User-Centred Design Approach in Designing Motorcycle Tire Dismounting Tool for One-Handed User

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***Abstract*— User-Centred Design (UCD) is an approach which aims to improve the management of user requirements in the product development process. The main aim of this approach is to incorporate the users into the product development process in very early phase, as to obtain direct requirements and immediate feedback from them. This paper presents the integration of prescriptive model of product development process and UCD within a practical environment. The integrated process was tested in one case study – the development of a motorcycle tire dismounting tool. Product testing and interview survey was conducted to collect feedback from the users. All the three evaluation criteria (efficiency, comfortability, safety) scored a positive feedback from the users for the designed tool relative to the existing tool. The result indicates that an integration of UCD in the product development process had enhanced the establishment of user requirements in the product.**

Keyword-User-Centred Design, one-handed user, Motorcycle tire, design approach

I. Introduction

The User-Centred design (UCD) approach is a model in which human factors are of central concern within the design process. This design approach connects user requirements, user goals, and user tasks as early as possible into the design of a system, when the design is still relatively flexible and when changes can be made at less cost [1]. UCD is aimed to guide the design and development of products and widely practiced in a range of industries, particularly in those with a strong end-user focus such as consumer products [2]. UCD emphasizes on products usability and understandablity [3].Usability is defined as the “extent to which a product can be used by a specified user to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of uses” [4]. Meanwhile, Rubin [5] defines usability as usefulness, effectiveness, learnability and likeability. According to ISO 13407, there are four design activities in UCD: Requirements gathering, requirement specification, design and evaluation. UCD is an iterative process as design and evaluation steps are built in from the first stage of projects, through implementation.

The essence of the UCD approach is that it provides a structure to assist the developer to assuring that relevant design issues have been considered in a user oriented manner. Mayhew [6] outline four steps in UCD approach which are: 1) Problem definition is where design engineer will identify a problem and begin to conceptualize a potential solution (e.g. a product or service); 2) Developing a detailed specification for product i.e. what should be implemented; 3) Building the product follows the specification process and; 4) evaluating the usability of product. Based on the result of survey carried out by [7] UCD had improved the usefulness and usability of product. In this project, a new motorcycle tire dismounting tool is developed to replace the existing tool in order to be used by one-handed user while improving the usefulness and usability of the tool. User requirements were captured and translated into product design specification. Based on the design specification, UCD approach was applied in the development of motorcycle tire dismounting tool. Four (4) main phases were involved during the development of process which is: planning, conceptual design, embodiment design and prototyping phase using the mentioned approach. Three (3) new concept designs of tool were produced at the end of the development process and the best concept design was selected based on the design specification with thorough involvement of user.

II. Tool and Motorcycle Tire Dismounting Process

An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it. Dismounting motorcycle tire is often carried out by motorcycle mechanic as well as an individual as they want to replace deflated tire. This task is carried out manually using two steel levers with different shape of tip at both ends as in Fig. 1. The tool is used in squatting position. The tool is forged in single piece to shape from low carbon steel with 270 mm length, 23 mm width and 6mm thick. Both end of the tool is smaller and thinner. At the one end the tool is bent 30° upward and in the opposite end the tool is bent 15° downward. The upward bend is used for dismounting and the downward bend is used for mounting the tire.

Fig. 1 Steel lever used to mount and dismount motorcycle tire

For operation, the tire will be laid on the floor and the first steel lever will be slot in at one spot then the lever will be pressed to loosen the tire from the rim. This level will be hold at this position as another lever is used to pull out the tire at another spot around the circumference of the rim. This is to ensure the tire does not return to its initial position. Fig. 2 illustrates the motorcycle tire dismounting process in practice. In general the dismounting operation takes around few minutes to complete, depend on the skill of an individual. This tool demands two handed user to operate it by default.

