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Design A Solar Water Pump Model To Study The Effect Of The Impeller Blades Number On The Pump Performance

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***Abstract*—In this study, the flow rate, velocity, head, the mass flow rate and the power in a designed and manufactured a solar water pump model (SWPM) were studied and determined experimentally in the Lab at the Bright Star University.**

The effect of impeller with different blades on the (SWPM) performance has been investigated. Three different impellers with 4, 6, and 8 blades are tested to determine the optimum blades number. The experimental results showed that the flow rate, velocity, head, the mass flow rate and the power are higher for the case of the impeller with 8 blades than that for the two cases of 6 and 4 blades respectively. The losses decrease by increasing the blades number due to the reduction of the secondary flow for a certain limit.

The experimental results showed better solar water pump model performance when impeller with 8 blades is used.

Keywords—Renewable energy, Blade number, Impeller losses, solar water pump model, performance, Design a pump, Volume flow rate, Velocity, Head, Mass flow rate, Power

I. INTRODUCTION

Solar-powered water pumping systems have become the interest of many people in recent years. Acknowledging that nature has provided a bounty of energy which can be converted into electrical energy has created innovative ways of discovering materials that can be used to make a system that supports turning heat into electricity. In this regard, the paper presented different concepts that relate to how the whole energy creation process is done and discusses useful ways of turning heat into useful energy. Furthermore, the recommendations dictate that while advancements in technology are given attention, the issue of the investment cost and how it will thrive in the market is still a question. Nevertheless, many developing and developed countries continue to express interest in this area, and most are actively using and exploring how solar power can be used in other ways. Photovoltaic systems which are used to pump water for people, livestock and plants are an important move for technology and the use of solar energy. A pumping water system using this PV technology has shown that is simple and that it does not require a lot of maintenance. In this regard, the idea gained the interest of farmers whose main concern is providing sufficient water not only for themselves but also for their plants and crops, and livestock. The only major difference to this is that the system relies on solar energy as a power source for the pumps.

II. LITERATURE REVIEW AND ITS OUTCOMES

i. Solar Pumps: Centuries of History

At the beginning of the 17th century, the first use of solar energy, for pumping water was developed by a French engineer named Solomon De Caux.

This led to subsequent achievements by several scientists. Yet, not before the 19th century did any major invention take place. In 1875, Mouchot built a solar steam engine for pumping water. In the late 1870s, Ericsson employed a modified design of a solar hot air engine as a small pump and W. Adams, an Englishman, demonstrated a solar pump in India and afterwards, Piffe of France used parabolic solar reflectors to power his rotary pump [1].

The twentieth century witnessed substantial achievements in solar pump development. In 1901, Aneas built a solar pumping plant in Pasadena, California, with a 4 hp capacity. This was the largest pump ever built to that time. Using an ammonia engine, H. Willsie and J. Boyle completed a 6 hp solar pump at St. Louis in 1904. By 1903, one pioneer, Shuman, utilized solar collectors with a total collecting area of 1263 m2 and succeeded in producing a 50 hp solar irrigation plant in Meadi near Cairo, Egypt. Its thermal efficiency was 4.32% [2].

With the advent of cheap fossil fuels, interest in solar energy, and thus solar pumps, declined. Not until the 1950s did any one company renew interest in developing solar pumps, when SOMOR an Italian company, marketed a number of 1 kW solar pumps [3].

During the 60s, there was intense research on developing solar pumps for use in remote areas for irrigation purposes in developing countries. In the 70s, the French company SOFRETES was able to install large-scale solar pumping installations, the largest o f which was in San Luis de la Paz, Mexico [4].

Photovoltaic (PV) pumps emerged as reliable and commercial products while solar thermal pumps received little interest, although potential for their development in the 90s is high Photovoltaic pumps are, however, currently being purchased by individual users worldwide, a fact that was a dream just fifteen years ago [5].

ii. Renewable and Solar Energy

Energy demand worldwide is increasing rapidly, mainly due to the world population increase and secondly due to the rapid technological advances that are expected to happen in the years to come [6].

