella sizes are currently on the market and each one serves a unique purpose, but no one umbrella encompasses all functions of the various sizes. The variable diameter umbrella will have a canopy that will be adjustable in size to encompass all umbrella uses, thereby increasing its functionality.

The Design Project Objectives and Requirements

The goal of this project is to design and optimize a variable diameter canopy umbrella.

Design Objectives
- Multiple points of adjustment achievable
- Canopy stores with no sagging

Design Requirements
The variable diameter umbrella must be able to open to its maximum diameter without sagging under its own weight. Adjustment of the canopy must not cause buckling in the actuation rods.

Design Concepts considered
The group considered an internally collapsing design, as well as a two-piece disposable design before settling on a variable diameter canopy design.

Several design concepts were considered and evaluated throughout the course of this project. Initial concepts were an internally collapsing umbrella and two-piece disposable umbrella. Through market and patent research the internally collapsing umbrella and the two-piece disposable umbrella were eliminated and the adjustable canopy umbrella was chosen.

Internally Collapsing Umbrella

The common umbrella is designed to collapse externally so that the umbrella canopy is exposed when the umbrella is in storage. The internally collapsing umbrella would collapse so that the ribs and canopy would store inside the handle. The handle would be cylindrical in shape and have a cap to contain the canopy and ribs while in storage. By having the umbrella store collapsed within this capped cylinder, the canopy would be protected from tearing and any residual water from use would be contained.
Two-Piece Disposable Umbrella

To make the umbrella more accessible and easy to have on hand at all times, a two-piece design was targeted. The design included a marker-sized handle, that would include the ribs, and an attachable canopy. If the umbrella was split into these two parts, it would be much easier to store and carry, and would allow for an array of possible canopies. Nylon canopies could be manufactured and sold, but if necessary, a newspaper could be attached as the canopy and would be able to protect the user in a pinch. For added functionality, the handle and ribs could easily allow the user to attach items readily found on the streets (e.g. newspaper, magazine) as the canopy.

Recommended Design Concept

The design incorporates a set of telescoping tubes which both support the canopy and allow for its extension.

1 Design Description

The chosen design incorporates a set of telescoping tubes which both support the canopy and allow for its extension. The innermost telescoping tube is attached to flexible plastic rods which run the entire length of the umbrella’s body. These flexible rods can be moved up and down the length of the umbrella by moving the base, to which they are attached, upwards and downwards. This movement pushes the telescoping tubes to which the flexible rods are attached outward thereby expanding the diameter of the canopy. Upon reaching the maximum travel of the telescoping tubes the base to which the flexible rods are attached can be affixed in place, allowing the umbrella to maintain its new diameter.

2 Analytical Investigations

The practicality of the movement of flexible tubes, the main mechanism which allows the design to function, needed to be determined. A mechanism which incorporates the movement of flexible tubes in order to push a material is not commonly used and a comparable existing mechanism does not exist. Analytical questions therefore were difficult to answer due to the exotic nature of this type of mechanism.

The question of whether or not this type of mechanism was mechanically possible was answered with a simple force analysis of a curved rod. It was determined that if an upwards force is applied to the bottom of a rod which is straight for a certain length and then
curved at the angle which this design will allow for (80°) then a lateral force will be applied thereby allowing the rod to apply a force to whatever is attached to its end.

3 Experimental Investigations

The design was first qualified by designing a fixture in which a set of telescoping tubes was inserted as a replacement for a standard support in a regular umbrella. The flexible actuating wire material used was .16dia nickel-titanium, or nitinol, and was chosen due to its high tensile strength, flexibility and resistance to buckling. This flexible wire was guided along the body of the umbrella using a guide ring affixed to the body.

Due to the high price of nitinol (>30 per ft.) a less exotic material needed to be selected in order to constrain the cost of the prototype. It is known that some plastic rods manage to be flexible but still strong enough to withstand the amount of tensile strain the design would put them under. Polyethylene terephthalate was chosen due to its relative lightweight characteristics and low price. Since the PETG rods need to be flexible but still resistant to buckling a thicker rod of .25”dia was selected. This plastic rod setup was placed in the original test fixture and proved to function in the expected manner.

4 Key Advantages of Recommended Concept

The recommended concept uses a mechanism that is both easy to conceptualize and execute. The design is simple in the sense that there is only two moving parts – the flexible plastic rod and the telescoping tube it’s attached to – and that there are fewer supports than a regular umbrella. The ability to use fewer supports than a standard umbrella comes from the fact that the telescoping tubes act as supports for the canopy. Since these tubes are relatively large (3/8”dia) fewer of them are required in order to give the umbrella the strength and stiffness needed to support itself. Our design incorporates just 5 of these supports whereas a standard umbrella contains 8 or more.

Financial Issues

This product is intended to be
mass produced at a cost similar to that of high-end golf umbrellas ($\leq 80$).

mainly constructed out of ABS and PETG plastic. Both of these materials are inexpensive to produce and machine. Manufacturing costs therefore should not be prohibitively expensive in a mass-production scenario. Due to the exotic nature of this type of product the sale price can be higher than that of a standard umbrella but not more expensive than what would be considered a “luxury” ($> 80$) umbrella since the construction materials are not considered to be high-end.

**Recommended Improvements**

The reduction in size of the PETG rods will reduce the overall size, weight and cost of the umbrella.

One of the potential improvements that can be made is relocating the pre-tensioning spring to the bottom of the outer shaft from its current position above it. This would allow the umbrella to literally spring open when the button is pushed therefore would act more like a standard umbrella. This would give our design the advantage of operating more similarly to a regular umbrella and therefore have less of a learning curve to use.

Another improvement that can be made is a downsizing of the PETG rods used to actuate the telescoping tubes. Since the size of the PETG rods is the current determining factor in the ultimate diameter of the outside shaft of the umbrella if their size can be reduced than the overall size, weight and cost of the umbrella can be reduced.