

PERSONAL RAIN PROTECTION DEVICE FOR PEDESTRIAN

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Dedicated to my family and friends.

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ABSTRACT

At present, the umbrella has established itself as a primary rain protection device and used by all as general everyday item. However, despite years of evolution and being widely accepted, the classic umbrella design still suffers from several design flaws. Hence, the objective of the present study is to design a new rain protection design for pedestrian which can possibly maintain the attractive features and address the shortcomings of classic umbrella. Areas for improvement in classic umbrella are identified through literatures review and interviews from users. Five users were interviewed and their feedback is analyzed to produce a User Persona. Based on the findings from literatures and interviews, a Product Design Specification (PDS) is established with over 16 design requirements defined ranging from Performance, Maintenance, Safety and so forth. Four concept designs are developed with respect to the PDS and based on the Scoring Matrix, Concept 1 (which scores the highest) is selected. Detailed design is performed based on Concept 1 where the each component are modeled in detail using CAD software and their dimensions, materials and weights are defined accordingly. Design for Manufacturing Analysis (DFMA) – Functional Analysis is performed with the established detail design and the design efficiency is computed to be 50 percent. Failure Mode Effect Analysis (FMEA) is performed and sleeve misalignment has been identified as the prominent potential cause of failure with highest Risk Priority Number (RPN). Finite Element Analysis (FEA) has been performed using ABAQUS software package in terms of structural analysis and two conditions were analyzed i.e. Extreme Condition (Heavy rain and strong wind) and Moderate Condition (moderate rain and wind). Based on the displacement result, it can be seen that design is experiencing large deflection i.e. 94cm at extreme condition which makes the design not practical in extreme condition. Consequently, the internal loads are extracted only for moderate conditions and the stress check result (based on manual calculation using MathCAD software package) indicates that the design can withstand the loads satisfactorily.

ABSTRAK

Pada masa kini, payung sudah menjadi alat utama yang digunakan oleh semua setiap hari untuk melindungi diri daripada hujan. Namun demikian, tidak boleh dinafikan bahawa payung masih mempunyai kekurangan dari segi rekaan. Maka, objektif kajian ini adalah untuk mencipta satu alat perlindungan hujan baru yang dapat mengekalkan ciri-ciri baik dan membetulkan kekurangan yang didapati pada payung. Ciri-ciri penambahbaikan pada payung disiasat melalui bacaan sumber buku and temubual dengan pengguna. Lima pengguna telah ditemubual and jawapan mereka digunakan untuk mencipta satu persona. Melalui hasil daripada pembacaan and temubual, satu produk spesifikasi yang merangkumi 16 keperluan rekaan telah dibentuk. Empat konsep rekaan dibangunkan selaras dengan spesifikasi, dan berpandukan pada jadual markah, Konsep 1 yang mendapat markah tertinggi telah dipilih. Rekaan terperinci diteruskan dengan Konsep 1 di mana setiap komponen dimodelkan dengan terperinci dengan perisian computer CAD dan saiz, barang buatan and berat ditentukan. Analisis kejuruteraan “Design for Manufacturing Analysis (DFMA-Functional Analysis)” mendapati bahawa efisiensi rekaan adalah sebanyak 50 peratus. Analisis kejuruteraan “Failure Mode Effect Analysis (FMEA)” mendapati bahawa ketidakserasian “sleeve” sebagai punca utama kegagalan dengan mencatat “Risk Priority Number (RPN)” yang tertinggi. Analisis kejuruteraan “Finite Element Analysis (FEA)” dijalankan pada 2 keadaan iaitu Keadaan Ekstrim (hujan lebat and angin kuat) dan Keadaan Sederhana (hujan dan angin sederhana). Berdasarkan pada keputusan anjakan, boleh disimpulkan bahawa rekaan ini adalah tidak sesuai untuk Keadaan Ekstrim disebabkan oleh anjakan yang terlampau besar iaitu 94cm. Oleh yang demikian, daya dalaman hanya diextrak untuk Keadaan Sederhana dan pemeriksaan stress (melalui pengiraan manual menggunakan perisian computer MathCAD) mendapati bahawa rekaan ini dapat menangani daya tersebut dengan jaya.