The average yearly energy demand increase is a strong function of Gross National Product per capita growth. Thus, with this in mind, the present rate of fossil fuel consumption will lead to an insufficient energy supply needed to satisfy world demand after the year 2020 [7].

The solution to this problem is either to use nuclear power or renewable energy.

It is our opinion that nuclear power is not acceptable by the world public at large.

Because of its hazardous effects on the environment, short term or long term, in addition, it is accompanied by huge risks of accidents that can ruin human lives and is politically dangerous due to the unrest at various countries in the world.

Therefore, renewable energy sources are the solution to the world's energy demand in the 21st century.

Renewable energy in general comes in three different forms: solar, wind and hydro.

Solar energy has a wide variety of applications: water heating, air heating, ventilation, air-conditioning, pumping, distillation, drying and cooking comprise the main solar domestic and home uses. Solar thermal systems, such as power plants and heat engines, comprise a second major application. Other applications include space, automobile, architectural and electronic uses [8].

iii. Classification of Solar Pumps

Solar pumps, in general, can be classified as mechanical solar pumps and nonmechanical solar pumps. Mechanical solar pumps (MSP) are sub-classified as thermocycle conversion or photocell conversion. Thermocycle conversion uses the Rankine, Brayton, or Stirling cycles for production of mechanical energy that is converted into electrical energy via an electric motor that drives the pump. Also, the mechanical energy achieved can directly power the pump. Photocell conversion uses photovoltaic, photochemical, or photoionic cells that convert solar energy into electrical energy that drives the pump.

Nonmechanical solar pumps (NMSP), on the other hand, do not contain rotary or mechanical motion. They operate mainly on solar collectors and a moving diaphragm with low boiling point fluids. Direct collection o f sunlight is another operation scheme of NMSP, and this is achieved by heat transfer using a special design of the pump that causes water suction or delivery [9].

iv. What is a Solar Water Pump? | How does a Solar System work?

Solar water pump operates on the electricity produced by the PV (photovoltaic) panels or the radiant heat generated by collected sunlight. This is the opposite of a diesel or grid electricity water pump. The solar powered pump uses solar energy for operation. It consists of a water storage tank, electrical cables, a breaker/fuse box, a DC water pump, a solar charge controller (MPPT), and a solar panel array.

A solar powered water pump is more efficient to operate. These pumps have low maintenance cost and operation. Solar pumps have a lower environmental impact compared to pumps powered by IC engines. The pump with a solar system is a delightful technology with which remote areas can be supplied with water both ecologically and socially. Therefore, it is always the economic technology of choice. Remote areas tend to require mostly diesel engines and human resources for water supply. Solar water pumps replace existing pumps and offer many benefits such as weather and socio-economy. These pumps are primarily suitable for reservoirs and irrigation systems.

These pumps utilize in places where grid power is not available, and substitution energy sources (especially wind power) cannot provide enough power.

The solar powered water pump can deliver water where power lines can't reach. These are commonly found in aeration, pond filtration, aquarium filtration, and well pumps. These types of pumps mainly use in areas that have power problems. Otherwise, you will not have a stable power supply. This is an ideal water withdrawal system for green energy that combines the advantages of reliability, economy, and environmental protection [10].

v. Solar-powered Water Pump Types

Solar pumps have many types, but the most major types are given below:

- **A.** Submersible Solar Pump
- **B.** Surface Solar Pump
- **C.** DC Solar Pump
- **D.** AC Solar Pump

a. Submersible Solar Pump

Submersible pump as shown in Fig. 1., lifts up to 650ft of water and can install in large wells. As long as the well water is more than 20ft above the surface, these pumps operate directly to turn off batteries, solar panels, and in some cases, electricity. When the sun is shining, the water is usually pumped the whole day, and water is stored in tanks to be used when needed. The water can't be pumped in bad weather because the sun can't shine in bad weather. Therefore, it is advisable to store the water only in good climate conditions.

