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Deployment of New Rotating Equipment Technologies in Oil & Gas Field

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Abstract

New Technologies in Oil & Gas Rotating Equipment Sector has always remained an interesting topic. Various Technologies that are beneficial to Indian Offshore Oil & Gas sector is covered. Conventional Oil & Gas exploration from shallow depth are slowly getting over and industry is moving towards Deepwater. Technologies deployed in Deepwater and in sub-sea are challenging and at the same time will involve extensive funded research. Technologies like Ultra High Pressure Water Injection Pumps, Multi-Phase Pumps (MPP) and MicroTurbines are discussed. Water injection is used for secondary recovery in Oil & Gas from an aging field and even some of the new fields requires gas lift or water injection right from its inception. Deep water Oil & Gas excavation required very high water injection pressures of the order of more than 300–400 barG. This is very challenging from the perspective of multistage pump design particularly in selection of number of stages and to cater for high axial thrust. In North sea subsea pumping is widely used in remote offshore locations at seabed pumping and for Deepwater offshore wherein building conventional Offshore platform is not lucrative. Multiphase Pumps are being deployed to handle varying Gross fluids (Oil, Water, Gas) with varying Gas Volume Fraction (GVF) and to achieve wider turndown rates. In the power range of 30–200kW, Gas Turbine Generator models are not available. Gas Engine and Diesel Engine models being reciprocating machines have operational/ maintenance intervention issues, diesel handling and logistics leading to increase Operating Expenditure. In this range Micro turbines working on Regenerative Gas Turbine Cycle can be deployed.

1. Introduction

New Technologies in Oil & Gas Rotating Equipment Sector has always remained an interesting topic. Various Technologies that are beneficial to Indian Oil and Gas/Refinery sector are discussed in this Technical Paper. Conventional Oil & Gas exploration from shallow depths with water depth of 40–100m are slowly getting over and industry is moving towards Deepwater. The Technologies deployed in Deepwater Offshore and in Sub-sea are challenging and at the same time will involve extensive funded research. Some of the research topics in future Oil and Gas/ Downstream industry are mentioned below:

- Ultra High Pressure Water Injection Pumps
- Multi-Phase Pumps (MPP)
- MicroTurbines

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2. Ultra High Pressure Water Injection Pumps

Easy Oil and Gas exploration days are getting over. Today exploration using Deepwater projects are done with water depths ranging from 1500–2000m and water injection pressures require for secondary recovery are higher than ever before. Required injection pressures for such Deepwater projects could range from 400-550 bar. Deploying water injection pumps to cater for such high pressure is a challenge. Safety and Reliability is of utmost importance while delivering such challenging design. Reliable and safe design is required. The rated design point for one such case is mentioned in Table 1 below.

Table 1. Pump Design Parameters

Design Parameters	*Rated Point 1*	*Rated Point 2*
Flow (m^3/hr)	450	500
Differential head (m)	4000	5500

Dictating parameters for generating such high head was speed, impeller diameter and number of stages. Two speeds were selected to meet the two rated point. 9000 rpm was selected for Gas Turbine and 6000 rpm was selected for Gas Turbine+Gear box drive or E-motor+ Gearbox drive. Investigated Design Options are provided in Table 2.

Table 2. Design Options

Design Parameters	*Option 1*	*Option 2*	*Option 3*
Speed, rpm	9000	6000	9000
Specific speed, ns	28	21	22
Number of stages	10	12	8
Head per stage	550	480	700
Impeller diameter , mm	220	280	250
Impeller arrangement	Back-to-back	Back-to-back	Inline
Concept	B	B	A

Concept A : Pump design with impellers arranged inline (API 610, BB5 type, Figure-1) is a very proven classic design. A balance drum installed after the last stage at NDE reduces the axial hydraulic thrust within the limit of double acting thrust bearing. In this between bearing design the mechanical seals at DE and NDE seal the suction pressure to atmosphere. This barrel pump is designed with a full pull out internal cartridge.

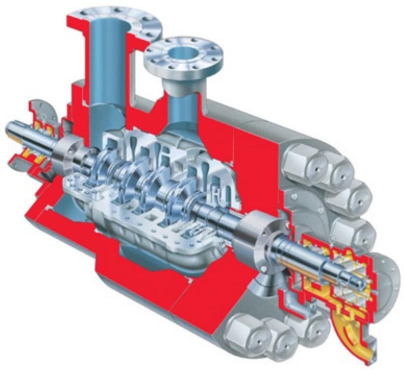

Figure 1. BB5 pump.

