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Use of DFA - Assembly Functional Analysis Tool to Reduce Number of Components

in Hot - Cold Water Dispenser

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***Abstract*—Hot - Cold Water Dispenser is a high end kitchen product mounted on sink of kitchen to meet the requirement of instant hot and cold water as desired. It provides cold water at ambient temperature and hot water at near boiling temperature of about 97ºC to meet the instant water need. This paper brief the objective, terminology & methodology of Assembly Functional Analysis as theoretical approach of Design of Assembly how to reduce the number of components or parts in the product without affecting the existing product performance with ease of assembly.**

Keywords—Check Valve; Design Efficiency; DFA; Functional Analysis.

I. Introduction

Hot Water Dispensers are classified as Hot Water Dispenser & Hot - Cold Water Dispenser. Hot Water Dispenser provides hot water instantly to meet the user requirements where as Hot - Cold Water Dispenser provides hot as well as cold water. From product assembly perspective, there is a small difference between the Hot - Cold & Hot Water Dispenser. check valve is used only in the Hot - Cold Water Dispenser.

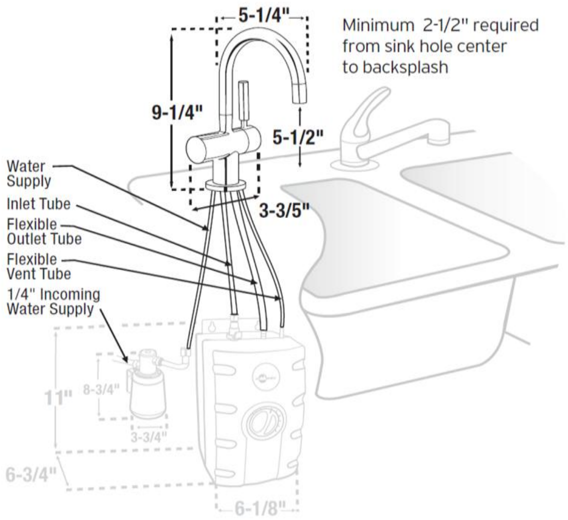

Figure 1 - Hot - Cold Water Dispenser

Figure 1 shows general parts assembly. One end of 3/8" flexible plastic tube is connected to main kitchen water supply point with brass nut and insert. Other end of the same tube is connected to water filter inlet port by quick push connector. Output port of water filter is connected with similar flexible plastic tube, whose other end has quick push connector and connected to inlet of faucet by flexible copper tube. In the valve body of faucet, inlet of faucet is divided in three water lines as inlet of Hot Water Tank, outlet of Hot Water Tank & main faucet discharge line which are operated by 3/2 direction control valve.

A copper tube followed by 1/4" polyethylene tube from faucet is connected to inlet port of hot water tank via aspirator unit. Aspirator unit has two outlets one goes to hot water tank and another goes to expansion tank. Output of expansion tank is connected to faucet by 5/16" plastic tube followed by copper tube. Outlet of hot water tank is connected to faucet via 7/16" silicone tube followed by copper tube. In between check valve is provided for preventing cold water flow into hot water tank when faucet is operated for cold water output.

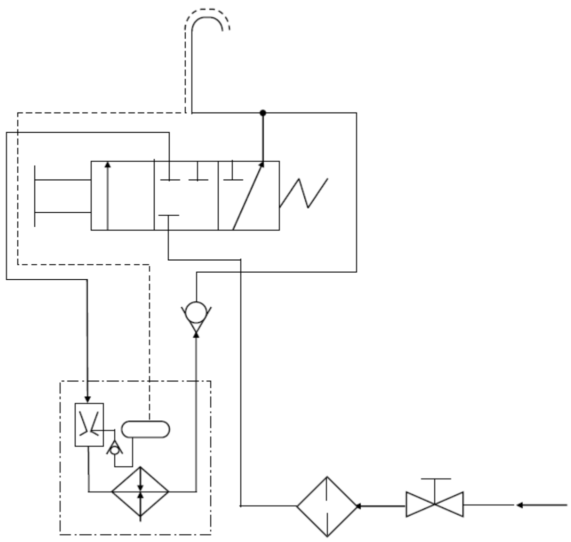

Figure 2 - Hot - Cold Water Dispenser

Figure 2 shows hydraulic circuit diagram of Hot - Cold Water Dispenser which is operated by 3/2 direction control valve. To get the hot water from faucet, handle lever need to be pushed downwards & rotated clockwise. By doing so cold water from water filter comes into the faucet via flexible copper tube & goes to hot water tank via copper tube followed by polyethylene tube. Hot water available inside hot water tank comes in outlet tube and flows to faucet after lifting the check valve.

