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Determination of Wear That Can Be Formed at the Cast Iron Wheels of the Centrifuge Pumps Used at Agricultural Irrigation*

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Abstract: The extent of this work is operating characteristics of a horizontal shafted centrifugal pump (which has cast iron with lameller graphite wheel) which has been operated for 7 hours on the average. A closed circuit pump system (circulating within itself) which was formed by attaching a horizontal shafted centrifugal pump which can be used in irrigation applications with a drum has been operated for 150 hours at laboratory conditions. To define the operating properties of the pump, its operating characteristics were measured in respect to TS EN ISO 9906/AC. Furthermore, observations have been done to determine whether there is a connection between operating characteristics of the pump and the wear and corrosion occured on the wheel or not. When spectral analysis, micro-structure and hardness measurements of the wheel materials on which first and second experiments were conducted and unused wrought iron wheel materials were analysed, it has been observed that the wheel materials used in the experiments do not bear the properties required by wrought iron standards. According to the results of the observations carried out by electron microscope on micro-structure of wheels, wear, in addition to corrosion on the outer surface of wheels has been identified.
Key words: Centrifugal pump, cast iron, wheel, wear, corrosion

INTRODUCTION

Modern irrigation methods should be utilized in order to use water economically and efficiently for the plants. In these methods therefore it is required to use pressurized water; in other words pump.

For this reason, the other most important element apart from water in modern irrigation methods are the pumps which enable water to be transmitted under specific pressure. It is needed to have better information about pumps and enterprises and technology which produce it in order to use water sources which are limited most efficiently and without wasting. Pumps vary according to their utilization area. Scientific researches study on developing features of pumps according to their utilization area and minimizing energy wastes. Pumps are being used in city water mains, conveying water to high buildings, irrigation of fields in agriculture sector, extracting oil from oil-wells, greasing and cooling devices of work benches and in many other fields (Yalçın, 1998).

Devices which enable conveyance of liquid by bestowing them hydraulic energy, in other words devices which turn mechanic energy into hydraulic energy are called pumps (İşcan et al., 2004). Pump gets little bit more of the hydraulic energy that would provide for the liquid from the environment; the distinction between is used for mechanical losses, local losses about flow and liquid-skin friction losses (Yalçın, 1998).

Friction which influences the structure of metal material negatively and causes material losses in further circumstances can be described as the removal of material from the surface with physical or chemical method (Buytoz and Eren, 2007).

Generally, friction is undesirable material loss which occurs with the effect of friction on fricative surfaces which move relatively to each other and contact with each other. Wearing rate depends on the type of material, shape and roughness of fricative

* This paper includes part of Elif Yüksel's PhD thesis.

surfaces, friction conditions and various chemical effects of environment. Moreover, researchers point that wearing resistance depends not only on internal structure of the material but also on the conditions material is exposed to (Arıkan, 2007).

As it is known the organ which meets material loss most frequently in pumping house studies are the wheel-pumps. There are many different elements on the change that occur in wheel-pumps. Corrosion occurs as a result of these effects. In agricultural irrigation practices, this situation is caused by corrosive effect of water and chemical substances in water.

Corrosion is an event which occurs in every field in which metal is used and which is a big problem that cannot be ceased totally and which is mostly chemical but also have electrochemical and metallurgic reaction types.

Metals are as minerals in nature. These minerals are turned into metal by using energy and with some of the special metallurgic methods. Most of the metals are not steady thermodynamically. In the event of suitable condition; metals want to turn into steady condition by giving back the chemical energy they carry. Therefore corrosion energy comes out and operates itself (Anonim, 2008a).

All the metal substances experience corrosion in specific levels in natural environment. Bronze, brass, stainless steel, zinc and aluminum, regardless of protection, corrode very slowly under usage conditions that are expected to last long. Structural corrosion of iron and steel moves fast unless metal is not protected suitably. Therefore this corrosive sensitivity of iron and steel is an important problem, because they are used commonly when their costs and physical features are considered (Anonim, 2004). Load and heat on the metals are also important elements in corrosion (Çetin and Gül, 2007). Coating metal surfaces with boron or chrome decreases corrosion of these materials importantly (Yılmaz et al., 2005 and 2007; Ay et al., 2006). Corrosion issue is an important problem generally for all pumps due to being in continuous contact with various liquid materials since nearly most of the materials of centrifuged pumps are composed of metals and due to their utilization area. Depending on the structure of liquid which the pump absorbs from a place and pumps to desired place (liquids with solid particles, acidic liquids, drinking water etc.) irrigation devices and equipments face with corrosive effects, frictions, damages and losses especially as a result of irrigation practices carried out with water with industrial wastes and as a result of this efficiency of pump decreases (Eker and Yüksel, 2005).

