A Review on Application of Composite Materials to Increase the Efficiency of the Centrifugal Pumps

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ABSTRACT- *During long operating cycles, the metallic, mating parts of your pump can sustain damage, resulting in costly repairs and delays. As the abrasive surfaces brush past one another, critical components experience fatigue and even product failure due to wear, galling, and seizing of pump equipment. The demand for pump reliability and performance is ever increasing. Today the primary characteristics sought by pump users are higher reliability, lower vibration levels and better efficiency across a wide range of operating conditions. This paper explains the methods to improve the efficiency of centrifugal pumps by using new composite materials with better performance. Up to 20 per cent of a pump's energy consumption is saved with the use of composite impellers, especially where the pump is required to work with a corrosive or erosive medium. The introduction of new composite materials that have the ability to cover applications that traditional composites were not suitable for, are now possible with the inclusion of PEEK (Poly-Ether Ether-Ketone) based composites in the American Petroleum Institute (API). Polymer-based composite materials have excellent strength and wear properties, and do not cause galling or seizing. This permits a dramatic reduction in clearances between rotating and stationary wear parts which lead to a multitude of performance advantages. This paper expounds the effects of replacing conventional wear rings between a centrifugal pump casing inlet and the rotatable impeller having a plurality of circumferentially spaced blades. A substitute wear ring is formed of a thermoplastic polymer, POLY-ETHER-ETHER-KETONE (PEEK) which is thermally stable and self-lubricating over a range of temperatures of from zero to 600° F. Because the thermal coefficient of expansion of PEEK is substantially different from the pump casing metal and the impelled metal, the use of the PEEK allows the efficiency of the pump to be increased by correctly selecting the diameters for construction of the wear ring for operation over a selected range of temperatures of the pumped fluid. This application reduces the clearance between the surfaces of the elements to substantially improve pump efficiency while at the same time vibration and wear are reduced substantially*

KEYWORDS- *American petroleum institute (API), Centrifugal pump, Composite materials, PEEK (poly-EtherEther-ketone).*

I. INTRODUCTION

Centrifugal Pump efficiency varies with Speed, Impeller diameter, design of the impeller fitted and different materials when offered to different specifications. In order to increase the efficiency ,a method for modifying wear rings and bushings in centrifugal pumps operating at temperatures ranging from zero to 600° F in centrifugal pumps is possible by retrofitting the pumps with wear rings and bushings made of thermoplastic Poly-Ether-Ether-Ketone, "PEEK". Because of its thermal stability over such temperatures and its self-lubricating nature, PEEK makes it possible to run much closer clearances between the impeller intake and the pump casing, improving hydraulic performance and reducing energy-wasting recirculation. The method also substantially reduces internal damage from mishaps in the pump. If desired, PEEK additionally increases the life efficiency and reliability by plugging impeller balance holes. This not only reduces recirculation, but also increases seal chamber pressure to prolong seal life. The method is believed to cover a higher percentage of all centrifugal pumping applications.

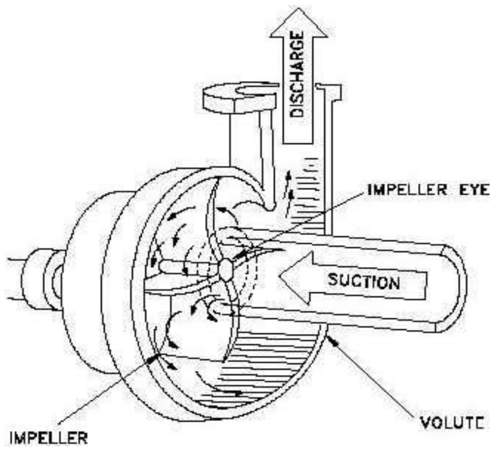

Fig1.Centrifugal pump

II. IMPELLER MODIFICATIONS BASED ON THESAME IMPELLER SHAPE TO INCREASE THE EFFICIENCY

A. Change of impeller design

The possibility of installing in the original pump Casing, an impeller with a new design selected from a wide range of available pumps can help in increasing the efficiency.

B. De-staging or Re-staging

Removing (or adding to a previously de-staged pump) one or more impellers from a multistage pump allows the performance curve to be moved upward or downward, achieving roughly thesame effects as modification of the diameter.

C. Volute / Diffuser modifications

The geometry of the static channels has a dramatic impact on the performance of a centrifugal pump. Thus modifying parameters such as the volute cross sectional area, the position of the volute cutwater, and the shape and distance of the cutwater to the impeller provides significant flexibility in the shape of the performance.

