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A New Product Design After Benckmarking Analysis Of Helis Gear Pumps And Optimization In Energy Consumption

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ABSTRACT

The various types of helical gear pumps can be produced to transfer the gasoline, diesel, chemicals, and oil. Helical gear pumps are used by motor power in fuel selling and transfer points, and by gear shafts at mobile transfer trucks. These pumps are classified in three main groups as internal gear, pallet, and helical pumps. The common feature of them is sucking the liquid from the container placed under ground level and transferring it to the high levels. The lower flow rates, noisy working, and the quick corrosion of gear when the pump is running closing outlet valve are the disadvantages of these pumps produced in our country. The aim of this study is to design a new generation of helical gear pump which will eliminate or at least decrease these disadvantages. It is expected to minimize energy consumption, and to protect the corrosion of gears coming from the high pressure at this new design. The dimensions of this pump will be appropriated to the chassis of the truck and at minimum weight. For this reason, benchmarking study is applied; the by-pass system of the pumps that are currently produced, the fluid voids between the teeth, and faults in the inlet-outlet design, and a new type design has been proposed. Besides these the transfer capacity of the pump is increased from 400 l/min to 600 l/min. The energy requirement for 1 liter of liquid is compared with the other products to measure its energy efficiency. The result is also positive at this point of view. Then, this new design is protected by patent registration.

Keywords: *Internal Gear Pump, Design Devolopment, Power Consumption*

Helis Dişli Pompalarda Kıyaslama (Benckmarkıng) Analizi Sonucunda Yeni Bir Ürün Tasarımı Ve Enerji Tüketiminde Optimizasyon

ÖZET

Benzin, mazot, kimyasal ve yağların aktarımı için farklı tipte dişli pompaların üretimi yapılabilmektedir. Dişli pompalar, transfer setlerinde ve akaryakıt dolum istasyonlarında motor bağlantısıyla, yakıt tankerlerinde ise

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“shaft” bağlantısıyla çalışmaktadırlar. İçten dişli, paletli ve helis dişli pompalar olmak üzere gruplandırılan pompaların genel özelliği, yerin altından akaryakıtı çekip yüksek metrajlara basabilmesidir. Ülkemizde üretimi yapılan helis dişli pompanın debi kapasitesinin düşüklüğü, çok sesli çalışması, pompa çıkış vanasının transfer sırasında kapatıldığında dişli ömrünü kısaltması gibi olumsuz sonuçları vardır. Bu çalışmada, söz konusu sonuçları azaltacak yeni bir tip ürün geliştirilmesi amaçlanmaktadır. Bu yeni üründe, minimum enerji tüketimi ve yüksek basınç oluşmasından kaynaklanan dişlilerde oluşabilecek zararların önlenmesi beklenmektedir. Pompa hacmi tanker şasesi bağlantısına sığacak ölçülerde ve montaj kolaylığı için minimum ağırlıkta olmalıdır. Bu nedenle benchmarking çalışması uygulanarak; hali hazırda üretimi yapılan pompaların “by pass” sistemi, dişler arasındaki akışkan boşluğu ve giriş-çıkış tasarımındaki hatalar gözlenmiş ve yeni bir tip tasarım önerilmiştir. Bu tasarım, diş sayısı azaltılarak ve giriş - çıkış kavitasyonu önlenecek şekilde yapılmıştır. Çalışmada yapılan analizlere göre, aynı enerji tüketimi ile dolum kapasitesi 400 litre/dk debiden 600 litre/dk debiye çıktığı gözlemlenmiştir. 1 litre yakıt transferi için gerekli olan enerji tüketimi, diğer ürünler ile karşılaştırmalı olarak incelenerek enerji verimliliği ölçülmüş ve sonuçlar alınmıştır. Bu yeni tasarım, patent ile koruma altına alınmıştır.

