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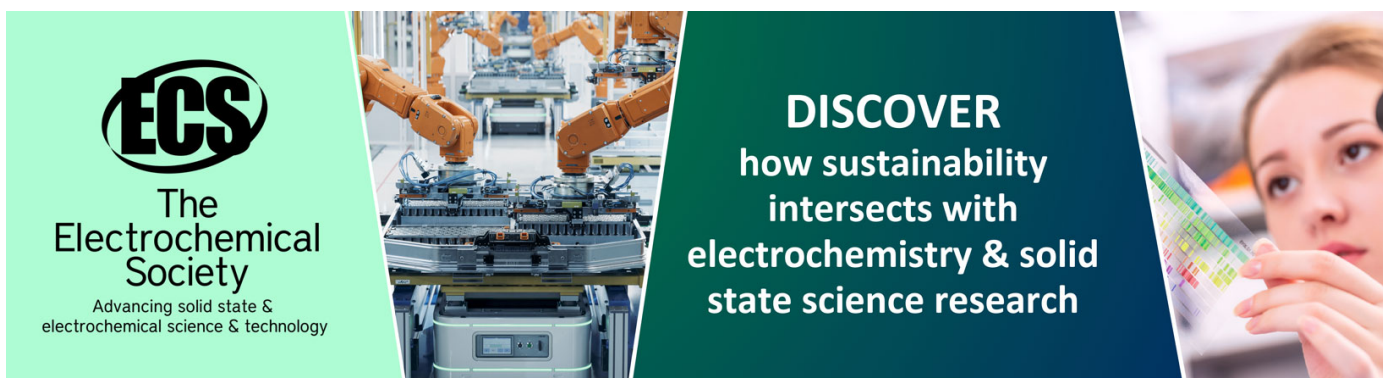
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Design analysis of suitcase stabilizer and zipper protector

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Abstract. In recent years we have seen a major shift and trend to the use of four-wheeled suitcase with the reason of easiness to manage and perhaps a better balance. Unlike four-wheeled suitcase with single storage platform with the edge opening models which provide rolling stability and comfort handling, four-wheeled suitcase with splitting storage platforms with the middle opening models is often given rolling instability and less comfort handling because the underside sometimes is uneven position and affects the movement of the wheels. Pushing beside and pulling behind a suitcase with rolling wheels instability over a long period of time can induce musculoskeletal disorders. Through the analysis of existing suitcase designs, the questionnaire was used to collect customer voice data from a random sample of 126 respondents. After that, a research was conducted to design products and simulate tensile strengths for several types of materials. Here, silicone is the best option for material of the product.

Keywords: suitcase stabilizer, zipper protector, manoeuvring

1. Introduction

Referring to Indonesian official government statistics, the number of domestic tourist trips from 2015 to 2018 continues to increase [1]. This increase occurred due to improved economic conditions, easier access to tourist destinations and better tourism infrastructure facilities. It seems that tourism has become a necessity for the people of Indonesia (see Table 1). In carrying out the trip, travelers need an ergonomic suitcase to provide comfort and safety to their belongings. The functionality of suitcase should be innovated and improved in order to adapt to the diversity of today's travel environment. The number of wheels is an important factor in choosing a suitcase. A suitcase with two wheels (rollers) is usually more durable and reliable when it has to be dragged on a surface that is not smooth, such as sidewalks or uneven roads.

The drawback, this suitcase is rather troublesome if we have to carry another bag. In addition, pulling a roller suitcase can also put pressure on the joints and cause injury to the shoulder. On the other side, a suitcase with four wheels (spinner) makes it easier to move when we have to carry other items, such as backpacks or handbags. However, this spinner suitcase might stall when carried on a non-smooth surface, so for its use it must be pulled like an ordinary roller suitcase. When choosing a suitcase, it is important to try handling the suitcase. In addition, for knowing whether the handle can be pulled easily, also to ensure that the length of the handle matches our height and the movement of the wheels give rolling stability.