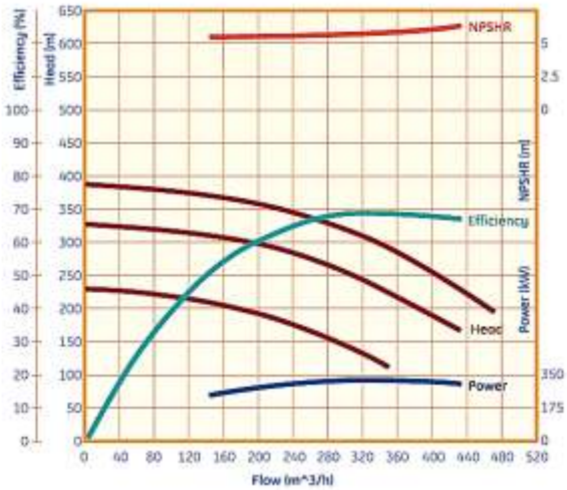

Fig 2. Centrifugal Pump Efficiency Performance curve

D. Volute cleaning and coating of the casing with ceramic paint

Saving energy is a key issue in plant operations today. In centrifugal pumps, the efficiency is directly affected by the friction encountered by the process fluid as it passes through the pump. This demands optimum surface finish in order to reduce friction. Further reduction can be achieved by applying specialized ceramic coatings along all the channels. A recent introduction in the pump industry, this process produces very positive results with regard to the ability to reach and treat even very narrow areas such as impeller vanes in multistage pumps which cannot be reached for polishing.

III. WEAR COMPONENTS OF PUMP AND THEIR USE PARAMETERS

The wear components are designed to support and stabilize the pump rotor and offer protection to the shaft, impeller and pump casing because they absorb wear and abuse from regular use and upset conditions. In addition to these roles, wear rings act as internal seals. They help to restrict the flow of media moving from the discharge side of the impeller through the wear ring clearances back into the suction eye of the impeller which is a cause of loss of efficiency .The smaller the clearance between wear ring interfaces, the better the pump efficiency. Traditionally, bushings and wear rings have been made from metallic materials, but there has been a revolutionary change and composite materials are being used as a replacement for these metal wear parts. Using reinforced polymer-based composite materials can lead to some dramatic advantages including minimized running clearances, lower vibration levels, extended wear life and lower repair cost. Minimized running clearances are possible due to the non-galling and non-seizing nature of reinforced polymer composites. Since galling and seizing are not an issue, clearances can be designed to approximately half of that recommended for metal-to-metal configurations.

These slimmer running clearances restrict internal leakage which results in greater pump efficiency. In addition to gains in efficiency as a result of reductions in running clearances, vibration levels are often favorably impacted. Close clearance bushings and wear rings are better able to generate a thin liquid film on which the rotor can glide. Basically, wear rings and bushings are transformed into hydrostatic radial bearings. This is more difficult to achieve when there is a larger space between the rotating and stationary interfaces.

IV. COMPOSITE MATERIALS

A composite consists of two or more distinct materials that, when combined, create a material that, is stronger, tougher and/or more durable than the individual materials would be standing alone. The API 610 9th edition, recognizes and lists polymer-based composites as an acceptableoption for replacing metal wear parts to improve pump performance in appropriate applications. It is important to point out that there are almost as many different types of composite materials as there are applications for their use. This is because the make up of a composite can and should be tailored to have physical properties and characteristics that match the demands of the application. Polymer-based composite materials are typically made up of a thermoplastic (often referred to as the matrix) and a reinforcing fiber material (often referred to as the filler). These classes of polymer-based composites contain the same two base materials, Poly-EtherEther-Ketone (PEEK) thermoplastic and carbon fiber. The molding of the blended resin allows the thermoplastic (PEEK) to flow around and encapsulate the filler (carbon fiber) creating a quite homogeneous material. The ratio between the polymer matrix and the filler is manipulated to yield materials with a desired range of properties and characteristics that match the requirements of the intended application. The type of filler, percentage of filler, and shape, size and orientation of the filler, all play an important part in determining the physical properties and different thermal characteristics of the composite.

A.**Composite impellers**

Composite impellers are only 15 per cent of the weight of traditional metallic materials. They can offer energy savings because of their light weight and also because they are not affected by corrosion, and they are suitable for upgrades. Energy savings from the composite pump impellers are produced by two sources. Firstly, the composite material being light weight, requires less energy to move the mass of the impeller. Secondly,it comes from the fact that they do not corrode so as a consequence does not change the design characteristics of the pump's impeller. When the metallic pump parts begin to wear from corrosion, efficiency drops drastically. This drop in efficiency not only has a significant impact on energy consumption but also increases the cost of maintenance. The life of the pump can be reduced to months instead of years as originally intended. Machining enables the composite impeller to be optimized for the service in which the pump is designed. Since these impellers are corrosion resistant to most liquids, they do not become imbalanced even after years of service and this reduction in vibration also translate into higher efficiency and a reduction in energy consumption. The lower weight not only reduces startup load but also reduces shaft deflection. This allows the rotating element to run with tighter clearances between the rings and the impeller giving the increases in efficiency and the reduction energy consumption.

