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Design and Setup the Sampling System to Modify and Reduce the Deposition in Sampling Fluid Pipe Lines by Reducing the Pressure Drop

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Abstract

Corrosion and deposition in Refineries and Petrochemicals is becoming one of the most critical and serious obstacle, and also can cause reduce the efficiency, performance, and analysis accurate of industrial instrument such as turbines, power plants, boilers, and especially sampling tube lines, because of increasing the pressure drop due to build-up deposits. To limit and minimize these deposits in sampling pipe lines would be uses a specially sampling system that design and discuss in this article. This kind of sampling system includes: isokinetic sampling, rapid condensation and cooling, pressure reduction, and process indicators, as well as safety devices to protect online instruments and plant personnel. All in all, by increasing the outer and inner diameter of sampling tube lines, wall thickness, Reynolds number, and required sampling rate, the pressure drop of flowing sample is decreasing and also with increasing the volume annual, the amount of deposits are significantly reduce, because of decreasing the pressure drop.

Keywords: Corrosion; Deposition; Pressure drop; Reynolds number; Isokinetic sampling

Introduction

Nowadays in Refineries and Petrochemicals instrument, corrosion and deposition are among the most expensive causes of outages in utility and industrial steam plants. Deposits and scale buildup on heat-transfer surfaces reduce efficiency, and when allowed to accumulate on steam turbines, such buildup can reduce the capacity. Corrosion-related failures can result in outages ranging from a few days to several months, depending on the affected systems, and can potentially cost tens of millions of dollars [1-3].

Deposit buildup in the sample lines can result in plugging of the sample line or seizing of sample isolation valves. Even when not directly affecting sample flow, deposits in the sampling system can affect the sample accuracy. Deposits can act as ion-exchange media and adsorb or release impurities during changes in the flow conditions. Even the best sampling-system design is still susceptible to deposition and plugging if the cycle chemistry at the plant is not maintained within industry standards, particularly when high concentrations of corrosion products (such as iron oxide or copper oxide) are present. Lengthy sample lines (for instance >30.480 m) or low sample velocities (for instance <1.2192 m/s) increase the probability of sample line blockage and can cause unacceptable time lags between sample collection and analysis. A sample flowing at 0.60960 m/s through 152.40 m of tubing will take over four minutes to reach the analyzers [4-7]

Peters and Leith measured the deposition efficiency of high Re number flows in large industrial curved pipes with different bend angles [8]. Brockmann extended the empirical model of similar research by accounting for the bend angle in addition to the Stokes number [9]. McFarland et al., using numerical results, developed an empirical model that accounts for the bend angle, the Stokes number, and the bend curvature ratio to estimate the deposition efficiency. In spite of the vast amount of work performed, there is still a need to identify conditions under which computer simulations can provide relatively accurate results. Computer simulations provide an efficient approach for studying flows through curved pipes under various conditions. Practical simulations can be performed by solving the filtered Navier-Stokes equation using a Large-Eddy Simulation (LES) for an instantaneous solution or by solving the Reynolds Average Navier-Stokes (RANS) equation for an ensemble averaged solution (with appropriate closure models for the Reynolds stress or the sub-grid stress tensors) [10]. For example, Breuer et al. and Berrouk and Laurence used LES to study particle deposition and their computed results are in good agreement with the work of similar research except for small Stokes number St<0.2. A RANS approach was selected for this work because of the large number of simulations expected. In addition, a Reynolds stress model was selected to complete the formulation of the RANS equation due to the anticipated presence of strong streamline curvatures [11,12]. In 2012, Pusheng et al. reveals that, Results of these computations show that turbulent bend flows possess, as expected, complicated patterns influenced by the flow Re number and the bend configuration. Computed results for the pressure drop through a bend are obtained from different near-wall treatments based on the k-e model and the RSM [13].

Materials and Method

As follows from the Figure 1, the sampling system for extracting and conditioning a representative sample of steam or water which design in this article is include isokinetic sampling, rapid condensation and cooling, pressure reduction, and process indicators, as well as safety devices to protect online instruments and plant personnel.