Table 1. Number of Domestic Tourist Travels in Indonesia [1]

Province	Number of Nusantara Tourist Travels (Person)			
	2015	2016	2017	2018
ACEH	3,023,768	4,306,217	4,410,969	6,518,831
SUMATERA UTARA	9,464,756	9,398,998	9,364,706	10,345,256
SUMATERA BARAT	5,022,693	5,019,290	5,483,028	6,402,187
RIAU	5,517,516	5,076,197	5,149,936	5,552,920
JAMBI	2,019,636	1,774,454	1,906,593	2,242,802
SUMATERA SELATAN	5,039,369	5,807,205	5,948,669	6,137,095
BENGKULU	2,405,938	1,922,418	1,950,249	2,018,556
LAMPUNG	6,193,525	6,153,283	6,002,487	6,881,006
KEP. BANGKA BELITUNG	2,468,705	3,162,558	3,831,465	5,197,635
KEP. RIAU	2,279,310	3,077,543	3,805,645	4,611,718
DKI JAKARTA	24,134,824	24,046,943	24,840,040	24,967,080
JAWA BARAT	44,397,263	43,619,718	43,779,162	53,203,387
JAWA TENGAH	38,976,233	40,120,408	41,182,591	43,110,598
DI YOGYAKARTA	6,331,609	6,436,655	6,498,739	7,858,137
JAWA TIMUR	40,738,635	43,207,169	43,689,273	53,244,287
BANTEN	9,383,584	9,514,226	9,551,703	13,275,125
BALI	8,316,585	8,465,669	8,143,614	6,621,617
NUSA TENGGARA BARAT	2,723,653	3,002,461	4,134,434	3,192,581
NUSA TENGGARA TIMUR	2,738,457	2,710,541	2,856,531	2,947,381
KALIMANTAN BARAT	2,987,871	2,944,441	2,996,380	3,257,024
KALIMANTAN TENGAH	2,356,531	2,362,315	2,398,510	2,745,542
KALIMANTAN SELATAN	3,450,676	4,271,433	4,300,487	4,520,927
KALIMANTAN TIMUR	3,849,431	3,132,595	3,205,261	2,613,107
KALIMANTAN UTARA	-	708,804	728,373	634,477
SULAWESI UTARA	2,635,068	2,722,230	2,759,200	4,313,069
SULAWESI TENGAH	3,235,758	3,392,641	3,427,266	2,260,800
SULAWESI SELATAN	859,079	8,692,154	8,812,173	9,616,232
SULAWESI TENGGARA	2,914,213	2,968,941	2,963,742	3,370,736
GORONTALO	829,411	1,222,232	1,206,547	938,557
SULAWESI BARAT	1,832,600	2,133,152	2,119,320	941,944
MALUKU	813,905	830,921	863,592	1,206,288
MALUKU UTARA	396,047	491,531	513,206	615,624
PAPUA BARAT	499,017	601,517	581,002	686,836
PAPUA	847,340	1,040,658	1,117,110	1,354,526
INDONESIA	256,419,006	264,337,518	270,822,003	303,403,888

The first commercially successful rolling suitcase was invented in 1970, when Bernard D. Sadow applied for a patent that was granted in 1972 as United States patent 3,653,474 for "Rolling Luggage". But Mr. Sadow's suitcase was ultimately supplanted by a more popular innovation, the now ubiquitous Rollaboard and its imitators. The Rollaboard was invented in 1987 by Robert Plath, a Northwest Airlines 747 pilot and avid home workshop tinkerer, who affixed two wheels and a long handle to suitcases that

rolled upright [2]. In addition, common suitcase materials such as wood, leather, aluminium, polycarbonate, polypropylene and plastic are products of their time while the theme is also being simplified related to better transportation technology.

In recent years we have seen a major shift and trend to the use of 4-wheeled suitcase due to a better balance and easiness to manoeuvre and manage, particularly if we bring more than one luggage on the trips. It required much less effort to 'wheel', as it can rolling along beside us rather than being dragged [3]. Generally, the four-wheeled suitcase is divided into two platform designs which consist of a single storage platform with the edge opening model and a splitting storage platform with the middle opening model. Unlike four-wheeled suitcase with single storage platform which provide rolling stability and comfort handling, four-wheeled suitcase with splitting storage platforms is often given rolling instability and less comfort handling because the underside sometimes is uneven position and affects the movement of the wheels which are generally in line with the average walking speed of individual pedestrian at around 1.5 m/s for normal and 1.8 m/s for fast walking condition.