V. POLY-ETHERETHER-KETONE (PEEK)

POLY-ETHERETHER-KETONE is a matrix (PEEK thermoplastic) dominated composite consisting of a compression-molded material of approximately 70% PEEK and reinforcing fibers with a random orientation.Offering outstanding wear and friction properties, extended dry run performance, broad chemical resistance, PEEK can reduce wear clearances up to 50%,in many cases without the risk of damaging many parts. PEEK polymers are obtained by step-growth polymerization bythe dialkylation of bisphenolatesalts. Since this is a PEEK dominant compound, it's Coefficient of Linear Thermal Expansion (CLTE) it is twice that of Carbon Steel .Due to the difference in expansion rates, it is best suited for and typically used for stationary, pressed-in parts such as bushings or case wear rings in applications above ambient temperatures. It is highly resistant to thermal degradation as well as attack by both organic and aqueous environments. Also, this material will contract at a higher rate than mostmetals and will be more suited for press-on applications n sub-ambient temperature environments.

Fig 4.PEEK material.

A. Characteristics Of PEEK Material

PEEK is a high performance thermoplastic that has both high strength and high temperature limits, e.g. up to 600° F.PEEK expands at a much greater rate than metals. This means that as operating temperatures increase, the interference fit between the impeller and the wear rings loosens. To account for the greater expansion of the PEEK wear ring, a heavy initial "cold" (ambient temperature) interference fit can be used, and the upper temperature limits for the pumped fluid must be specified. PEEK has excellent chemical resistance and may be used for pumping numerous hydrocarbons from crude oil to propane. It is also suitable for condensates, boiler feed water, sour water and a wide variety of other dirty water services. Other services include ammonia, caustic, DEA and carbonate. It has been used as the premier material for sealing elements in compressor valves and has been widely applied in pumps, as well as other compressor application. However, PEEK wear rings are not suitable in pumping sulfuric acid, nitric acid, HF acid, or chlorine. For hostile environments, PEEK is a high strength alternative to fluoropolymers. PEEK carries a Variable flammability rating and exhibits very low smoke and toxic gas emission when exposed to flame.

B. *Types ofPeek Materials*

1 .Ketron PEEK (H101)

This general purpose grade is unreinforced and offers the highest elongation and toughness of all PEEK grades.

2. 30% Glass-reinforced Ketron PEEK (H301)

The addition of glass fibers significantly reduces the expansion rate and increases the flexural modulus of PEEK. This grade is ideal for structural applications that require improved strength, stiffness or stability, especially at temperatures above 300°F (150°C).

3. 30% Carbon fiber-reinforced Ketron PEEK (H201)

The addition of carbon fibers enhances the comprehensive strength and stiffness of PEEK, and dramatically lowers its expansion rate. It offers designers optimum wear resistance and load carrying capability in a PEEK-based product. This grade provides 3.5 times higher thermal conductivity than unreinforced PEEK - dissipating heat from the bearing surface faster.

4.Virgin PEEK

Its high mechanical properties at elevated temperatures, combined with excellent chemical and hydrolysis resistance, make it the most popular advanced thermoplastic material available today.

5. Glass filled PEEK

It exhibits higher modulus than VRPK(neat PEEK),thus offering more resistance to deformation under load at elevated temperatures. This material is an ideal candidate for many structural component applications carrying high static loads.

C.*Peek as Wear Material*

Polymer composites contain thermoplastics as PEEK. This is a ductile material which absorbs shocks and vibrations, dampening the effects of resonating metal components. PEEK wear components are always mated against metal wear surfaces. They possess high strength properties, excellent impact resistance and an extremely low coefficient of friction but they are much softer than metals and are intended to be the sacrificial component should severe upset conditions develop. Composites can withstand hard contact with little or no damage and can handle intermittent dry run episodes. In cases where dry run is quite extensive, the composite will suffer surface melt but will not damage expensive metal parts such as impellers, shafts or pump casings.

VI. CONCLUSION

To conclude with ,this paper exemplify that thermoplastic composite materials have been and can be applied to either the rotating or stationary wear parts in a broad range of centrifugal pumps. On the application of PEEK material, the reduced clearance obtained minimizes the recirculation to maximize the rotor stability and overall efficiency. These materials also provide greater hardness deferential between wear part, the composite material serving as wear component and minimizes the shaft run out. Polymer based composite materials have many qualities and characteristics that can lead to improved pump performance and longer mean time between pump repairs. Composites are also sacrificial in nature and they will not damage expensive metal parts .In cases of severe upset conditions and pump failure composite materials help to protect metal parts, mitigating damage and lowering the overall cost of repair .They also reduce the deflection and the vibration for dramatically reduced energy consumption and repair costs. Pump users need to understand these differences and it is important that composite parts be designed to compensate for the thermal expansion differentials.

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