Fig. 2 Current practice of the motorcycle tire dismounting process

III. A REQUIREMENT TO DESIGN PRODUCT FOR ONE-HANDED USER

A majority of existing products are designed without the consideration of one-handed users. Most products demand two hands to operate by default. This situation unintentionally denies access to a certain segment of users [8]. According to the World Health Organisation (WHO), 7% of the populations of all countries suffer from disability. In Malaysia, the statistics revealed by the Department of Social Welfare shows that the registered numbers of disabled people is 197,517 [9]. The types of disabilities include; 1) visually impairment, 2) hearing impairment, 3) physical handicap, 4) Mental impairment, 5) Learning disability, 6) Cerebral palsy and 7) miscellaneous. Among these types of disabilities, physical handicap is the second highest, at 66,250. According to the International Labour Organisation (ILO), the right to training, employment and job development for disable people is often overlooked [10]. To help disabled people be self-reliant in society, the Department of Social Welfare in Malaysia has provided economic assistance by purchasing items manufactured by the disabled, and various types of activities have been devised to respond to their needs in ways that facilitate participation in society. In cases where transport is needed, i.e. wheelchair, the department also provides facilities (subsidy to) to be purchased [9]. Noraini et al. [11] study job opportunities for disabled people in Malaysia and aim to find job opportunities for disabled people in Malaysia. They found that the majority of disabled people (67.96%, 507 people) work in non-professional (skilled) jobs, and 41.22% (209 people) of them are physically handicapped. They also found that opportunities for disabled people with physical handicaps to work in professional, semi-professional and non-professional non-skilled sectors is low, 2.3%, 2.7% and 7% respectively. In the context of Malaysia, ex-Prime Minister Dr. Mahathir Mohammed announced that a more aggressive effort should be implemented to ensure that the 1% allocation for employment of the handicapped in the public sector was achieved and that the private sector should emulate this (News Straits Times 13 January 1990 in Noraini et al. [11]. Ahmed et al. [8] found that one-handed users often need assistance to use personal care products.

IV. THE APPLICATION OF UCD IN DESIGNING MOTORCYCLE TIRE DISMOUNTING TOOL

The UCD approach to the development of a motorcycle tire dismounting tool is illustrated in Fig. 3. The role of design engineer, user and methods that were employed at each phase of the product development process was stated. In addition the arrows show how the product development process proceeds from one phase to the advance phase through zigzag movement between design engineer and user domain. In the following section, detail explanation of process and the role user at each phase is highlighted. To demonstrate the implementation of UCD in the development of motorcycle tire dismounting tool one volunteered user was actively participated in this project.

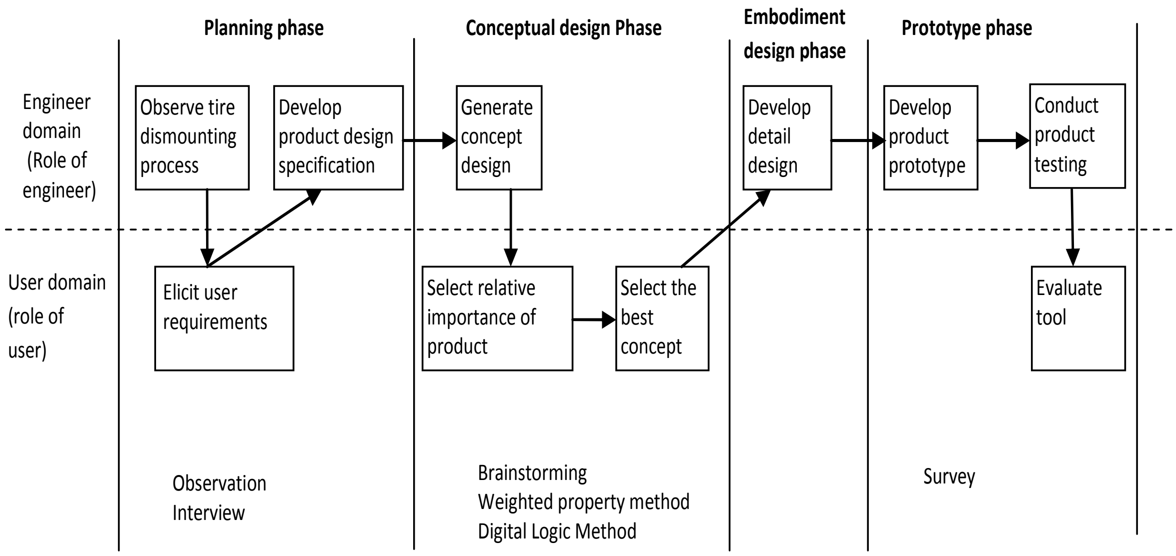


Fig. 3 UCD approach in the development of motorcycle tire dismounting tool

4.1 Preliminary Study

A preliminary study has been conducted to understand the current practices of dismounting and mounting motorcycle tire. Two research methods employed were; observation and interview. The observation method was employed to understand the difficulties faced by one-handed user to dismount and mount motorcycle tire using an existing tool. Observation has been used as a method of research in the social sciences for many years. Observations are undertaken in real time, and if carried out in their natural environment, can capture the context of the event [12]. This method has been employed to understand how novice and experienced design engineers approach design tasks [13]. Interviews were carried out to capture the user requirements. Sudin [14] carried out semi-structured interviews to understand the evolution of requirements during the design process with aim to draw conclusions about the way design engineer go about development and manage changes in the development of a specification carried out for a project.

