Pipeline transportation technology: An overview

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The present paper attempts to focus attention on the rapidly-growing technology of pipeline transport and its importance as a viable mode to transport certain commodities. The emerging areas of growth are highlighted.

THE demand for transport in India is increasing very rapidly due to increased social interaction between people and economic development. This has increased passenger and freight movement across the country. The current transportation needs are met by a combination of various modes. To develop a well-designed transportation system in the country in the near future, it is necessary that the technological and economic characteristics of the various modes be appreciated.

Characteristics of pipeline transportation

Pipelines form an unique mode of transportation. They can move large quantities of certain types of commodities, mainly fluids, over long distances at relatively low cost. The operations are environmentally friendly, dependable and continuous. The pipelines can be laid on a wide variety of terrains without much difficulty.

Compared to normal surface modes like railways and road vehicles, the following advantages are particularly attractive:

i) They do not require the return of 'empties' to the starting point and as such are ideal for uni-directional traffic.

ii) They are insensitive to surface conditions such as storms, inclement weather, etc.

iii) Operating costs are low.

iv) Capital cost being the major cost of transportation, inflationary influences have a small effect on transport cost.

v) They are environmentally friendly.

Types of technology

The current status of pipeline technology can be broadly classified into three categories:

- Conventional or 'energy' pipelines
- Slurry pipelining
- Capsule pipelining

Conventional or energy pipelines

Use of pipelines to transport water, oil, natural gas (viz. single phase fluids) is a well known technology and is known as conventional pipelines. Since the transport of energy is the prime objective in most of these pipelines, they are also known as energy pipelines.

The mechanics of such single phase fluid flow has been studied in detail and the design and operational phases have been particularly perfected. The result is that this form of transport has been acknowledged as the most economical form for bulk and long distance transport of certain energy items like natural gas and oil. In India, we have an impressive list of crude oil, product and gas pipelines installation, both on shore as well as off shore. Currently, all the existing oil product pipelines, totaling about 4,000 km in length, are owned by the Indian Oil Corporation and the total transport of oil product is about 16 MTPA. Recently (1997), a new petroleum product pipeline company, Petronet India, has been formed by three major public sector petroleum companies. Petronet has plans to lay nearly 1,700 km of pipelines in the near future to transport 18 MTPA of petroleum products initially.

Even though the conventional pipeline technology is in near-perfect condition, the future is likely to witness further progress in this mode due to developments in areas such as:

1. Route location through GPS and related technologies.
2. Development of new materials for pipes and linings.
3. Newer construction techniques.
4. Development of drag and turbulence reducing additive materials such as polyox, CDR[1], etc.
5. Prevention of pipeline corrosion.

Slurry pipelining

In this mode, the solids are first ground to fine grain size and made into a slurry with a liquid medium. The slurry

is then pumped through the pipes to a desired destination. Even though the concept of slurry pipelining was known at the turn of the century, it was only in 1957 that it became a practical reality. The first long distance pipeline to be established was in Arizona, USA, to transport 0.4 MTPA of gilsonite over a distance of 115 km. Since then the applications are growing. Table 1 shows details of some important long distance slurry pipelines. The wide range of materials handled and the enormous capacity of a slurry pipeline is noteworthy. For example, a simple 20 cm diameter pipeline can handle about 250 tonnes of solid (say coal) per day!

Slurry pipeline transportation is particularly advantageous in those processes where the raw material is to be first pulverized for further processing. Thus iron ores meant for pelletization, coal for firing thermal stations,

Table 1. Some slurry pipeline installations in the world

Product/location	Length (km)	Diameter (m)	Throughput (MTPA)
Coal			
Black Mesa, USA	439	0.457	4.8
Belovo-Novosibirsk, CIS	256	0.500	3.0
Copper concentrate			
Irian Jaya, Indonesia	112	0.114	0.3
KBI, Turkey	61	0.127	1.0
Bougainville, Papua-New Guinea	27.4	0.152	1.0
Copper tailings			
Japan	64	0.200	1.0
Cebu, Philippines	19	0.508	24.0
Gilsonite			
Bonanza, Utab, USA	115	0.152	0.4
Iron ore concentrate			
Samarco, Brazil	396	0.508, 0.457	6.2
Chongin, North Korea	98	–	4.5
Savage River, Tasmania	85	0.228	2.3
Kudremukh, India	67.7	457 m 0.406	7.5
Kaolin			
Georgia, USA	25.7	0.203	
Lime stone			
Kensworth, Beds, UK	92.2	0.254	1.7
Calveras, USA	28.0	0.194	1.5
Mill tailings			
Odate City, Japan	68	0.300	0.6
Phosphate slurry			
Valep, Brazil	120	0.244	2.0
Golasfertil, Brazil	14.4	0.152	0.9
Sand			
Tatabanya, Hungary	8	0.200	2.5
Uranium-bearing gold slime			
Barldrosco, South Africa	19	0.152	0.97

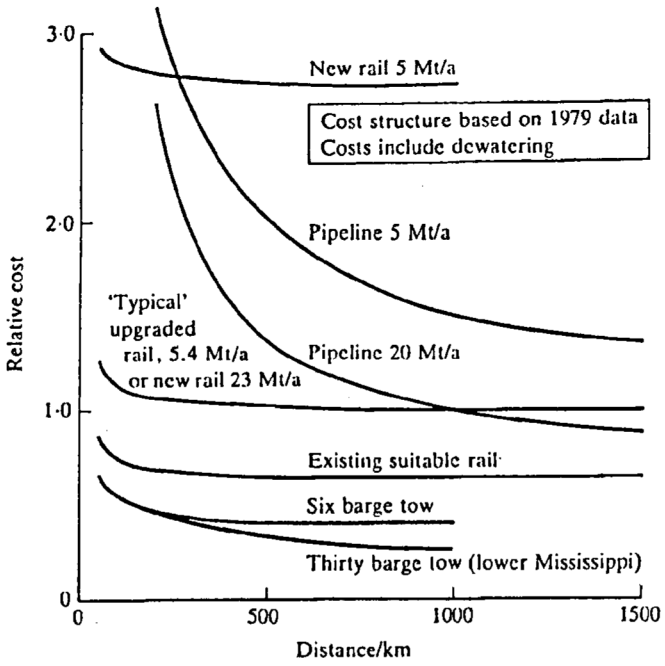

Figure 1. Coal transportation costs[2].

lime stone for cement industry, wood chips for paper industry are some examples of the situations where transportation by slurry pipelines can be a viable alternative mode.

