JMM Gimbal Stabilizer

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***Abstract*—To develop and improve the traditional gimbal stabilizer for smartphone or camera-based acquisition device, the handle part is the main point to be considered. Product Design and Development (PDD), Ergonomic Design, and Rapid Prototyping (RP) have been applied for creating the guideline of the conceptual model of this developed gimbal stabilizer. Dimensions and physical characteristics of the gimbal's handle have been created by applying the concept of ergonomics to fit the people who use it. Using this proposed design can help the users to minimize fatigue during prolonged imaging activities.**

***Index Terms*—Ergonomic Design, Gimbal Stabilizer, Imaging Acquisition, Product Design and Development (PDD), Rapid Prototyping (RP).**

I. Introduction

Smartphone has become technology and it is counted as one of the big influencers to change the way of life of the people currently. People are able to share stories via social media instantaneously by using smartphone camera. Blur and shaky of footage can happen when smartphone users are doing some activities. A support equipment such as camera stabilizer was invented for professional photographer to use in motion picture industry. For amateur and person who interested in taking photograph and video by using smartphone, gimbal stabilizer is a device which can reduce smartphone vibration and movement.

Smartphone users can connect to social media platforms and share their stories, findings and experiences at anywhere and anytime. According to Thailand National Statistical Organization, around 89.6 percent of people in Thailand has a mobile phone (approximately 56.7 million person) Social networks such as Facebook, Line, Twitter, Instagram are the top activities that smartphone users spend time on their smartphones [1].

Nowadays, people using smartphone to take pictures or short video clip instead of using a full-size video camera because smartphone is small and light enough to be carried or moved easily. But there are some problems that might happen when the people are taking videos by using the smartphone [2].

These have led to our research to develop and improve the gimbal stabilizer for smartphone where the *handle part* is the key part to be considered. The new design of handle shape might reduce the fatigue and the failure occurred during imaging activity. Curvature surface of hands and postures performed during taking photos will be taken into account by applying the concept of ergonomic design. Some direct messages obtained from the interviews and questionnaires help the researcher to understand about the hidden needs and requirements of the user on the commercial gimbal stabilizer. The users feel uncomfortable while they are using the equipment for a long time.

II. Related Works

In order to create and develop the new design of gimbal stabilizer, three main considerations are mentioned and analyzed in this section.

A. Camera Stabilizer

Steadicam is one of the camera stabilizer items used to isolate the camera from any movement made by the user. It is a well-known device to keep camera stable and can take high quality footage while the user is moving. The steadicam appears to be very effective at isolating movements. However, the steadicam may not be the best choice to use for casual video taking because of the weight and size of the device. [3] The picture of steadicam is shown in Fig.1.

Fig. 1. Steadicam [4].

Three axis roll-pitch-yaw has been presented in an advance gimbal-camera stabilizer. This skeleton is attached to a platform. Each of axis is independently driven by motors with encoder feedback.This gives angular position and velocity feedback. The device creates natural movements of the arm and counteracts any unwanted movements to make creating seamless motion of video footage. Panning operations can be done by using joystick, and the phone can be instantly positioned by hand [5]. The advance gimbal is shown in Fig. 2. However, guiding slots at the handle provide the difficulties to the user's hand. Since, for operating task with one hand, the user might not perform well to align the fingers one each particular slot. Straight handles are suitable for the actions or activities that the force is applied perpendicular to the straightened forearm and wrist; the force is applied vertically. The user might feel some stresses distributed ranging from the palm though the shoulder. The weight of the device or handle is one of the main issues that need to be concerned during the product design stage.

Fig. 2. Advance gimbal [6].