One volunteered user was participated in this study. The first task of user is to dismount the motorcycle tire by using an existing tool. This task was aimed to create user experience of using the tool. In the second task the user was asked to use only one hand to dismount the motorcycle tire by using the same tool. This task was aimed to understand users' difficulties to carry out the task with one hand. The results of observation showed that the users faced difficulties to lock the motorcycle tire in position as the task was carried out by using only one hand. The user often uses their foot to hold the tire in position during the dismounting process. In addition, time taken to dismount motorcycle tire by using only one hand was relatively higher comparing by using both hands. In general the results of observation can be concluded that the task of dismounting motorcycle tires using an existing tool demands two-handed users and it is not user friendly for one-handed user. Thus, a new tool for dismounting motorcycle tire needs to be developed for intended used by a one-handed user.

4.2. Product Design Specification

Preparing design specifications was important to provide design guidelines for the engineers of the product. In addition, the design requirements also provided criteria for the design evaluation during the latter design phases [15]. In this project, Pugh's checklist [16] was used to determine relevant issues of the product and observation process helps design engineer to formulate the specifications for the intended tool. The most relevant specifications in the design of a motorcycle tire dismounting tool were the following:

Performance

- *Operated by one-handed persons*
- *Dismount motorcycle tires in a short time*
- *Lock the motorcycle tire in position during the dismounting process*
- *Not harm the motorcycle rim*

Ergonomic

- *Easy to use*
- *Need low effort to use the tool*
- *No sharp edge*

Safety

- *Not harm the user*

Material for lever

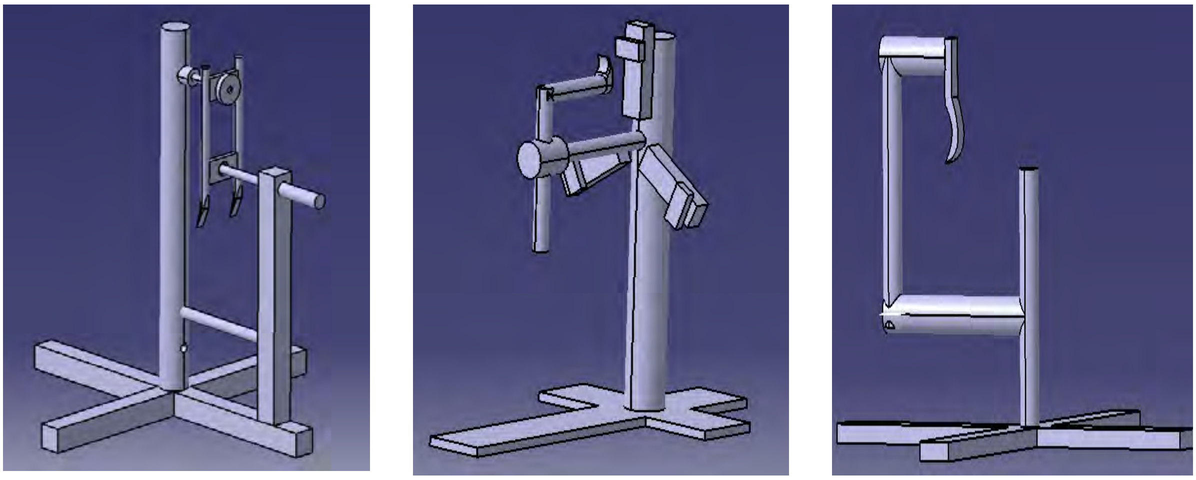
- *Low coefficient of friction to steel*
- *Can withstand up to 10kN load resistance*

Standard

- *Use to dismount standard size tire for the 100 to 125 cc of motorcycles*

4.3. Concept Design Generation using Brainstorming Method

Concept generation is one of the important stages in the product development process. In this stage the potential solutions of the required sub-function of a product is determined. The potential solutions for each sub-function are represented by mean of sketching or words. Later on the most promising solution for each sub-function will be selected. The combination of the selected solution for each sub-function is used to generate a few solutions for the problem. In the concept generation stage, three different concepts of the motorcycle tire dismounting tool were developed based on the chosen working principle. The brainstorming technique was employed to generate concept designs. In the brainstorming session, many ideas were produced, although not all are reported here. Both researchers carried out the initial screening of concepts. Finally, three concepts were past the screening process for further evaluation. These three concepts, as shown in Fig. 4, were drawn with the help of CATIA V5 solid modelling software for ease of design property predictability in the conceptual design selection stage. Description of each concept design is in Table 1.