Concept B : Back-to-back (opposed impeller) design is widely used in industry. Two groups of impeller are arranged opposite to each other balancing axial hydraulic thrust and thereby need a smaller thrust bearing than Concept A. Center bushing and throttle bushing are only subjected to half of the total pressure and act as Lomakin type bearings. This design is best suited for high number of stages and suited for volute type pump with axial split inner case. For very high pressure a diffuser type casing is preferred since radial split inner casing is easier to seal. Pressure to be sealed to atmosphere is pressure generated by first set of impellers which is about half the discharge pressure.

All the three options were evaluated in view of designers experience and imposed standards such as API 610, Tenth Edition (2004). Parameters that were evaluated include Speed, Head per stage, Hydraulics, Shaft Stress, Design Pressure, Rotodynamics, Sand Handling, Axial Thrust bearing and size. All above aspects were evaluated. Rotodynamics was not acceptable for Option-3 and hence it was disregarded. Option-2 was proposed because the speed, rotodynamics, sand handling capability met Customers requirements. It was identified that during the design of prototype pump, attention has to be paid to the tightness of the delivery cover / barrel casing joint and to the rotodynamics. Furthermore the wear parts have to be protected from abrasives adequately to meet reasonable life expectancy.

3. MultiPhase Pumps

Subsea pumping technologies are preferred more and more in subsea tie backs, subsea boosting and sub-sea processing. The main application of subsea pumps is in mature assets which have lost their own nature pressure or in wells in ultra deep water located far off from their host facilities when the reservoir pressure is not high enough to boost the oil flow. Refer Figure 1 showing a typical subsea processing system. There are several green fields that don't have enough boosting pressure to transfer oil to platform or shore facilities, or that are located far from the host facilities. This means they need artificial boosting or pumping right from the beginning of project.

Gas lift and Waterflooding are two solutions to drive more hydrocarbon gas lift increases the Gas Volume Fraction (GVF) and requires an expensive compressor package topside. Waterflooding increases the water cut of the reservoir and separation requires installing heavy equipment. Subsea multiphase boosting has numerous advantages some of the key ones are listed below:

- Reduces the size of topside facilities
- Stabilises flow in wells that cannot naturally produce to remote facilities
- Eliminates offshore flaring and saves the relevant cost
- Reduces the shear and decreases emulsion formation, which leads to flow assurance issues
- Permits oil and gas production in harsh environment
- Extends subsea tie back distance

Based on subsea system design requirements such as GVF, water cut, viscosity, differential pressure, sand content, different pumping technologies are used. Two main categories of subsea pumps, the positive displacement pump and rotodynamic pump. Subsea pumps can also be categorised in two main applications, “subsea” and “downhole”.

There are several types of pumps deployed for offshore applications. The major ones are:

- Helico Axial Pumps (HAP)
- Twin Screw Pumps (TSP)
- Electro Submersible Pumps (ESP)

3.1 Helico Axial Pumps (HAP)

These are engineered centrifugal pumps for high capacity and relatively low differential pressure and utilize axial impellers. As shown in Figure 2, design includes a compression cell that contributes to compress gases and mix with fluid to handle higher GVF rates. Other name of this type is "Poseidon pump". HAP covers differential pressure less than 2900 PsiG and total flowrate (oil, water and gas) at suction conditions from 50,000 bpd to 450,000 bpd, GVF ranging from 70-80%. Figure 2 represents the effect of GVF on the operating ranges of HAP.

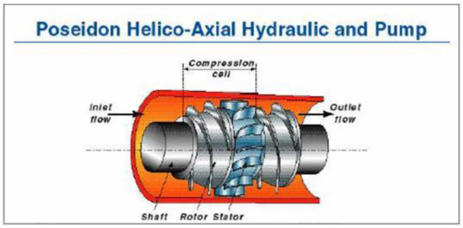

Figure 2. Helico Axial Pump.

3.2 Twin Screw Pumps (TSP)

These pumps can handle high viscous products with low shear that is not possible in HAP. Speed is directly derived by suction list and viscosity. The higher the GVF, the smaller the screw to provide a sufficient number of locks (space). The maximum differential pressure in different capacities is almost constant. TSP is not susceptible to fluid density; therefore it can handle slugs much better than HAP. TSP is designed for vertical and horizontal installation, while HAP is only available in vertical design.

