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Comparative Study of Specifications Between Local and Imported Water Pumps and an Energy-Efficient Local Developed Pump

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K E Y W O R D S

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A B S T R A C T

Conserving energy is one of those important requirements of the environment. In this research, an eco-friendly power saving Water pump [Air coolers] is developed. This development is based on GQFD. The model of this developed Water pump is drawn by a CAD solid model (version 7, Autodesk AutoCAD 2011). The electrical motor is responsible for the rotation of the pillar and further distributes Water inside the Air cooler [regardless of the size]. In the developed model motor is canceled where the rotation is throughout attachment to the Air cooler. A further prototype of this model is made were common and environmental quality requirements are assessed so as to verify the feasibility of the developed Water pumps. Results show that the power saving (developed) Water pump is of better-quality characteristics relative to available Water pumps available in the Iraqi market and higher head (1.60 m), Velocity in RPM (4600), and flow rate (8.6 L/sec). Also, the developed Water pump is of less noise, a number of parts, pollution, and is safer [regarding environmental requirements]. Due to the development results show save in voltage and current.

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1. INTRODUCTION

Quality is directly linked to productivity, competitiveness, customer satisfaction elimination of waste, and other non-added activities, and overall companies' success. Development is one of the reasons for companies achieve their goals and profits. Companies must measure consumer satisfaction as one of the means to consumer conservation. Thus, a very satisfied consumer increases loyalty, stays for longer periods, repeats the procurement process, gives less attention to competitors' is prices, and proposes new ideas for the company regarding the product [1,2]. In most industries, attracting new consumers is a more costly process than maintaining existing consumers. The key to maintain consumers is by increasing satisfaction and meet their needs and desires.

Through the starting point that is product development, which is imperative to the success, survival, and growth of companies [3, 4]. Quality now is a very significant factor in customer decision in selecting amongst competing products, concerning if the customer is an industrial organization, individual, or retailer [2].

Feigenbaum refers to quality as the means for best of specific conditions in the actual use and the selling price [5]. While quality refers to these product characteristics that satisfy the needs of the customers and as a result ensure customer satisfaction [6]. Quality parameters (dimensions) may be quantitative and qualitative characteristics. Or maybe categorized as; performance, reliability, features, aesthetics, durability, serviceability, and, perceived quality [2, 7]. Product development isn't merely a design, manufacturing, or marketing problem. It's a cross-functional attempt, and nearly all of the functions of the company take part in it. Moreover, product development isn't merely an intra-firm activity. The needs and attitudes of the customers undergo continuous changes, and consumers are used to getting, where customers and their feedbacks provide a base for new opportunities and product enhancements [8].

Environmental influences result in every stage of the life of a product, and various products emerge various environmental profile types. The environmental impacts are related to the use, disposal, and manufacture. Due to the fact that the environmental impacts happen at different stages in the life-time of a product's, it's important adopting a so-called lifecycle approach for product development. About 80% of the environmental profile of a product is fixed under concept creation in the development of a product, during which, there is a necessity in making an estimation of the environmental impacts that will have the greatest possibility of occurring during the whole lifetime of the product [9]. Dieter, and Schmidt [10] identified the following accountable characteristics of an environmental design is;

i. Reduce energy use and natural materials in its manufacturing.
ii. Reduces product energy consumption.
iii. Reduce product chemical emissions.
iv. Easy to disassemble.
v. Manufacturing products without generating hazardous waste.
vi. Avoid the use of hazardous materials.
vii. Use identifiable and recyclable plastics.
viii. Product content of recycled materials.
ix. The ability of products to be recycled.

From the above-mentioned characteristics, there is a direct relation to environmental design, while energy consumption is indirect since conserving energy results in reducing the strain on the environment and decrease electricity costs. Energy conservation provides support for eco-friendly lifestyle through the provision of energy, saving money while saving the earth. Also, energy conservation results in increased environmental quality (save energy to reduce pollution and other negative environmental effects). Moreover, the investment in energy efficiency produces the achievement of energy requirements for about 1/3 to 1/2 of the cost of purchasing more power on the open market. In addition to that, a higher level of efficiency reduces wear, load, and maintenance requirements on the whole electrical system, which allows enhanced reliability of the power grid. [11, 12]. In the following paragraph literature review is presented to explore the researcher's potential related to developing environmentally friendly products based on different characteristics at different stages of the design phase.