Apart from the need of decreasing damage losses based on raw material and processed material, we also need to use energy sources as economically as we can. Nearly 25-50% of world electric energy is consumed in industry and 20% of this is consumed at pump systems. It is explained that with a better system design and by choosing suitable pumps 30% of this energy can be saved. Moreover 5-10% of world electric energy is consumed ate pump systems. This shows that pump systems are important for life-long cost of electric energy consumption. Life-long cost of a pump system consists of the sum of first purchase, operation and maintenance costs detected for the life-span of the system. In a typical pump system, maintenance and energy cost compose great part of life-long cost. System efficiency is used in life-long cost calculations. The aim of this system is to detect which system would be at the least cost in the longest duration. Concepts of life-long cost and system efficiency due to pump utilization enable the choice of system according to usage need. From the point of pump producers, the importance of preparing statistical data which has not been considered until today and presenting these data to pump users have increased (Nalbantoğlu, 2001; Ertöz, 2003).

In this study based on the basic data above and application terms; sand was added in specific ratio in order to enable corrosion in water used in laboratory conditions. Pump performance experiments carried out in these conditions were done by NKU Agriculture Faculty, Agricultural Machinery Department Irrigation Machines Test and Research laboratory. It is tried to detect the changes occurred in pump characteristics for each wheel trial during 150-hours of operation process of pump and the corrosion occurred in wheel.

MATERIAL and METHOD

In this study was conducted with horizontal shaft single-stage end-suction scroll type centrifugal pump which is used in agricultural irrigation. Pump system used in experiment which was created in laboratory is given in Figure 1.

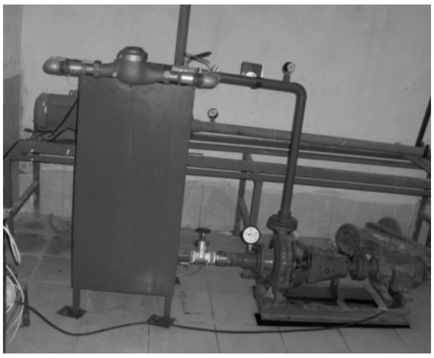


Figure 1. Pump system used in experiment

General technical features of the pump used in the experiments are given Table 1.

In order to create experiment conditions, pump was connected with the store and water was enabled recirculation. In the experiment, sandy water mixture was obtained by adding 10g sand into 200l water tank, being 50g sand for $1m^3$ water. There is no specific standard value for the sand which irrigation water include but nonsettleable sand values of some pump firms are known. These values vary between 25-120 g/m^3 (Anonim, 2008b; Anonim, 2007). This literature data was used in the detection of sand amount added in the water in this experiment.

Pump was operated 7 hours a day on average and pressure-line adjusting valve was operated when the pressure of manometer show 1 bar. The reason for this was that the pump was operated in 1 bar in drip irrigation applications in field conditions. This process was carried out for 150 hours. Operation process was detected regarding the survey results with farmers considering average operation duration of a pump in field conditions during one season (Yüksel and Eker, 2009).

Cycle number used in experiments was calculated with tachometer; debit was calculated with counter method, negative pressure with vacuum meter, positive pressure with manometer, and power obtained from the network was calculated with electrical counter. Moreover, manometrical height of pump was calculated with the help of this equation:

$$H_m = m + v + z \qquad (1)$$

H_m: Manometrical height (m)
m : Pressure value measured at output (bar)
v : Vacuum value measured at input (mmHg)
z : Vertical rise between pump input and output sections (m)

Efficiency of the pump was calculated with this equation:

$$\eta = \frac{Q.Hm.\gamma}{102.N} \qquad (2)$$

Q : Debi (l/s)
η : Pump efficiency (%)
H_m : Manometrical height (m)
γ : Density of water (g/cm^3)
N : Power (kW)

In the experiment, pump suction line valve being totally open; operation characteristics were calculated in 9 different valve spans from totally closed condition of pressure-line adjusting valve to totally open.