B. A Check-List for handle design and the effects of tool handle shape on hand performance, usability and discomfort

• The troubles with handle

The main reason for creating the new items is to enhance the capability of the humans to easily communicate with machines. Designers or the experienced people, in general, design the specific characteristics of the handle. Recently, most of handles are too small, too stiff, and they contain sharp edges or awkwardly placed that make the user feel uncomfortable. Applying their hands or fingers to grab, control or hold for a long time cause the pain around forearm and palm of the hand. Most of contact between hand and equipment are inaccurate and unsafe which can cause injuries to the user. Bulky items like refrigerators and heavy office equipment still have to be moved and contacted by using human hand [7]. The appropriate design is very important for preventing upper-extremity musculoskeletal disorders (e.g., carpal tunnel syndrome, hand-arm vibration syndrome or tendonitis) [8-9]. In order to determine the optimal diameters for maximizing finger-force exertion, comfort, contact area; Harih and Dolsak (2013) have developed ananatomically accurate static digital human-hand model (DHHM) [9]. Applying this method, therefore, the chances of cumulative trauma disorders (CTD) could be minimzed. The handle with higher contact area and anatomical shape of the handle, extensive deformation of the soft tissue can be avoided; preventing excessive load on the hand. The obtained design; anatomically-shaped tool-handles based on the developed DHHM with optimal power-grasp posture, can increase the contact area and the subjective comfort-rating, thus increasing user performance and lowering the risk of CTD.

• Power grip

Since the human body is capable of a wide variety of positions, there are many researches that mention about the design of physical parts containing some extra curvature surfaces, features or shapes to support the human body parts, especially, sensory organs; eyes, ears, nose, tongue, and skin. The design of handle is one of the popular topics which are quite challenge to create the platform or pattern for fitting the area of interest. The position of fingers need to be bunched tightly around an object and overlapped by the thumb [10]. Illustrated in Fig. 3 is the position of the thumb and fingers on the handle. The appropriate handle with enough thickness can help to separated fingertips from the palm.

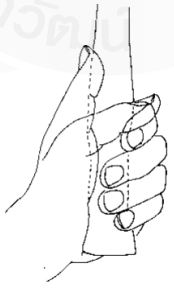


Fig. 3. Power grip–thumb can be straightened as a precision component [11].

Moreover, the large area of contact is very important criteria for preventing strength of the grip. The spots of local high pressure are not recommended to prevent strength of grip that makes the user feels uncomfortable. The basic pattern and the design of the power grip are relied on the alignment between the thumb and a

handle where the thumb should be straight along the back of a handle.

• *Size and Shape*

For the size of the handle, length should be around 10 to 15 centimetres in order to fit with the palm, longer length for large-handed population, shorter length if the butt end of the handle is to fit into the palm, when it should be rounded. Thickness should be 3 to 4 cm in diameter, to allow the thumb to just cover the end of the index and middle fingers. The shape of the grip or handle can be varied according to the size and length of the device. Normally, cylindrical shape of the polymer material is used as the grip for twisting round the handle (e.g., a one-piece rolling pin). If the rolling pin has an axle inside it, the handle will give a more secure grip. Uniform diameter and smooth surface along the length can make the user hand slide along the handle (e.g., an axe handle).

Thickened at the center to make secure grip and prevent sliding; it is seen in a sheep-shearing hand-piece. This is not shifted within the palm, but there is much wrist and arm movement. Some environmental conditions (e.g., oil, sweat or dust) have direct effect on the way to maintain the grip in place with high secure level. Flattening for the thumb and fingers, to prevent unwanted twisting (e.g., a saucepan handle). No sharp edges or high spots in the area of grip. These can decrease comfort and security of the grip and they may cause injury to the user. The raised area or an edge along the handle length is quite interesting and useful on the end of the non-grip area of the handle, to act as a guide to save the position of the hand, and as a warning sign.

C. Examples of the popular tool handles available in the market.

Presented in Table I are the comparisons of image assistance devices which are *selfie stick*, *tripod*, *Steadicam*, and *handheld gimbal*. Remote control indicated that user can take picture or video remotely without touching the smartphone screen. The specific characteristics of these devices were compared where "*the stabilize mechanism*" was the key consideration. The handles were designed to provide different p atterns of grip; therefore they could be suited to the hand tool interaction in particular hand areas [12].

The hand grip exertion and ability to use the handgrip were negatively correlated with personal assessment of hand and finger discomfort, so that a lower level of hand and finger discomfort corresponded to higher hand grip exertion and usability. These results provide a better insight into the performance and usability issues when using hand tools which can be utilized by tool manufacturers in order to improve industrial hand tool design. Ergonomically designed hand tools can reduce the fatigue of the user, mechanical illustration, the chance of developing an injury and risk factors for musculoskeletal symptoms. In addition, to improve the quality and performance of hand tools, it is possible to improve an efficiency and work productivity. The design of tool handle which interfaces with the human hand is a major importance thing. The shape of the handle should be designed to get the best performance, usability and contact area between the hand and the handle part to provide better pressure distribution and reduce the shape edge in order to decrease the contact stress that will occur with hand, leading to reduced discomfort.

