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Developed Safety Product Design for High Worker with Quality Function Deployment Method and Antropometri Approach

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Abstract*: Personal Protective Equipment (PPE) on Occupational Health and Safety body harness used in high altitude workers has not been able to meet employee satisfaction. There are weaknesses in the body harness, such as the use of which is still manual so that it can cause worker negligence in hooking the body hook harness to the rope and the breaking of the rope can also cause a fatal accident risk. Based on the problems that have been found, the need to develop the APD body harness. This research uses QFD (Quality Function Deployment) method and Voice of Customers tools and House of Quality 1 to develop APD body harness. In addition, the anthropometric approach is used as a reference of design-making in the development of PPE. This research has a conclusion that the need for the development of PPE products that can protect workers from accident risk by providing innovative airbags to protect the worker's body from impact if dropped, airbag run automatically with microcontroler and accelerometer sensor.*

Keywords*: Occupational Health and Safety, APD, Elevation Worker, Quality Function Deployment, Anthropometry.*

1. Introduction

Occupational Safety and Health (OSH) is a safety aspect that must be applied to the company or contractor. The purpose of K3 is to reduce the risk of accidents and diseases that arise from work, so as to obtain a conducive and friendly work environment (Sastrohadiwiryo, 2005).K3 applied in accordance with SOP can prevent and reduce the risk of work accident. So as to create a friendly working environment and able to improve the performance and sense of security to the workers. But based on the empiries study, altitude worker is one of the jobs that has a very high work accident risk.

Work can be said to be high if the height is already able to cause workers to be injured if fallen. High-altitude workers are required to use Personal Protective Equipment such as safety belt, body harness, helmet and so on. PPE used by workers at altitude such as safety belt and body harness has not been able to protect workers maximally due to various factors. Obstacles found in the field based on interviews with some workers in Yogyakarta that workers are often negligent, lazy to tie the rope and wrong procedures in using PPE. Therefore, this study proposes the use of inflators as air triggers for PPE in altitude workers with the aim of reducing the risk of death to fallen workers with some considerations such as easy-to-use procedures and can work automatically so as to anticipate employee negligence.

2. Theory

A work accident is an unforeseen and undesirable event and disrupts the regulated process of an activity and can cause harm to both human and material victims. Of the many occupational accidents that occur, construction workers have a greater risk of work injuries, especially accidents that result in injuries such as falling from the building where the workplace. The construction industry is considered one of the most dangerous industries with high serious and serious injuries to workers (Jebelli, R.Ahn, & L.Stenz, 2016).

One of the most common workplace accidents in construction workers is falling from a height. Crashes from altitude are the main cause of death, in addition to the death of these accidents are also often cause disability so that workers can not work again (Latief, Suraji, Nugroho, & Arifuddin, 2011). Based on the data, fall is a major cause of accidents in the industry. On the statistics of the bureau reported 291 cases of fatal accidents in 2013, out of a total of 828 cases of accidents (Brasch, 2010). The case of occupational accidents in Indonesia is very high, based on data (HSE, 2007) that Indonesia is ranked 2nd in the world after China in the case of work accident. The construction industry has a high rate of accident and mortality risk compared to other major industries, with over 60,000 cases of fatal accidents happening worldwide each year. Falling from a height is one of the main causes of death and injury in construction (Chen, Chen, Bo, & Luo, 2016).

Work safety on the construction industry in Indonesia based on the research from (Machfudiyanto, Latief, Arifuddin, & Yogiiswara, 2017) shows that the implementation of OSH standards is still below the safe line. By 2015 in Indonesia work accidents at high altitude has been accounted about 38% of all occupational injuries (Kompas, 2016). There are 105.383 and 105.182 cases of occupational accidents in 2014 and 2015. Meanwhile, for severe cases resulting in deaths has been recorded about 2,375 cases by 2015 (BPJS, 2016). In January 2017 a construction worker at Bekasi City was killed because they slipped when doing casting at a height of 7 meters, the victim's fell and landed with his head first touch ground (Sindonews, 2017). In April of 2017 at Solo City three glass cleaners worker were killed in a broken bones condition because falling from the 7th floor building due to procedural errors in wearing the gondola (Kompas, 2017), while in the city of Jakarta workers slipped from 6th floor Atrium Mulya building when doing pipeline repairs (Sindonews, 2017).

3. Method of Research

3.1 Survey

Conducting interviews with relevant agencies such as OSH experts and altitude workers. The interview was conducted to obtain criteria based on the customers needs to develop the design of the worker safety tool at the height called "totybelt". The criteria will then be obtained by the method of Quality Function Deployment.

