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Consumer's Perception and Impact of pH on Detergent in Automatic Washing Machine Based on Fuzzy Logic Controller

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Abstract

Water is a key factor in the success of the washing process. The hardness of water effects pH and pH determines the solubility. The results reveal that people living in hard water areas seldom use water softeners as compared to those living in soft water areas; the absolute percentage of people living in hard water areas and using water softener is quite low and they use more detergent. A limitation of the study is that it is based on self-reported water pH and not on actual analytical laboratory results of water tested for this property. On the other hand, an implication of the current research is that many consumers are aware of the adverse effect of pH on the outcome of the washing process and they apply various methods to neutralize this effect.

***Keywords*:** *crisp set, detergent, FIS, fuzzy set, pH, fuzzy logic toolbox.*

1. Introduction and Preliminaries

Very few published researches and very little data can be found on the relation between detergents and pH and its effects on the laundry process in automatic washing machines. Arai [1] studied the effect of concentration and kinds of detergent and the impact of oil on soil removal efficiency of hard water. Cameron [2] showed that lime deposits on fabrics may have caused discoloration of fabrics and made them harsh and scratchy to touch, i.e., water hardness reduced the satisfaction of the consumer with the washing process. In another study, the same author revealed that these mineral deposits could decrease the life of appliances and reduce the efficiency of the detergent. He also reported that more than 30% of additional detergent may have been required to allow powdered detergents to perform as effectively in hard water as they did in soft water [3]. Nagarajan and Paine [4] used an experimental method to evaluate how relative water hardness controls the performance of different ion exchange builder types under conditions closely simulating those of detergent's end-use. Brown *et al*. [5] discussed the effect of water hardness on washing quality using commercial detergents. They determined the water hardness for 10 samples of water. They found that a wide variation in water hardness which ranged from very soft to very hard. They also evaluated the effectiveness of six commercial laundry detergents of different formulations. The authors showed that the detergent containing a non-ionic surfactant with a phosphate builder gave the best whiteness results, regardless of water hardness. Hard water effect pH and it determines the solubility [6]. pH effect on wash time in automatic washing machines is discussed by Saqlain. M. *et al.* [17]. S. Hatagar et al. [18] proposed a design for FLC having three inputs to calculate wash time. T. Ahmed et al. [19] compared conventional washing machines with FLC based washing machines and deduced that FLC based machines can choose a right wash time programed in them based on inputs while in conventional washing machines the user selects the wash time based on his own knowledge or wash experience. M. Akram [20] proposed a design for automatic washing machines having only two inputs and one output. The wash time is obtained by using defuzzification methods.

The literature survey revealed that the number of studies about the effect of hard water in fuzzy logic based automatic washing machines' washing performance in general is very limited, even though there are many published researches on the laundry habits of consumers focusing on the resource efficiency of washing (Pakula and Stamminger,[7]; Hustvedt, [8]; Laitala *et al*., [9]; Yamaguchi *et al*., [10]) and on the main washing factors such as temperature, detergent type etc. (Rowe, [11], Laitala *et al*., [12]; Jack,[13]; Kruschwitz *et al*., [14]). Furthermore, the data available in literature do not provide satisfactory information as far as the impact of pH on consumer's perception of washing results and the amount of detergent used is concerned. Accordingly, the current research is conducted in order to identify the effect of pH on detergent in automatic washing machines. Also, the satisfaction of consumers with the washing process is examined and correlated with the pH. Washing habits and practices vary a lot throughout the world Pakula and Stamminger, [15]. Thus, the aim of the study is to investigate the awareness of consumer about the effect of pH on household laundry and how far it is gauged by the consumers' washing result.

1.1. Model and Calculations

Since pH of water has an impact on detergent, so different pH of water are taken. Fuzzy Logic Controller design for automatic washing machine consists of the following three Linguistic Inputs and one output.