I. Literature Review

He [13] has researched the way of reducing the central energy consumption off the air-conditioning, where a case study of Nanchang HKLS air conditioning system improvement in China has been utilized. The energy-saving measures, the quality of the air-conditioning is regulated through the reduction of cooling load demand. Their energy-saving idea improves the efficiency of the entire system via enhancing the central air conditioning design and device control coordination. Their results show 5-10% in the entire energy-saving of the above central air conditioning system.

Mohammed [14] studied a process of executing an analytical design for Six Sigma using an electromechanical Water pump as a case for application in the State Company for Electrical Industries. It is the identification of VOC, benchmarking with competitive products, and designing

– redesigning the product. Used the important tools like Design for manufacturing and assembly (DFMA) and Quality Function Deployment (QFD) are applied to improve the product. The water pump is redesigned by simplifying the product as the number of parts is decreased from 12 to 7 parts. This redesign also resulted in increased efficiency for the current design from 12% to 44% through decreasing assembly time as he used. QFD to catch the VOC and Design for Six Sigma to improve the above-mentioned product. Chandak et al. [15] presented the screen for humidifying air developed, with a concept of rotating the screen via water where it's kept static and the screen has been continuously rotated through the water in a way that every screen part becomes wet for the sake of humidifying the air which is sucked by the fan. Air coolers that work with no water pump conserve electricity, Pump gives a temperature decrease of 30ºF in 15 min. It was discovered that electrical consumption is reduced by 23.5% and water consumption reduced by about 59.25%. However, the consumption of water is increased when the atmospheric temperature increases. It has been concluded that this cooler's efficiency is rather comparable high with traditional cooler in the market.

Salman and Al-Makhul et al. [16] studied the air cooler type BF3 size 2500 m^3/ hr. of two speed motor. The researchers add another water pump to the first water pump in order to increase the amount of water drop over pads. Results show that the addition of another water pump is highly significant on cooling efficiency ($F1, 19 = 15.98$, $p = 0.0018$). Furthermore, the addition of an anther water pump has a significant effect on inside temperature which improves the performance of Air cooler. In 2007, the San Francisco, California adopted an energy-saving environmentally friendly program for the city. From the moment where San Francisco launched its "green purchasing program", it presented more than 0- or low-emission vehicles to the city fleet and was successful in saving 6800 trees and over 500000 gallons of water per year via buying recycled content paper. Moreover, the city reduced the municipal use of pesticides by approximately 2/3 and radically increased low-mercury purchases, as well as long-life lamps of a fluorescent [9].

Halog et al. [17] employed QFD as a critical tool for environmental decision making to select optimum environmental performance improvement. A mathematical model is employed for the sintering production process in Germany. The proposed model is developed to find out emissions, deployed for further analysis of cost budget constraint. Their study demonstrates that it is better to address substances that contribute critically to the deterioration of the environment based on their impact potentials. So as to improve critical emissions of the sinter production process that can be effectively reduced. Masui et al. [18] applied QFD for environmentally conscious design in the early stage of hair drier manufactured in Japan. They incorporated environmental aspects with other design requirements into QFD. Their results showed a high priority for (Airflow, air temperature, the amount of energy consumption), also showed that QFD for the environment could be applicable at the early stage of product design.

2. MATERIALS and METHODS

In the Iraqi market, there are three types of water pumps in terms of origin are; Iraqi, Chinese, Iranian. Almost all three pumps have the same characteristic as the outer shape [except for the Submerged / Chinese], but they differ in the direction of rotation, Price, etc. Iraqi water pump is manufactured at (SCEI) in Baghdad/Iraq at a cost of almost 8-10 % of the total price of Air cooler [depending on the size of Air cooler]. This price is higher than imported peers because of the price of imported water pump is less than Iraqi. According to customer requirements the development product (Iraqi Water pump). The VOC is collected by a questionnaire where 100 copies (as shown in figure 6) are distributed in Baghdad government since it is the capital of the Iraq with a growing population (expected to be the number of Iraqi populations in Baghdad 12 million population in 2020 [19]. The response is of customers' requirements was interpreted and categorized as shown in Figure 1, the number over each bar chart shows the total counts of customer responds.