After 150 hours of operation of the pump, various material tests were carried out in the wheel in order to detect data about corrosion. For this reason, microstructures of the samples were observed with Olympus PME3 metallographic microscope and the images were transmitted to the computer via digital camera. Hardness tests of the samples were carried out with Wolpert D/A Testor 3B hardness testing device. Chemical components of the sample were conducted with ARL 3460 spectral analysis test device. Microstructure images of the sample were observed with Hitachi TM 1000 scanning electron microscope and were transmitted to the computer.

RESEARCH FINDINGS

Results for the pump characteristics

Before the experiment measurements for the pump characteristics were carried out.

Measurement results for the debit, manometrical height, power and pump efficiency were given in Table 1.

Table 1. Technical features of centrifuged pump.

Pump type	Debit (m^3/h)	Pressure height (mSS)	Cycle (d/d)	Power (kw)	Wheel material	Wheel diameter (mm)
single-stage end-suction scroll type centrifugal pump	18	19	1450	3	Lamelar graphite cast iron	280

Table 2. Pump characteristics measured before wheel experiments

Parameters	Stages								
	1	2	3	4	5	6	7	8	9
Q (l/s)	-	0,009	0,62	1,60	1,65	2,03	2,03	2,13	2,18
Hm (m)	3,07	3,65	3,69	3,62	3,56	3,53	3,64	3,58	3,58
N (kW)	0	0,09	0,15	0,31	0,35	0,21	0,16	0,15	0,26
η (%)	0	0,36	15	19	17	34	45	51	29

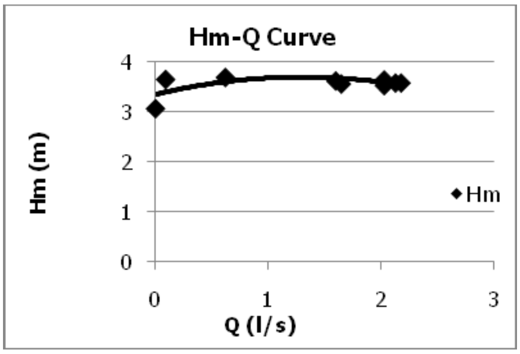


Figure 2. Manometrical height-debit curve measured before the experiment

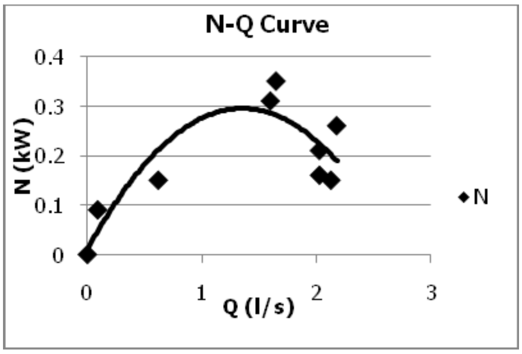


Figure 3. Manometrical power-debit curve measured before the experiment

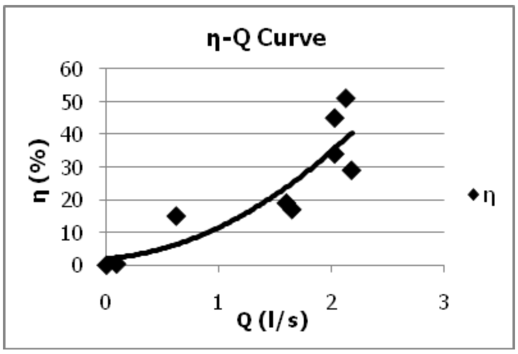


Figure 4. Manometrical efficiency-debit curve measured before the experiment

Material test applied on wheel and results

Some tests of materials were applied on pump wheels before the experiment.

Macro structure images of pump wheel whose trial was done in the first 150 hours before the experiment was obtained before the experiment and the images were given below (Figure 5).

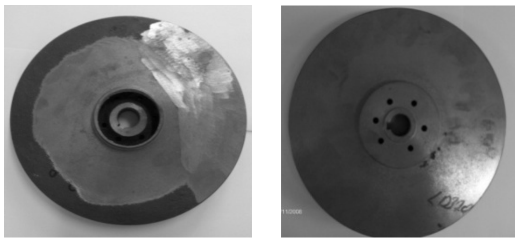


Figure 5. Macro structure images of pump wheel whose trial was done before first 150 hours of experiment.