3.2 QFD Method

The method used in this research is Quality Function Deployment using HOQ 1 tools ;

- Determining the target respondent of toty belt.
- Distribution of open questionnaires with interview method to obtain consumer criteria.
- Reliability test againts consumer criteria with 30 respondents using linkerd scale 1-5.
- Assessment of important rating on consumer criteria with scale of linkerd 1-5 to 30 related to respondents.
- Assessment of CCE to compare toty belt product with competitor product with consumer criterion
- Conduct calculations on House of Quality 1
- Obtain design specifications.

3.3 QFD Criterion

Customer needs based on results with 20 respondents who agree with the innovation on safety equipment "toty belt". There are 2 types of criteria that exist in QFD namely customers requirements and manufacture requirements shown in table 1.

TABLE I: Requirement

Customers Requirements	Engineering Requirements
Works Automatically	Anthropometry
Light Weight	Weight
Safety Rope	Tearproof Material
Secure Levels for Worker	Airproof and Waterproof Material
Visible Color on Darkness	Automatic System
Tool Size	Color
Comfort When Worn	Multifunction
Ease in Use	Flexible
Product Durability	
Features	

Table 1. describes the customers requirement which is the factor / criterion needed as a reference to develop toty belt design based on customer needs. There is a difference between the needs of consumers and technical needs, technical needs are more directed to the means that can support in the manufacture of toty belt based on technicians, while the consumer needs is a purely desirable consumer needs. Both criteria later will be linked / related to get the design specification.

TABLE II: Important Rating and Cumulative Customers Error

Criteria	Toty Belt Product		Competitor Product
	IR	CCE	CCE
Works Automatic	4.53	4.5	2.5
Light Weight	4.07	3.2	4.0
Safety Rope	4.17	3.2	3.8
Secure Levels for Worker	4.67	4.4	3.4
Visible Color on Darkness	3.67	3.7	3.0
Tool Size	4.07	3.5	3.8
Comfort When Worn	4.57	4.1	3.4
Ease in Use	4.57	4.1	3.5
Product Durability	4.27	3.4	3.8
Features	3.83	3.9	2.9

Table 2 is an assessment based on the questionnaires results that has been distributed to 30 respondents, assessments from questionnaires are IR and CCE assessments. IR is used to determine the most important criteria of the overall criteria. CCE is used to determine the position of advantages and weakness of the toty belt product with competitor products based on the criteria.

TABLE III: Design Specification

Design Spesification	Score
Anthropometry Databank	36.6
> 2 Kg, < 3 Kg / Anthropometry percentil 50	76.8
Ballistic Nylon	46.07
Ballistic Nylon	46.07
Arduino Nano	40.8
Belt (R 247, G 42, B 49) Phosphor (R 255, G 246, B 136) Nylon (R 254, G 254, B 254)	33
Woker Tools Slot / LCD	60.6
Belts Can Match User's Body	52.6