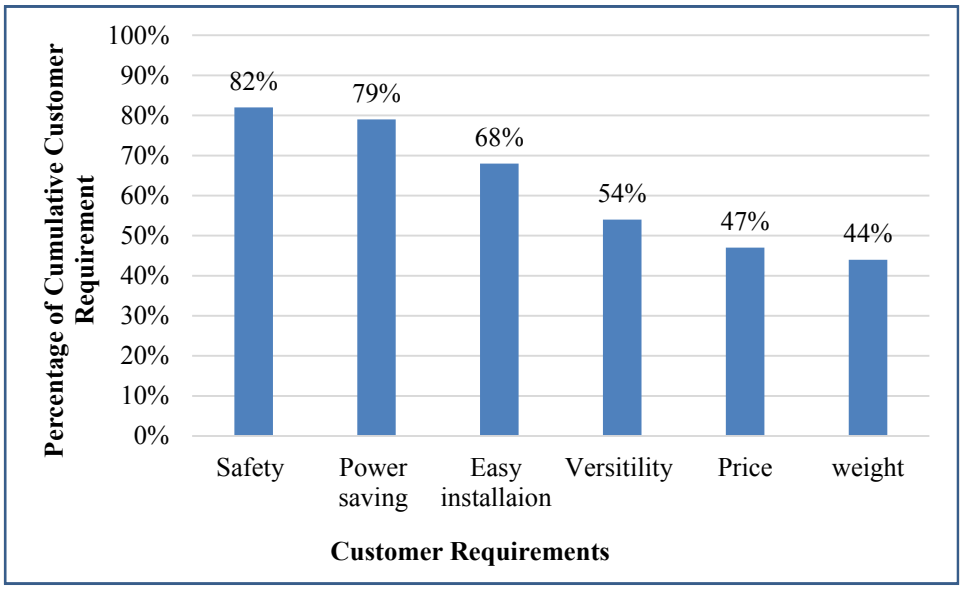


Figure 1: Prioritization of Customers' requirements

The data are analyzed using the Analytic Hierarchy Process (AHP) to obtain the priorities. Figure 2 shown the prioritization of the water pump. Where the first level represents the CRs (integrated), while level two is the sub-criteria of each criterion.

