Muslim Ablution Eco Water Tap: From First Design Alpha Prototype to Second Design

W Trusaji¹, M ‘A A Rafsanjani¹, A R Irhamna² and D Irianto³

¹ Engineering Management Department of Institut Teknologi Bandung
² Mechanical Engineering Department of Institut Teknologi Bandung
³ Industrial Engineering Department of Institut Teknologi Bandung

wildan@mail.ti.itb.ac.id

Abstract. Muslim in Indonesia uses a lot of water to do an ablution activity, and it is not caused by wasteful character of Indonesia’s Muslim society, but because of the design of conventional water tap is not intended to conserve water in ablution activity. To solve the problem, a conceptional Muslim ablution eco water tap design was made. The concept of the product is, it has a mechanical based system to create an auto shutdown mechanism. Thus, the water usage for ablution is predicted can be decreased. However, after the first design alpha prototype is built, faults of the design are directly detected. Thus, this paper tries to analyze the first design alpha prototype and suggest a refinement to create the second design. In this paper, two deficiencies from the first design are identified and a second design is proposed.

1. Introduction
Muslims are obligated to do a prayer five times a day. Before do the prayer, muslims are requested to do ablution activity called wudu’. Indonesian muslim uses a big amount of water to do a wudu’. The causes of this phenomena is not caused by wasteful charateristic of Indonesian Muslim, but because the convetional water tap is not designed to conserve water in wudu’ activity.

To solve this problem, Rafsanjani, Trusaji, & Irianto [1] tries to develop a concept of a water tap that uses mechanical mechanism to create an autoshoff feature. This autoshutoff feature is predicted can reduce the water usage because in wudu’ activity there are a lot off water that come off without touching with any bodypart, especially when both hands are occupied to wash the other bodypart. In addition to that, it also tries to create embodiment design, detail design, and prototype of the first concept design.

The concept is promising. However, it still lack of functionality proof. The first design alpha prototype (FDAP) needed to be simulated. After that, the design need to be improved based on the analysis of the prototype simulation. This is a crucial step because prototyping in early stage design often influences design project succeses [2]. Prototype simulated use can improve the design through design refinement [3] and reveal serious design problem [4].

This research tries to simulate and analyze the FDAP. Based on that, a second design is proposed through design refinement process. The second design is proposed as the main result of this research. The paper is arranged as follow: Introduction, methodology, analyzing of FDAP, design refinement process, and analysis & conclusion.
2. Methodology
There are common names for comprehensive physical prototypes such as: testbed, alpha prototype, beta prototype or preproduction prototypes [5]. Main difference between alpha and beta prototype is in the main function of the prototype and where the prototype is simulated. The main function of alpha prototype is for system integration checking. Thus the alpha prototype is simulated in laboratory condition. The beta prototype is for field testing purpose, and it is simulated in real environment when the product is used by consumer.

To get the second design through a refinement of FDAP, an iterative testing framework is used [6]. The framework consist of four step iterative cycle, that is design, build, run, and analyze. Scope of this paper is only run and analyze the FDAP, then the second design is arranged. Design process of Pahl & Beitz [7] is used as the detail step in the arranging the second design. The design processes are clarifying task, concept design, embodiment design, and detail design. The design process proposed by Pahl and Beitz is choosed because it is based on elaborate analysis of the fundamental technical system, systematic approach, general problem solving process, and perhaps it is the most known and used either by industri or by education [8]. Thus, the methodology used in this paper is described as follow:

![Figure 1. Modified iterative testing framework.](image)

3. Analyzing of the FDAP
Notation:

- $A$: Cross sectional area of valve ($m^2$)
- $k$: constant factor characteristic of the spring
- $\rho$: Fluid density (water) ($kg/m^3$)
- $x$: deformation of the spring
- $g$: Gravitational acceleration ($m/s^2$)
- $\mu_k$: coefficient of friction
- $\sum h$: Vertical distance between water tap and water tank
- $N$: normal force exerted by each surface
- $p$: Distance between the joint and the farthest part of the valve

The concept of the first design is using spring system to create an autoshutoff mechanism. In addition to that, it uses pushing the lever method to create an opening for water by making two hole in valve system and tap body concentric to each other. When there is no force is applied to the lever, the spring push the valve into initial condition where those two hole is not concentric to each other. Thus, the water will not come off or leak off.
The FDAP simulated run is not well as expected. The lever is very hard to push, so the valve system won’t create an opening for the water. The second run is simulated but the spring system is taken off from the prototype. However, the lever only move when a very high force is applied to it. The force is enormous, so the product won’t be practical for the user.

Based on those finding, a static analysis is taken to find the reason why the lever is very hard to moved. From that, it is found that by using push concept with two cylinder of valve and tap body, the design create an unitenional effect of hydrostatic force. So to create an equilibrium, the user need to applied a force equal to hydrostatic, spring force, and friction between valve and water tap body. Thus, the force that needed to create an equilibrium in x-axis is as the follow

\[ \sum F_x = 0 \]  
\[ F_{lever} = F_{hydro} + F_{spring} + F_{friction} \]  
\[ F_{handling} = A \rho g \sum h + kx + \mu_k F_{Nmax} \]
Figure 6. 2D-Free body diagram of first design

A numerical simulation of the equation is done to give an insight about the practicality of the design. Only hydrostatic force that considered, since the the spring force can be easily altered and the friction force is assumed negligible. The cross sectional area of the FDAP’s valve is 314 mm². If most people have a water tank 3 meter higher than the water tap, then hydrostatic force that applied to the valve is 9,23 N.