The luggage was found to have little impact on individual walking speed, while subjective control on speed influenced a lot [4]. A suitcase or trolley can exhibit undamped rocking oscillations from one wheel to the other when pulled fast enough. When unstable, the suitcase either increasingly rocks until overturning or reaches a stable limit cycle. The friction force at the rolling wheels constrains wheels to roll without slipping. This constraint imposes a coupling between the translational motion and the three-dimensional rotational motion of the suitcase that drives the rocking instability [5]. Pushing and pulling of a suitcase with instability handling can induce musculoskeletal disorders due to hand forces for manoeuvre which leads to increased muscle tension caused of difference in motion direction of the wheels, roller friction and floor resistance.

The airline and the baggage industry have very different views about which party must be responsible for registered baggage damaged during transportation. The problem is compounded by the fact that there are currently no definitions or standards that apply to airline compatible luggage. While much attention has been given to the carry-on baggage issue, many feel that the problems surrounding checked baggage are at the heart of the matter [6]. In this case, the main suitcase zipper is often used as a loophole in the content burglary of passenger luggage in airplane baggage, giving rise to misgivings that bothers the passengers and reducing comfort during travel. This issue also helped encourage this research.

Research on suitcase stabilizers and zipper protectors begins with a personal travel experience when pushing a four-wheeled suitcase with a splitting storage platform and middle opening model that rolls up the wheel with instability and makes the arms stiff. It turns out that other consumers have also complained about the same experience through their articles on the internet. With splitting platform design, the weight of the suitcase on the underside is put together and only depends on the strength of the zipper. The method of packaging belongings must also consider the weight distribution between two splitting platforms because it will affect whether or not the underside flattens which will certainly affect the position of the wheels on each platform and impact on the ease of handling and maneuvering of the suitcase.

Therefore it is necessary to do engineering that produces an equipment with ergonomic function design that can provide additional strength to the zipper on the middle side as a load joiner between two platforms while ensuring that the underside of the suitcase can be set flatted so the whole loads can be equally distributed on all four wheels ensuring ease of movement. In addition, the number of cases related to flight baggage theft by breaking into zippers also helped encourage this research. It would be nice if the main zipper of the suitcase can get an additional cover as well as protection to minimize burglary through zippers. This is because it relates to the comfort and safety of four-wheels suitcase users, so it is important to pay attention.

2. Materials and methods

There were 2 methods used in the research, questionnaire and simulation. Questionnaires were used to know how the customer response to this product. Data collection to support the solution through a

questionnaire was distributed to 126 respondents who had experience in using a four-wheels suitcase with a middle opening model. Then the data is processed refers to the science of ergonomics and human factor engineering based on the literature that has been done before through the journals, articles, books, and websites. Data processing and analysis is continued by making conclusions based on the problem statement, side stress simulation analysis and make suggestions of important design factors to the four-wheeled suitcase manufacturers and users.

Next is to perform tensile test simulation, in order to find out the suitable material for this product. Simulation is performed by treating material with various force to certain parameter. We choose four material that common usage in manufacturing industry: rubber, polycarbonate, PVC and silicon. Next stage is to perform calculation simulation by using excel and analyze impact of strain against various force treatment.

Formula of tensile strength test [12] is shown below:

$$\text{Stress } (\sigma) = \frac{F}{A} \quad (1)$$

Where σ = stress (N/m²), F = force (N), A = cross-sectional (m²)

$$\text{Strain } (e) = \frac{\Delta L}{L} \quad (2)$$

Where e = strain, ΔL = delta length (m), L = length (m)

$$\text{Modulus Young } (E) = \frac{\sigma}{e} \quad (3)$$

Where, E = Modulus Young (N/m²), σ = stress (N/m²), e = strain

Simulation is performed by manipulating forces from 50N-100N and analyze the impact of ΔL , shown by formula below:

$$E = \frac{F/A}{\Delta L/L} \quad (4)$$

$$\Delta L = \frac{F \times L}{E \times A} \quad (5)$$

3. Result and discussion

The results and discussion of the research are discussed directly by the statement of the problem regarding a four-wheel suitcase with middle opening model which is currently becoming a trend and is widely used by many people because of its lightweight and affordable price. Through existing design analysis, this suitcase model has relatively large room for improvement.

Here, we have distributed questionnaires to 126 respondents, in which 71.24% feedback came from colleagues in the oil and gas industry who travelled out of province regularly, another 6.34% came from expatriates working partner in the information technology industry, and the 22.22% remaining comes from local employees whose routine travelling out of the town. Based on results of the questionnaire, the following data were obtained, as seen in Figure 1.

