

# Significance of pipeline transportation of solids engineering essay



Pipeline transportation – using either hydraulic or pneumatic system – is now considered to be an appropriate alternative to the conventional bulk material handling systems. Hydraulic conveying of solid materials through pipes has progressed enormously since its beginning well over a century. Millions of tons of coal, sand and mineral ores are transported every year over hundreds of kilometers. It is uniquely preferred in dredging operations. In coal industries, hydraulic systems are used during mining, transport, combustion and also for marine transport. Hydraulic handling techniques for ash disposal from coal-fired power plants and furnaces are currently being used worldwide. In chemical and mineral processing industries, conveying of particulate solids consisting of solid material dispersed in a liquid medium is involved.

In an important and extensive study led by Zandi [166], the team reported their findings on the application of freight pipelines and concluded that most varieties of freight pipelines are technologically feasible modes of transport for pulverized materials.

## **1. 2 IMPORTANT FEATURES OF FRIEIGHT PIPELINES**

A freight pipeline system has many good features besides being attractive from an environmental point of view. Some of the features are:

Traffic reduction,

Air pollution reduction,

Accident reduction,

Less land disturbance while laying pipeline than other modes of transportation like while laying Railway line for Rail Transport and while laying track for Aerial Rope-ways etc.,

Reduction in energy consumption when compared to Railways or Roadways etc.,

Potential for complete automation right from the place of the origin to destination, and

Reduction of freight loss and damage.

### **A freight pipeline has some limitations:**

Highways and railroads carry traffic other than freight, whereas pipeline transport is limited to transportation of pulverized material only.

Water is commonly used in slurry pipelines as the conveying liquid. When it is scarce at the point of origin of the freight slurry the pipeline can make the situation even more acute.

The pumping unit is an essential part of a hydraulic transportation system. It feeds the pipeline and provides the necessary energy for the transportation.

## **1.3 THE PUMPING UNIT**

In practice, pumps of various kinds such as centrifugal pumps, positive displacement pumps, and jet pumps are used for different purposes. The selection of a pump is generally based on the head and discharge requirements.

## 1. 4 CLASSIFICATION OF PUMPS

Pumps are classified in many ways. Krutzsch[60] classified them into two groups - (i) Dynamic Pumps and (ii) Displacement Pumps ( Figs. 1. 1 & 1. 2) based on the principle by which the energy is imparted to fluid or slurry.

Although the centrifugal and positive displacement pumps are more efficient than jet pumps and air lift pumps, an increase in concentration even by 1% of solids would deteriorate the performance of these pumps. The centrifugal and positive displacement pumps besides being costly need special maintenance when they are put to use in submerged environments. Therefore, due to simplicity in construction, light weight, absence of moving parts, valves and less maintenance, the jet pumps are found to be a better alternative for hydraulic transportation of materials.

Fig. 1. 1 Classification of Dynamic Pumps (Krutzsch[60])

Fig. 1. 2 Classification of Displacement Pumps (Krutzsch[60])

### **JET PUMPS**

Secondary - Liquid

Liquid - Liquid

Jet Pump

Secondary - Liquid + Solids

Solids Handling

Jet Pump

Secondary - Gas

Secondary - Liquid

Secondary - Gas + liquid

Jet Compressor

Injector

Pneumatic

Jet-lift or

Air lift pump

Secondary - Gas + Solids

Gas-Solid

Injector

### **Primary – Liquid**

(Hydraulic jet pump)

### **Primary – Gas**

(Air lift pump)

Fig. 1. 3 Classification of Jet pumps

## **1. 5 CLASSIFICATION OF JET PUMPS**

Of all the different types of pumps reported, jet-pumps form a special class and the classification of it is summarized and presented in Fig. 1. 3.

## **1. 6 WORKING PRINCIPLE OF TWO TYPICAL JET PUMPS**

### **1. 6. 1 Air-Lift Pump**

#### **Riser**

The Air-lift pump is a very simple device as could be seen through line sketch in Fig.-1. 4(A) having merely a vertical pipe (the riser) immersed in a pool of liquid. Gas (usually air) is injected via an orifice system from the bottom or from the side of the riser. Three typical ways of injections are shown in Fig. 1. 4 (A, B, C). Due to the buoyancy force of air bubbles, it lifts the liquid. Although the efficiency of a gas-lift pump is low, its simplicity and absence of moving parts make it attractive as a means of lifting corrosive and toxic liquids. At times airlift pump is used to lift solid particles also.