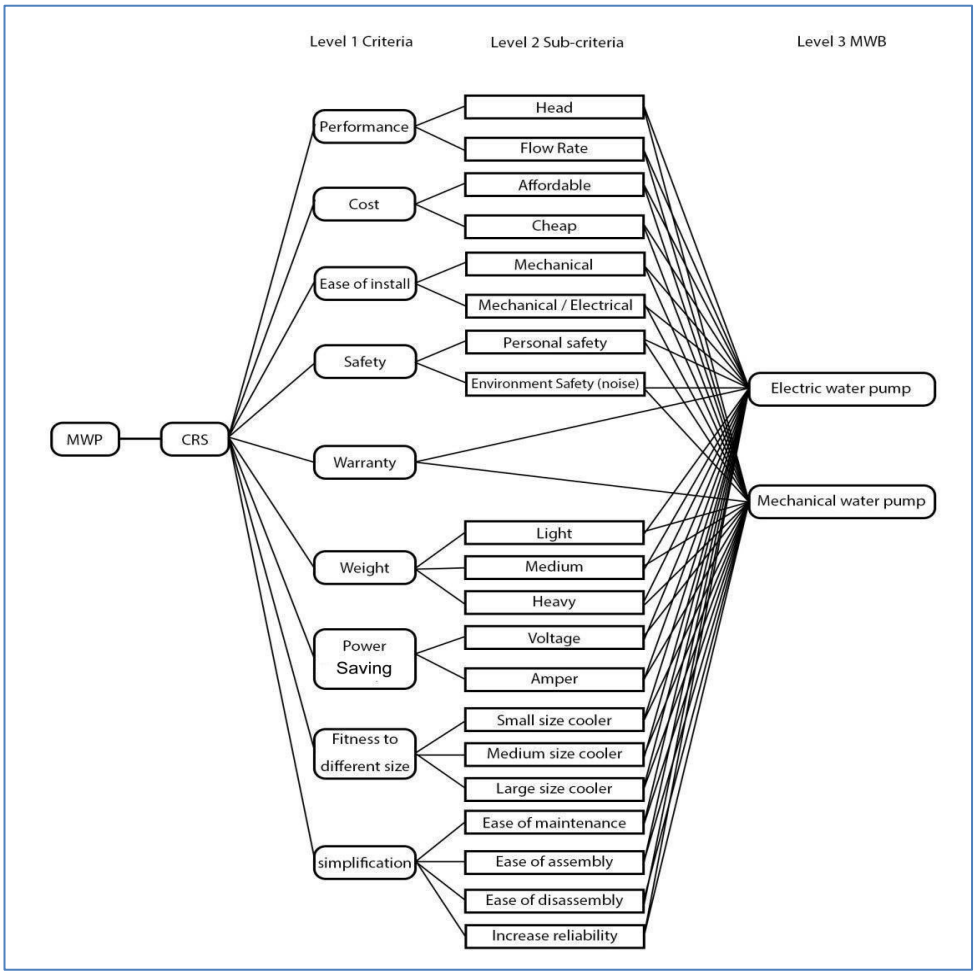


Figure 2: AHP from Questionnaire for CRs

According to the AHP process to prioritize customer requirements, 40% of the results are directed towards the environment (Simplification, Safety, Power consumption). Safety is in second place in the sequence of priorities of (13.6%). The safe product should be safe to manufacture, use, and dispose of after use. Safety can be defined as a product that does not result in property loss or injury. Recall related to an unsafe product could be extremely costly with regard to a tarnished reputation, replaced product, and product liability suits. The results of using AHP as shown in Figure 3.