Concept 1 Concept 2 Concept 3

Fig. 4 Concept designs of motorcycle tire dismounting tool

TABLE 1
Description of Each Concept Design of Motorcycle Tire Dismounting Tool

Concept 1	Concept 2	Concept 3
Working posture: standing Operation mode: rotate the tire Tire locking mechanism: mechanical locking Operation steps: • Put tire and rim on the base vertically • Slot in the lever tip between the tire and rim • Push the lever to dismount the tire from the rim • Lock the tire by using lever • Lock the lever by using nut • Rotate the tire to dismount the tire from rim entirely	Working posture: standing Operation mode: rotate the lever Tire locking mechanism: rim clamping Operation steps: • Put the tire and rim on the holder vertically • Lock the rime by adjusting clamping mechanism • Slot in the lever tip between the tire and rim • Fit the lever in at the pivot • Rotate the lever to dismount the tire entirely	Working posture: squatting Operation mode: rotate the tire Locking mechanism: None Operation steps: • Put the tire and rim on the base horizontally • Slot in lever tip between the tire and rim • Rotate the tire to dismount the tire from the rim entirely

4.4. Performing Concept Design Selection Using Weighted Property and Digital Logic (DL) Method

Selection of design concepts began by identifying the evaluation criteria. According to Pahl and Beitz [17], the evaluation criteria should be based on the requirement list, thus unfulfilled requirements may lead to elimination of variants found to be unsuitable in principle. In the evaluation of motorcycle tire dismounting tools, the chosen criteria for concept designs selection were; *ease of use, performance, simple construction and cost*. These criteria were determined simply by converting the statement of objectives into measurable parameters that could be estimated with some confidence. These criteria take into consideration both the technical and the economic aspects of the product. In performing concept design selection for motorcycle tire dismounting tool, the role of user is to determine the relative importance of product properties using Digital Logic (DL) Method based on his preference. Later on DL Method was employed by the user to determine the relative importance of the design concepts based on each product property.

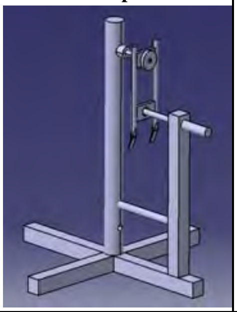
4.5. Digital Logic (DL) Method to Determine the Relative Importance of Design Property and Concept Design

In case where numerous product properties are specified and relative importance of each property is not clear, determination of the weighting factors α can be largely intuitive which reduce the reliability of selection. The DL method can be used as a systematic approach to determine α. In this procedure evaluation is arranged such that only two properties of product are considered at a time. Every possible combination of properties and no shaded of choice are required, only a yes or no decision for each evaluation. In comparing two properties the more importance property is given numerical three (3) and the less importance is given zero (0). The total number of possible decision $N = n(n-1)/2$ where n is number of properties under consideration. A relative emphasis of weighting factor α for each property is obtained by dividing the number of positive decision for each property to the number of possible decision (N). In the development of motorcycle tire dismounting tool the user was participated in determining the relative importance of design properties and concept designs of tool. Table 2 and Table 3 show the relative importance of product properties and concept designs determined by user, respectively.

TABLE 2
Determination of Relative Importance of Product Property Using DL Method

Product property	Number of positive decisions N = n(n-1)/2						Positive decision	Relative emphasis weighting factor, α
	1	2	3	4	5	6		
Ease of use	0	3	3				6	0.33
Performance	3			3	0		6	0.33
Simple construction		0		0		3	3	0.16
Cost			0		3	0	3	0.16
Total number of positive decisions							18	1.00

TABLE 3
Determination of the Relative Importance of Design Concept for each Design Property using DL Method

Product property	**Concept 1**	**Concept 2**	**Concept 3**
			
	3	0	
Ease of use	3		0
		3	0
Positive decision	**6**	**3**	**0**
	3	0	
Performance	3		0
		3	0
Positive decision	**6**	**3**	**0**
	3	0	
Simple construction	0		3
		0	3
Positive decision	**3**	**0**	**6**
	3	0	
Cost	0		3
		0	3
Positive decision	**3**	**0**	**6**

4.6. Performing Final Concept Design Selection Based on Weighted Properties Method

Weighted-property method was employed in the conceptual design selection of motorcycle tire dismounting tool. At the beginning, each design property was assigned to a weight factor α depending on its importance in service using DL method. To get the score of each design concept for a particular design property, the weighting factor, α for each property was multiplied with number of positive decision scored by the particular concept for the said property. For instance, the score for ‘ease of use’ property for concept 1 was 1.98 as it was obtained by multiplying weighting factor α of ‘ease of use’ property which is 0.33 (refer to Table 5) with the number of positive decision scored by concept 1 for ‘ease of use’ property. The individual scored value of each concept was then summed up to give the comparative total score for each concept design. Concept design for the higher score was selected for the best concept design.