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LIST OF SYMBOLS / ABBREVIATIONS

α	-	Wind driven raindrop angle
ρ	-	Air density
A	-	Cross Sectional Area of Raindrop
A_xF	-	Axial Force
$BM1$	-	Bending moment in axis-1
$BM2$	-	Bending moment in axis-2
C	-	Drag Coefficient
$DFMA$	-	Design For Manufacturing Analysis
F_{air}	-	Air resistance acting on raindrop
$F_{gravity}$	-	Gravitational force of raindrop
FEA	-	Finite Element Analysis
$FMEA$	-	Failure Mode Effect Analysis
g	-	Gravity (acceleration)
m	-	Mass of raindrop
P_{rain}	-	Raindrop Impact Load
P_{wind}	-	Wind Load
PDS	-	Product Design Specification
$Sh1$	-	Shear force in axis-1
$Sh2$	-	Shear force in axis-2
T	-	Torsion
TP_{rain}	-	Total Raindrop Impact Load
V_x	-	Wind velocity
V_z	-	Raindrop terminal velocity
V_r	-	Raindrop resultant velocity

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The umbrella design has been around since 4000 years ago [1]. From an icon of wealth to an everyday item, the umbrella has been a significant equipment in human history since its founding. Originally intended to protect a person from sun, the umbrella later evolved and popularized as rain protection device. Furthermore, it was classified and perceived as a women accessory until 18th century when a gentleman named Jonas Hanway started to popularize its use among men [2][3]. At present, the umbrella has established itself as the primary rain protection device used by all as a general everyday item.

Although the umbrella has evolved over the years in terms of its built material, function, size and etc., but the main stick and canopy design of the umbrella has remain unchanged since its birth. The classic design, though is commendable in many aspects, is not free from design flaws and has room for improvements. To start with, the classic design does not provide adequate protection from the rain where user can still get wet despite using an umbrella, probably because the umbrella was not designed for rain protection in the first place. Secondly, the classic umbrella design tends to fold inside out in strong winds leaving users exposed to rain. From safety point of view, the classic umbrella design which has pointed tips of wire poses risk of poking someone's eye in

the surrounding which makes it not suitable in crowded place. Besides, the design is criticized every now and then as not appealing to male users, which is comprehensible given the fact it initially exists as a women accessory.

Many innovators in recent years have shown great interest to challenge and improve the classic umbrella design. An innovative design has been introduced by Taiwanese designers, called the Rain Shield [4]. The design eliminates the complicated shaft and rib structures of a classic umbrella by using a single curved steel wire, which results in several notable improvements such as no risk of poking passerby or umbrella turning inside out [4]. Aerodynamic Senz Umbrella, is a design by three students where the umbrella is shaped aerodynamically to cut through the wind [5]. The umbrella is reported to be able to withstand wind speed up to 100 km/h [6]. The Rain Shader is an innovative concept from a UK umbrella company where the ribs are pointed down rather than out to avoid poking passerby in crowded places, hence makes the rain shader perfect for sport spectators [7]. Another notable innovation is the KAZbrella. KAZbrella is the patented “inside-out umbrella” designed by Jenan Kazim, an aeronautical engineer [8]. The design has revolutionized the way umbrella opens and closes, where the top of the umbrella (wetside) is enclosed when the umbrella is fold upwards to collapse, leaving dry canopy on the outside to handle [9].

Despite many interesting new innovations and creations as mentioned, the classic umbrella is still leading as the primary rain protection device in market. This is probably because the new innovations failed to maintain the desirable aspect of the classic umbrella, though they managed to solve the shortcomings. Hence, the search for an efficient rain protection device which also fares well with the users is still ongoing.

1.2 **Problem Statement**

Umbrella, being the widely used rain protection device among working professional is commonly criticized for not providing adequate protection from rain, not practical in moderate and strong wind (easily turned inside out leaving user exposed to rain), exhibit risk of poking passerby and design not appealing for male users. A design that can solve the mentioned shortcomings while still maintaining the attractive feature of umbrella is welcomed.

1.3 **Objective**

To design a personal rain protection device for pedestrian.

1.4 **Scope of Study**

1. Produce a persona of the user
2. Study the drawbacks and areas for improvement of the existing umbrella designs in the market.
3. Establish a Product Design Specification (PDS).
4. Develop conceptual design and perform final design selection using scoring matrix.
5. Perform engineering analysis i.e FMEA & DFMA and other necessary engineering calculations.

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