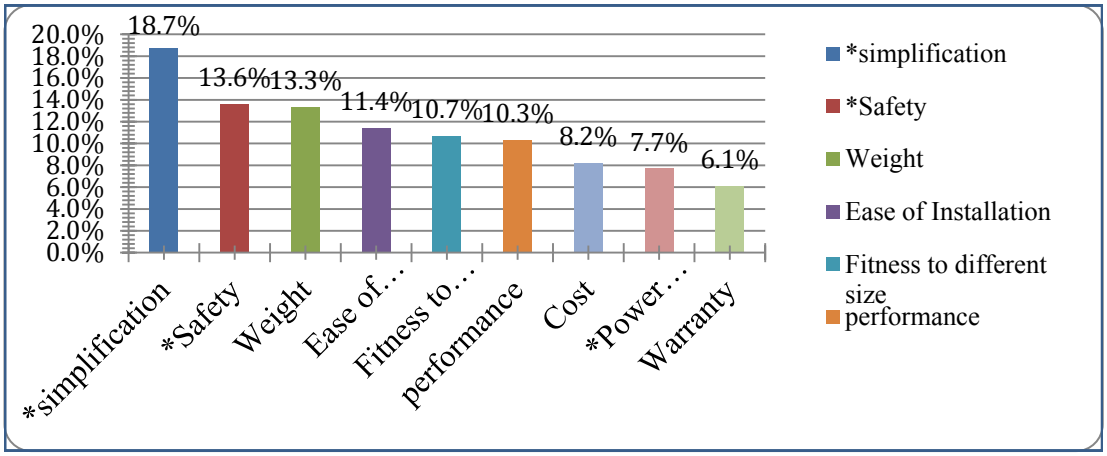


Figure 3: Customer Requirements Prioritization

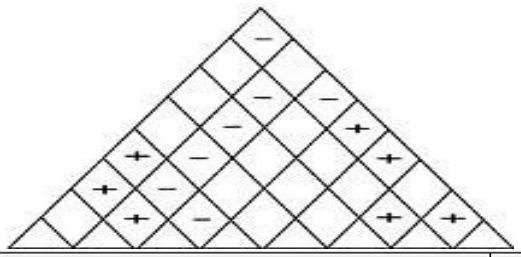
To identify how the customers' design requirements and environmental requirements can be satisfied through design, GQFD has been used as shown in Figure 4. Basically, correlations, relationships, and direction of Improvement that are used in the phases of GQFD can be seen as presented in Table I.

TABLE I: Legend Identifying Symbols in GHOQ

Correlations	Sign	Directions of Improvement	Sign
Positive	+	Maximize	▲
Negative	-	Medium	□
No Correlation		Minimize	▼
Relationships	Sign	Weight	
Strong	●	9	
Medium	○	3	
Weak	▽	1	

Green Quality Function Deployment (GQFD) is used through the tow phase as a methodology to develop a power-saving water pump. Feedback shows their direct and indirect concern toward different environmental aspects are; reduction of energy use and natural materials on its manufacturing, product energy consumption, personal and environmental safety, and product chemical emissions. According to the mentioned customer requirements the development product (Iraqi Water pump) as a case study to meet customer demands' in power saving, therefore, reducing energy consumption throughout the operation. The developed product design progress is interpreted by drawings of mechanical drawings employing CAD solid models (Version 7). The Bill of Materials (BOM) of the Iraqi Water pumps are manufactured at State Company of Electrical Industries (SCEI) in Baghdad/Iraq before the development is shown in Table II, while The Bill of Materials (BOM) of the developed Water pump is shown in Table III, and Figure 5 shows the CAD model (2D) for developed model. This developed Water pump has two main development aspects. First, removed the electrical part as a whole, hence the Water pump is activated mechanically without needing the electricity through connecting the developed Water pump with the Air cooler

via two screws and nuts {(No.9) as shown in Table I} it is used for the purpose of installing developed Water pump inside the air cooler



		Direction of Improvement	Functional Requirements								Customer Competitive Assessment			
Relative Weight	Customer Importance	GQFD Phase 1	Less energy consumption	High performance	Water Coverage Area	Quiet	Safety	Installed easily	Easy to repair	Harmless to the living environment	Developed pump	Current Iraqi Pump	Imported/ Iranian Pump	Imported/ Chinese Pump
5.5%	5	Head	●	●	●	○	○	○	▽	○	▲	▼	▼	▼
4.8%	9	Flow Rate	○	▽	●	▽	▽	●	○	▽	▲	▲	▲	▲
4.0%	17	Affordable		●					○			□	▲	
4.2%	14	Cheap		▽					●		□			□
3.8%	19	Voltage	●		○	▽	●			●	□	▲	▼	▼
3.9%	18	Amper	●		○	▽	●			●	□	▼	□	□
4.1%	15	Number of parts	●	○		○		●	●	○	□	□	□	□
4.9%	8	Type of material	▽	●		●	○	○	○	○	▲	□	□	▲
4.3%	13	Volume			●	○		●	●	▽				
6.0%	4	Warranty		●			○		●		▲	□		□
2.5%	21	Small size cooler	●	▽	▽	○			●	○				
3.3%	20	Medium size cooler	○	○	○	○			○	○	▲	▲	▼	▼
5.2%	7	Large size cooler	●	○	●	▽			▽	▽	□	□	□	□
7.4%	1	Personal safety	●	●			●			●	▲	▲	▲	▲
6.2%	3	Environment Safety	●	●			●			●	▲	□	□	□
6.7%	2	Mechanical	●	○	●	●	●	●	○	●	▲	▲		
4.7%	10	Mechanical / Electrical	●	○	●	▽	▽	●	○	○	▼		□	▲
5.3%	6	Ease of maintenance		▽					●		▲	▲	▼	▲
4.7%	11	Ease of assembly		▽			○		○		▲	□	▼	▼
4.1%	16	Ease of disassembly		▽			○		○	●	□			
4.6%	12	increase Reliability	●	●			○				▲	▲	□	□
		Importance Rating Sum (Importance x Relationship)	519.85	444.84	314.94	185.75	350.16	252.03	359.5	377.67				
		Relative important	19%	16%	11%	7%	12%	9%	13%	13%				
		Target Value	5	5	4	3	4	3	4	4				