Fig. 1. 4 various air injection methods

### **1. 6. 2 Jet-Lift Pump**

Jet lift Pump is a pump having no moving parts and utilizes fluids in motion under controlled conditions as shown in Figure 1. 5(A). A high-pressure stream of fluid directed through a nozzle(s) provides the motive power. Four typical ways to inject the driving fluid are also shown in the same Fig. 1. 5(A, B, C & D).

(D)

(C)

(B)

(A)

Fig. 1. 5 Line sketches of some typical jet pumps

The resultant jet of high velocity fluid creates a low-pressure area at the entrance of mixing chamber (throat) causing the suction liquid to flow into this chamber. There is an exchange of momentum at this point producing a uniformly mixed stream travelling at a velocity intermediate to the motive and suction velocities. Jet nozzle converts the pressure energy into velocity, while the diffuser mixes the fluids and converts velocity back into pressure energy. Jet pumps are usually tailor-made to suit the conditions of service.

## **1. 7 DIVERSE APPLICATIONS**

Three diversified applications of Jet-Pumps in different industries are reported below:

### **1. 7. 1 Coal Unloading from a Sea Vessel**

Fig. 1. 6 Slurry system for unloading coal from a vessel

### **1. 7. 2 In Mining Industry**

Some of the possible applications of jet pumps in mining industry are as follows:

Lifting of drill cuttings in pulverized form and / or water, while shaft deepening,

Conveying hydraulically winnowed materials in underground mining,

Extraction of materials from under-water deposits, and

Removing of mud from settling sumps of draining plants in mines

### **1. 7. 3 Dredging**

Wakefield [154] designed and successfully implemented (Fig. 1. 8) jet pumps for beach and sand bar management. It was the world's first fixed sand by-passing scheme, and was implemented at the Nearing River mouth, Surfers' Paradise, Queensland, Australia. A line of 10 jet pumps was arranged at right angles to the direction of the littoral drift.

Without the sand bar management system in place, the mouth of the Nerang river (Queensland, Australia) was expected to move northward and by the year 2050 it is expected to be north of Runaway Bay as shown in Fig. 1. 9.

The pumps were suspended from a jetty and each jet pump was spaced about 30m apart. The jet pumps were lowered to a depth of 10 metres below the normal sea-bed. Their operation created a trench of sand trap at right angles to the beach. The sand moving from the South gathered in the trench and was pumped through a pipeline under the entrance to the Northern beach. The system has a capacity to pump sand at rates of either 335 or 585 cubic metres per hour.

Further, Wakefield suggested the hybridisation of jet pump and centrifugal pump to have advantages of both the pumps. Sometimes two jet pumps may



be combined in series (multi-stage), the first one pressurizing the second to suppress cavitation and greater secondary flow.

Fig. 1. 7 Nerang river entrance – general arrangement

Fig. 1. 8 Schematic diagram of sand bypassing system

Fig. 1. 9 Movement of the mouth of the Nerang River over the years

### **1. 7. 4 Deep Sea Mining**

All over the globe, the Ocean beds are littered with huge quantities of poly-metallic nodules. The nodule resources on the sea floor amount to approximately 1 to 5 times the land resources. It is estimated that it takes from 2 to 3 million years for a nodule to grow to a nominal dimension of 2 to 3 cm in equivalent diameter (Vega [151]). Unlike fossil resources, they are renewable. About 10 million tonnes of nodules form every year (Qasim [111]). Research is going on all over the world for deep ocean mining of Manganese nodules. Several lifting systems have been considered. Of them, the air-lift and jet-lift pumps are considered to have good potential for deep-sea mining applications. It is quite natural for a country like India to tap such valuable resources for its own benefit.

Fig. 1. 10 Schematic diagram of extraction of minerals from sea-bed

### **The Indian Initiative:**

Fig. 1. 11 Polymetallic Nodules on the Seafloor

The first discovery of polymetallic nodules was made by scientists onboard the research vessel “ H M S Challenger” during 1873. In comparison, India

(by the efforts of the National Institute of Oceanography, Goa) recovered nodules in the Arabian Sea during 1981 onboard “ R. V. Gaveshani.” In 1982, India was recognised as a Pioneer Investor in deep seabed mining, by the United Nations Convention on the Law of Sea.

Subsequently, a massive effort was put in by India for exploration of polymetallic nodules in the Central Indian Ocean Basin (CIOB) by using a number of research vessels. This national programme (running into crores of rupees) is being funded by Department of Ocean Development, New Delhi.