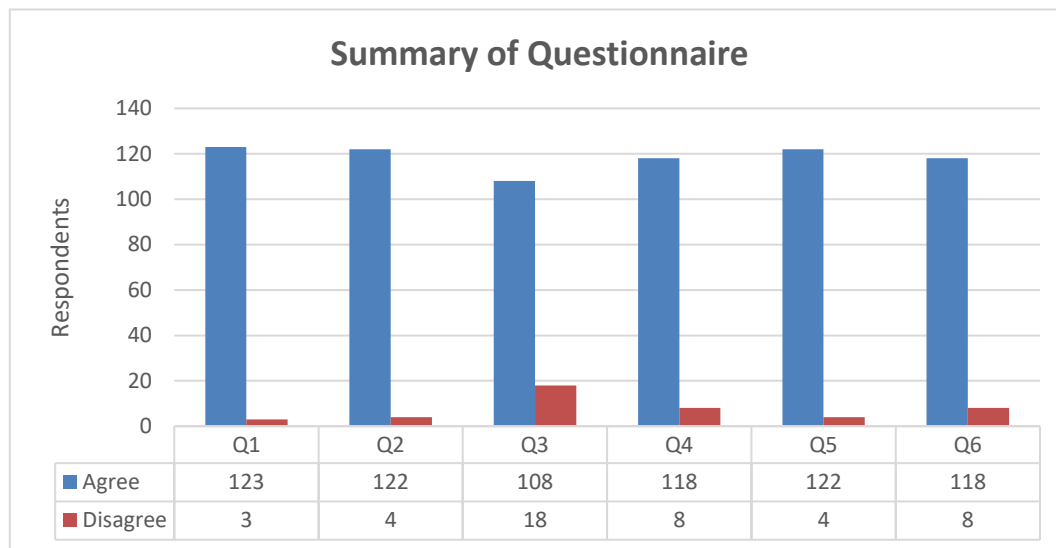


Figure 1. Graph of Questionnaire Summary by 126 Respondents

There are 96.8% of respondents who declared to have a four-wheeled suitcase with a middle opening model (Q1). As many as 96.8% of respondents chose this type of suitcase because of its affordable price (Q2) and 84.9% of them added criteria that the model was becoming a trend (Q3). Furthermore, 93.7% of respondents expressed their concern about the rolling wheels stability (Q4), while 96.8% paid attention to the level of security in the use of zippers which often became a loophole for baggage theft (Q5). In fact, 93.7% of respondents are interested in buying additional equipment that can improve handling stability when pushing the four-wheeled suitcase and increase security on the side of the zipper as its main opening system (Q6).

The current trend of four-wheeled suitcase is designed with lightweight material and a hard-structural body with various colours and shapes, most of which are dominated by middle opening model that use zipper as a locking system, making them more affordable. The variety of colours is integrated into the suitcase design to show the feminine or masculine style according to the personal nature of the owner. The adjustable handle is allowed for users of different heights to be able to move the heavy load easier and more efficiently. By using a four-wheeled suitcase, it allows pushing beside that gives smooth rolling over various surfaces and better manoeuvrability through small spaces and aisles as well as pulling behind like a two-wheeled suitcase with a 360 ° turning radius [7].

Figure 2 shows four-wheeled suitcase with middle opening model. With splitting platform design, the weight on the underside of a four-wheeled suitcase with middle opening model is put together and only depends on the strength of the zipper. Many cases are found where the underside of the suitcase is often unflattens, so it affects the wheel position. This may occur because of robustness limitations of zipper clamping especially if the suitcase is often filled with unequal loads between two sides of the splitting platform on which the belongings are packed. In this case, unflatten underside of the suitcase causes each of wheel goes wild undirected so that it more difficult to handle. Pushing beside and pulling behind a suitcase with rolling wheels instability can induce musculoskeletal disorders due to hand forces for maneuver which leads to increased muscle tension caused of difference in motion direction of the wheels, roller friction and floor resistance. If this happens many times and in a long period, then it can cause physical injury that can be chronic.