The prior critical section in design of sampling system is isokinetic

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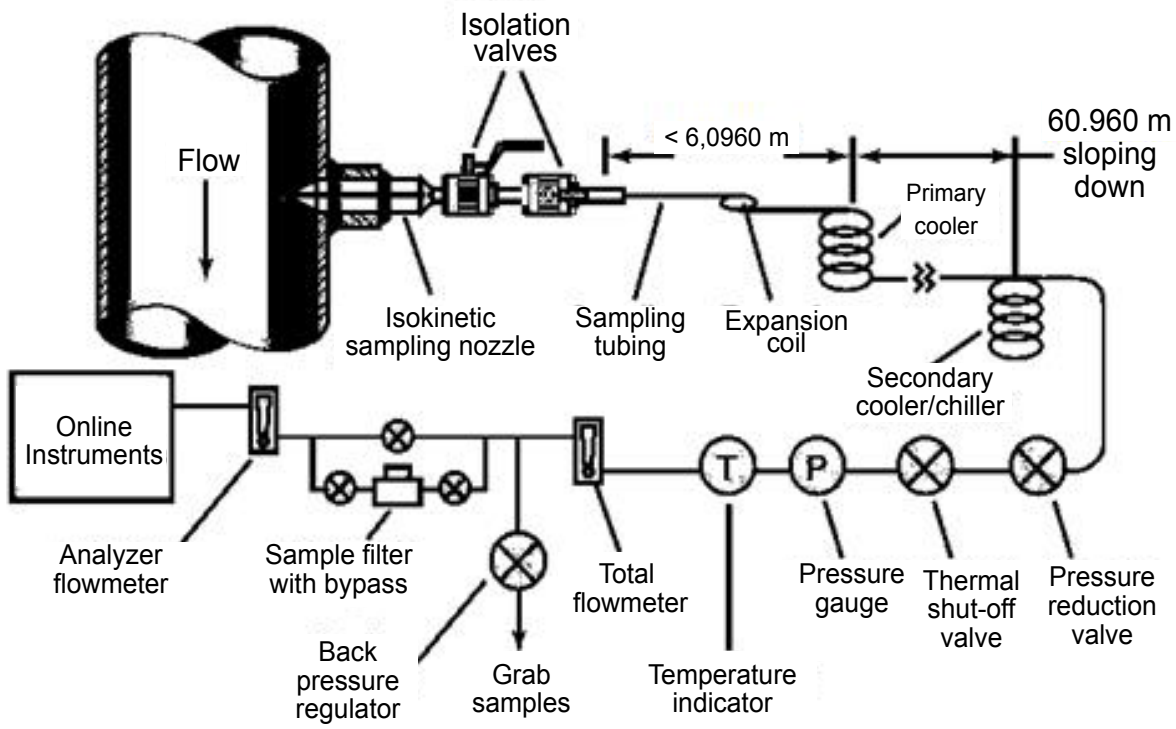

Figure 1: Scheme of Sampling System.

sampling nozzle, also should be conduct this design at the first of exists sampling system. The most important point is, if this design is uncorrected, sampling nozzle can provide a sample that do not in condition of pipe lines. In addition, proper design of sampling nozzle should be in terms of effects of flow, vibration due to forces on the nozzles, and also temperature and pressure.

In isokinetic sampling nozzle should use the isokinetic sampling. This type of sampling called extraction a representative section of process as a sample without altering in physical and chemical properties. In isokinetic sampling all phases (solid oxides and precipitates, liquid droplets, and vapor) of sampled fluid inter to the sampling nozzle with same velocity vectors (meaning the same velocity and direction of flow). One of the most important reason for sampling stream of isokinetic sampling is typically at two phases (gas-liquid, gas-solid, liquid-solid) and always the second phase has more different chemical properties compare with the primary phase (water and stream); in addition, the second phase (droplets or particles) typically has a different density and inactivity compare with the primary phase (gas or liquid).

In present study, supposed the fluid stream in pipe lines completely turbulent flow. And also in a velocity profile across the pipe lines and stream that very well mixed, the components of fluid as same as uniform across the pipe lines distributed homogenous. This phenomenon can cause sampling from one section along the pipe diameter unnecessary and sampling from one section along the pipe diameter is enough in this research. In light of this points, in this article using a single-port sampling nozzle. The single-port sampling nozzle that uses in this article compare with multi-port sampling nozzle has an important advantage. And that advantage is the single-port sampling nozzle being inserted only about 12% of the way in to the pipe but multi-port sampling nozzle which must traverse most (but not all). Also single-port sampling nozzle design by ASTM standard. The ASTM Standard D1066.

