CHAPTER 1: INTRODUCTION

1.1 General Introduction

Pipeline transport has been as an alternative to the conventional modes of transportation. It is an innovative technology for conveying of coal, ore, minerals and collection and disposal of solid waste. Wilson et al. (2006) have stated that pipeline carriage is an environment friendly and economical as compared to rail and road transport. The use of a pipeline upholds dust free atmospheres, involve generally less space and involves minimum operating staff as stated by Bray et al. (2007) and Shen (2010). Conversely, high quality of pumping equipment, higher capital cost involved, limited size of commercially available pipe, lesser field data in literature and slurry as non-fully understood science makes design and analysis of pipe networks complicated.

The knowledge of pipeline transportation of solid-liquid combinations has undergone substantially progresses in the past half century. However, there is still an inadequate understanding of some facets governing the flow characteristics of these systems. According to Kaushal et al. (2013) the flow of concentrated multi sized particle slurry is very complex.

Solid–liquid mixture flows are primarily divided into two parts as settling and non-settling flows. In non-settling flow, very fine particles (clay) are present in the slurry and particle's settling velocity (fall velocity) are so small, the solid particles tend to settle very slowly and Brownian motion may be sufficient to keep the particles on hold indefinitely. However, at any cross-section of the pipeline, the volume of slurry particles is same. Hence the flow is "homogeneous". The presence of these solids increases the mixture viscosity compared to that of the carrier liquid. These mixtures exhibit a non-Newtonian consistency as per Wasp et al. (1977).

On the other hand, in settling flow, coarse particles (gravel) are present in the slurry. The particle diameters and the fall velocities are higher. The turbulence effect of the flow is not sufficient to lift the particles from the ground. The solids concentration varies considerably across the vertical axis of the pipe, so the flow is "heterogeneous". During the slurry movement in a pipe, the particles tend to slide along the bottom of the pipe. The viscous drag of the liquid flow above the bed of solids drags the solid particles.

In general, the slurry flow behaviour may be reflected in between these two extremes. The particles in slurries are generally of an intermediate size (silt and sand) and the behaviour is midway amid the extremes above. With this "moderately-settling" slurry flow in a pipe, the particles have a tendency to settle out in laminar flow, but are more-or-less uniformly distributed through the vertical axis of the pipe in turbulent flow. The turbulent flow of this slurry is stated as "pseudo homogeneous".

The boundary between settling and non-settling flows is ambiguous. As discussed in Yücel et al. (1978), Durand (1953) and Newitt et al. (1955) specified that the range of particle settling velocity of V = 0.60 to 1.50mm/s is the boundary between two types of flows, such that the higher velocities are settling flows, and the lesser velocities are non-settling flows. Wilson et al. (2006) stated that slurry of small particles (less than 40µm) in turbulent motion, exhibit in a homogeneous fashion, while the limit for pseudo-homogeneous flow is given for particles larger than 100 µm. The present project has been undertaken to gain insight in slurry flow modelling. The characteristics of slurry such as unsteady flow rate, complicated ingredients, high concentration and viscosity of liquid carrier are subjected to pipeline blockage and high energy consumption.

The hydraulics of slurry pipelines is analogous to the hydraulics of water pipelines. Though, slurry is a flow of a combination of fluid and solid, critical velocity and the head loss equation are prepared to compute the essential energy for the mechanism. The head loss for mixture flows depends on the material and diameter of pipe, concentration of transported material and flow velocity. Transporting liquid-solid fluid (slurry) through pipeline needs higher operating pressure and substantial demands for good quality pumping equipment and other accessories. To stay competitive in the world market, the industries are forced to decrease the power consumption of slurry transport. To achieve this, many scientists and researchers are working on pipe network analysis and optimisation.

Appropriate slurry pipeline design entails knowledge of the frictional pressure loss caused by supplying a specific solids concentration under laminar or turbulent flow circumstances, size and shape of slurry particles. This information is used to choose the pipe diameter and pump capacity to continue the flow rate and discharge pressure necessary for avoiding slurry deposition. Enormous efforts have been made in over a period to give a better selection of slurry pumps and optimisation of power consumption.

1.2 Optimisation

Optimisation is the process, to build something better. An engineer or scientist raises a new idea and this idea is modified further through optimisation technique. Optimisation involves in trying deviations on an initial concept and using the information gained to improve on the idea. Optimisation is the process of modifying the inputs to mathematical process, or experiment to find the minimum or maximum output or result. The input involves the variables; the procedure or function is identified as the cost function, objective function, or fitness function; and the output is the cost or fitness. If the procedure is an experiment, then the variables are physical inputs to the experiment.

Optimisation is known as one-dimensional, if there is only one variable. Multidimensional optimisation problem have more than one variable. Optimisation becomes gradually difficult as the number of dimensions increases. Dynamic optimisation means that the output is a function of time, though static means that the output is independent of time.