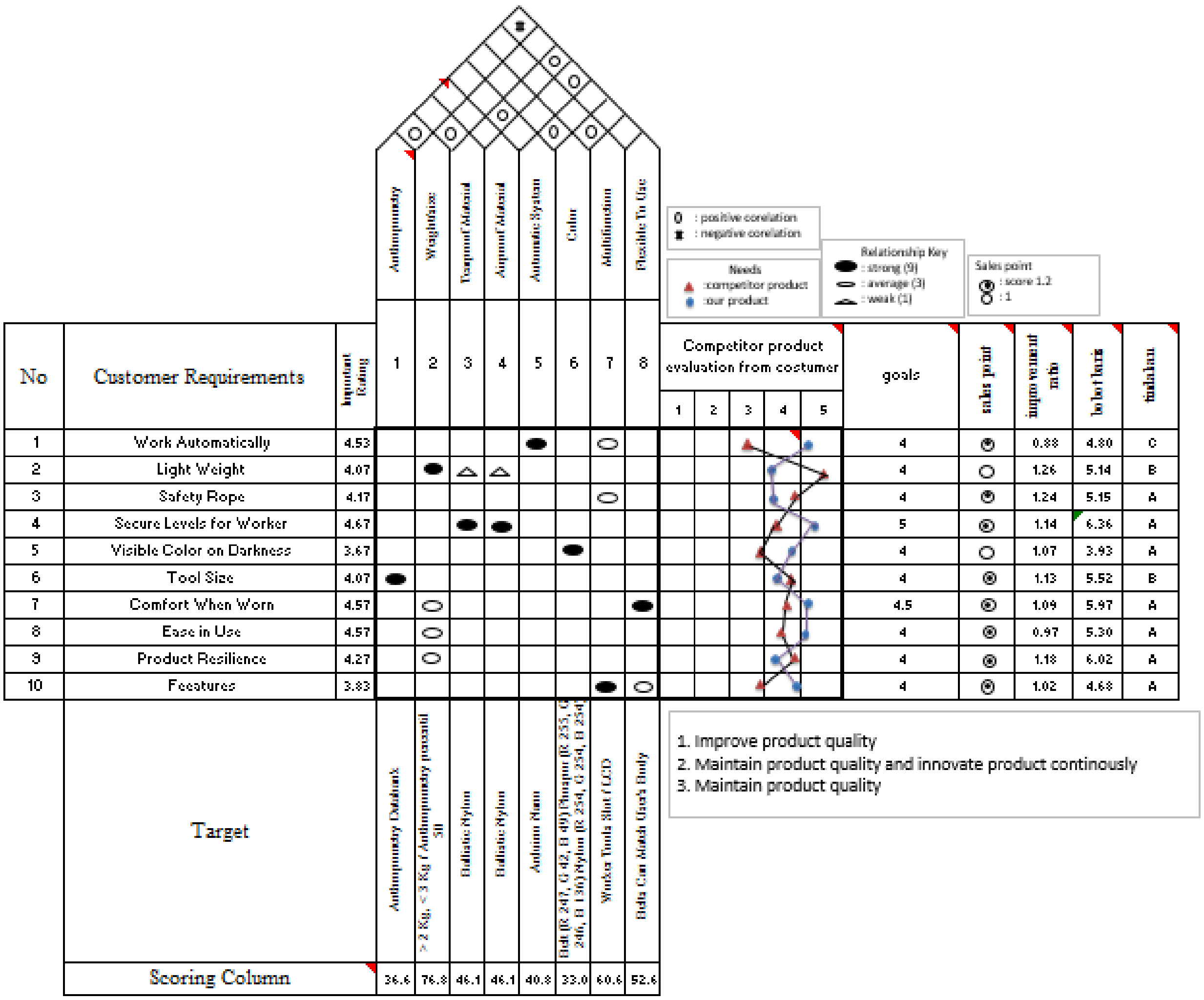

Fig. 1: Table House of Quality

Table 3. Is HOQ 1, the subjectivity of the expert / writer has important role in HOQ table assessments. Subjectivity must be based on market conditions and market reality. HOQ 1 includes visualization of CCE value comparisons, relation engineering requirements and customer requirements also an actions stating the needs to develop consumer criteria. Specification design is obtained based on engineering requirmation relation and customer requirement. Design specification characteristic is elaborate and detailed because the specification will be used as a reference in making design improvements.

3.4 Anthropometry

The use of the Anthropometric approach as a design method has intention for Totybelt can be used comfortably according to the size of the human body. The suitability size of the tool with the human body gives a positive impact on health and work productivity. Anthropometric data were obtained based on anthropometric laboratory databank Indonesia, with 30 samples and critical age around 20-30 years.

TABLE IV: Is an anthropometric calculation on Totybelt.

No	Anthropometry Dimension	Product Dimension	Assessment Result
1	Hip Width	Diameter Belt	34 cm
2	Thigh Thick	Thigh Diameter on Body Harness	23 cm

No	Anthropometry Dimension	Product Dimension	Assessment Result
3	Shoulder Height From Sitting Position – Elbow Height From Sitting Position	Body Harness Height From Navel to Chest	36 cm
4	Upper Arm Length	Body Harness Shoulder Length Parts	30 cm
5	Bone Segment Length	Airbag Length to Lower Body Part From Belt	74 cm
6	Stomach Thickness	Inner Airbag Diameter	34 cm
7	Length in Sitting Position- Shoulder Length in Sitting Position	Airbag Length From Neck to Upper Head	30 cm
8	Head Part Length	Airbag Diameter From Head Parts	30 cm
9	Lower Arm Length	Lower Parts Airbag Diameter	41 cm

3.5 Acceleration Measurement

To work automatically, product must be able to detect workers who are in a fall condition. Therefore, it takes some simulation of product to collect acceleration data on ADXL345 sensor with sampling for 1 millisecond in graphic form. The simulations performed are as follows, simulated products when workers walks, workers idle, and workers fall.

Simulation results in this experiment when the product is dropped from a height of approximately 5 meters. In fall conditions it can accelerate more than 50 m / s2

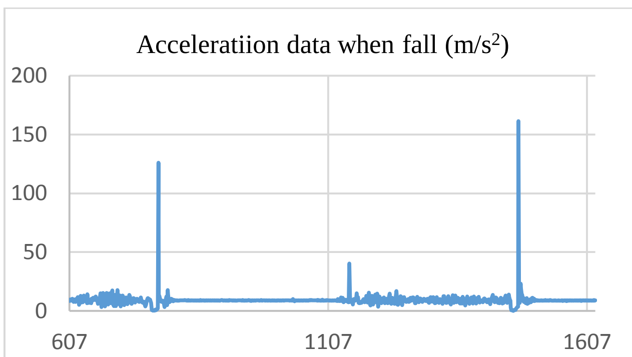

Fig. 3: Acceleration happened when fall

Then the result is acceleration data when walking on that worked on the sensor is only about 5-20 m / s^2.