TABLE I
IMAGE ASSISTANT DEVICES-COMPARISONS

Product	Functions
 Selfie stick [13]	• Remote control : Yes • Battery : N/A • Stabilize mechanism : N/A • Tripod : N/A
 Tripod [14]	• Remote control : No • Battery : N/A • Stabilize mechanism : N/A • Tripod : Yes
 Steadicam [15]	• Remote control : No • Battery : N/A • Stabilize mechanism : Yes (Analog) • Tripod : N/A
 Handheld gimbal [16]	• Remote control : Yes (Built-in) • Battery : Yes • Stabilize mechanism : Yes (Motor) • Tripod : Optional *Remote control indicated that the user can take picture or video without touching the smartphone screen.

III. RESEARCH BACKGROUND

Presented in this section are the background of the research for identifying the user's behaviors and perceptions in smartphone and supported devices. These people will be accounted as the target group of the new gimbal stabilizer design. Two phases of Product Design and Development (PDD) have been described in the following subsection.

A. Phase 1: Customer's behaviors on smartphone

After collecting some ideas about customer's behaviors on smartphone, to create the drafted design of the new gimbal stabilizer, three main activities were established; *data collection process*, *data analysis*, *discussion results and conclusion.*

1. Data collection

In order to create gimbal stabilizer for smartphone, market survey has been conducted by using questionnaire. Questions have been made to determine importance parameters such as average smartphone usage time for a day, popular activity on smartphone, opinions about design of gimbal stabilizer, and the most important question which is price of gimbal stabilizer that users are willing to pay for this equipment.

2. Data analysis

There are 3,238 participants answered in this questionnaire. Results from the questionnaire indicated that around 92.7% of participant has age between 13 and 26 years old. 85.5% of participants are high school student and university student. Around 42.3% of participants used their smartphone to take pictures or videos every day. 96.6% has faced the problem with image or footage blurring when smartphone users try to take the pictures and videos. More than 80% has never used the gimbal stabilizer and about 93.9 % of the people are willing to use the gimbal stabilizer if this equipment can improve quality of videos. The results obtained from the questionnaire indicated that the most popular design of gimbal stabilizer is one handheld design which is traditional design of gimbals that are available in the market. 3,000 baht is the price that most of questionnaire participants are willing to pay for this equipment.

3. Discussion of questionnaire results and conclusion

After our group obtained findings from questionnaire, there are some concerns about cost of make a functional prototype. Since the creation of prototype is not a mass production, so the cost of creating functional prototype might be more than 3,000 baht. One handheld is popular design of gimbals in the market, but most of handles are cylindrical shape with no curvatures that support user's palm of the hand. Handle part is only component that touches with the user's hand. The researchers have tried to improve the design of the handle part to make sure that it fit perfectly with user's hand.

B. Phase 2: Translating requirements to be design

In order to translate the requirements of the target customers to be the gimbal design, factors affecting gimbal stabilizer functions are considered and classified into three groups; *weight of smartphone*, *weight of gimbal stabilizer*, and *size of smartphone*.

• *Weight of smartphone*

The phone that is inserted into the gripper has different size and weight which can be affected with the stabilize control system of the gimbal. The more weight of the phone, the more force of the motor that have to apply to the stabilize control system.

• *Weight of gimbal stabilizer*

The first thing that the customer will decide to buy the product is how heavy of the product is. The weight of the product is related directly to the time that how long the customer can hold the gimbal stabilizer.

• *Size of smartphone*

The size of the phone is related directly to the balance of the stabilizer control system of the gimbal stabilizer. The gimbal stabilizer has to calibrate itself every time when the operator turns on the switch. The system will find the balance of the stabilize system by using the weight, size, and position of the phone that is inserted into the gripper. In order to create the new design of gimbal stabilizer, research background about product design and development, and ergonomic design have been studied and analyzed.