Optimisation can have discrete or continuous variables. Discrete variables have only a finite number of possible values, whereas continuous variables have an infinite number of possible values. Discrete variable optimisation is also known as combinatorial optimisation, because the optimum solution consists of a definite combination of variables from the fixed pool of all possible variables. Variables frequently have limits or constraints. Constrained optimisation includes variable equalities and inequalities into the cost function. Unconstrained optimisation permits the variables to grasp any value.

1.3 Newtonian Fluid and Non Newtonian Fluids

In a Newtonian fluid, the relation between the shear stress and the strain rate is linear, the constant of proportionality being the coefficient of viscosity. Water is an example of a Newtonian fluid.

In a non-Newtonian fluid, the relation between the shear stress and the strain rate is nonlinear, and can even be time-dependent. Therefore a constant coefficient of viscosity cannot be defined. Multi-viscosity motor oil, which changes viscosity with temperature, is a common example. Non-Newtonian fluids include catsup, paint, liquid detergent, liquid polymers, slurry (solid-liquid) and a variety of other liquids.

Critical velocity is the speed that a falling object reaches when gravity and resistance force equalize on the object. The critical velocity is one of the significant parameter that must be precisely known for the optimized design of a slurry transportation pipeline. The importance of this velocity is that it signifies the lowest speed at which slurry pipelines can function and corresponds to lowest pressure drop in slurry transport.

The forecast of the power requirement per unit mass of solids carried over a unit distance is key parameter in design of slurry pipeline. Operating cost (power consumption) and consequently the entire economics of the hydro-transport rest on it. In the literature, a considerably large number of empirical and semi empirical correlations can be found for prediction of the frictional pressure drop. Most of these equations have been established based on inadequate data. Usually, those models are not suitable for flows with deposits. Models covering this type of settling-slurry flow are lacking. Very little is known about friction circumstances of settling-slurry flows with deposits as very small studies have been done in laboratory- and field pipes to understand their behaviour better. The pressure drop is a key parameter in the design of slurry pipelines, as it delivers evidence on the power required to continue a flow rate above the critical deposition velocity. The pressure drop in pipeline is directly proportional to the energy consumption. To optimize the pumping cost of slurry, the pressure drop must be minimum.

1.4 Motivation

Pipeline transport is useful for transmission of massive quantity of coal, ore, minerals, dredging and filling, collection and disposal of solid waste. It is an alternative to the conventional modes of transportation. The use of a pipeline upholds dust free atmospheres, insists generally less space and involves minimum operating staff. The hydraulic transportation of solids in turbulent flow by pipelines frequently involves large amounts of energy. However, it has been a serious matter for researchers, designers, academicians around the world to develop accurate models for pressure drop, velocity profile, and concentration distribution in water and slurry pipeline to ensure optimum pipeline design. With this background, the motivation of the present work is to optimize the design of water and slurry pipeline which is a function of multiple variables. These variables may be discrete or continuous. Hence, this work explores the options with recent advance computational techniques namely Genetic Algorithm (GA) methodology.

The second motivation is to explore the opportunity of improving some existing correlations available in literature into Indian context. The commercial size of pipe available in India is different from foreign country.

The third motivation is Hindalco Industries Limited; Renukoot (U.P) is facing the problem of pipe choking during slurry transportation of fly ash. Once the pipe is choked, either the pipeline is dismantled and the pipe is cleaned or it is replaced by new pipes. The company authority has approached to Civil Engineering Department of IIT (BHU) for some guidelines or better design of slurry pipe network.

1.5 Thesis Objectives

On the basis of literature review and research gap (Section-2.4) in the existing literature following objectives of the thesis have been made.

1. To develop an optimal design of pipe network system for transporting water and slurry.
2. To develop a computational code using Genetic Algorithm as optimal tool.
3. To compare the results with the existing network.

1.6 Organization of Thesis

The organization of this thesis is as follows:

Chapter 1 of the thesis contains an overview of slurry pipeline network. Characteristics of fluid are also discussed. That is further extended the motivation of my present work and objective of the thesis.

Chapter 2 is a general literature review considering current issues in the optimal design of pipe distribution networks, including linear programming, non-linear programming, and enumerative approaches. From the literature review the research gap is identified in the field of pipeline optimisation.

Chapter 3, discussed the mathematical model. This chapter overview the genetic algorithm (GA) technique and its application to pipe network optimisation.

Chapter 4 contains a comprehensive review of GA applications to Newtonian fluid (water). The present technique is used to find the optimum design for water pipe network used in literature by other authors. The results are compared with the existing solutions.

Chapter 5 contains a comprehensive review of GA applications to Non-Newtonian fluid problems. With some modification in GA parameter, the technique is used for solid liquid (slurry) flow in pipe. The two cases were discussed, one for slurry with fine particles size (one micron). In other case, the slurry particles size are considered as 0.1 millimetre

Chapter 6 presents an overview of the theoretical framework related to the research area studied in this thesis. A real world network is selected and the pipe design is optimized through present technique and field validation is done satisfactorily.

Finally, the concluding remarks are given in Chapter 7. Conclusions and future scope are discussion here. All papers published are given in separate attachments.