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Optimization of distillation processes using sensors

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Abstract

The processes distillation performance depends greatly by many factors who affected the final result - ethanol production. One of these factors is temperature sensors and these are analysing in next presentation.

Keywords: alcohol industry, distillation process, sensors

1. Introduction

Distillation processes are usually performed in a closed apparatus enviroment, so the status and dynamics are not as evident as they are in manufacturing processes. In order to be able to control a distillation process, a priori knowledge of its properties and dynamics is required, together with information of the process quantities that caracterize the actual status of the process [1-5].

Sensors are used first in chemical industries and they are use in food industry in this case at distillation process to improve the control parameters (temperature, flow, pressure) at feed composition [6,7].

2. Materials and methods

A distillation process can be described as a sequence of products and operations who are doing in the distillation columns.

Developed mathematical method and models for the separation behavior of distillation columns used the concept of *equilibrium stages* (theoretical tray) and incorporated the tray efficiency, either as the Fenske *overall efficiency* or the Murphee *vapour efficiency*.

Regarding those factors who affecting the process, is necesar to improve the process control with performant types of sensors. Process properties are either:

- thermodinamic variables: temperature, pressure, concentration;
- process parameters, catalyst activity, wich caracterize the conditions under wich the process run;
- control quantities, wich caracterize the settings of he process as the position of a valve or the status of a pump.

Theoretically, the process can be described exactly with a complet set of this quantities. In practice, only a few of the termodynamic variables and control quantities can be measured or set. Frequently one has use substitutional information:

- process indicators are empirically correlated with one or more thermodynamic variables;
- product proprieties may also be used as process indicators
- control parameters are corelated with control quantities.

Control quantities and control parameters, being set by actuators, caracterize the input to the process from the outside.

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The measurment of thermodynamic variables and process indicators has to be performed by sensor systems.

The whole variety of sensor systems used in food process industry can be classified on the basis of the purpose of the information provided by the sensors systems, as displayed in the upper of Figure 1. From another point of view, sensors systems may be classified by the quantity mesured (lower half of figure 1). Firest there are classical quantities such as temperature, pressure, flow or level wich can be mesured by “in-line” sensors. Second are collective properties of mixture such as viscosity, density or pH, wich depend on the composition of the source material.

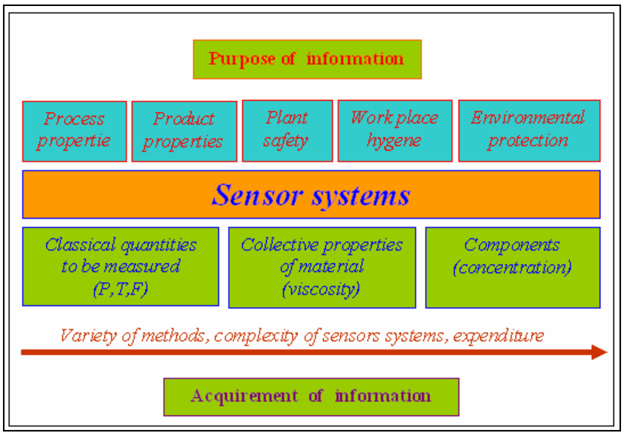

Figure 1. Classification of sensors systems in distillation production process

The fundamental function of the sensor system is to measure the property Qi, to transform that property to information for the information processing system.This information may be just the signal itself or may consist of additional items including measuring units, identifications of the respective sensor system and other additional information wich may be relevant to the processing system.

With regard to the internal structure of sensors systems, three types are usually distinguished in process engineering: in-line, on-line or extractive, and off-line. Table 1 shows a comparison of these types of sensors systems

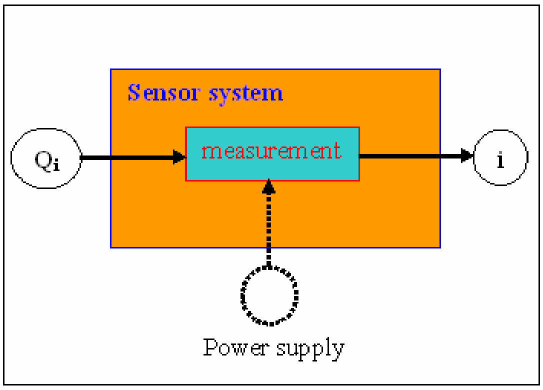

Figure 2. Structure of a simple sensor system. Q_i – quantity of the source fluid to be measured; i – output signal.

Table 1. Caracterization of in-line and off-line measuring methods

	In-line	*On-line*	*Offline*
Sample extraction	-not necessary-	Automatic	manual
Sample transport	-not necessary-	Automatic	manual
Sample conditioning	-not necessary-	Automatic	manual / automatic
Measurement	automatic	Automatic	manual / automatic
Evaluation	automatic	Automatic	manual / automatic
Data presentation	automatic	Automatic	manual / automatic
Availability of results	Continous	Continous, quasi-continous	discontinous

Most measurements of temperature and pressure are performed with in-line sensors, wich are frequently designated transmitters. In this type of sensor system, the measuring device is in close contact with the source material and at least the primary signal is generated directly. It possibly has to be conditioned for further processing. Only electrical power is nedeed as input to operate such sensor system.

Only a few methods transform the property to be measured into a signal directly. Examples are most temperature and pressure sensors mounted in-line. The same sensors may be used to measure other quantities indirectly.

Table 2 shows the sensing principles or devices that are most frequently used in distillation process engineering.

Figure 3 shows the type of resistance thermometer used in experiment, and figure 4 shows example of use on-line sensors system for measuring temperature inside the plant.

