Design of Centrifugal Pump for High Temperature Fluid

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***Abstract— Abstract*-Centrifugal pumps are used extensively for hydraulic transportation of liquids and chemicals over short to medium distance through pipelines where the requirements of head and discharge are moderate. A centrifugal pump designed to handle the liquids at high temperature is normally single stage, end suction type having radial configuration to facilitate the motion of liquids. Some of the special features of the centrifugal pumps are volute casing design, horizontal installation design, Air cooled, back pull-out design ,robust impeller with more number of vanes, special seals and proper material of construction to ensure longer life. During the design of pump at high temperature the requirement of longer life and reliability have to be balanced by the constraint of high initial cost and efficiency. Whereas working of the pump at high temperature, the different parts of the pump gets heated and thus it changes the physical properties of the different components of the pump. Due to the changes in the properties of the components the pump performance is gets affected. Also there is leakage in the mechanical seal and some parts may get damaged while working of pump at high temperature.**

***Index Terms—* Centrifugal pump, Design, High Temperature fluid, Material**

I. INTRODUCTION

The hydraulic machines, which convert the mechanical energy into hydraulic energy, are called pumps. The hydraulic energy is in the form of pressure energy. The mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid; the hydraulic machines are called centrifugal pumps. The flow in a centrifugal pump is in radial outward direction.

II. NEED OF CENTRIFUGAL PUMP AT HIGH TEMPERATURE

Following are the reasons of using high temperature fluids upto 350^0C.

a) Liquids which are solid or semi-solid state at ambient temperature (at 35^0C) which are heated upto their liquidisation temperature to permit them to be moved more easily or to be applied, spread, processed, or otherwise utilized. Examples Asphalts, Molasses, Roofing tar, Sulphur, Lead.

b) Liquids which are a process by-product or are being used in a product that uses heat as a catalyst to initiate, sustain, accelerate, or complete a reaction. Examples Refineries (Cracking, Distilling), Asphalt blending and mixing, Polymer Production (Styrene).

c) Liquids used to transfer heat to equipment such as: Plastic Molders, Snow Removal Equipment, and Food & Candy Making Equipment, Chemical Pumps and Equipment. Examples Dowtherm (Dow Chemical), Theminol (Monsanto), Mobil herm (Exxon Mobil).

d) Also in the laboratory, pumps are used for liquid metals and other fused heat transfer media,Sodium,sodium potassium alloy,lead,and fused salts with melting points approaching 1000^0F (537^0C) are among the liquids which have been circulated at a temperature above the 1500^0F (815^0C) with centrifugal type pumps.

There are lot of problems created while operation of the pump at high temperature fluid having temperature upto 350^0C with respect to working of the pump at the atmosphere temperature of fluid having temperature 35^0C. The major problems are mechanical seal leakage, pump casing failure, impeller failure, bearing failure.

Presently Kirloskar Brothers Limited manufacturing the pumps working upto 150^0C temperature of fluid (Ex. sugar factory juice, heated water, sulphuric acid, nitric acid, Molasses, roofing tar). But the customer requirement is reaching upto the 350^0C (Ex. Thermal oils, Therminol, sodium potassium alloy, Mobil herm).Thus it is very necessary to design and analyse the pump at high temperature.

III. THEORIES AND PRACTICES

The high temperature pump is mainly divided into the three parts such as Pump Externals, Pump Internals and Sealing.

Pump Externals

Externals metal parts are considered to be those that are in contact with the liquid on the inside and exposed to ambient conditions on the outside. Selection of the suitable metal of external pump construction will depend on the following:

- Dimensional changes due to thermal expansion
- Resistance to corrosion(typically heat increases a corrosiveness)
- Maximum practical temperature limit for the pump as determined by thermal shock resistance, loss of strength, or other factors.

Pump Internals

Generally, the selection of internal materials is based on the same considerations as those involved in the selection of the external materials. The emphasis on importance shifts slightly however.

Thermal shock for example, becomes less of a concern. Thermal shock of the internals is less likely as ambient sources do not come into direct contact with them.

Loss of hardness plays a very serious role in internal material selection. Induction hardened steel idler pins for example

Manuscript received September 20, 2014.

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tends to lose their hardness at elevated temperatures. Nitrided steel idler pins (Nitralloy) retain their hardness over the full temperature range. For this reason, Nitralloy pins are used for high temperature applications beyond 450°F (230°C).
Dimensional change due to thermal expansion plays an enhanced role on two fronts.

1) Clearances in the pump are critical to pump operation and maximum efficiency. Heat causes the metal parts to expand, decreasing the internal clearances. Extra clearances must be added to insure that the pump does not seize due to this thermal growth.

2) These thermal expansion rates vary from material to material. While steel and tungsten carbide are each capable of withstanding temperatures through 800°F (425°C), a tungsten carbide pin pressed into a steel head will be rated to much less. Steel has a higher coefficient of thermal expansion than tungsten carbide and as such, the fit between these parts loosens at elevated temperatures.

Sealing

Liquid containment is always a concern, but when h750°F (400°C), it becomes even more critical. Mechanical seals are more commonly used for the following reasons

- They are virtually leak free, which saves product, reduces messes, and reduces operator exposure risk.
- They do not require frequent attention and adjustment.
- They do not require outside lubrication
- They reduces shaft wear
- They are easy to replace

IV. DESIGN OF CENTRIFUGAL PUMP AT HIGH TEMPERATURE FLUID

Geometry of pump

The geometry of pump and its components are made in such a way that there should be very less heat transfer between some components and more heat transfer between the other remaining components. The geometry is also decided in such a way that there is very less thermal stresses induced in critical components of pump such as mechanical seal, bearing. Etc.