These solar pump types mostly use in deep water and undrilled areas. These pumps also use for livestock watering, pond aeration, home water systems, irrigation, pressurization, and well pumping. The maximum recommended pump depth is 50m.

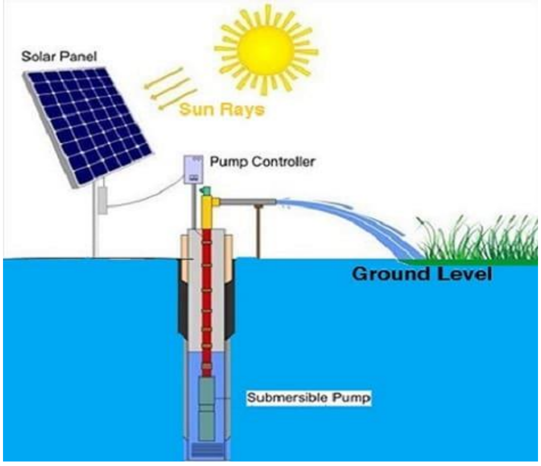

Fig. 1. Submersible Solar Pump.

b. Surface Solar Pump

These types of pumps use in streams, storage tanks, shallow wells, or ponds as shown in Fig. 2. When the well water supply depth is 20ft or less from the ground, we use a surface solar water pump. In general, they cannot pump very high water from deep wells and can pump water up to 200ft or more. These pumps can easily lift water from depths of up to 20m.

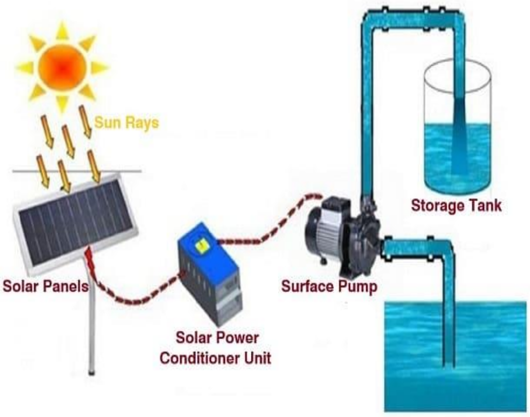

Fig. 2. Surface Solar Pump.

c. DC Solar Pump

This pump has an electric motor that uses DC as shown in Fig. 3. Therefore, no battery or inverter is required in this pump.

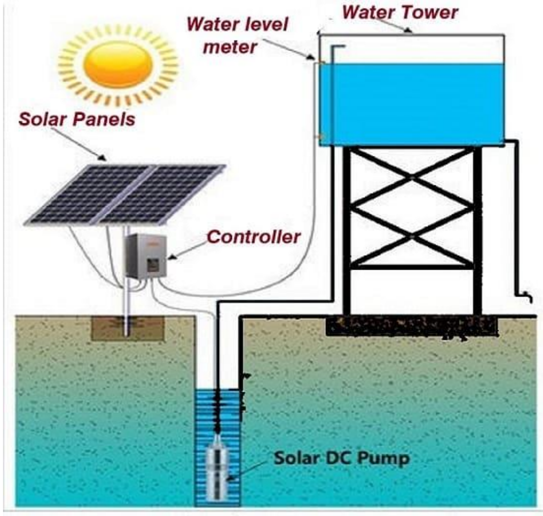

Fig. 3. DC Solar Pump.

d. AC Solar Pumps

The electric motor used in this type of pump works with alternating current. With the help of an inverter, the direct current produced by the switchboard is converted into alternating current. This conversion can lead to power outages during production and use.

III. Solar Pump Applications

The major applications of the solar pumps are given below:

A. These pumps use to supply water for animals.

B. They use for irrigation systems.

C. They also use to supply water for drinking and cooking purposes.

D. These pumps may also utilize as booster pumps for pumping fluids over long distance.

E. Solar pumps use for water treatment applications.

F. These also use for the extraction of oil and gas.

The impeller is the most important part in a pump since it is the place where the mechanical energy is converted into hydraulic energy.