Figure 1 shows the comparative costs of coal transportation by slurry pipeline, barge and rail for the USA.

It is interesting to note that pipeline transport is shown as being less economic than rail transport when existing rail is utilized, but becomes more attractive when new or upgraded rail has to be used. Although river transport is the most economic proposition, it is only applicable where suitable navigable waterway systems exist, such as the Rhine or Mississippi regions.

Some of the areas in which slurry pipelining is likely to have an impact in the near future due to development of related technologies are:

1. Vertical hoisting of minerals (hydraulic hoisting, seabed mining, bore hole mixing, etc.).
2. Coal water mixtures and coal–oil mixtures.
3. Coarse-particle conveying.
4. Mineral waste transport and disposal.
5. Ship loading and unloading.
6. Non-aqueous slurry media (oil, methanol and liquefied carbon dioxide).

Improved techniques, changes in economic conditions and environmental pressures and concern about surface waste disposal in the near future are likely to make slurry pipeline technology a viable mode of transport in a large number of industrial and infrastructure development activities. While the fuel policy committee,

Government of India, has noted that coal slurry pipelines are more suitable to meet the fuel requirement of thermal stations (which is fairly large and regular), the requisite R & D efforts towards general use of slurry pipelining in the country is inadequate.

Capsule pipelining

The major limitations of slurry pipelining – pulverized solids and its contact with the transporting fluid is not always acceptable. When it is required that the solids to be transported should not come in contact with the fluid and that it be transported in an integral fashion, capsule pipelining provides a solution. In this, the material is put in cylindrical containers (capsules), and a train of capsules is pushed by the fluid medium. Each capsule is only slightly smaller than the pipe; say of the order of 0.9 diameter of the pipe. This technology, which originated in the early sixties, has received considerable attention in developed countries, notably in Canada and the USA and due to the efforts of R&D many successful applications have been reported. The characteristics of solids transported, viz. their size and relative density, which are important in slurry mode, are particularly unimportant in capsule pipelining. Thus it is possible to use this technology to transport many kinds of articles, as for e.g. finished products, grains, corrosive materials, etc. An interesting application of capsule pipelining has been in the handling of radioactive materials in nuclear plants. Marcoule and Chinon nuclear plants in France use capsule pipelining to transport irradiated fuel elements from reactor to the cooling and storage pools thus avoiding costly radiation safety features necessary in surface transport.

A variation of capsule pipelining to transport coal is the Coal Log Pipeline (CLP)[3] technology. This is an emerging technology to transport coal hydraulically through a pipeline. The coal logs are manufactured at coal mines by compaction or extrusion processes and then injected into a water-filled pipeline for long distance transportation to power plants. The University of Missouri, Columbia patented the process in 1990. The current status of this technology indicates that CLP can be expected to play an increasing role in coal freight transport in the 21st century.

Another variation of capsule pipelining is pneumatic pipelining where air is the driving fluid. A proven technology of the kind is the 'capsule liner' of M/s. Sumitomo Metal Industries[4]. This is a multipurpose mass transport system consisting of trains of wheeled capsules loaded with freight in a pipeline using low air pressure. The capsule trains run in the pipeline at regular intervals making transportation safe, automatic and reliable. This system is particularly suitable for a range of materials including limestone, coal, ore, sand and excavated earth. An example of capsule liner usage is the one at Tachigi Prefecture, Japan, which transports 2 MTPA of limestone over 3.2 km in a pipeline of 1.0 m diameter with an energy consumption of 0.7 kWh/ton km. The 'capsule liner' system is superior to both truck and conveyor systems and Sumitomo claims an operating efficiency of over 95% in its installations over the last ten years.

There does not appear to be any capsule pipelining application in India. Further, no serious R & D efforts on the adoption of this emerging technology appear to be in progress in major Indian research institutions.

Conclusion

Pipeline transportation plays an important role in the matrix of transportation modes of a country, especially in the transportation of fluids and certain bulk materials. The different pipeline transportation technologies currently available for implementation have been described.

Slurry pipeline and capsule pipeline are emerging technologies for long-distance transportation of coal, limestone and similar critical bulk material. In view of their special characteristics – safety, reliability and their environmentally friendly nature, slurry and capsule pipelines are considered to be crucially important technologies in USA. It is believed that pipeline technology will play an increasing role in freight transport in the 21st century with far-reacting implications. This calls for increased R & D efforts to internalize these technologies for successful application in our country.

1 Blizzard, G. E., in *Hydraulics of Pipelines* (eds Fowler, D. T. and Wegener, D. H.), Am. Soc. Civil Engineers, New York, 1994, pp. 172–175.

2 Jacobs, B. E. A., *Design of Slurry Transport Systems*, Elsevier Applied Sci., London, 1991.

3 Capsule Pipeline Research Center (CPRC), University of Missouri, Columbia, Internet search, 1997.

4 *The Pneumatic Capsule Pipeline System (PCPS – 'Capsule lines')*; Sumitomo Industries Ltd., Japan, Internet search, 1997.