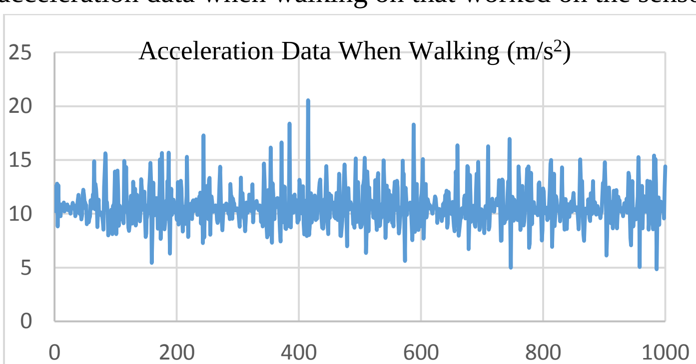

Fig. 4: acceleration happened when walk

Then the result is acceleration data when idle on that worked on the sensor is only about 5-20 m / s^2

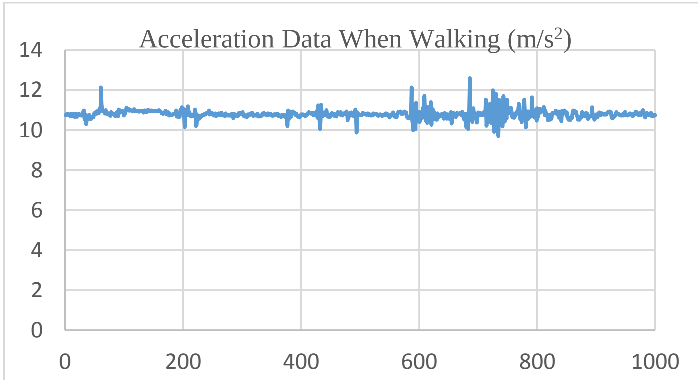

Fig. 5: acceleration happened when idle

4. Result and Analysis

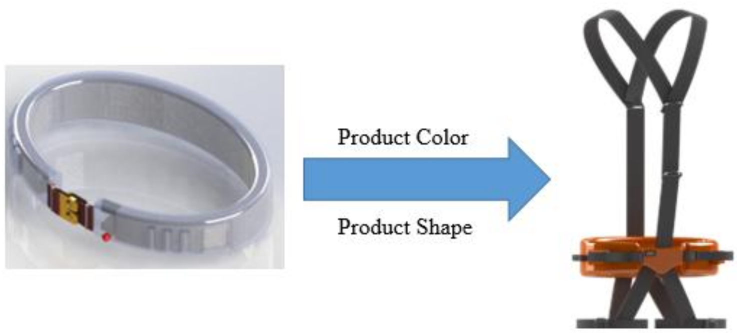

Fig. 6: Product Development

Figure 2. There is a change in color of the product because it is related to the color used in the safety equipment that already exists at the work of height. The orange color used in the new product design is in appropriate with the observations result from several respondents who give orange-colored suggestions as a characteristic of height safety equipment and phosphor color for belt to be seen in the dark.

In addition to the color aspect, there is a significant change in terms of product shape from the design with the results achieved due to the design based on Customer Requirement from high altitude workers and Occupational Health and Safety experts who want to be given additional features such as the combination between Body Harness with a belt that contains airbags. Then in the middle area there is a pocket, which is use to put the electronic circuit of this Totybelt tool. OLED LCD is used to support microcontroller, as a marker of activation of automation and on / off.

The anthropometry approach has the function of perfecting the design in the ergonomic approach. Anthropometry can provide a convenient size for the users. In addition, researchers also do not need to do a research of previous product sizes in the field, just taking samples of size in the data bank anthropometry.

This tool works when the acceleration sensor on the ADXL345 reaches more than 50 m / s. So the sensor will send electric current into the arduino nano as a sign of someone is falling. Then the arduino sends an electric current into the inflator that will emit gas as a pump for airbag to becomes bubbling.

5. Conclusion

Customers are not satisfied with Personal Protective Equipment (PPE) for high altitude worker on the market because, it cannot protect workers in case of negligence when work or use of wrong Standart Operational Procedure (SOP). Toty belt is a product that can answer the worries of customers because it can protect high altitude worker in case of negligence / fall from high workplace. In addition, the totty belt is also supported with a microcontroller that can activate airbag mechanism with accelerometer sensor if the worker fall. Toty belt gives satisfaction to customers because If this tool is used then the workers will feel more secure.

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