Macro structure images of pump wheel whose trial was done in the second 150 hours before the experiment was obtained before the experiment and the images were given below (Figure 6).

Figure 6. Macro structure images of pump wheel whose trial was done before second 150 hours of experiment.

Scanning electron microscope (SEM) and metallographic microscope was used for obtaining the micro structure images of pump wheel materials. In order to obtain better images from the samples cut out off pump wheel with metallographic microscope materials were rubbed before and then etched with 5% nitric acid solution. TS EN ISO 945 (presentation of cast iron – graphite micro structure) standard was taken into regard in processing the image with metallographic microscope (Anonim, 2006).

Micro structure image of cast-iron wheel material whose trial was not carried out is given below (Figure 7).

Figure 7. Micro structure image of cast-iron wheel structure whose trial was not carried out.

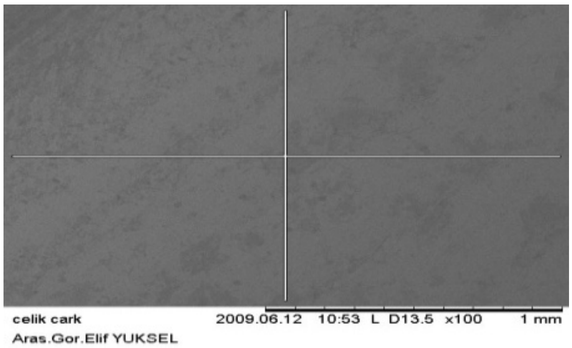
Graphite type of materials whose micro structure images were given is A+C, perlite rate is 80-85 % and graphite size is 2-4.

Scanning electron microscope (SEM) images of cast-iron pump wheel whose trial was not carried out is given below (Figure 8).

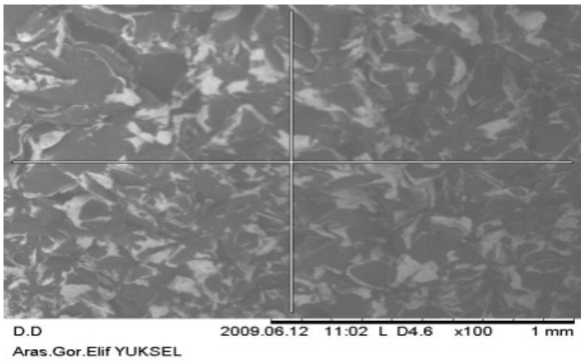
In Figure 8a, images of outer surface of pump wheel is given. When the image is observed it is seen that there is no crack or scratch on the surface. In Figure 8b an image from the inner surface of cast-iron material cracked for observation is seen.

Chemical components of pump wheel are extracted with spectral analysis test device.

Spectral analysis results of cast-iron wheel material whose trial was not done is given in Table 3.



(a)



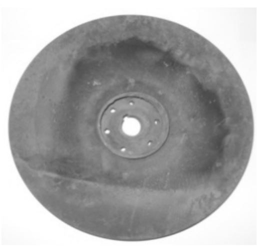
(b)

Figure 8. SEM images of cast-iron pump wheel whose trial was not carried out.

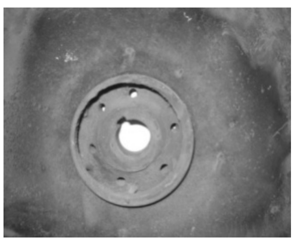
Macro structure images of pump wheel whose trial was done during first 150 hours was obtained at the end of experiment and given below (Figure 9).

Table 3. Chemical components of material whose trial was not done

%C	%Si	%S	%P	%Mn	%Ni	%Cr	%Mo	%Cu	%Sn	%Ti	%Al	%Pb	%B	%Bi	%Mg	%Fe
3,7566	1,9109	0,0150	0,0456	0,5615	0,0375	0,0164	0,0001	0,0861	0,0031	0,0706	0,0001	0,0001	0,0001	0,0001	0,0001	93,4962



(a)