Hence the parameters related to the impeller are directly affecting the performance of the pump [11-16].

In this paper a solar water pump model (SWPM) will be designed and manufactured to study the effect of the impeller blades number on the pump performance and to:

a. Determine the volume flow rate, the velocity, the head, the mass flow rate ($\dot{m}$)and the power of the (SWPM) for three different impeller blades (4, 6 and 8 blades).

b. Study the effect of the impeller blades number (4, 6 and 8) on the model performance.

IV. THE DESIGNED PUMP'S MODEL

The authors of this research designed and manufactured the equipment of the pump's model in the ***Fluid Mechanics Laboratory at The Bright Star University, El-Brega, Libya***, as shown in Fig. 4.

Fig. 4 The designed and manufactured pump.

V. THE IMPELLER BLADE

Impeller design is the most significant factor for determining performance of the designed and manufactured a new solar water pump model (SWPM). A properly designed impeller optimizes flow while minimizing turbulence and maximizing efficiency.

In general, centrifugal pumps can be classified based on the manner in which fluid flows through the pump. It is not classification based on the impeller alone, but it is based on the design of pump casing and the impeller.

The impeller of a centrifugal pump can be of three basic types as shown in Fig. 5.

i. ***Open impeller:*** Open impellers have the vanes free on both sides. Open impellers are structurally weak. They are typically used in small-diameter, inexpensive pumps and pumps handling suspended solids.

ii. ***Semi-open impeller:*** The vanes are free on one side and enclosed on the other. The shroud adds mechanical strength. They also offer higher efficiencies than open impellers. They can be used in medium-diameter pumps and with liquids containing small amounts of suspended solids. Because of minimization of recirculation and other losses, it is very important that a small clearance exists between the impeller vanes and the casing.

iii. ***Closed impeller:*** The vanes are located between the two discs, all in a single casting.

They are used in large pumps with high efficiencies [12].

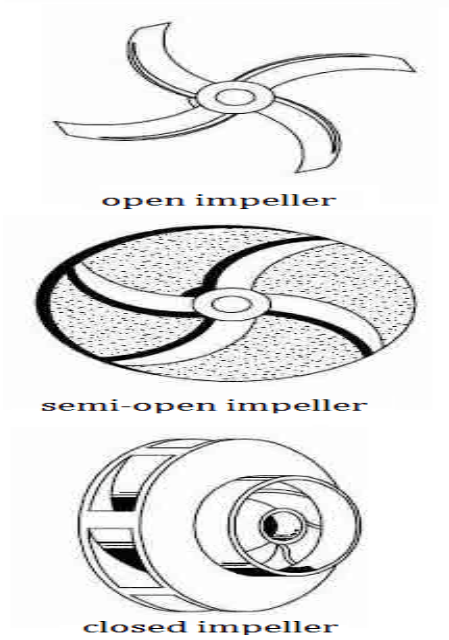

Fig. 5. Types of Impellers.

In this work three different semi-open impellers with 4, 6, and 8 blades designed and manufactured as the following:

VI. The impeller Blades of the designed pump's model

Three deferent semi-open impeller Blades: semi-open impeller with 4 blades, semi-open impeller with 6 blades and semi-open impeller with 8 blades of the designed pump's model respectively as the following:

A. semi-open impeller with 4 blades as shown in Fig. 6.

Fig. 6. semi-open impeller with 4 blades.

B. semi-open impeller with 6 blades as shown in Fig. 7.

Fig. 7. semi-open impeller with 6 blades.

C. semi-open impeller with 8 blades as shown in Fig. 8.

Fig. 8. semi-open impeller with 6 blades.