1) Cloth type
2) Dirt type
3) pH of water

Linguistic Output

1) Detergent

Table1. Variation of Linguistic Inputs for the Proposed Model of Washing Machine

No.	Cloth type	Dirt type	pH of water
1	Jean	Non Oily	6
2	Cotton	Oily	7
3	Parachute		8

Table 1 shows the variation of linguistic inputs for the proposed model of washing machine. The above mentioned FLC inference is designed for 18 rules to select detergent.

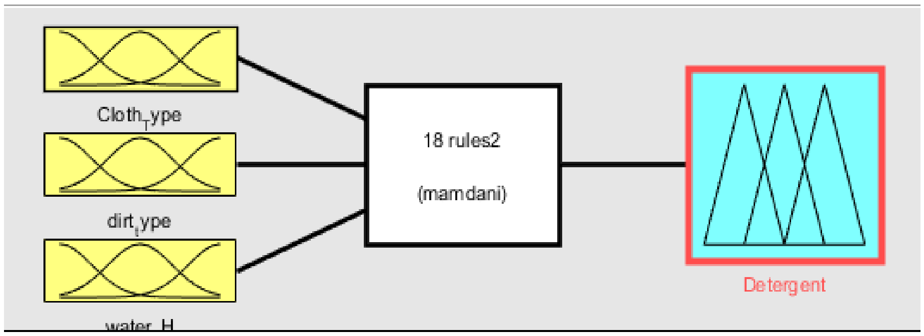

Figure 1. FLC for Washing Machine using MATLAB

The Membership Function (MF) of cloth type, dirt type and pH of water are 1 to 3, 1 to 2 and 1 to 3. MF for detergent is between 1 and 10.

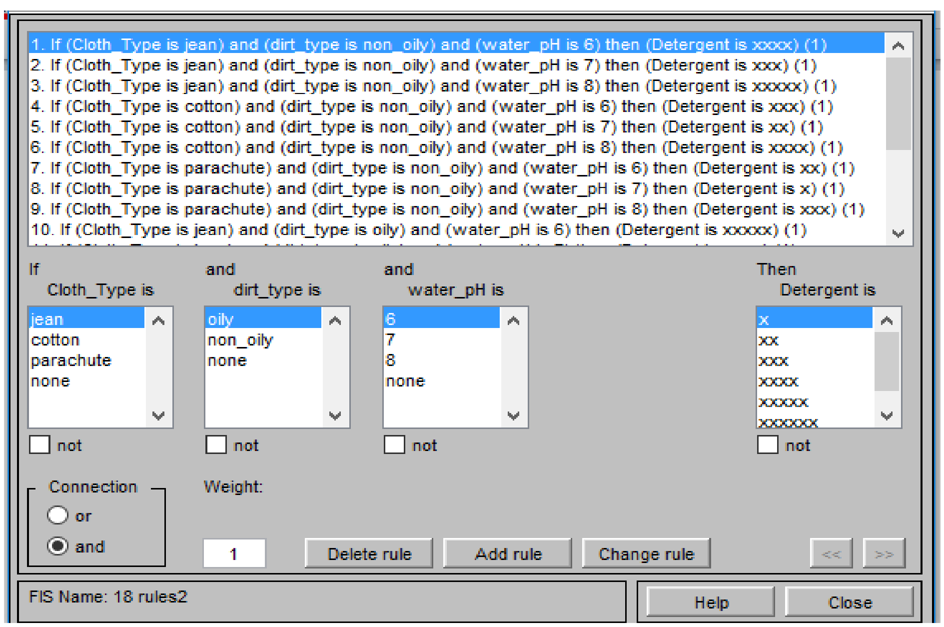

Figure 2. MATLAB Rule Editor in Term of Verbose

18 rules are formed by applying the conditional statement seen in figure 2. The MF of cloth type, dirt type and pH of water are shown in fig 2.1(a), 2.1(b) and 2.1(c), respectively. The MF of cloth type, dirt type and pH of water which are 1 to 3, 1 to 2 and 1 to 3 respectively have been obtained from MATLAB fuzzy logic toolbox.