Figure 4: GQFD (Phase 1: HOQ for Developed Water Pump

TABLE II: Components of Current Iraqi Water Pump

No	Name	No	Name
1	Stator (lamination)	12	Small Bushing
2	Rotor lamination	13	Fan
3	Shaft	14	Nuts
4	Bearing Cap	15	Rivets
5	Sheet Metal	16	Plastic Support base
6	alloy in rotor	17	Top plastic Cover
7	Copper strip	18	Final plastic Cover
11	Winding Wire	19	Impeller
9	P.V.C lead Wire	20	Plastic impeller cover
10	Clamp cell	21	Bottom end shield
11	Large Bushing	22	Top end shield

TABLE III: Components of Developed Iraqi Water Pump

No.	Name	No.	Name
1	Rubber Slinger	10	Lower Slinger Cover
2	Shaft (Stainless Steel)	11	Cotton Oiled slinger
3	Top Plastic Cover	12	Piece Iron for installation
4	Extended Studs	13	Spiral Spring
5	Nut	14	Plastic Support base
6	Upper Slinger Cover	15	Exit slot water
7	Cotton Oiled Slinger	16	Plastic Impeller
8	Upper Iron Cover	17	Plastic impeller cover
9	Lower Iron Cover		

Figure 5: CAD Model (2D) For Developed Water Pump

3. Results and Discussion

This Water pump offer power saving due to the removal of the electric motor also the power consumption of electricity is reduced as each Liter of water requires from 0.1 kW to 0.2 kW to heat a single gallon of water (for example, for bathing and washing (US Department of Energy, 2000). (1999) [20]. The environmental emissions relative to electricity generation in a closed container are termination [air cooler] therefore, promoting environmental safety. The second aspect of this developed product is the personal safety that is raised by altering the implementing positions of the developed water pump in upward instead of its current position downward in water bath (for the Iraqi and imported Water pump). Hence water is with almost direct contact electrical connections of the water pump that may cause unexpected electric shock during, connection, usage, or replacements. To test the properties of the developed water pump the detailed design is converted to a prototype model so where the properties of the developed water pump are shown in Table 4. Also, the properties are compared with pumps that are available in the local market (Iraqi, and imported).

From Table IV it could be noticed that although the developed Water pump is of higher weight than others, it had higher performance quality characteristics of the head, and flow rate that offers using it in different sizes of air coolers. Also, the noise generated during operation is the least due to the absence of an electric motor inside the developed water pump this is another environmental aspect that is also accountable according to human safety. It should be noticed that the development does not affect the velocity (r.p.m) of this water pump as it is recorded of highest value. While the price is calculated not as a selling price

since this water pump is developed prototype. And from the Tables above, it could be noticed that the number of parts is reduced from 22 to 17 parts are reduced materials result in decreasing manufacturing time, assembly and disassembly, and decreasing the number of plastic parts. It worth mentioning that the easiness of disassembly is another aspect of environmental characteristics.

TABLE 4: Comparison of Quality Characteristic between Imported, Iraqi, and Developed Water Pumps

Quality dimensions	Electric Water pump made in China	Electric Water pump made in Iranian	Water pump made in Iraq	
			Current Water pump	Developed Water pump
Weight(gr)	825	840	1584	850
Head (m)	1.50	1.30	1.40	1.60
Flow rate (L/ sec)	5.10	4.49	4.59	81.6
Noise(Decibel)	55	55	55	42.7
Voltage(V)	220	220	220	None
Current (Amp)	2.1	1.9	2.32	None
Power (W)	73	65	65	None
Selling price (ID)	8500	8000	11000	*7000
Velocity (Rpm)	2900	2800	2800	46192