To get the cold water from faucet, user needs to press the lever & rotate handle in anticlockwise direction. By doing so, cold water from water filter flows to faucet and gets dispensed without going cold water inside the hot water tank. In this condition, check valve prevent cold water to enter into hot water tank.

II. DETAILS OF SCOPE

For proper functionality of a faucet in conjunction with a hot water tank, a check valve assembly is utilized. The check valve assembly prevents the cold water from entering the heating tank through the port where normally the hot water exits the tank. This check valve is typically attached to the faucet external to the valve body.

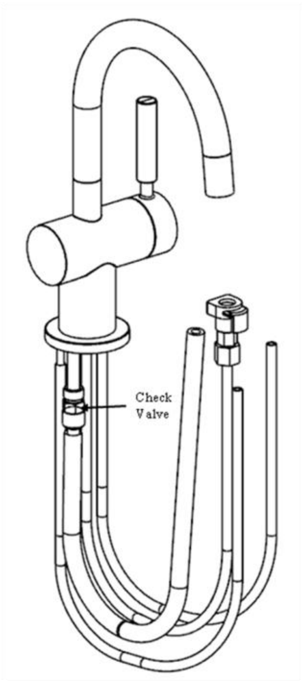

Figure 3 - View of Hot-Cold Faucet and check valve

In an existing faucet - Hot-Cold Water Dispenser system , the check valve is a separate assembly. One end of the check valve is connected to a copper tube which is brazed to the valve body. The other end is connected, with a clamp, to a silicone tube which is then connected to a hot water tank.

The current check valve assembly system consists of 12 parts (6 parts in the check valve assembly, 2 parts for connection to the copper tube, the copper tube, and the clamp for connecting the silicon tube).

Considering cost, sourcing time, ease of assembly & as design Engineer, our responsibility is to reduce the number of component thereby reduce the cost of product without affecting the functionality. The benefit of doing so is to reduce the number of parts, ease assembly and improve serviceability, without changing the overall external appearance of the dispenser.

III. METHODOLOGY

Design for assembly (DFA) is a process by which products are designed with ease of assembly in mind. If a product contains fewer parts it will take less time to assemble, thereby reducing assembly costs. In addition, if the parts are provided with features which make it easier to grasp, move, orient and insert them, this will also reduce assembly time and assembly costs. The reduction of the number of parts in an assembly has the added benefit of generally reducing the total cost of parts in the assembly. This is usually where the major cost benefits of the application of design for assembly occur.

Design Rules for DFA

1. Reduce part count and part types
2. Strive to eliminate adjustments
3. Design parts to be self-aligning and self-locating
4. Ensure adequate access and unrestricted vision
5. Ensure the ease of handling of parts from bulk
6. Minimize the need for reorientations during assembly
7. Design parts that cannot be installed incorrectly
8. Maximize part symmetry if possible or make parts

Theoretical but systmatic approach of reducing number of component in assembly is called as Functional Analysis or Design Efficiency. In the Assembly functional Analysis, all the parts are separated into two groups, primary and secondary components which are noted as A & B parts respectively. All the functional parts which compromise the product performance and specifications are set in the A group. The parts which are not related with the primary specification, or perform a secondary role, as fixture, connecting cables and others usages, are set in the B group. DFA suggest that, design efficiency must exceed 60%.