Anahtar Kelimeler: *İç Dişli Pompa, Tasarım Geliştirme, Güç Tüketimi*

I. INTRODUCTION

The gear pumps are used to transfer the liquid fuel, industrial oils, and various liquid products. The body and the gears may be under high pressure because of the cavitation effect. The safety coefficients and the economic life of the pump are important criteria in design, and to minimize the production cost is indispensable for the producing industries. The body width, screw diameter, and weight of the gear pump are analyzed with the environmental pressure to optimize the design parameters [1]. An equation is proposed to calculate the flow rate of a gear pump. The involute curve formula is described which is used for the gear design [2]. The various types of displacement pumps are evaluated and the advantages and disadvantages of gear pumps are analyzed [3]. For trouble shooting, vibration measurement techniques and Pareto Analysis ire employed [4]. At the end of these studies, different pump design variables and quality measurement procedures are identified.

The pumps used for transferring fuel and oils are applied with various connection types. The pumps used on the fuel tanker trucks are powered through a shaft from the engine of the truck. At this type application, the weight and the dimensions of the pump are very important. The breaking and crack rate of the pump body and the coupling equipment which are mounted on the chassis of the truck, is increasing because of the vibration coming from the various road conditions. This type of usage required minimized weight and dimensions of the pump. In the transfer and displacement sets, the power is feed from the engine with asynchronous motor. The energy consumption of the pump to transfer one liter of liquid has great importance. The pumps have considerable place in the energy saving studies. The energy consumed by pumps in developed countries is 20% of total consumption according to the research of the American Hydraulic Institute. It is declared that the 30% of this energy can be saved with selection of suitable pumps and a good system design [5].

It is seen that benchmarking can be done to improve the quality and productivity. In this study the design characteristic of various types of helical gear pumps produced by various producers are evaluated and tried to develop a new type of pump working together with the R&D department of

IPT. The pumps are analyzed according to their volume, weight, inlet diameter, numbers of teeth, and the engine power. The aim was to improve the Er 1214 D model pump that is patented for İPT.

The design parameters, dimensions, and the motor power of the produced helical gear pumps are comparatively mentioned at the application section. At the end of this benchmarking study a new design is improved and the prototype is produced. The energy consumption tests are applied in the IPT test department; the results of these tests can be seen at the results section in comparison with the other pumps. It is realized that while the capacity of the new designed pump is increased, and the energy consumption is optimized.

II. LITERATURE REVIEW

The energy consumption of the fan motors, pumps, and the electrical motors used in various industries is more than half of the total consumed energy. The result of a survey performed by the American Hydraulic Institute presented that the 20% of the total energy consumption of developed countries is used by various types of pumps. It is announced that the 30% of this energy can be saved by good system design and selection of suitable pumps.
The energy efficiencies of the ovens, light bulbs, refrigerators, are defined before the pumps, and have been obliged to illustrate their energy efficiency of the products on the label as a result of global energy efficiency studies. European Union reached the last stage to label the P< 2.5 kW circulating pumps. It is compulsory to put the energy efficiency classification of the circulation pumps in Germany [5].

The study of Yumurtaci and Sarıgül is tried to explain how the energy saving can be done on the pump systems which consume electrical energy densely [6]. The study of Saqib and Khan (1993) is about that overall efficiency is improved to an average of 65% through a comprehensive retrofit and repair program, total energy savings of about 4·8 million kWh can be made in the current estimated energy usage of about 12 million kWh per year [7].

Benchmarking is getting more important to measure the performance of some operations, like supply chains, by comparing with the best of the industry, and to make some developments. The position and the competitive force of a business in the market can be stated and the road map can be prepared to increase the competitive force by the comparison operated with the competitors [8].

It is also included in this study to explore the competitive strategies of the best of the industry, and for determining the performance level for optimum practice interval and to design a benchmarking system to achieve these [9].

The importance of Total Quality Management depends on the beginning of evolution process of businesses to survive. The organizations need to compare themselves with other organizations. The changes at market and competition environment forced the modernization in the management and human resource departments. It seems the innovative and flexible organizations will be successful in the future [10].