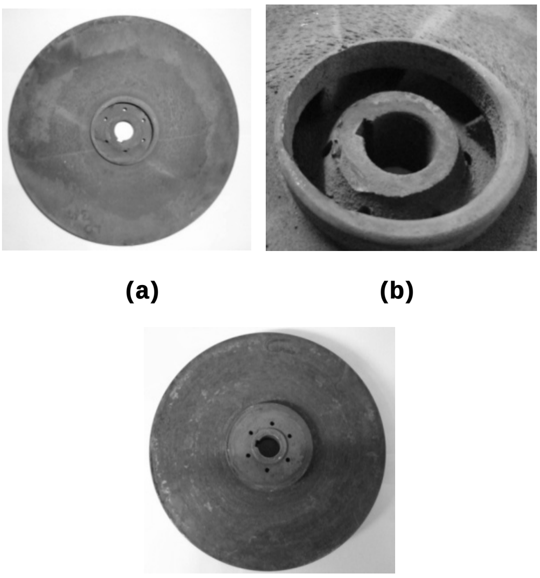
(b)

(c)

Figure 9. Macro structure images of pump wheel whose trial was done in the first 150 hours.

As it is seen in the images, traces of tarnish and corrosion are observed prominently on both sides of the wheel (Figure 9). However when the images in Figure 9a and b are considered it is seen that corrosion is denser compared with the image in Figure c.

Macro structure images of pump wheel whose trial was done during second 150 hours was obtained at the end of experiment and given below (Figure 10).



(a) (b) (c)

Figure 10. Macro structure images of pump wheel whose trial was done in the second 150 hours.

As the case in the wheel image of first 150 hours, traces of tarnish and corrosion are observed prominently on both sides of the wheel (Figure 10). Especially at the outer part of the hub traces of tarnish and corrosion are observed prominently. On the other side of the wheel corrosion has started but has not covered the entire surface yet.

Micro structure image of the wheel whose trial was carried out in the first 150 hours is given below (Figure 11).

Graphite type of materials whose micro structure images were given is A+C, perlite rate is 85-90 % and graphite size is 3-5.

Micro structure images of pump wheel whose trial was done during second 150 hours was obtained at the end of experiment and given below (Figure 12).

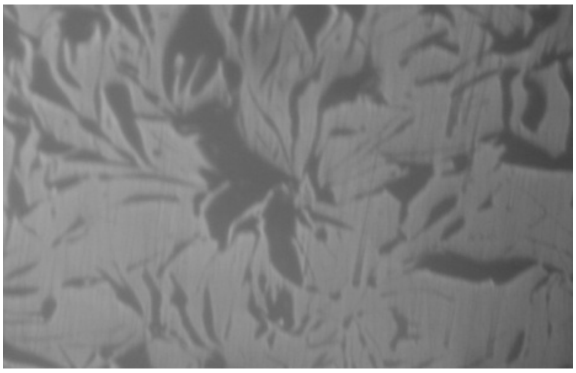


Figure 11. Micro structure images of pump wheel whose trial was done in the first 150 hours.

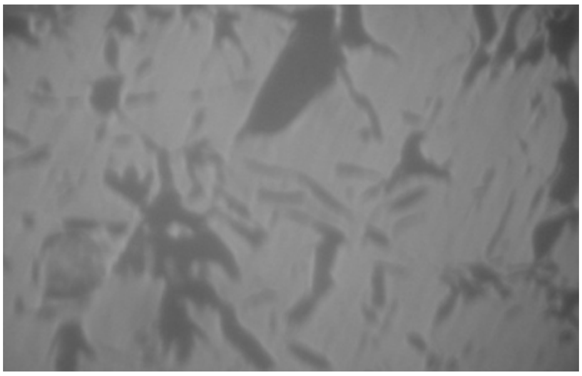


Figure 12. Micro structure images of pump wheel whose trial was done in the second 150 hours.

Graphite type of materials whose microstructure images were given is A+C, perlite rate is 70-75 % and graphite size is 2-4.

SEM image of the pump wheel whose trial was carried out in the first 150 hours is given below (Figure 13).

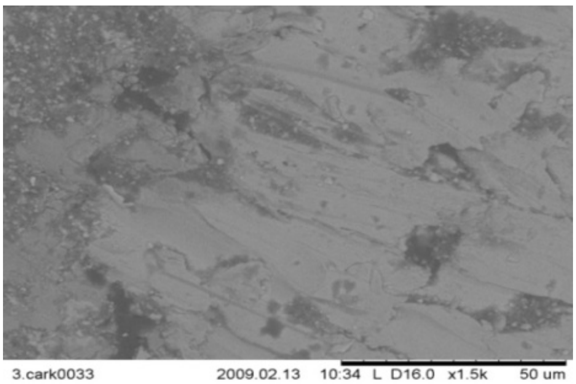


Figure 13. SEM image from the corroded surface of pump wheel

Traces of corrosion are observed prominently in the image obtained from the outer surface of pump wheel (Figure 13).