3.3 ElectroSubmersible Pumps (ESP)

ESP pumping module consists of driver unit and pumping unit. Driver is installed upstream of the pump and can be either an electric motor or water turbine. Pump installed is not designed to handle high GVF because the electric motor is cooled by passing liquid. ESPs are suitable in flow range 1000-20000 bpd and in future ultra deep wells (10000 ft) to drive the fluid to seabed. After boosting to the seabed, HSP or TSP can drive the fluids to host facilities. ESP in series installation can provide enough differential pressure to boost fluids to host facilities.

4. Microturbines

Often low electrical loads of satellite unmanned installations (approximately 100 - 300kW) and ao the sparing philosophy (N+1) required, existing gas turbines may not be an optimal option for these field developments. Claimed efficiency of these Microturbines is in the range 26-32%. Since the shaft is rotating at very high speeds > 20000rpm, air bearings are employed. Microturbine works on the principle of recuperative gas turbine shown in Figure 3. These Microturbine packages are available as UL compliant, NFPA, NEC, ATEX. These units have load following and build in synchronization and load balancing feature. PLC based controller is also available as an option. It has been claimed that these Microturbines are suitable to burn casing gas from oil production, condensate gas from liquid processing, gas too rich or too lean to meet pipeline standards, sour gas with H_2S upto 7mol%. This technology can minimize flare and vent stack emissions. There are number of installations in North Sea, South China Sea and Gulf of Mexico. Offshore noise enclosure fabricated in SS316 is kept pressurized using blowers and provided with gas detection and space heaters for moisture protection. Claimed minimum fuel pressure is 0.2 PsiG.

MicroTurbines are considered as one of the possible power generation options, however gas-engine generator drivers are a proven alternative until mature HSSE design of micro turbine is in place and proven.

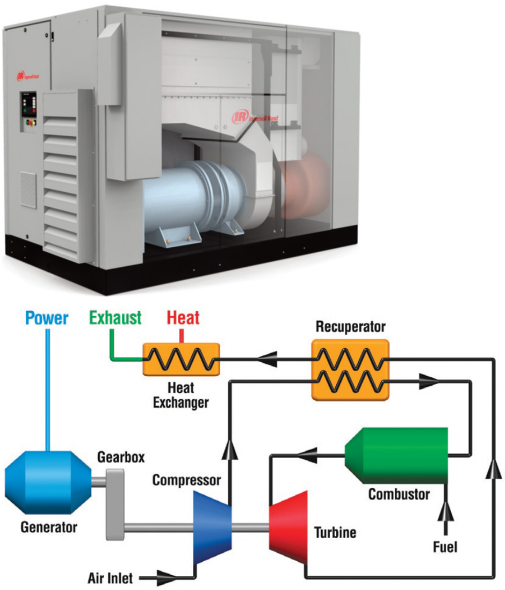

Figure 3. MicroTurbine Unit & Recuperative Cycle.

Reliability of Microturbines largely depends on the quality of fuel gas and fuel gas conditioning skid is recommended. Normal offshore configuration for these Microturbines is 2X100% with a dedicated diesel engine black start generator. Normal mode of operation is to run the two microturbines; should one trip the other will continue and in the event of both trip due to common mode failure then the diesel engine generator kick in automatically.

Following points must be taken care while implementing Microturbines for remote offshore location:

- Tuning of fuel control valve with actual site fuel gas must be carried out during commissioning.
- Get guarantee on combustion liner replacement frequency with Vendors as often based on borescope inspections the replacement frequency could be higher.
- Overspeed test must be carried out during Factory Acceptance Test at Vendors work as most likely this equipment will be identified as Safety Critical and annual overspeed test would be required to be carried out at site
- Operational and maintenance access of the electronic control modules must be properly verified during detailed design with Vendor. Fault codes and Alarm descriptions must be carefully agreed to prevent site troubleshooting at later date
- Engine and Alternator changeout are expected every 6 years and operating cost should accordingly be considered.

5. Conclusion

Technologies discussed above can be deployed in Indian Offshore environment considering the project specific requirements. Microturbines should be explored for limited power requirements to the tune of 30-200kW. Prototype UltraHigh Pressure Injection Pumps in pressure range 450-500 bar for secondary recovery must be properly tested at Vendor works to verify rotodynamic stability and ensure sand cutting capabilities before deploying offshore. Taking on board lessons learnt from North Sea, Multiphase pumps can be explored for offshore fields with depleting pressures or remote subsea fields thereby reducing elaborate offshore platforms.

6. References

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2. Centrifugal Pumps for Petroleum Petrochemical and Natural Gas Industries. 10th ed. ANSI/API 610; 2004
3. BB5 picture courtesy Flowserve
4. HAP picture courtesy FRAMO
5. MicroTurbine picture courtesy Capstone