III. APPLICATION

The technical benchmarking values for the commonly used helical gear pumps Z11 [11], Roper Z17 [12], Yıldız Pump YHL [13], Viking Pump SG-14336 [14] and IPT's Er 1214-D [15] can be seen below in Table 1.

Er 1214 D Model is the lightest in weight, and smallest in dimensions; but the flow rate is low. The highest flow rate Roper Z17 and Yıldız YHL models has 6 teeth. The tooth chamber volume can be increased by decreasing the number of teeth to increase the flow rate of the pump. The average working speed of the pump is determined 850 rpm. The inlet and outlet diameter are measured 2-3". 2 1/2 " or 3" inlet and outlet diameter is observed for high flow rates and it is decided that 2" diameter is deficient.

Table 1. *The Benchmarking Study for the Different Producers' Helical Gear Pumps*

Prod. Name	Code	Power rate (L)	Pressure (kg/cm^2)	Engine Speed (RPM)	Inlet Diameter (inch)	Number of tooth	Engine power (kW)	Pump Measure (cm)	Weight (kg)
Roper Pumps	Z11	312	8.6	750	2	6	4.3	49.7*24*21.2	54
Roper Pumps	Z 17	482	8.6	750	3	6	7.1	51.1*29.3*21.1	61
Yıldız Pompa	YHL	540	15	450	2 1/2	6	11	31*30*32.7	90
Viking Pump	SG-1436	392	20	1450	3	12	15	35*25*17	71.5
IPT A.	Er 1214 D	400	8	830	2	8	7.5	20.8×26.7×21.8	44.5

The overall design of the pumps is searched in comparison. The cavitation of the Er 1214 D model pump is high and this causes the lower flow rate because of the outlet of Er 1214 D model is more narrow than the other pumps. The noisy running with the closed outlet is caused by the lower chamber capacity of the by-pass system.

The dimensions of Er 1214 model are not changed at the end of the benchmarking work for the new design because it has the minimum place requirement. The diameters of both inlet and outlet are determined 2 1/2". Number of teeth is decreased to 6. The surface modeling software of Catia program is employed to avoid unnecessary wall thickness of the body. The volume of the by-pass system is increased.

This improved new type pump is manufactured. The energy consumption is measured by using an ammeter both in suction and compression. The tests of the pump are done at different speeds by using speedometer and inverter (Fig 1.).