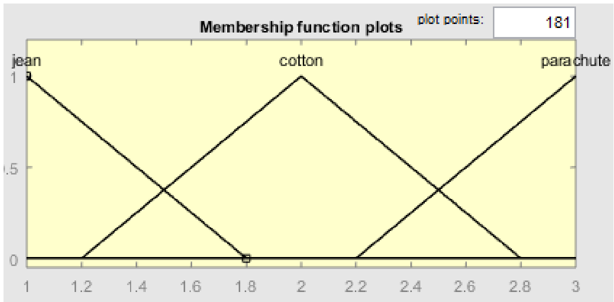

Figure 2.1(a)

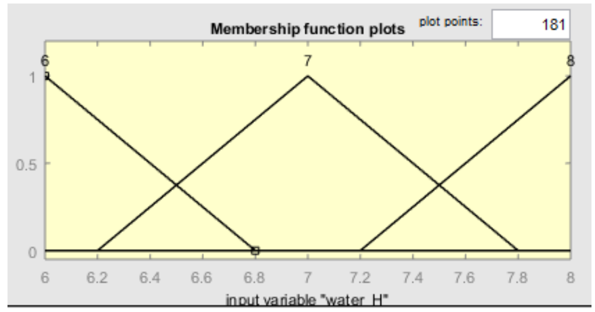

Figure 2.1(b)

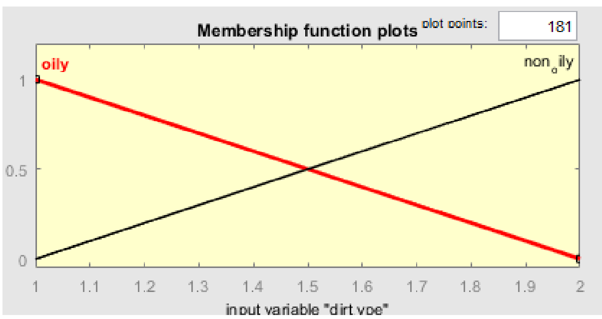

Figure 2.1(c)

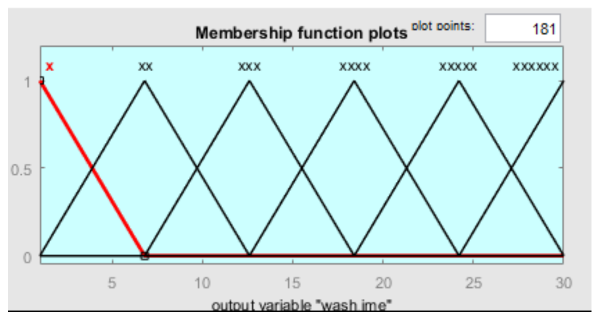

Figure 2.1(d)

The input and output parameter's membership function values, names, upper and lower limits are being set based on a given problem. The MFs with upper and lower limits of input and output parameters are shown in fig 2.1(a) to fig 2.1(d), respectively. Fig 2.1(a) to fig 2.1(d) show MFs of input and output respectively and also their upper and lower limits.

After determining the MFs and their upper and lower limits required for the modeling of necessary parameters, a total of 18 rules have been established to define the relationship among those parameters. In order to apply fuzzy logic to washing, it is necessary to establish fuzzy logic rules. These rules can be seen in table 2.

The rules too have been defined in an imprecise sense and hence they too are not crisp but fuzzy values. The three input parameters, after being read from the sensors, are fuzzified as per the MF of the respective variable. These variables, in addition with the MF curve, are utilized to generate a solution (using min-max criteria in MATLAB). Lastly, the crisp value of the wash time is obtained as an answer in table 2.