One of the mine site (A) of 150, 000 sq km has been allotted to India and as per the condition of the ISBA, 50 % of the area has been relinquished to this body.

Deep-sea Technologies & Ocean Mining Group of National Institute of Ocean Technology, Chennai, aims at developing a highly reliable Deep-sea mining system which will develop technologies for harnessing resources from ocean to meet the country’s growing mineral requirements and increase the country’s self sufficiency

#### Fig. 1. 12 Schematic of Deep-sea Mining System

There are three methods – (i) hydraulic lift system, (ii) continuous line bucket mining system and (iii) modular or shuttle mining system used to mine nodules from the deep sea. Looking into various reports, hydraulic mining system, which uses the principles of hydraulics in lifting the nodules to the surface, appears to be the best alternative. The transfer of nodules to

transport ships could be achieved by one of the two modes – slurry transfer or conveyor transfer.

Some other applications of Jet-Pumps could be summarized as in next section.

### **1. 7. 5 Other Applications of Jet Pumps**

Coal and cinder transport in power plants,

Mixing and transport of raw materials in chemical and metallurgical industries,

Chemical plant circulating systems,

Oil well pumping,

Aircraft fuel pumping,

Boiling Water Re-circulation (BWR) pumps in nuclear reactors,

As a priming device,

Mill scale disposal in steel casting industry,

It is worth noting the advantages and disadvantages of Jet-Pumps.

## **1. 8 ADVANTAGES AND DISADVANTAGES**

### **1. 8. 1 Advantages of Jet Pumps over Conventional Slurry Pumps:**

Simple in construction

No moving parts

Worn parts can be easily and inexpensively replaced

No valves

Reliable operation and low maintenance costs

The motive pump handles only clear water and may be kept away from jet pump

### **1. 8. 2 Disadvantages:**

Slurry concentration cannot be controlled at a constant level,

Cannot pump over longer distances unlike centrifugal pumps,

Air-jets or liquid-jets are required to form homogeneous slurry,

The pumps are to be tailor-made for different situations.

Several parameters are involved in a hydraulic conveying system, which are briefly reported below:

## **1. 9 PARAMETERS INVOLVED**

Important parameters of hydraulic conveying system which affect its performance are summarised under the following six subsections.

### **1. Pipe Related (Geometrical Parameters)**

Pipe diameter

Pipe surface roughness

Pipe Inclination

Orientation

Pipe coating

## **2. Conveying Media Properties**

Density

Velocity

Pressure

Temperature

Viscosity

## **3. Properties of Material to be conveyed**

### **(a) Geometrical properties**

Particle size distribution

Shape (sphericity)

Surface characteristics

### **(b) Material physical properties**

Density

Type of material

Coefficient of restitution for impact between particles

Coefficient of friction between particles

### **(c) Pipe and Material Conveyed**

Coefficient of restitution for impact between particle and the pipe wall

ii) Coefficient of friction between particles and the pipe wall

### **(d) Pipe and Conveying media – Friction factor**

### **(e) Particle velocity**

### **(f) Material flow rate**

## **4. Conveying Media and Material Conveyed**

Drag coefficient

## **5. Pipe, Conveying Media and Material Conveyed:**

Mixture ratio

Diffusion Coefficient.

## **6. Jet Pump Parameters:**

Primary nozzle – inner diameter,

Surface roughness,

$(s/dt)$  – the ratio of the distance between the nozzle to the throat entrance

$(s)$  and the diameter of the throat  $dt$ ,

Area ratio  $(R)$  – ratio of area of the nozzle to the area of the throat,

Length and diameter of the throat and

Diffuser included angle.

## **1. 10 MOTIVATION FOR THE PRESENT STUDY**

In spite of several researchers having done extremely useful work in the area of two-phase flow, only a little work has been done systematically in flow through jet pumps. Wakefield's sand by-passing system on the Nerang River being a commercial one and patented one experimental data on parametric study was not published. Many times the experiments were done without taking into account the interference due to some of the components of the system. Some researchers have discussed the importance of interference. But many researchers have used data generated on experimental set-ups having different degrees of interference and tried to obtain generalised correlations, when the fact remains that the data cannot be compared without having full appreciation of the interference effect included in the analysis. As such, it is important to have a complete understanding of the interference effect, which requires a suitably designed experimental set-up besides having a theoretical model capable of taking care of mixing of primary jet with solid-liquid mixture coming from the secondary side.