To assist user in determining the relative importance of concept design, the mapping of product properties to the design characteristics was provided to the user for reference. For a particular product property, one or more design characteristics of concept design were considered. For example, to evaluate the ‘ease of use’ property, the characteristic of ‘operation mode’, ‘locking mechanism’, ‘working posture’ and ‘operation steps’ were considered. Table 4 shows the mapping of the product property to design characteristics of the concept designs. The characteristics of the concepts considered for each product property was indicated by ‘x’ mark. Finally, the selection of the best concepts was based on the total value obtained by the concepts. As shown in Table 5, concept-1 scored the highest and was the best candidate for the motorcycle tire dismounting tool.

TABLE 4
Mapping of Product Property to Design Characteristics

	Design characteristics			
Product property	Operation mode	Locking mechanism	Working posture	Operation steps
Ease of use	x	x	x	x
Performance		x		x
Simple construction	x	x		
Cost	x	x	x	x

TABLE 5
Determination of the Best Concept Design for Motorcycle Tire Dismounting Tool using Weighted Property Method

Design property	**Weighting factor, α**	**Concept 1**		**Concept 2**		**Concept 3**	
		+ ve decision	Score = +ve decision x α	+ ve decision	Score = + ve decision x α	+ ve decision	Score = + ve decision x α
Ease of use	0.33	6	1.98	3	0.99	0	0
Functionality	0.33	6	1.98	3	0.99	0	0
Construction	0.17	3	0.51	0	0	6	1.02
Cost	0.17	3	0.51	0	0	6	1.02
Total score			**4.98**		**1.98**		**2.04**

4.7. Product Evalution based on Product Testing and Interviews

Intial evalution on the tool was carried out through product testing and interview survey. In total 10 volunteer users were participated in this process. All of participants are university student and they have experience in dismounting and mounting motorcycle tire using the existing tool. This experience is vital as they can compare their previuos experience with their experience as they are using the designed tool. The first part of product testing, the users are required to dismount and mount the motorcycle using the designed tool. Later on they are asked to do relative comparison between the designed and existing tool by answering three ‘yes’ or ‘no’ question with regard to efficiency, comfortness and safety of the tool. Table 6 shows the initial feedback of users for the designed tool. In general the desingned tool received positive feedback from the users for all the three evaluated criteria.

TABLE 6
Users Feedback to New Designed of Motorcycle Tire Dismounting Tool

Criteria	**Percentage of users feedback**	
	Yes (%)	**No (%)**
Efficiency	80	20
Comfort	70	30
Safety	70	30

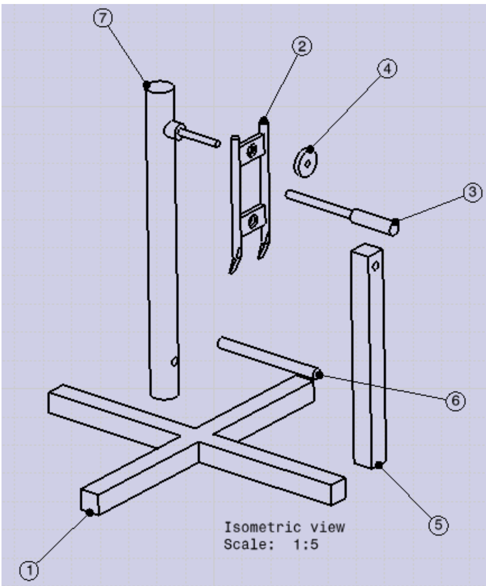


Fig.5 Exploded views of a complete design of motorcycle tire dismounting tool

V. CONCLUSIONS

This paper presents the application of UCD approach in the development of motorcycle tire dismounting tool aimed for one-handed user. The project was started with preliminary study which aims to understand the difficulties faced by one-handed user using an existing tool. Later on, design product specification was developed as a result of interview and observation. Three (3) concept designs were generated and user was involved in determining the relative importance of product properties and conceptual design. Finally weighted property method was employed to determine the best concept design. The application of UCD to develop a product with a strong user focus helps to ensuring the relevant design issues been considered in user related manner. Through interview and observation user requirements for developing motorcycle tire dismounting tool is possible. In this project, the decision for the best concept design relies on the user as active participation in determining the relative importance of product properties and concept design of the tool. Finally the evaluation on usability and usefulness of the tool indicated that the tool met the requirements of users through the application of UCD approach.

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