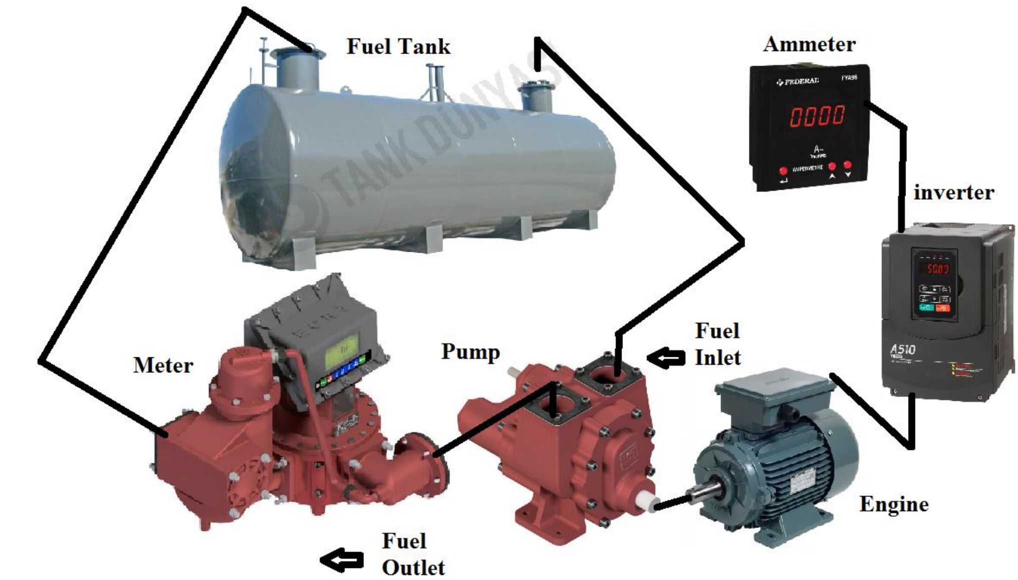

Figure 1. *Fuel transfer power consumption test setup*

IV. RESULTS

The consumed power in kW between 200 and 1200 rpm is shown at Fig. 2, and the flow rate in Lpm/Rpm values are at Fig. 3.

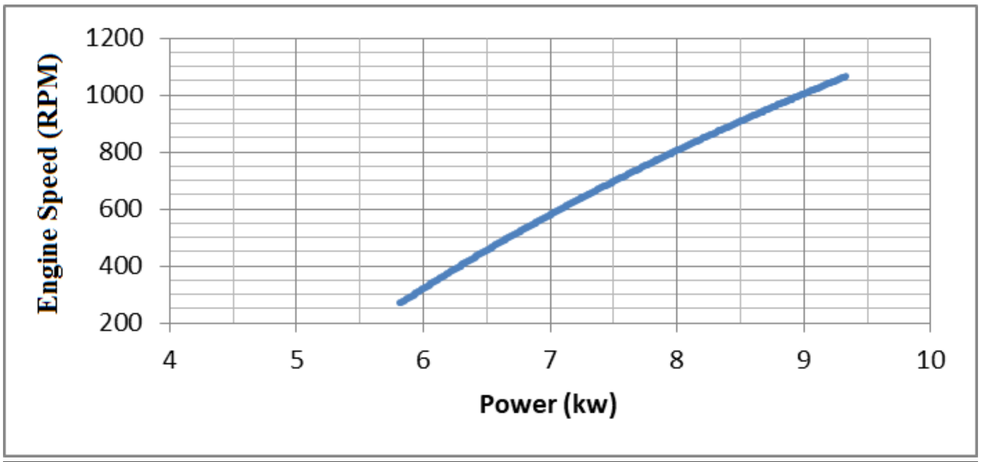

Figure 2. *The power consumption of the pump for different working speeds*

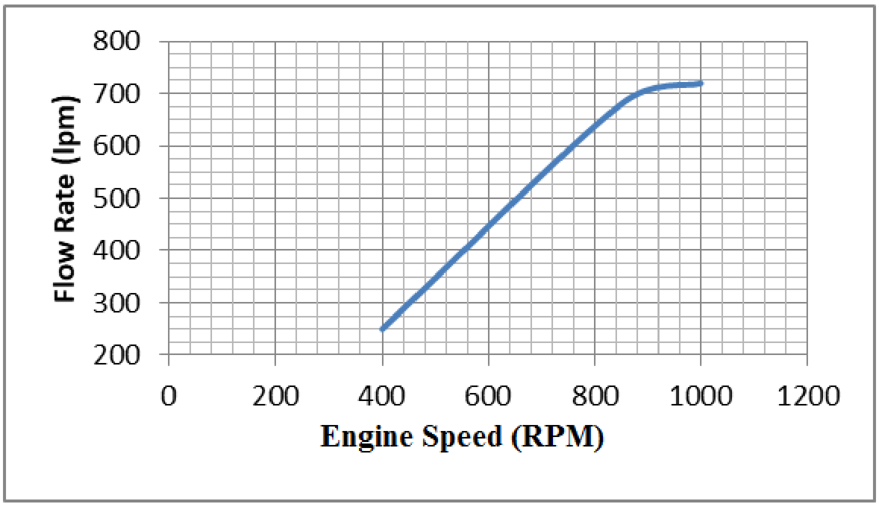

Figure 3. *The flow rate changes at different working speeds*

The flow rates, power requirements, and energy consumptions of all pumps are compared in benchmarking study these values are tabulated in Table 2. Energy consumption of the new designed pump in Wh/Ton at various running speeds can be seen in Table 3.