"Standard Practice for Sampling Steam" included a multiport sampling nozzle, which in its most basic form consisted of a piece of pipe with multiple holes in it. The sampling pipe extended most or all of the way across the process pipe and was supposed to simultaneously sample from several locations across the diameter of the pipe. However, research has shown that such a multiport design operates non-isokinetically, is prone to plugging, and is susceptible to failure due to vibration.

Figure 2 Depicts, the ideal flow path of particulate matter and droplets into isokinetic and non-isokinetic sampling nozzles. In isokinetic sampling, the extracted fluid is representative of the composition in the process pipe, including particles and droplets. When the sampling is non-isokinetic, the concentration of particles and droplets can be higher or lower than that found in the process fluid. V_B=velocity of process fluid; V_N=velocity in the sampling nozzle.

Results and Discussion

In any sampling system, especially the sampling system which uses in this article, there will be an exchange of contaminants and particulates between the flowing sample and the sample line surfaces. Eventually, an equilibrium state will be reached. In order to minimize deposit in the sampling pipe lines and decrease the require time for achieving the primary equilibrium between impurities in flowing sample and tube, sample tubing after cooler/primary condenser the size of flowing velocity should be maintained around 1.5240-1.8288 m/s.

In current study linear velocity and Reynolds number are two critical parameters for controlling the net amount of deposition of

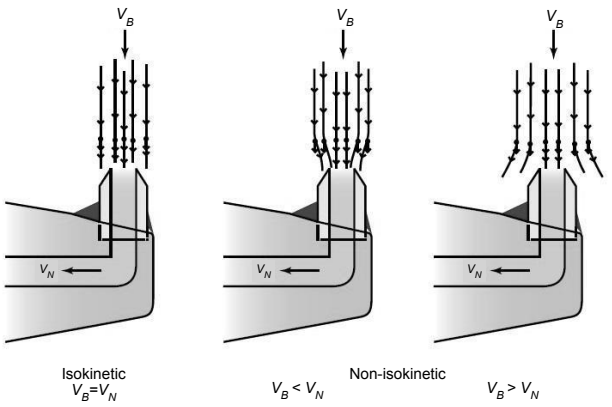

Figure 2: Graphical representation of Propagation mode of the Plants.

particle matter in sampling pipe lines; therefore, the suitable range of Reynolds number and linear velocity should be Re>4000 and 1.5240-1.8288 m/s, respectively.

In steam sampling systems, one of the most important design discussions is length and size of sampling pipe lines from sampling nozzle to primary sample cooler/condenser. Being long and oversized of sample pipe lines can cause a significantly pressure drop and heat loss in fluid extracted. Total of sample pipe lines would be more short as possible for preventing the pressure drop and lag time when the fluid sample inter to the isokinetic sampling nozzle to when fluid sample analysis. The last but not the least important factor for these kinds of sampling systems is low resistance time of fluid sample in tubing for limit the chemical reactions, such as: oxygen scavenging and sorption on oxide.

As follows from the Table 1 shown below, try to compare sampling rate, Reynolds number, estimated pressure drop, and annual volume of water consumed for several tubing sizes, refer to these results, by increasing the outer and inner diameter of sampling tube lines, wall thickness, Reynolds number (it means the turbulent range of flowing sample is increasing), and required sampling rate, the pressure drop of flowing sample is decreasing and also with increasing the volume annual, the amount of deposits are significantly reduce, because of decreasing the pressure drop and when the pressure drop get the 68.95 KPa per 30.480 m of tubing, the pressure drop by increasing the other parameters such as Reynolds number, inner diameter of sampling tube lines, and wall thickness, is remains constant.

In similar study Lee Machemer, 2014 claimed that with increasing the required sampling rate, the estimated pressure drop per 30.480 m of tubing (KPa) is decreasing and these parameters has a linear relationship to each other. In current study also with increasing the required sampling rate, the estimated pressure drop per 30.480 m of tubing (KPa) is decreasing, but after 8500 cm^3/min with increasing the required sampling rate, the estimated pressure drop remains constant at 68.948 KPa, Figure 3; furthermore, at Figure 4, with decreasing the wall thickness from 0.16510 cm until 0.12446 cm the estimated pressure drop per 30.480 m of tubing is decreasing dramatically. But after 0.12446 cm until 0.17018 cm the wall thickness is increasing and the estimated pressure drop per 30.480 m of tubing (psi) is decreasing steadily. It means 0.12446 cm is the critical point to convert the direct relation between wall thickness and estimated pressure drop per 30.460 m of tubing to the inverse relation, because of working condition of current experiment. Then after 0.17018 cm until 0.17526 cm wall thickness is approximately constant but estimated pressure drop per 30.480 m of tubing is decreasing and after that become to the constant at 25.400 cm. This result also is in agreement with similar study of Lee Machemer [14].