D. The three different semi-open impellers with 4, 6 and 8 blades as shown in Fig. 9.

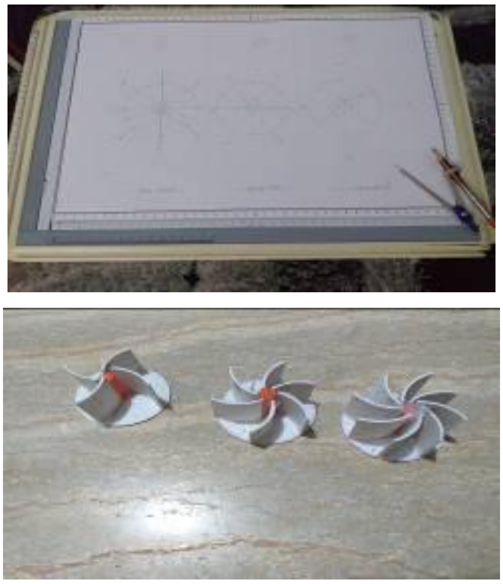

Fig. 9. semi-open impellers with 4, 6 and 8 blades.

VII. THE SOLAR PANEL

A solar panel array. Recent advancements in solar harvesting technology are bringing the immense potential of incident radiation from the sun into economic viability for the future.

Solar energy is radiant light and heat from the Sun that is harnessed using a range of technologies such as solar power to generate electricity, solar thermal energy including solar water pump as shown in Fig.10, solar water heating, and solar architecture.

It is an essential source of renewable energy, and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems concentrated solar power, and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

Fig. 10. A solar panel used in this research.

VIII. THE DESIGNERS OF THE SOLAR WATER PUMP MODEL (SWPM)

Fig. 11. below shows the designers of the (SWPM) in the Fluid Mechanics Laboratory at The Bright Star University, El-Brega, Libya, while they are working in a lab and often in the design process present a variety of challenges, Where students of the graduation project discuss different perspectives, but gathering those differing viewpoints provides an invaluable foundation. Failing to involve a comprehensive stakeholder group at project kick-off and in early design decisions will almost certainly result in a cascade of future problems impacting design.

