3.11 Flow in piping systems

To cause a flow of a liquid medium in a pipe, a driving force is required just as the electrical analogy, to overcome the frictional resistance of the liquid particles. The necessary energy for this is usually delivered by a driven pump or by a high static head.

The enlarged Bernoulli equation (3-8) is therefore completed by the so-called head loss h_v. The permanent expenditure of mechanical power is mainly converted into thermal energy and cannot be re-gained. The pressure drop, however, comparable with the electrical voltage drop at a resistance, can be calculated if the influencing parameters are known (flow pattern, fluid velocity and pipe dimensions).

The head loss $\mathbf{h_v}$ of straight pipes is obtained per unit of length e. g. per meter. This dimensionless quotient **Jg** is obtained from the quotient of the head loss $\mathbf{h_v}$ and the considered pipe length **l** and is described as the slope of the hydraulic gradient:

$$Jg = \frac{h_v}{l} \tag{3-22}$$

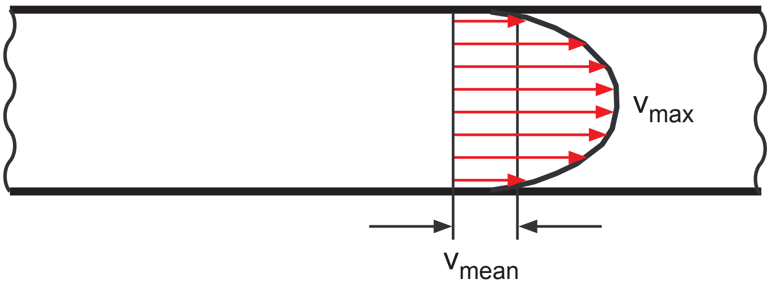

Figure 3.11.-1: Velocity profile at laminar flow

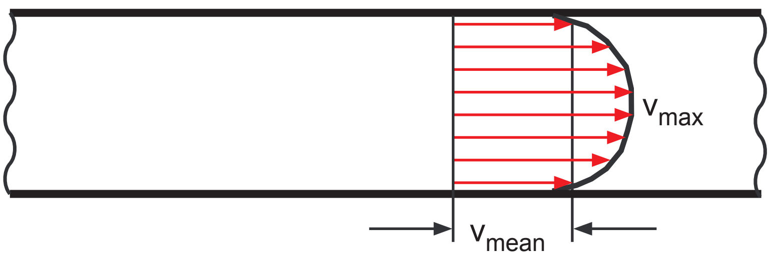

Figure 3.11.-2: Velocity profile at turbulent flow

The velocity profile in a pipe is not unique. In the immediate proximity of the pipe wall the velocity is almost zero, while the liquid reaches a maximum in the center of the pipe. In addition, the flow profile depends on the Reynolds number. As mentioned before the laminar flow prevails at very low velocities. The flow profile for laminar flow conditions is a parabola (Figure 3.11.-1). The highest fluid velocity is in the middle of the pipe while it steadily decreases towards the outside. The mean speed of a parabolic velocity profile is approx. 50% of the maximum value.

At turbulent flow conditions the velocity distribution is more proportionate than for laminar flow as shown in Figure 3.11.-2. The maximum speed occurs - as for laminar flow - in the center of the pipe. The mean speed, however, reaches fundamentally higher values than at laminar flow with the exception of a very thin boundary layer near the wall, so that the resultant mean speed reaches about 80 % to 87 % of the maximum speed in the center of pipe.

The flow is, in the boundary layer, laminar. The friction losses in the boundary layer can be calculated by means of equation (3-25). The friction losses outside the boundary layer are of another nature and arise mainly from shock losses in the turbulent fluid.