Table 2. *Comparison of various pumps energy consumptions*

Pump model	Flow Rate (L/s)	Power (kW)	Energy Consumption (Wh/Ton)
Z11	18.720	4.3	229.70
Z 17	28.920	7.1	245.50
YHL	32.400	11.0	339.50
SG-1436	23.520	15.0	637.75
Er 1214 D	24.000	7.5	312.50
New Design	36.000	7.9	219.44

Table 3. *Energy consumptions of the new designed pump at various running speeds*

Speed (RPM)	Flow Rate (L/s)	Power (kW)	Energy Consumption (Wh/Ton)
103	5.820	1.2	206.18
203	11.760	2.3	195.57
303	17.700	3.1	175.14
404	23.100	4.0	173.16
500	27.000	4.8	177.77
605	31.500	6.1	193.65
702	34.800	7.4	212.64

V. EVALUATION RESULTS AND CONCLUSION

The design parameters, measures, and motor powers are analyzed comparatively at the materials and methods section. At the end of these analyses a new pump is designed and produced. The produced new pomp is tested at the IPT fuel transfer test unite and the data collected from these tests are evaluated by comparing with the data of other pumps. This new pump design increases the capacity and optimizes the energy consumption.

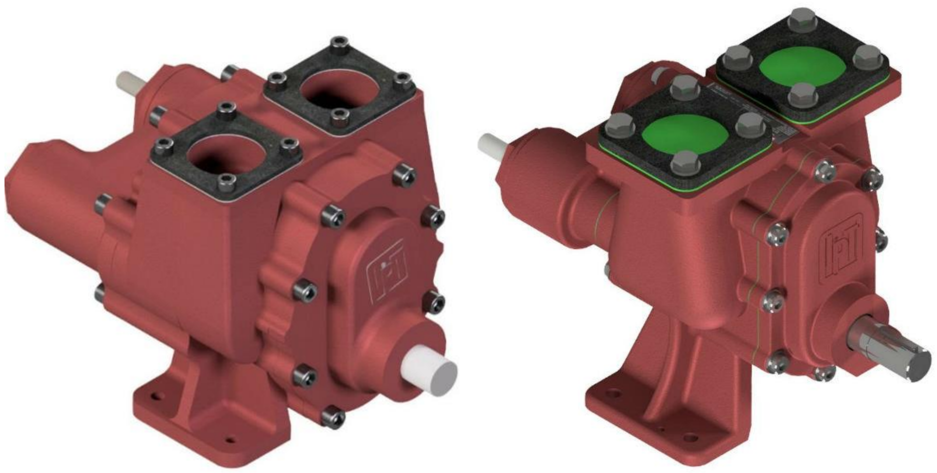

Figure 4. *The designed pump at the end of benchmarking (left) and Er 1214-D design (right)*

A new design geometry is developed that can be used at all fuel transfer pump practices by this study (Fig. 4). There is no noise increase when the by-pass system is running. This new design that has the same dimensions wins 33% in flow rate and 38% in energy saving.

The average energy consumption of the pumps analyzed for benchmarking is 352.99 Wh/Ton, and the Er 1214 D model consuming 312.50 Wh/Ton; the new design pump has 219.44 Wh/Ton. The filling time of 40 tons truck is decreased from 100 mins. to 40 mins. Analyzes exhibited that the pump consumes minimum energy between 400-500 rpm. Until 800 rpm the speed flow rate ratio is linearly increasing, after 800 rpm the acceleration of flow rate is decreasing. This decrease comes from the increase in cavitation.

The analysis of the pumps produced by domestic and international organizations that are placed in the benchmarking study the pump developed with the R&D group of IPT is the one that has the minimum energy consumption, maximum transfer capacity, and noiseless running conditions. This new design is protected with the patent registration.

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