1.1.1.Defuzzification. Defuzzification is the conversion of a fuzzy quantity to a precise quantity, just as fuzzification is the conversion of a precise quantity to a fuzzy quantity. In Table 2, defuzzification is done using centroid method and the quantified results are obtained from fuzzy interface technique [16].

$$\text{Detergent} = \bar{X}\,(\text{Centroid}) = \frac{\sum_1^{10} x.\mu(x)}{\sum_1^{10} \mu(x)} \qquad (1)$$

Table 2. Defuzzified Results

	Linguistic input			Linguistic output
Sr. No	**Cloth type**	**Dirt Type**	**Water pH**	**Detergent**
1	Jeans	Non Oily	6	8.2
2	Jeans	Non Oily	7	6.4
3	Jeans	Non Oily	8	9.43
4	Cotton	Non Oily	6	6.4
5	Cotton	Non Oily	7	4.6
6	Cotton	Non Oily	8	8.2
7	Parachute	Non Oily	6	8.2
8	Parachute	Non Oily	7	4.6
9	Parachute	Non Oily	8	6.4
10	Jeans	Oily	6	6.4
11	Jeans	Oily	7	4.6
12	Jeans	Oily	8	8.2
13	Cotton	Oily	6	4.6
14	Cotton	Oily	7	2.8
15	Cotton	Oily	8	6.4
16	Parachute	Oily	6	2.8
17	Parachute	Oily	7	1.57
18	Parachute	Oily	8	6.4

By the use of fuzzy logic control we have been able to obtain the amount of detergent for different types of dirt, different pH of water and different types of cloths. The conventional method required human interruption to decide the appropriate wash time for different cloths. In other words, this situation analysis ability has been incorporated in the machine which makes the machine much more automatic and represents the decision making power of the new arrangement. Here, the sensors sense the input values and by using the above model the inputs are fuzzyfied.

Then, by using simple if-else rules and other simple fuzzy set operations the output fuzzy function is obtained and by using the criteria the output value for amount of detergent is obtained.

2. Results and Discussion

2.1. Effect of pH on Detergent

Detergents can have poisonous effects on all types of aquatic life if they are present in sufficient quantities including the biodegradable detergents. All detergents destroy the external mucus layers that protect the fish from bacteria and parasites; they can also cause severe damage to gills. Detergents also add another problem for aquatic life by lowering the surface tension of water.

MATLAB results are shown here for cloth type cotton, dirt type oily and varying pH of water. In cloth type "1" assigned to "cotton", Dirt type "1" assigned to "oily" and water pH are 6,7 and 8.

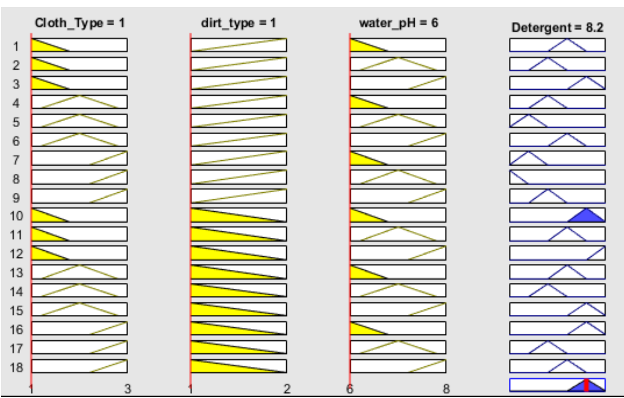

Figure 3(a)

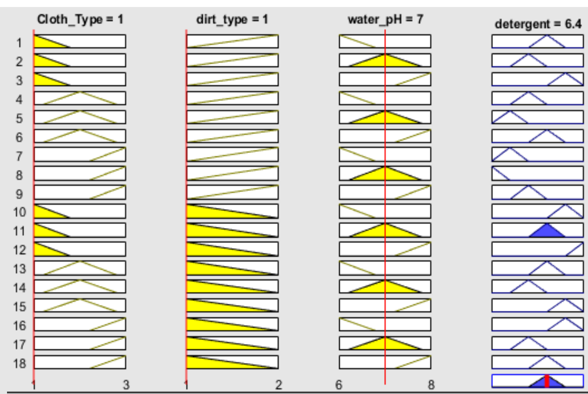

Figure 3(b)