SEM image of the inner surface of the pump wheel whose trial was carried out in the first 150 hours is given below (Figure 14).

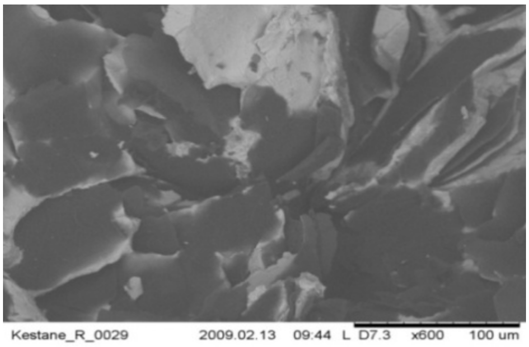


Figure 14. SEM image taken from diffraction section of corroded pump wheel material.

In the image obtained from the inner surface of the pump wheel, it is seen that the inner structure of the cast-iron material has a flower-like image. When the image is observed, it is seen that there is no deformation and corrosion has not advanced up to here and it has no difference with the inner surface of the wheel material whose trial has not been carried out yet (Figure 14).

SEM image of the pump wheel whose trial was carried out in the second 150 hours is given below (Figure 15).

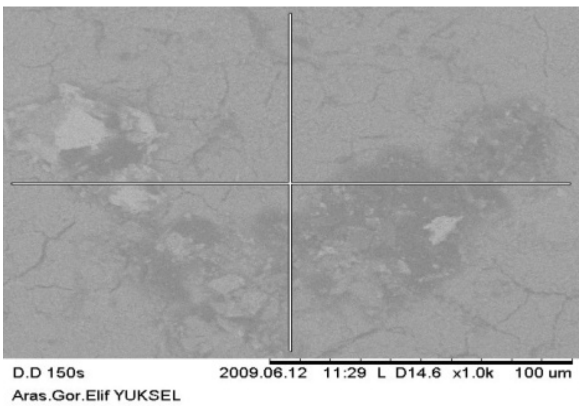


Figure 15. SEM image taken from corroded surface of the pump wheel material.

When the outer structure of the pump wheel is observed, although there is no prominent change in the material tissue of the cast-iron material, it is seen that there are little gaps in the very middle and there are fine small cracks spread all over the surface (Figure 15).

SEM image of the inner surface of the pump wheel whose trial was carried out in the second 150 hours is given below (Figure 16).

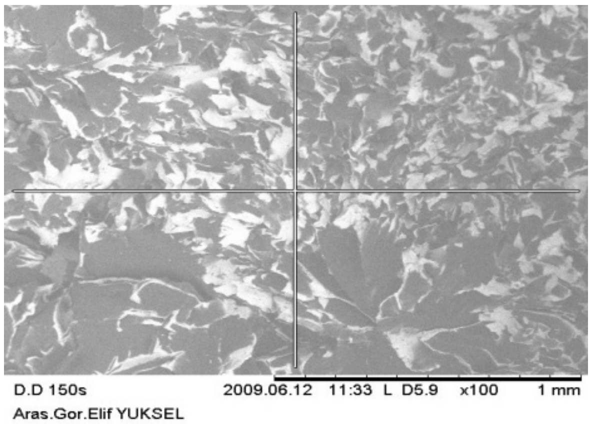


Figure 16. SEM image taken from diffraction section of corroded pump wheel material.

In the image obtained from the inner surface of the pump wheel, it is seen that the inner structure of the cast-iron material has a flower-like image. When the image is observed, it is seen that there is no deformation and corrosion has not advanced up to here and it has no difference with the inner surface of the wheel material whose trial has not been carried out yet (Figure 16).

Spectral analysis results of the pump wheel whose trial has been carried out in the first 150 hours is given in Table 4.

Spectral analysis results of the pump wheel whose trial has been carried out in the second 150 hours is given in Table 5.