To conduct DFA, Functional Analysis has three important steps to reduce the number of components in order to reduce cost by increasing reliability. Those are,

A. To identify primary & secondary components.

First step of DFA-Functional Analysis is to identify the primary & secondary components. To identify it, we need to ask four basic questions for all parts of the product. If answer of any one question is YES, it called as Primary Component - A & answer NO is called as Secondary Component - B.

Those question are,

Q-1 Must the part move relative to other part to perform its function?

Q-2 Must the part be made up of different material?

Q-3 Must the part be a separate component?

Q-4 Must the part be disassembled due to serviceability?

By answer of these question, we get primary & secondary components.

B. To calculate design efficiency.

Once we have exact number of primary & secondary components of products, our next step will be calculation of design or functional efficiency. The functional efficiency of product can be calculated as,

$E = A/(A+B) \times 100\%$,

where A is number of essential or primary components,

B is number of non-essential or secondary components.

As per the DFA guidelines, functional efficiency must be greater than 60% and have scope to reduce number of components until reach design efficiency or more than 60%.

C. Re-design the product.

Based on the design efficiency, we need to take the decision of product redesign. Redesign is the process of modifying or changing an existing design with the objective of improving one or more of its aspects. If we apply mathematical logic to above design efficiency equation, we need to increase either numerators or reduce the denominators value. We can achieve this by,

1) Eliminate Secondary component “B”
2) Combine Secondary Component “B” With Primary Component “A”.
3) Reduce total number of components.

IV. FUNCTIONAL ANALYSIS

Our area of interest is how to reduce number of components in check valve considering cost, sourcing & ease of assembly in the Hot - Cold Water Dispenser. As it is used for one direction flow, it allow cold water flow into the hot water tank during hot water application and restrict flow of the same cold water into the hot water tank during cold water application. From the function of check valve, it will not possible to eliminate the entire Check Valve and or its function from the Hot - Cold Water Dispenser.

So it seems that we can either reduce the number of component of Check Valve and or combine the Check Valve Function into the Hot - Cold Water Dispenser instead of eliminating it. Functional Analysis or Design Efficiency is one of the important tool in the DFA used in such applications, it will give us guidelines how to reduce the number of component or how to combine the function of check valve in the Hot - Cold Water Dispenser itself. Let us see how the functional analysis tool work for our application.

A. Functional Analysis: With existing check valve & Hot - Cold Water Dispenser.

check valve in water dispenser is used to allow one direction flow, it allow hot water to dispense from hot water line & restrict the flow of cold water into the hot water tank by. This application is illustrated in figure 4.

Figure 4 shows the arrangement of existing check valve with water dispenser faucet, it connected between tot water tank and faucet which allow hot water and restrict cold water entering into the tank. Valve body connected with check valve and hot water tank by machined plastic tube as shown in figure 4.

Check valve assembly made from 06 parts, those are named as lower body, lower body O ring, ball, straighter, upper body, upper body O ring . To connect check valve with Faucet 04 number of parts used, those are machined plastic insert, valve body & two O rings. Other end of check valve connected to hot water tank by silicone flexible tube & clip. So entire assembly contains 12 number of components, which are in our further scope to reduce.

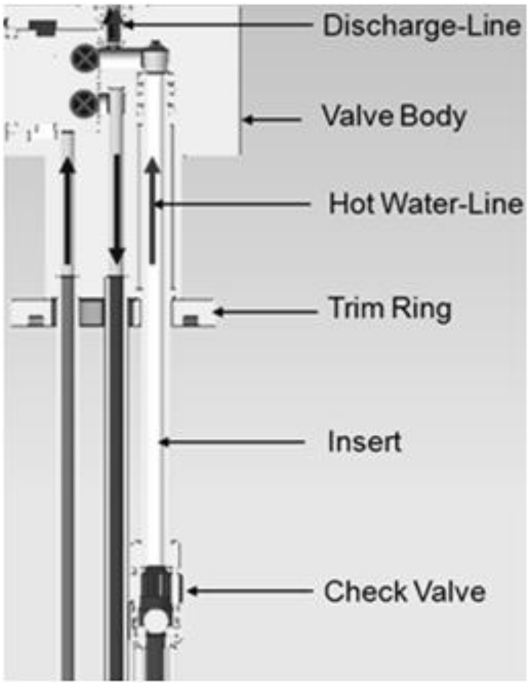

Figure 4 - Existing check valve and dispenser assembly

As per the DFA-Functional Analysis guidelines, first we need to identify the primary & secondary components with their counts. Let us apply learned theory to figure 4 to identify the types of component.