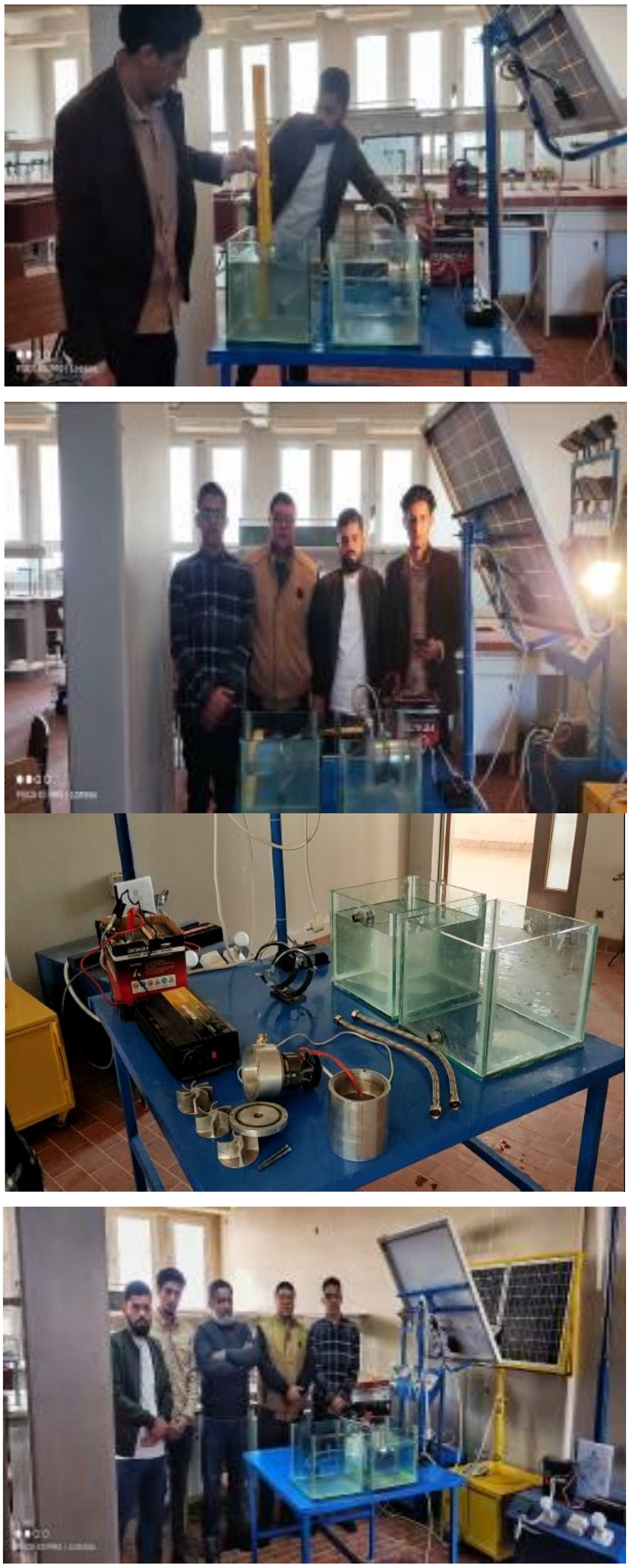

Fig.11. The designers(Students of the BSc research Project, the technician, and the supervisor of the solar water pump model.

IX. RESULTS AND DISCUSIONS

This part will discuss the result of the case study and analyze all the parameters that influence the designed solar water pump model (SWPM). And Study the effect of the impeller blades number on the pump performance. Determine the flow rate, the velocity, the head, the power of the designed and manufactured pump for three different impeller blades (4, 6, and 8).

X. THE DESIGNED SOLAR WATER PUMP MODEL (SWPM) MAIN RESULTS INVESTIGATION.

The volume flow rate (Q), the discharge velocity (V), the head of the pump (Hp), The mass Flow Rate (ṁ) and the power (P) for three different impeller blades (4, 6, and 8) on the (SWPM) performance has been investigated. The three different impellers blades are tested to determine the optimum blades number.

The findings from the theoretical and experimental work of the designed pump were as following:

[1]. Volume Flow Rate (Q) Calculation

The volume flow rate (Q) of three different impellers with 4, 6, and 8 blades can be calculated after computing the volume and time, the final results shown in Fig. 12.

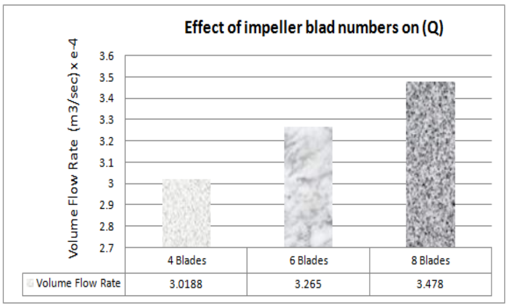

Fig.12. Effect of Impeller Blade Number on (Q).

[2]. Discharge Velocity (V) Calculation

The velocity of three different impellers with 4, 6, and 8 blades can be calculated by Continuity Equations, the final results shown in Fig. 13.

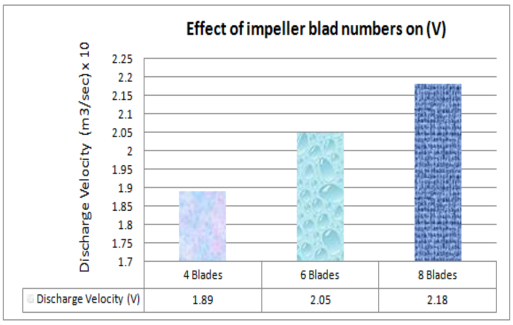

Fig. 13. Effect of Impeller Blade Number on (V)

[3]. Head of the Pump (Hp) Calculation

Hp of three different impellers with 4, 6, and 8 blades can be calculated from the Bernoulli Equation, the final results shown in Fig. 14.