IV. JMM Gimbal Stabilizer

After translating the customer's behaviors and requirements from the self-administered questionnaires, the drafted design was constructed. The key theme of this developed design was raised by using the concept of "*it's just me, myself and I*" where the users can activate and generate clean and clear images and video clips without blurs and distortions affected from the external issues by themselves. This one was quite similar to the function of "*selfie stick device*". This new alternative direction that can assist the digital-life application, "*Just Me, Myself and I*" (*JMM*) gimbal stabilizer has been established and developed in this research. The components of smartphone stabilizer were smartphone grabber, handle part and structure of the gimbal stabilizer.

A. Expected design from the questionnaires and direct interviews: "Handle Part"

The design of gimbal stabilizer and prototypes are decided to be spline-structure characteristic where the design that most of the people prefer to use is one hand operate design with the built-in remote control and joy stick in the handle part. The design of the gimbal stabilizer is concerned about the compact size. The key concepts for this new model are focused on *portable size*, *foldable*, and *easy to use*. The handle part is universal design which has round shape

without any sharp edges. The diameter of the upper and lower part of the handle will be larger than the middle part which can prevent from falling. There will be a hand strap for slipping on which perfectly fit with the user's hand. The drafted idea of the proposed approach of gimbal stabilizer model is shown in Fig. 4.

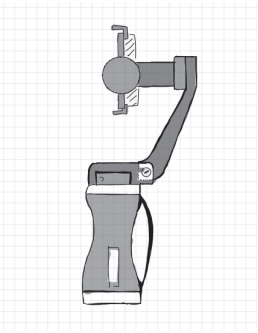


Fig. 4. Conceptual model of Gimbal stabilizer.

B. Concept of "3F's approach" for handle part

The research of interest in this developed JMM gimbal stabilizer is the "handle part"; therefore, the emphasized directions of handle characteristics and specific details such as shape, dimension, and weight will be presented and mentioned in the design phase (Table II). JMM gimbal stabilizer embodies the following themes:

1. Form

Size and dimension of the handle part of gimbal stabilizer should be equal to 15 cm in height and 4 cm in diameter, respectively. The design of handle part will be shaped and constructed by applying the ergonomic design. The landmarks for the anthropometric data are shown in Fig. 5 to 7. Landmarks are points on the hand between which measurements were taken between on the right hand of all subjects.

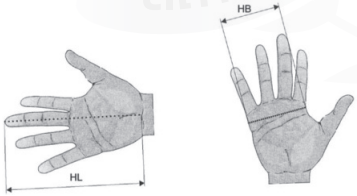


Fig. 5. Landmarks for hand length and hand breadth.

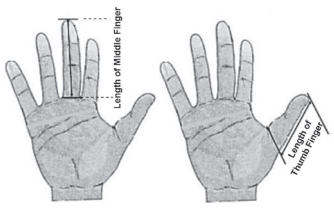


Fig.6. Landmarks for measurement of middle finger and thumb finger length.

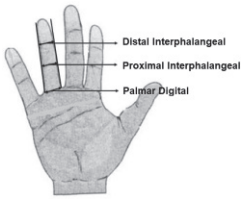


Fig.7. Landmarks for measurement of breadth of fingers [17].

TABLE II
TOOL HANDLE DESIGN FOR POWER GRIP

Anthropometric data variables	Definition
Hand length	Defined by measuring between the wrists until the longest fingertip on the hand, usually be the middle finger and wrists
Hand breadth	Defined by measuring the length of palm perpendicular to hand length
Length of thumb finger	Defined by measuring between the palmar digital until the tip of thumb
Length of middle finger	Defined by measuring between the palmar digital until the tip of middle finger
Grip diameter	Defined by measuring the largest cylinder can be held within the condition that thumb and the tip of middle finger must be in contact
Diameter of distal interphalangeal (All fingers)	The diameter of finger at the distal interphalangeal joint
Diameter of proximal interphalangeal (All fingers)	The diameter of finger at the proximal interphalangeal joint
Diameter of palmar digital phalanx (All fingers)	The diameter of finger at the palmar digital joint

On the gimbal stabilizer handle part, there are no edges around holding area which can prevent from creating a mechanical irritation, obstructing blood flow and increasing a chance of developing an injury. According to *Kent Hatcher, Director of Consulting and Ergonomics Engineer for humantech.* [18] The drafted 3D virtual model of JMM gimbal stabilizer is shown in Fig. 8 and 9.