Consider the valve body as first component for Functional Analysis & ask the four question as explained in theory to identify primary or secondary component

Part: Valve body

Q-1: Must the part move relative to other part to perform its function

Answer: NO, Relative motion between valve body and mating part is not required to perform the function.

Q-2: Must the part be made up of different material?

Answer: Yes, Since valve body made from metal where as machined tube made from plastic.

Q-3: Must the part be a separate component?

Answer: Yes, Since valve body manufactured from casting process and plastic tube is machined which are two distinct part assembled.

Q-4: Must the part be disassembled due to serviceability?

Answer: Yes, Since O rings are consumable items & require continuous maintenance or replacement for them.

Answer of any one question is YES out of four, called as primary component. Thus valve body is primary component-A. Apply the same theory of question-answer for rest of the 11 parts to identify A & B parts in table form.

Table 1 - 4Q for existing check valve design

Sr.	Part	Q-1	Q-2	Q-3	Q-4	A/B
1	Valve Body	NO	YES	YES	YES	A
2	Plastic Insert	NO	YES	YES	YES	A
3	O Ring 1	NA	NA	NA	NA	B
4	O Ring 2	NA	NA	NA	NA	B
5	Upper Body	NO	NO	NO	NO	B
6	Straighter	NO	NO	NO	NO	B
7	Ball	YES	YES	YES	YES	A
8	Upper Body O Ring	NA	NA	NA	NA	B
9	Lowe Body O Ring	NA	NA	NA	NA	B
10	Lower Body	NO	NO	NO	NO	B
11	Silicone Tube	NO	YES	YES	NO	A
12	Clip	NA	NA	NA	NA	B

From above table, we get an exact number of A & B components, now second step is to calculate design efficiency / functional efficiency of check valve to identify the opportunity to reduce the number of components. Number of component-A are 04 where as number of component-B are 08 & total number of components are 12.

The functional efficiency of the design is given by,

$$E = A / (A + B) \times 100\%,$$

$$= 4 / (4 + 8) \times 100\%,$$

$$= 33\%$$

Not acceptable, since E < 60%. Hence we have scope to reduce or combine the number of components together so that efficiency can be improved to or more than 60%. From the mathematical logic to increase design efficiency, we need to either increase numerator or decrease denominator. It means increase number of primary component-A or reduce secondary component-B, this can be achieved by two ways either eliminate component-B or combining secondary component-B with component-A.

B. Functional Analysis: With new check valve & Hot - Cold Water Dispenser

After the identification of primary & secondary component with its design efficiency, our next step is to redesign the product since Functional Efficiency was below the 60%. We can eliminate the possible number of component-B or combine number of component-B with A without affecting the performance, function & assembly.

As check valve cannot be eliminated and or its function from dispenser, so we tried to find out the cost effective solution to incorporate the check valve function in the new design of the faucet. Check valve is integrated into the valve body of the dispenser. As shown in following figure 5 only ball and the O Ring is assembled inside the valve body which serves the function of check valve. O ring is placed on the end of the plastic insert which acts as a seat for the check ball. The check ball is trapped in such a way, it allows them to & fro motion inside the valve body which is functionality of existing check valve assembly.