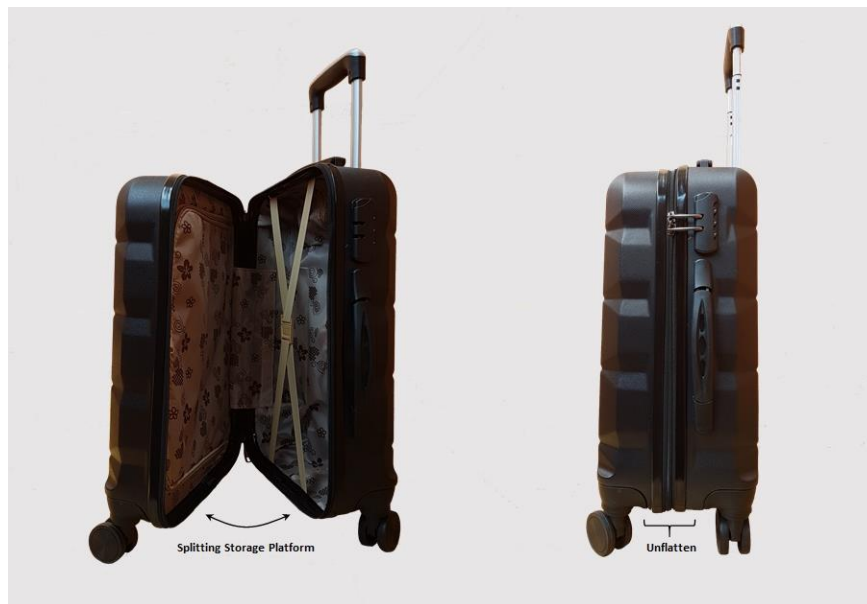


Figure 2. A Four-Wheeled Suitcase with Middle Opening Model.
(a). A Splitting Platform Design, (b). Unflatten Underside

To solve the rolling instability issue of a four-wheeled suitcase with middle opening model, then we performed an analysis of the existing design and provided increased strength around the main opening zippers through the addition of equipment made from selected material that meet the simulation at a later stage. By design, this additional equipment has a width of 4.5 cm and a length in accordance with the size of a suitcase available on the market, such as 192 cm for a size of 20 inches. As a hook at both ends side, it used material made of a mixture of quality plastic coated steel which can be locked. Furthermore, it complements with a suitcase lock cover box made of quality plastic with a length of 9 cm, 9 cm wide and 2.2 cm high, which can be set its position. The name tags can be added on the upper side of this box as well as a luminous reflector for safeness when the suitcase owner walks in a place with lack lighting. The design is presented in Figure 3.

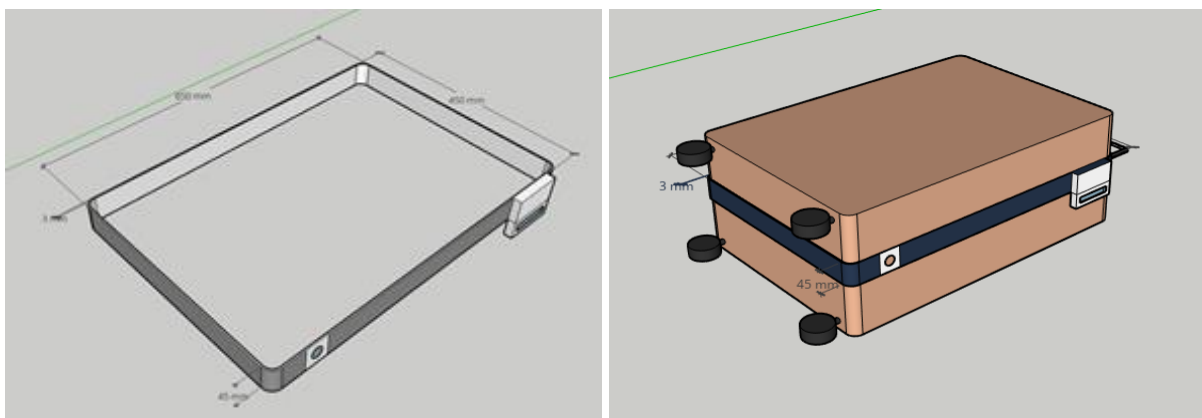


Figure 3. Design of Suitcase Stabilizer & Zipper Protector: Detached and Attached on a Suitcase.