Conclusions

In a nutshell, the current sampling system that used in this article includes: isokinetic sampling, rapid condensation and cooling, pressure reduction, and process indicators, as well as safety devices to protect online instruments and plant personnel. And fined that, by increasing the outer and inner diameter of sampling tube lines, wall thickness, Reynolds number, and required sampling rate, the

Outer dia.(cm)	Inner dia.(cm)	Reynolds number	Annual vol.(m^3/yr)	Estimated ΔP per 30.480 m of tubing, KPa
0.63500	0.30480	6.8×10^3	352.043	455.054
0.81280	0.38608	8.6×10^3	560.241	282.685
0.95250	0.62230	1.4×10^4	1461.169	193.053
1.27000	0.93980	2.1×10^4	3327.377	82.737
1.65100	1.04140	2.8×10^4	3444.725	68.947
1.77800	1.24460	3.4×10^4	3777.841	68.947

Table 1: Reynolds Number, annual volume, and pressure drop (ΔP) for water (T = 37.8 °C) flowing through various sizes of tubing at 1.5240 m/s.

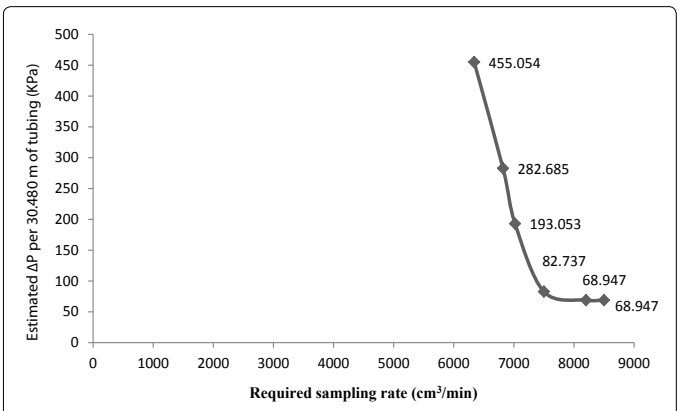

Figure 3: Influence of required sampling rate (cm^3/min) on estimated ΔP per 30.480 m of tubing (KPa).

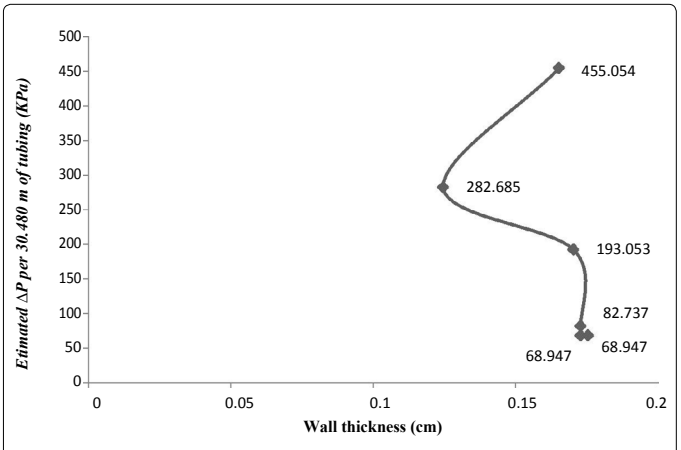

Figure 4: Influence of wall thickness (cm) on estimated ΔP per 30.480 m of tubing (KPa).

pressure drop of flowing sample is decreasing and also with increasing the volume annual, the amount of deposits are significantly reduce, because of decreasing the pressure drop. And hope by design and using this sampling system in Refineries and Petrochemicals can cause increase the efficiency of instruments and thermodynamic cycle, and also increase the accurate of fluid sampling analysis.

Nomenclature

ΔP	Pressure drop, KPa
Re	Reynolds number, Dimensionless
S_t	Stokes number, Dimensionless
V_B	Velocity of process fluid, m/s
V_N	Velocity in the sampling nozzle, m/s
T	Temperature, $^{\circ}C$

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