Let us assume that user is capable and convenient to apply equilibrium force with amount of 9,23 N. However when 9,23 N or more force is applied to the lever, it will not move the lever forward but it create a torsion in joint. It happen because the force is not in the same axis with the hydrostatic force. Thus, an analysis on moment equilibrium at O point is taken. It can be assumed that moment of hydrostatic, spring, and friction are negligible since those are in the same axis with the point O. Therefore, the moment acting in this analysis are because of the handling force and normal force and it is as follow:

\[
\sum M_o = 0
\]

\[
F_{\text{handling}} \cdot y - \text{distance to point } O = F_{N_{\text{max}}} \cdot p
\]

\[
9,23 \cdot ((114 - 35) + 40) = F_{N_{\text{max}}} \cdot 79
\]

The force applied to the lever create \( F_{N_{\text{max}}} \) normal force around 13,9 N. That additional \( F_{N_{\text{max}}} \) force makes the friction force bigger, so user need more force to push the lever. This first design has two deficiencies. First, user need a big force to create a water opening. Second, force applied to the lever makes a moment in joint O and it creates a bigger friction force. Thus, the first design must be refined and all the parameter need to be calculated to create a force that user feels convenient and to eliminate the unintentional effect of moment.

4. Design Refinement Process

The first step of creating the second design is task clarification. Since the second design is based on the analyst of FDAP, the task of design refinement is mainly to remove flaws in first design. Thus, the second design must have an ability to minimize the \( F_{\text{Lever}} \) that needed to create an opening and remove the moment created by \( F_{\text{Lever}} \).

The development team agrees that the concept of the product should be the same. The product still uses spring to create an autoshutoff mechanism. In addition to that, the push concept is still used.
Although that, the handler is removed because it create a complexity for the user. The good design is the most simple one [9].

In embodiment design, all of the product component can be arranged in such way to achieve the goal being given in clarifying task step. To remove the moment, the arrangement of the position of Flever is crucial. Thus, the lever is positioned in the same x-axis with valve and tap body. In that way, the Flever now in the same x-axis with Fhydrostatic and Fspring, so the moment in joint O reduced to zero. The detail arrangement of all the product component is showed at Figure 7.

The embodiment phase can’t solve the minimize Flever problem, so in the detail design that problem must be addressed. The equation of hydrostatic force serve as starting point to solve problem. In that equation, nominal value all of function is parameter except cross sectional area of valve (A). Thus, A can be designed in such way to minimize the F Lever. Since Flever is proportional with the A, the valve in second design is arranged to has a tiny cross sectional area as small as possible. It can reduce the hydrostatic force, so the user is more convinient to use the product. The detail design of second design is showed at Figure 8, Figure 9, and Figure 10.

![Figure 7. Embodiment design of second design](image)

![Figure 8. Right view of opening position](image)

![Figure 9. Isometric view of second design CAD](image)

![Figure 10. Right view of closing position](image)

5. Analysis and Conclusion
The FDAP maybe seems like a failure. However, the FDAP serves critical role for the development team to grasp more understanding of the problem. The FDAP serve as media communication between development team member who has diferent discipline. Besides that, it can help to foster team’s innovation to create the second design or the further version design.

There are two main differences between first and second design. First difference is the position of lever. The lever of first design is positioned below the hydrostatic force and spring force, so it creates a moment. In other hand, the lever of second design is positioned in the same x axis with hydrostatic force and spring force, so the moment is negligible. Second difference is the area of the cross sectional of the valve. The valve diameter of first and second design are 20mm and 13mm respectively. Thus, the second
design has the half amount of hydrostatic force from first design. Differences between the first and second design are summarized in Table 1.

| Characteristics/Features | First Design                        | Second Design                        |
|--------------------------|-------------------------------------|--------------------------------------|
| Position of lever        | Below hydrostatic force              | Same level with hydrostatic force    |
| Moment generated by pushed lever* | Significant, around 1,19 Nm     | Negligible                           |
| Normal force created by moment* | Significant, around 13,9 N  | Negligible                           |
| The diameter of the valve (area) | 20mm (314 mm²)            | 13mm (132,7 mm²)                     |
| Hydrostatic force*       | 13,9 N                               | Half of the first design, 6,85 N     |
| Handler                  | Used                                 | Not used                             |
| Part(s) of tap body      | Main body only                       | Has two parts, main body and upper body. |

*The calculation is based on the water tank is 3m high assumption

The second design can remove the moment created by pushed lever and can reduce the hydrostatic force to almost half of hydrostatic force in first design. However, the muscle strength of human arm need to be measured. Based on that measurement, the parameter characteristic of spring (k) can be set to ensure the convinience of the user. Thus, in the next step, the target for spring force need to be identified and calculated based on the measurement of human biomechanics.

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