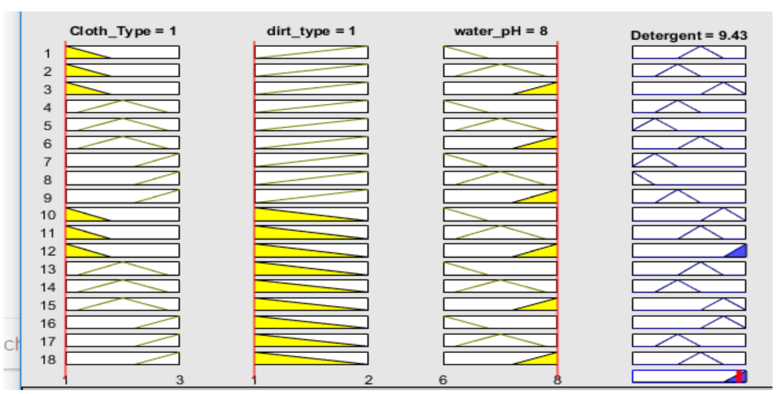

Figure 3(c)

Figure 3(a) shows that when we choose water with pH **6**, cloth type cotton and dirt type oily, the amount of detergent required is 8.2 units. Figure 3(b) shows that when we choose water with pH **7**, cloth type cotton and dirt type oily, for above mentioned inputs the amount of detergent required is 8.2 units. Figure 3(c) shows that when we choose water with pH **8**, cloth type cotton and dirt type oily, for above mentioned inputs the amount of detergent required is 9.43 units.

2.2. Relation between pH and detergent

Defuzzified results of MATLAB's fuzzy logic toolbox are shown in table 8 for cloth type cotton, dirt type oily and varying pH of water.

Table 3. Defuzzified Result Comparison by Varying pH

Water pH	Cloth type	Dirt type	Detergent
6	cotton	Oily	8.2
7	cotton	Oily	6.4
8	cotton	Oily	9.43

2.3. Graphical Representation

Graphically, it can be seen that pH of water effects the amount of detergent. When we increase the pH of water, wash time also increases. On the contrary, when we choose neutral water with pH =7, wash time is less than the other pH alternatives as shown in Table 4.

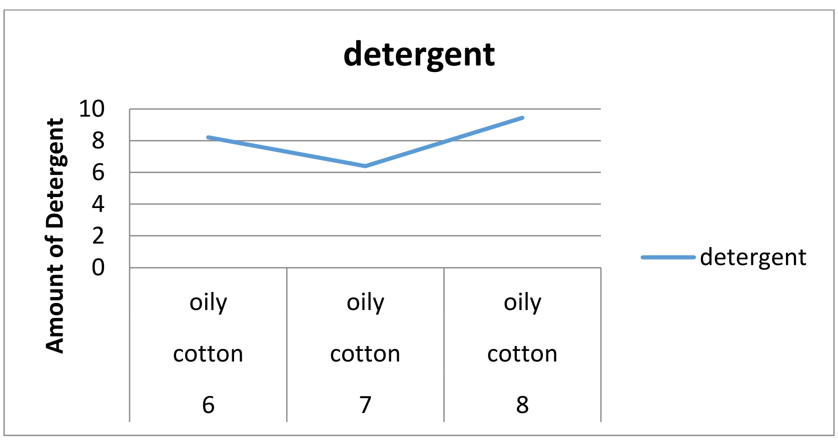

Figure 4. Defuzzified Result Comparison by Varying pH

2.4. 3D surface view of MATLAB results:

Surface view of aforesaid inputs vs output i.e. cloth type, dirt type, pH of water and wash time as shown below in Figure: 3(d), Figure: 3(e) and Figure: 3(f).