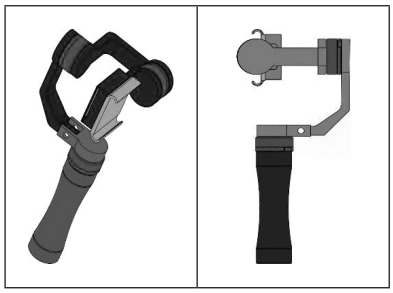


Fig. 8. The expected design of Gimbal stabilizer.

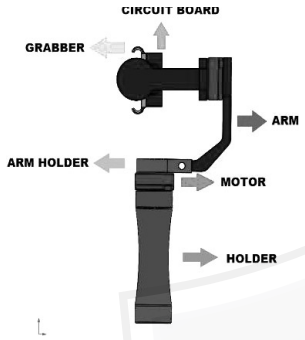


Fig. 9. 3D spline model with components.

2. Fit

The gimbal stabilizer consists of three main parts which are *handle*, *smartphone grabber*, and *stabilizer mechanism*. The dimensions and the details of the main components are explained in Table III.

• *Gimbal Handle*

Handle is the main point of contact between the user and the device This is where user hand movements are translated into smooth camera panning and tilt motions.

The shape and dimension of the handle was defined by the land mark reference of the palmar grip diameter. The middle part of the handle was designed to be smaller than the ends to prevent slippage of the hand along the handle axis.

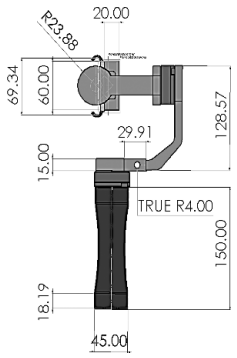
• *Smartphone grabber*

Adjustable grip which can hold different size of smartphone.

• *Stabilizer mechanism*

Stabilizer mechanism for controlling and stabilizing the smartphone consists of *three brushless motors* for 3-axis and *a control board*.

TABLE III
COMPONENTS OF SMARTPHONE STABILIZER

No.	Components	Picture
1	Smartphone grabber – The outer and inner length of the grabber are 69.34 mm and 60.00 mm, respectively.	
2	Handle part – The diameter and length of the handle part are 45 mm and 150 mm, respectively.	
3	Structure – The total height of the structure is 128.57 mm.	

3. Function

The function of gimbal stabilizer is to stabilize the smartphone by using the main components which are *control board* and *three motors* (brushless motor) as shown in Fig. 10. A tripod or a hand strap will be applied as an optional feature of this gimbal stabilizer.

Control board [19] Gimbal motor (T-Motor) [20]

Fig. 10. The main components for functioning stabilizer.

C. System-level design and detailed design

In order to identify the physical characteristics of the JMM gimbal stabilizer, all components were classified and expressed about their specific requirement, and operational/general stage conditions. These data can help the designer to minimize some mistakes that might be occurred during the design stage. Illustrated in Fig. 11. is the main frame of the developed design.

For stabilizer mechanism, four items are required: *motors*, *control board*, *battery*, *and input device*. All these items are the heart balancing movement and condition. However, time spent for checking and controlling these items is quite long, and they will be added to the prototype later after finishing entire designed part.

For handle and frame grabber, two modules will be considered and presented firstly in this research since the main concerns among image assistant components when the user uses the gimbal stabilizer device are well-fit handle, and camera grabber.

The price condition is the main issue that has direct effect on purchasing decision; therefore, the proper items will be mentioned and applied by doing some researches, especially, the handle part.