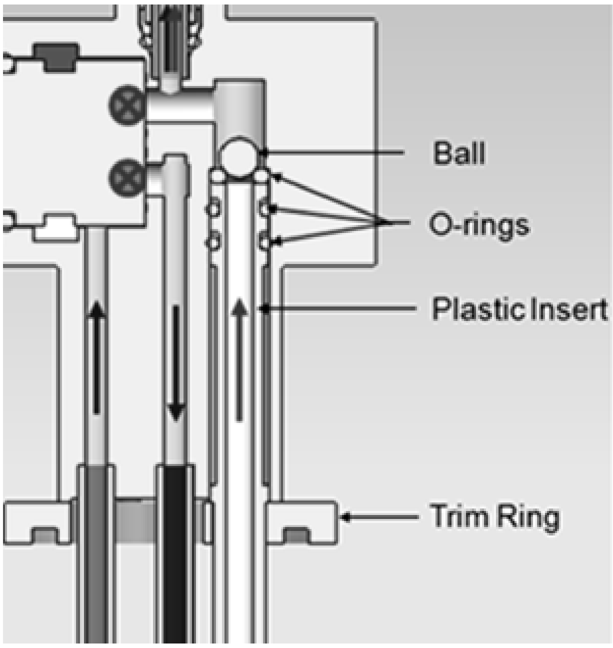

Figure 5 - Redesigned check valve & dispenser assembly

What we did in this new design concept is,

1. Eliminated one O-ring (i.e. Component – B)
2. Combined Upper Body & Straighter to Valve Body &
3. Combined Lower Body & Clip to plastic insert.

And while doing all these, we make sure that performance of product did not get affected by any means.

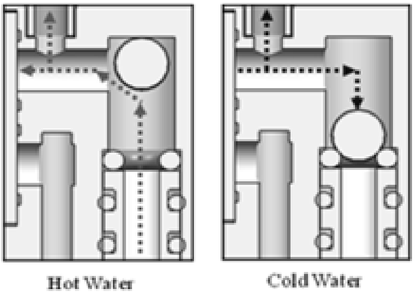

Figure 6 - Illustration of new check valve function

When the lever of the faucet actuates for hot water, pressurized hot water starts flowing out of the hot water tank into the faucet where it lifts the ball above the exit point to flow water into the spout. This is illustrated in the left hand of figure 6.

When the lever actuates for cold water, cold water flows to spout and at the same time it also try to flow to the tank since have only one passage until have mechanism to stop it. Due to the weight of the ball and the cold water pressure the check ball sets on the o-ring and blocks the cold water from the unintended flow to the tank. Hence the internal check ball serves the function of the external check valve assembly This is illustrated in the right hand of Figure 6.

Now apply the same theory of asking four questions to new design to identify the primary & secondary component, so that we can calculate the Functional Efficiency of the product or assembly.

Table 2 - 4Q for new check valve design

Sr.	Part	Q-1	Q-2	Q-3	Q-4	A/B
1	Valve Body	NO	YES	YES	YES	A
2	Ball	YES	YES	YES	YES	A
3	O Ring 1	NA	NA	NA	NA	B
4	O Ring 2	NA	NA	NA	NA	B
5	O Ring 3	NA	NA	NA	NA	B
6	Plastic Insert	NO	YES	YES	YES	A
7	Silicone Tube	NO	YES	YES	NO	A

From the above table 2, we get the exact number of A & B components for new design, now we can calculate design efficiency / Functional Efficiency & its further opportunity. Number of component-A are 04 where as number of component-B are 03 & total number of component we know i.e. 07.

The functional efficiency of the design given by,

$$E = A / (A + B) \times 100\%,$$

$$= 4 / (4 + 3) \times 100\%,$$

$$= 57\%$$

Not acceptable since E < 60%.

Hence we have further optimization opportunity, we can eliminate one O ring & combine Ball seat O Ring with plastic insert by over-molding process. By doing so we can increase efficiency up to 66% & 80% respectively.

V. CONCLUSION

Using the DFA-Functional Analysis tool, we redesigned check valve assembly in Hot - Cold Water Dispenser in such way that it reduced number of parts, ease assembly and improve serviceability, without changing the overall external appearance of the dispenser.

In this paper we reduced number of component from 12 to 07 parts by eliminating the secondary component-B & or combining the secondary component-B to primary component-A. Here we tried to keep number of primary components as it is since these are the required for functioning of product.

We increased functional efficiency of dispenser from 33% to 57% without affecting the product performance. From all these achievement, it seems that DFA-Functional Analysis is one of the best tool to achieve the cost effective solution for reduction of number of components without affecting performance with ease of assembly.

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