In case to study the strength for the proposed design, tensile strength test is used to simulate the certain material that is suitable for this product. The purpose is to find out the material that have properties: rigid and stable. For the simulation result, the evaluation was conducted for four materials that common usage in manufacturing industry. Those material is rubber, polycarbonate, PVC and Silicon. Tensile strength simulation is done by using functions of Microsoft Excel that manipulate some force treatments on the material, followed by analyzing the impact of force treatment to delta length of the material. Next is to set other parameters for controlling each material, in which each material has the same cross-sectional area at about 135 mm² and a length of 450 mm. Here, the materials properties are shown on the Table 2.

Table 2. Materials Properties of Rubber, PVC, Silicon, and Polycarbonate [12]

Material	Modulus Young E / GPa	Yield strength σ_y / MNm ⁻²	Tensile strength σ_{ts} / MNm ⁻²
Rubber	0.01 - 0.1	-	30
PVC	0.2 – 0.8	45 - 48	-
Silicon	107	-	-
Polycarbonate	2.6	55	60

Based on the simulation result, after treating materials with various forces from 50N - 100N, there is a difference in impact of strain occurring on each material. The most impact comes from rubber. Delta L (strain) of rubber is 1.67 mm for 50N force and 3.33 mm for 100N force. The less impact comes from silicon. The strain of silicon is 0.0009 mm for 50N and 0.0018 for 100N. Polycarbonate and PVC are between those two materials. It is found that silicon is the best material for this product because it gets less strain. It shows if silicon has a rigid and stable composition so that it is suitable with the purpose of this product.

Furthermore, the characteristics of a rigid and stable material such as silicon on this additional equipment will provide high security impact to the suitcase where the main zipper protected by it would close a loophole in the content burglary of passenger luggage in airplane baggage, providing a sense of freedom from psychological stress due to loss of belongings. Figure 4 shows tensile strength simulation result by several types material.

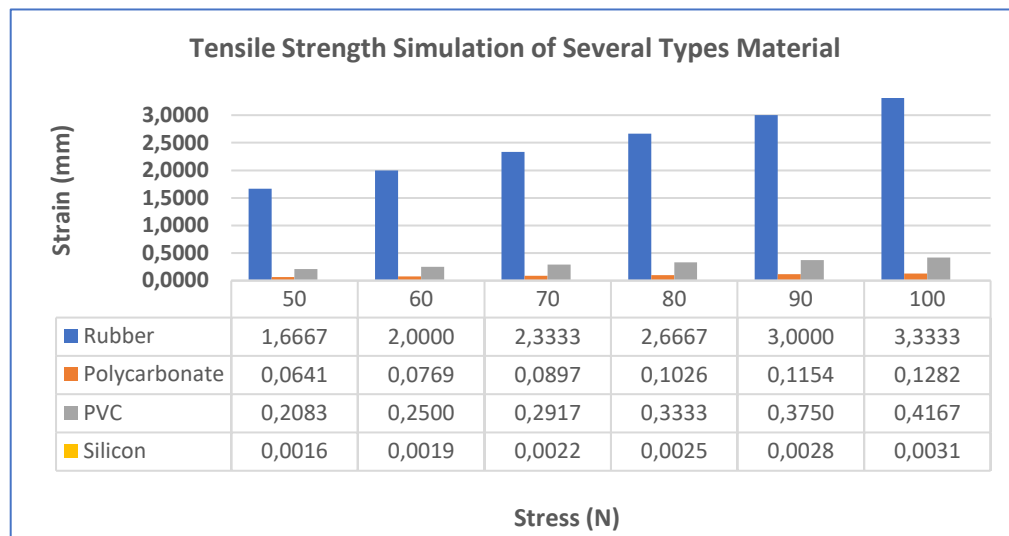


Figure 4. Graph of Tensile Strength Simulation Result by Several Types Material

4. Conclusion

The current trend of four-wheeled suitcases dominated by the middle opening model that uses zippers as a locking system needs improvement as indicated by the questionnaire data. This type of suitcase often causes rolling instability and uncomfortable handling which can cause musculoskeletal disorders. To overcome this problem, existing design analysis is carried out with applying material selection methods and gives a solution by providing increased strength around the main zipper opening through the addition of equipment made of selected material that meet tensile simulations, namely silicon. The characteristics of rigid and stable materials such as silicon provides additional protection to minimize theft through zippers. Thus, this ergonomic solution could minimize insurance and hospitalization costs by increasing safety, giving a feeling of freedom from psychological stress and increasing the welfare of all suitcase users. In addition, this solution also provides an important design factor for the suitcase manufacturers.

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