*This Price is predicted since it is developed

The velocity of the power saving water pump is calculated according to the speed equation (Movement transmission) as follows [General Speed Law];

Motor Speed × pulley diameter for Motor = Fan Speed × pulley Diameter for Fan:

X1= motor speed (rpm)
X2= fan speed (rpm)
X3= water pump speed (rpm)
Y1 = pulley diameter for Motor (mm)
Y2 = pulley Diameter Fan (mm)
Y3 = Bush dimension power saving water pump

$X1 \times Y1 = X2 \times Y2$

$X2 = X1 \times Y1 / Y2$ …… fan speed

$X2 \times Y2 = X3 \times Y3$

$X3 = X2 \times Y2 / Y3$ …… Water-Pump speed

Now, can calculate the speed of the power saving Water pump according to the following data

X1 = 1400 r. p .m Y1 = 66 mm
X2 =? Y2 = 152 mm

$X2 = 1400 \times 66 / 152 = 607$ r.p.m

X3=? Y3 2mm

$X3 = 607 \times 152 / 2 = 46132$ r.p.m

This is the speed Water pump and notes that it is a high speed and therefore the amount of water raised will be very large. And the results of the tests were identical where the devices shown in Figure 6 were used according to their work i.e. The devices used in the examination were accurate and error-free, they are of different origins of manufacturing.

Figure 6: Devices Used in Electrical power measurement

The cost of the new product (developed Water pump) is calculated as follows: Stored materials in (SCEI) are used and reuse of these materials. These materials include the top plastic part, plastic impeller, plastic impeller cover, and the plastic main structure of the water pump. Comparison of electrical parameters of developed and all other water pumps available in the Iraqi market are shown in Table V. From this table, it is obvious the developed water pump is of less current, Voltage, Power, and Power factor (reduce the load of the device) When used the motor and studied the loads for each case as described below. It can be defined as the ratio between the effective power and the virtual power, which is equal to the full phase angle - which is the voltage and current difference. The device that used contains two motor loads (motor and water pump) when reducing the load of the water pump, it means improving the power factor. In normal case, the power factor should be in the range between 0.75 and 0.85, but it needs to keep in mind power factor depend on Factories manufactured [11, 21].

Therefore, saving energy, decreasing emissions related to electrical generation, and clearly safer to the environment and human beings during implementation, usage, and maintenance.

TABLE V: Electrical Parameters Comparison for Current Iraqi Pump, Iranian, Chinese, and Developed Pump

	Current Iraqi pump	Iraqi developed	Iranian pump	Chinese pump
Volts (v)	220	220	220	220
Current (Amp)	2.32	1.85	2.1	2.13
Power factor	0.8	0.8	0.8	0.8
P=V*I* Cos Ɵ	408.32 W	325.6 W	369.6 W	374.88 W

The work of the developed water pump was not an effect on the load of the motor of Air cooler and its efficiency. The system was tried for 12 hours a day during the 3 months of the summer period, the reason the system did not affect the motor is due to the presence of the oil Bush in the structure of the developed Water pump, as well as the part No. (1) Figure 4, were made of hardened linen, which makes the rotation easy and does not cause any load on the motor.
The reliability of any system depends on the parts that constitute it. Electrical Iraqi water pump before developed has consist of 22 part and work with electrical but the developed pump consists of one mechanical part with fewer parts than the previous pump, then the higher reliability of the developed pump, also it was suggested to measure the reliability of the pump in the dissertation, as this the research draws from the dissertation.

4. CONCLUSIONS

- Power saving is an important aspect that consolidates environmental requirements.
- The developed water pump generates better quality requirements when compared to the current Iraqi, or other imported water pumps.
- The developed power-saving water pump is safer on usage, in replacement, or maintenance.
- Although the developed water pump is activated mechanically the velocity measured in RPM is higher compared to those available in the local market, regardless of their origin.
- The developed Water pump is a power-saving of less current, Voltage, Power, and Power factor with load i.e. when connected to Air cooler [regardless of the size].