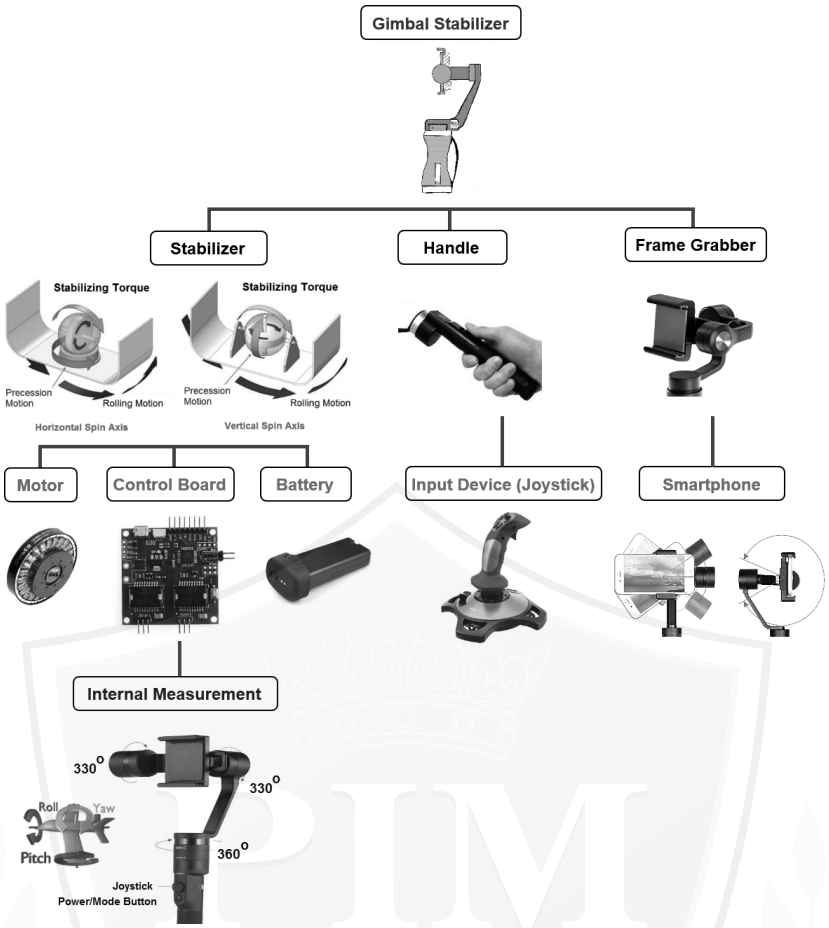


Fig. 11. The main frame of JMM gimbal stabilizer.

D. Extra considerations

From the main frame diagram, the *stabilizer* module contains and requires more details when compared to *handle* and *grabber* modules, since it is the most important function that support the whole system to keep high-stability during data acquisition. With insufficient motor, board or battery, the gimbal tries to balance the phone but goes into failure to function properly; it can adversely affect the stability of the product. To obtain compact-comfort style for this developed equipment, three items taken into account and explained as;

• *Brushless motor*

Brushless motors offer several advantages including high torque to weight ratio, high efficiency, increased reliability, reduced noise, longer lifetime (no brush and commutator erosion), With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling.

• *Control board–Inertial Measurement Unit (IMU)*

Inertial measurement units are responsible for sending camera acceleration and positioning data to the gimbals controller. IMU sensors for gimbals have a built-in gyrometer that required calibration before the equipment can operate. These sensors are sensitive to temperature change and the sensor required re-calibration overtime so the gimbal maintains good stabilization performance.

• *Gimbal Batteries*

Gimbal is powered by rechargeable Lithium Polymer (Li-po) or Lithium-Ion (Li-ion) batteries [21].

E. Prototype and refinement

In order to identify the proper design of the handle, six different designs (Fig.12) were created and used as the guidelines for demonstrating the proposed approach where the size, comfort and geometric shape were the key components and evaluated by 31 participants, 10% of them are the experienced people in the optical/image processing applications. The average time spent for holding each sample was 2 min. The factors were rated with the scores from 1 to 10. The results were shown in Table IV. The score of 1 means that the participant is not satisfied with the design whereas 10 presents high satisfaction level of the design.

Fig. 12. Six designs of the gimbal's handle.