Table 4. Chemical components of the material

%C	%Si	%S	%P	%Mn	%Ni	%Cr	%Mo	%Cu	%Ti	%Sn	%Al	%Pb	%B	%Bi	%Mg	%Fe
3,7486	2,0192	0,0187	0,0598	0,6002	0,0398	0,0184	0,0001	0,0848	0,0739	0,0028	0,0001	0,0015	0,0001	0,0001	0,0017	93,3303

Table 5. Chemical components of the material.

%C	%Si	%S	%P	%Mn	%Ni	%Cr	%Mo	%Cu	%Ti	%Sn	%Al	%Pb	%B	%Bi	%Mg	%Fe
3,7669	2,0238	0,0190	0,0554	0,5898	0,0395	0,0180	0,0001	0,0848	0,0694	0,0030	0,0001	0,0022	0,0001	0,0005	0,0019	93,3256

Brinell hardness measurement method was used in the hardness measurement of materials.

Hardness measurement values of the pump wheel whose trial was done in the first 150 hours was taken from two points. Results are as such:

123-125 HB

Hardness measurement values of the pump wheel whose trial was done in the second 150 hours was taken from two points. Results are as such:

123-125 HB

Weigh losses of the pump wheels for the first 150 hours were detected by being measured on assay balance.

While detecting the weigh losses of pump wheels for the first and second 150 hours, wheels were measured twice before and after the trial and their average was taken. Weighing results for the first 150 hours were given in Table 6, weighing results for the second 150 hours were given in Table 7, weighing loss graphic for these weighing results were given in Figure 17.

Table 6. Weighing results of pump wheel whose trial was done in the first 150 hours

Weigh of pump wheel before usage(g)	7365
Weigh of pump wheel after 150 hours of operation (g)	7360

Table 7. Weighing results of pump wheel whose trial was done in the second 150 hours

Weigh of pump wheel before usage(g)	7506
Weigh of pump wheel after 150 hours of operation (g)	7491

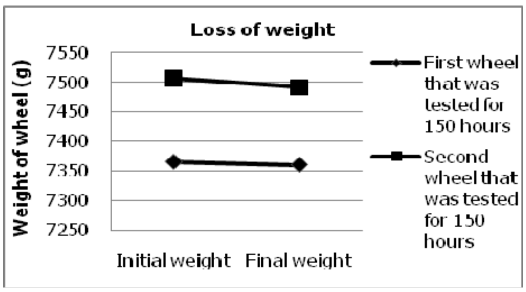


Figure 17. Loss of weight grafics showing the difference between initial and final weights of the first and second wheels that both were tested for 150 hours

It is seen that the weighing loss occurred in the pump wheel whose trial was done in the second 150 hours was more than the first one.

RESULTS and DISCUSSION

When the spectral analysis of cast-iron (lamellar graphite) pump wheel whose trial was done but has never been used, it was detected according to the standards of cast-iron that; carbon amount is lower than it must be and silicium amount is higher and therefore hardness is lower than it must be. As a result when the spectral analysis, micro structure and hardness measurements of pump wheels for the first and second trial and never used cast-iron materials were observed, it was detected that pump wheels used in the experiment do not have the exact features asserted in cast iron standards.

When the scanning electron microscope (SEM) of cast-iron pump wheel materials whose trial was done was observed, it was detected that there are thin hair cracks spread all through the surface, metal surface is in partial contact, traces of erosion which is an abrasion type that occurs with the effect of corrosive fluid that moves relatively were detected. When the images taken from the cracked inner surface of the material are observed, it was detected that there is no difference between the inner surface of the material and pump wheel itself so deformation has not reached here yet. In the micro structure observations of pump wheels done with SEM, it was detected that corrosion has occurred on the outer surface of pump wheel due to abrasion. Both effects may cause pump wheel not to work properly by influencing first outer later on inner part of the pump wheel. That the abrasion of cast-iron material structure is observed more on the outer surface and therefore craters that occur due to fractures on the structures would cause cracks in the further periods. In order to take structural precautions that would prevent both abrasion and corrosion on both inner and outer surface of the pump wheels, correct production methods must be used. For this reason, surface hardening methods are suggested. Developing surface quality due to hardness would also enable water flow and friction between water and pump wheel would be minimized. At this stage of pump wheel production, good results can be attained in the sense of efficiency in construction, abrasion problem and minimizing corrosion by using functional graded material. Although this issue is not credited enough today, in the future issues such as loss of material, consumption of energy and water would gain importance. As a result, great advantages will be obtained with the application of advanced material technology on pump wheel structures.

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