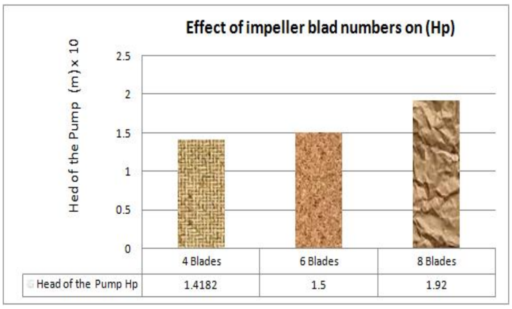

Fig. 14. Effect of Impeller Blade Number on (Hp).

[4]. The mass Flow Rate (ṁ) Calculation

Power of three different impellers with 4, 6, and 8 blades can be calculated from the Continuity Equations, the final results shown in Fig. 15.

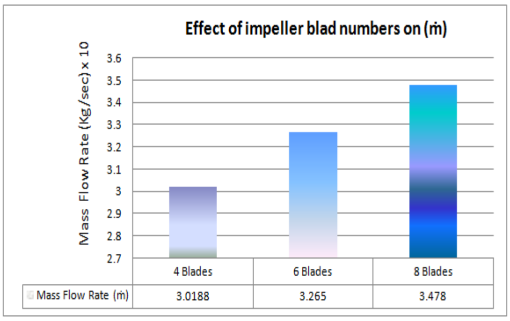

Fig. 15. Effect of Impeller Blade Number on (ṁ).

[5]. Power of the Pump (Ƥ) Calculation

Power of three different impellers with 4, 6, and 8 blades can be calculated from the following equation, the final results shown in Fig. 16.

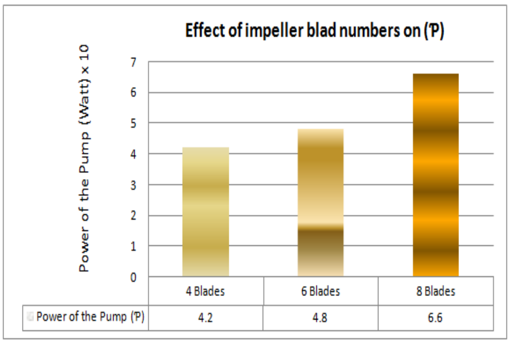

Fig. 16. Effect of Impeller Blade Number on (P).

The experimental and the theoretical results of the designed pump showed that the flow rate, velocity, head, and the power are higher for the case of the impeller with 8 blades than that for the two cases of 6 and 4 blades respectively as shown in the above Figures. The losses decrease by increasing the blades number due to the reduction of the secondary flow for a certain limit. The results showed better centrifugal water pump performance when impeller with 8 blades is used.

XI. CONCLUSION

Design and manufacture a new solar water pump model (SWPM) can be used as visualization, to view the effect of the impeller blades number on the model's performance, where a model of a new solar water pump designed and manufactured in the Fluid Mechanics Laboratory at The Bright Star University, El-Brega, Libya, to determine the volume flow rate, velocity, head, the mass flow rate and the power of the pump's model.

Three different impellers with 4, 6, and 8 blades are tested to determine the optimum blades number. The experimental results showed that the volume flow rate, velocity, head, the mass flow rate and the power are higher for the case of the impeller with 8 blades than that for the two cases of 6 and 4 blades respectively. It was found that the optimum value of blades is 8 blades. The losses decrease by increasing the blades number due to the reduction of the secondary flow for a certain limit.

The experimental results showed better solar water pump performance when impeller with 8 blades is used.

As a conclusion, the objectives of this research had been successfully achieved.

XII. SUGGESTION FOR FURTHER WORK

This study has covered its objectives and achieved satisfactory results. However, the following suggestions are recommended for future research:

a) For future measurements it is advised to create a more blades such as 3, 5 and 7 blades.

b) For future work it is advised to study the effect of different blade angle.

c) For future work it is advised to study the effect of straight-blade impeller.

d) For future research the impeller diameter can be studied and analysis.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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