TABLE IV
SATISFACTION SCORES OF SIX TYPES OF GIMBAL'S HANDLE

No.	Prototype	Model Details	Factors (avg. score from 1-10)		
			Comfort	Size	Design
1		**Top:** Taper down **Body:** Straight and small concave area connecting to the bottom section **Bottom:** Oval with one side flat **Extra:** Motorbike Grip	7.290	7.387	7.387
2		**Top:** Step with spline curve **Body:** Middle crater/ Convex **Bottom:** Concave up slopes increasing from the base point	8.129	8.000	7.000
3		**Top:** Thin prism with chamfer on one side **Body:** Spline and concave **Bottom:** Long prism	6.806	7.258	7.419
4		**Top/Body/Bottom:** Spline with finger groove **Extra:** Hollow shape	6.129	7.032	6.968
5		**Top:** Thick prism with chamfer on one side **Body:** Spline and concave **Bottom:** Long and thick prism **Extra:** Popular in the market	5.935	6.000	7.129
6		**Top:** Short cylinder and taper down **Body:** straight and Small concave **Bottom:** Concave and short cylinder	8.548	8.032	7.452

The model No. 6 presented the maximum satisfaction level for all the 3 factors; this design was chosen for making the prototype. The design of model No.6 was shown some special details about the comfort grip and fit with the user hand where the two mirrored sides (left and right) are exactly the same. Shape of the top left quadrant was the same as the bottom left quadrant, and the curvature surface of the top right quadrant was the same as the bottom right quadrant.

After 3D spline model has been made by using SolidWorks, Rapid prototyping (RP) method has been used to create a prototype by using 3D printer. The XYZ da vinci 1.0A 3D printer operated by using fused filament fabrication (FFF) technique. The material used is ABS plastic, which gives high strength and durability. ABS filament is used as printing material, filament has been heated to temperature around 240 ^{o}C which make the print material become molten plastic that can be formed into different layer of the workpiece. The 3D printing is classified as one of additive manufacturing where the product has been built layer by layer to form a geometry shape. The suggested material for manufacturing process. The prototype of this design is shown in Fig.13.

- *Handle part*: Polypropylene coated with rubber
- *Stucture and smartphone grabber*: Polypropylene
- *Stabilizer mechanism*: Polypropylene

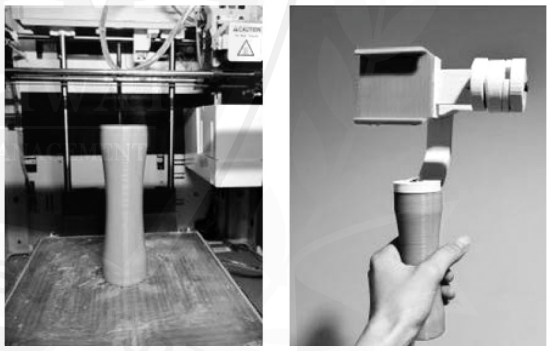


Fig. 13. 3D printed handle part (Left) and Prototype of JMM g imbal stabilizer (Right).

V. DISCUSSION AND CONCLUSION

Blur and shaky video footage can happen when the person who takes the video are walking or doing some activities. The gimbal stabilizer is an equipment which can solve this problem. User can use handheld device while shooting video without causing camera vibration or shake. Powered by three brushless motors, the gimbals have the ability to keep camera level on all axes as operator moves smartphone. Self-administered questionnaires were used for collecting data in order to obtain the customer's requirements. The 3D spline model is created based on concept of ergonomic.

The main problem of the traditional design was shown through *handle part* that makes the user feels fatigue because of the finger groove with silicone anti-slip handle. When the user holds the handle for a long time, the moisture (i.e., sweat) around the palm and finger areas makes the user feel discomfort or uncomfortable fit. These had let to our research to create an alternative design to provide compact-comfort way for the user to carry with less fatigue and this new model will afford the best feeling of the user's hand with two mirrored-side structure. The proper curvature surface (spline contour) proposed in this research can support all hand sizes without slipping during grabbing the handle.

After 3D spline model of the gimbal stabilizer is created, 3D printer has been used to create the first prototype. All components of gimbal stabilizer were printed out using 3D-printing RP process where the ABS plastic was the main raw material. Since each component was printed out separately, the assembly process was required and performed to get the complete prototype.

This research aims to present the new direction of the physical characteristic and design of the handle that will be evaluated and identified that, whether or not, the handle part can fit perfectly with user's hand. This first prototype will be applied for the next step to add the stabilizing mechanism to move as the real function.

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