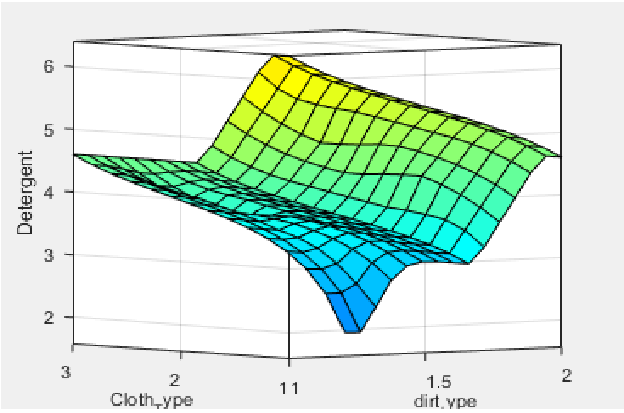

Figure 5(d)

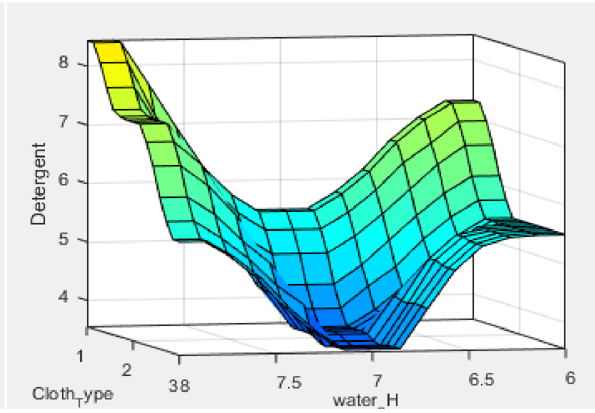

Figure 5(e)

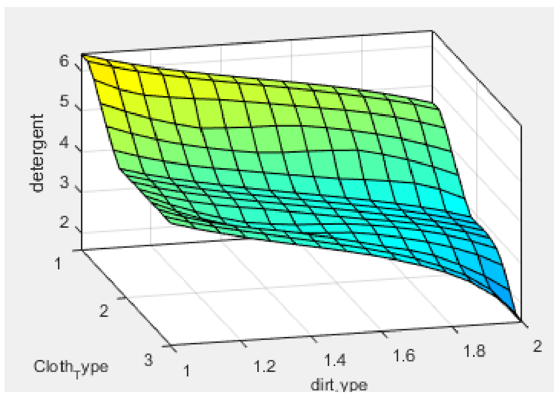

Figure 5(f)

The results (above surface view) show the way the machine will response in different conditions. For example, if we take the type of dirt and dirtiness of cloth value as 1 and pH of water 7, then the amount of detergent required according to the model is equivalent to 6.4 units. This is quite convincing and appropriate.

3. Conclusion

By using fuzzy logic control we have been able to obtain the amount of detergent for different degrees of dirt, quantity of cloth and pH of water. It also shows that by choosing water with pH 7 the amount of detergent can be saved up to 40%. The conventional method required human interaction to decide the wash time for different clothes. In other words, this situation analysis ability has been incorporated in machine which makes the machine much more automatic and depicts the decision making power of the new arrangement. After calculating the fuzzy logic controller which depends on the real working of washing machine by using MATLAB simulation, the system gets the simulated values based on the research. Then, these simulated values are used in hardware implementation. The results of this simulation based study are very good as clearly shown in the graphs. When we compare the acquired results with the expected results, it shows that the model which has been developed in this paper is extremely useable. The limitation of the current research is that the results may alter depending on the kind of washing machine manufactured by a company, model, detergent type or efficiency of the machine. MATLAB/Fuzzy logic toolbox has been used to materialize this study. It can be practically implemented by using necessary mechanical and electronics engineering concepts.

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