General features

Pumps are as per EN 22858 (DIN 24256) and ISO 2858. The design is of back pull out type. Large varieties of models are available to operate at 1450 rpm, 1750 rpm, 2900 rpm and 3500 rpm at 50Hz/60Hz.

Pump casing

The casing has axial suction and top centre line delivery. Smooth hydraulic passages enhance high efficiency. Castings are made through REPLICAST Process

Impeller

The impellers are of enclosed type. Hydraulic balancing of impellers is achieved either by back vanes or by balance holes. The impellers are statically and dynamically balanced. Reliable fixing of the impeller on shaft is achieved by using helical insert under impeller nut.

Shaft

The shaft is supported by two antifriction bearings to take residual axial thrust and prevent axial float or radial run out. It is fully protected from the handled liquid by means of a shaft sleeve and graphite gaskets between impeller nut, impeller hub and shaft sleeve.

Stuffing Box

The stuffing box is sealed by grafoil packing or by metallic bellow type mechanical seal. Conversion from gland packing to mechanical seal is achieved by changing some standardized parts. Re-machining of stuffing box is not necessary. As liquid temperature is high pumps are provided with stuffing box cooling provision.

Bearing

The bearings are oil lubricated with bearing oil cooling arrangement. All pumps are provided with reinforced bearing arrangement as standard supply.

Direction of Rotation and Drive

Clockwise viewed from driving end. Pumps can be driven by electric motor or engine.

Material of construction

Table I: Material of construction

Casing / Casing Cover	Cast steel ASTMA 216/216M
Impeller	Cast steel ASTMA 216/216M
Wear Ring	Cast Steel
Shaft	ASTMA 434 – 4140 CL BB ANEALED
Shaft Sleeve	ASTMA 434 – 4140 CL BB ANEALED
Bearing housing/ Bearing cover	CAST IRON- 210 FG-260
Bush	SILICON CARBIDE
Motor Side bearing	(BALL BEARING) STAINLESS STEEL

CONSTRUCTIONAL FEATURES

- Pump with stuffing box cooling and bearing cooling arrangement
- Pump in all Cast Steel construction i.e. MOC code 10. (All CF8M MOC very rarely offered.)
- Pump with Grafoil packing rings for gland packed execution.
- Pump in solid gland in cast steel material, Instead of spilt gland.
- Pump with special close clearance stuffing box bush.

- Gaskets:
  - Spiral wound gasket in between casing and casing cover.
  - Other gaskets coming in liquid contact are in Grafoil.
- Mechanical seals are metal bellow type and as per the recommendations of seal manufacturers.
- Stuffing box jacket is formed using viton 'O'ring or welding sheet metal to casing cover depending upon considering temperature of fluid.
- Metallic oil breather.
- Pump casings are casted through REPLICAST Process.

UNIQUE FEATURES

- Pump can be offered with CE (Conformity Europe née) marking.
- Depending upon the application, area classification ATEX marking can be done.
- Heat barrier is created by way of cooling the stuffing box region & sufficient space is kept between stuffing.
- Box and bearing, so that heat is not conducted to bearings.
- Special heat resistant painting.
- REPLICAST casting.

DESIGN FEATURES

Volute casing pump

The pump casing used for the pump is having gradually increasing volute area.

Horizontal installation

The pump is always kept in the horizontal position. Due to installation in the horizontal direction it has the advantage of less vibration, good balance and safety.

Single stage

Only single pump casing and single impeller is used in this pump.

Handling the heat transfer (thermal) oils with temperatures up to 350^{0}C

This pump is designed for the temperature up to the 350 c temperature

Air cooled

The fins are provided on the bearing housing or on the bearing bracket .So due to that the heat transfer rate increases and thus the temperatures of the bearing are decreases. There is no necessecity of providing the external cooling.

Back pull out Design

The whole driving unit assembly can be dismantled for any maintenance or repair work without disturbing the pump casing with the suction and delivery piping.

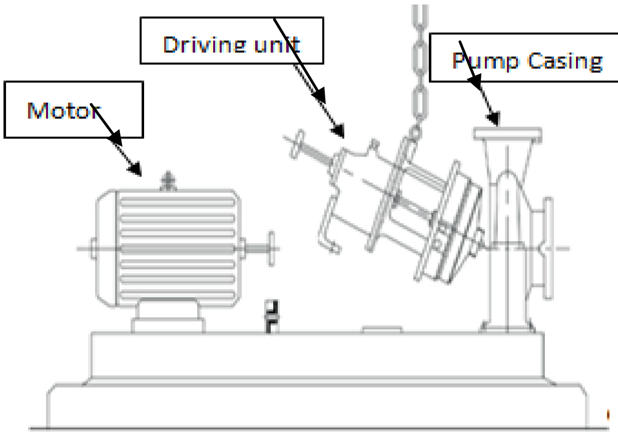

Fig1. Back pull-out arrangement

Direct coupled with driver by coupling

In order to reduce the vibration, pump is directly coupled to the driver with the help of coupling. compact design.

ACKNOWLEDGEMENT

I wish to express my sincere and heartfelt gratitude to **Mr.Santosh Patil Associate Manager Kirloskar Brothers Limed** for his unfailing inspiration, whole-hearted co-operation and painstaking supervision, through provoking discussions, criticism and suggestions given by him during the entire period of this paper completion.

I wish to express my thanks to entire team of **Kirloskar Brothers Limited** for their motivation, support and assist to extend.

Last but not the least, I wish to express my deep sense of gratitude to my family, for supporting and encouraging me at every step of my work. It is the power of their blessings, which has given me the courage, dedication, confidence and zeal for hard work.

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