References

[1] M. Shu, “Quality function deployment integration with design methodologies,” Master of Applied Science (Quality System Engineering) at Concordia University Montreal, 2017.

[2] D. C. Montgomery, Chery L. Jennings, and Michele E Pfund, “Manging, controlling, and improving quality,” John Wiely and Sons Wiely, INC, USA, 2011.

[3] G. Knowles, “Quality management,” Download free eBooks at bookboon.com, 2011.

[4] M. Li-sha, M. Jian, W. Zi-ping, “Overview of key quality characteristics identification of complex electromechanical products,” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Vol.14, No. 2, PP. 01-06, 2017.

[5] G. Salvendy, “Handbook of industrial engineering technology and operations management,” Third Edition, A Wiley-Interscience Publication, 2001.

[6] J. S. Oakland, “Statistical process control,” Sixth Edition, This edition published by Routledge, 2011.

[7] S. Levine and K. Kendall, “Energy efficiency and conservation: opportunities, obstacles, and experiences,” Vermont Journal of Environmental Law, Vol. 8, No.1, pp. 107-109, 2006.

[8] J. Majava, H. Haapasalo, P. Belt and M. Mottonen,“ Product development drivers in literature and practice,” International Journal of Product Development, Vol.18, No.6, PP. 512-530, 2013.

[9] T. McAloone, and N. Bey, “Environmental Improvement through product development - a guide,” Svendborg Tryk, Denmark, 2009.

[10] G. E. Dieter, and L. C. Schmidt, “Engineering Design, Fifth Edition,” McGraw-Hill Companies, 2013.

[11] R. Banerjee, “Importance of energy conservation,” International Journal of Innovative Research in Advanced Engineering (IJIRAE), No. 4, V.2, PP. 2349-2163, 2015.

[12] S. Levine and K. Kendall, “Energy efficiency and conservation: opportunities, obstacles, and experiences,” Vermont Journal of Environmental Law Vol. 8, No.1, pp. 101-109, 2006.

[13] Y. He, "Energy Saving of central air-conditioning and control system case b study: nanchang hongkelong supermarket," Master Thesis, Savonia University of Applied Sciences, Business and Engineering, Varkaus, 2010.

[14] O. M. Mohammed, "Design for X in Concurrent Engineering Environment," Thesis, M.Sc. (Industrial Engineering), University of Technology, Department of Production, Engineering and Metallurgy, 2014.

[15] S. Chandak, A. Chandak, S. Pipleya, V. Dubey and A. Yadav, "Study of a pump less air cooler," Shri Vaishnav Institute of Technology and Science, Indore (MP), India, IJARIIE-ISSN(O), Vol-2 Issue-3, pp. 2395-4396, 2016.

[16] S. B. Salman and F. F. AL-Makhul; "Study the effect of add secondary water pump to air cooler type bf3 on the efficiency of air," Dept. of Agric. Mechanization/ College of Agriculture/ University of Baghdad, Dept. of Agric. Mechanization, College of Agriculture, University of Baghdad, Elixir Agriculture 96, pp. 41211-41213, 2016.

[17] A. Halog, F. Schultmann and O. Rentz, "Using quality function deployment for technique selection for optimum environmental performance improvement," Journal of Cleaner Production 9, 387–394, 2001.

[18] K. Masui, T. Sakao and A. Inaba, "Development of a DFE methodology in japan - quality function deployment for environment," National Institute of Advanced Industrial Science and Technology, 2003.

[19] A. Abdul Redhah, "Modeling a framework for Baghdad petroleum product's consumption", Thesis, University of Technology, Industrial Engineering, 2017.

[20] U. S. Environmental Protection Agency, "Local government climate and energy strategy series, energy-efficient product procurement, a guide to developing and implementing Greenhouse Gas Reduction Programs," Energy Efficiency in K-12 Schools, Washington, DC 20460, https://www.epa.gov/sites/production/files/2017-06/documents/k-12_guide.pdf, 2011.

[21] Eaton, "Power factor correction: a guide for the plant engineer," United States Environmental Protection Agency, www.eaton.com, August 2014.