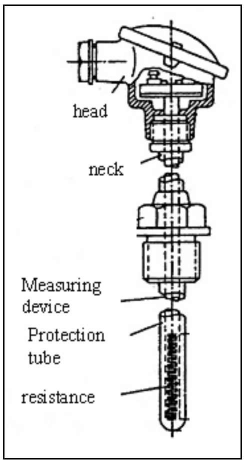

Figure 3. Resistance thermometer

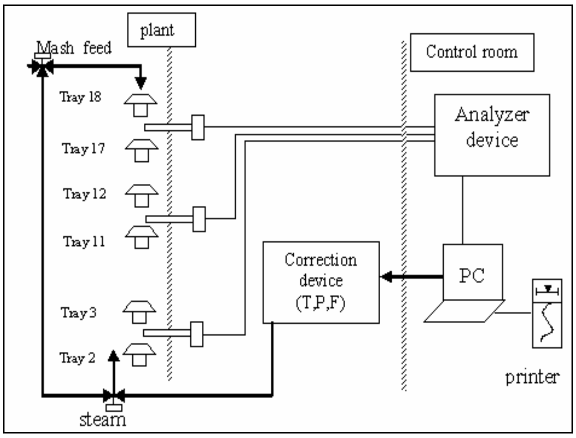

Figure 4. Process analyzer/correction with process computer

Table 2. Methods and groups of methods most frequently used in food industries

Methods for classical quantities to be measured	**Non-specific methods**	**Group-specific methods**	**Specific methods**
Temperature: resistance thermometry; thermocouples Pressure: elastic elements with capacitive, inductive, piezorezistive or piezoelectric signal conversion Flow and mass flow measurements: magnetic-inductive; differential pressure; ultrasonic methods; others Level: displacement methods; hydrostatic methods; electric and electronic methods; radiometric methods	Density-measuring systems: radiometric; others Viscosimetry Thermal conductivity Acoustic methods	Electric conductivity Calorimetry Dielectric constant Photoionization Methods with group-specific auxiliary reactions	Paramagnetism Photometry: absorption (ultraviolet, visible, infrared, near-infrared); remission Gas and liquid chromatography Mass spectrometry Titration methods Special methods for measuring humidity Analysis methods with auxiliary reactions: chemoluminescensce; absorption in aerosols or liquids

Table 3. Experimental data obtained by using nickel senors

hour	**Mash feed** ***[l/h]***	**Steam Press.** ***[bar]***	**Mash Temp.** ***[^0C]***	**Plate 2** ***[^0C]***	**Plate 11** ***[^0C]***	**Plate** ***[^0C]***	**Temp. Distil.** ***[^0C]***	**Ethanol** ***[%]***	**Ethanol quantity** ***[l]***
8^{05}	105	6,0	27,4	76,8	30,2	22,8	-	-	-
8^{32}	207	5,5	56,5	80,5	70,7	63,5	26	85	0,5
9^{02}	687	4,8	60,8	92,5	81	77	14,8	88	23
9^{42}	566	5,5	59,3	100,4	91,9	85	12,8	82	78
10^{40}	679	6	53,8	100,4	93,7	88	12,5	82	116
11^{32}	610	4,2	53,1	100,4	95,8	91	11,5	82	107
12^{22}	636	5	50,3	100,4	95,7	95	11,4	78	81

Table 4. Experimental data obtained by using copper senors

hour	**Mash feed** ***[l/h]***	**Steam Press.** ***[bar]***	**Mash Temp.** ***[^0C]***	**Plate 2** ***[^0C]***	**Plate 11** ***[^0C]***	**Plate 17** ***[^0C]***	**Temp. Distil.** ***[^0C]***	**Ethanol** ***[%]***	**Ethanol quantity** ***[l]***
8^{05}	108	5,7	23,4	72,5	28,3	20,8	-	-	-
8^{32}	209	5,3	56,9	77,5	70,5	65,5	19,5	81	0,3
9^{02}	695	4,9	59,5	87,4	83,8	76	14,5	86	20
9^{42}	570	5,6	56,5	93,6	90,7	86	12,3	84	77
10^{40}	670	6,2	57,6	100,2	94,3	89	12	81	110
11^{32}	630	4,9	56	100,4	95,8	93	11,5	80	116
12^{22}	625	5,2	54,5	100,4	95,2	94	11,2	76	77

3. Results and discusions

First set of 3 sensors are made by nickel and recommend measurment field is +60 … +250 0C. Second set are made by copper and recommend measurement field is –50…+150 0C. The plant are made by J.C. Göppingen and number of plates is 14 for distillation and 5 for rectification section.

Mash are prepare from potatoes, quantity is 7400 litre, 6,8 % alcolholic content and pH = 6,1.Mash are divide in two parts: one (3700 litre) used for first set of sensors and second (3700 litre) used for second set of sensors. Experimental results are shows in table 3 and 4.

In first case, total ethanol quantity was 405,5 litre and in the second case 400,3 litre.

4. Conclusion

The conclusion after experiment was:

- Nickel On-line sensors are very good adaptability comparative copper on-line sensors, because the correction process are very quickly using this type of sensors;
- The results of measurements have to be transferred to the process control system as rapidly as possible to correct the process parameters;
- Sensors used on-line measurements is necessary to have the following features: measuring range, accuracy, time constants, reliability, maintainability, life cycle cost;
- Property can be measured with either in-line or on-line instruments is more avantageos. There are many methods, and the possibilities in designing a sample handling system are an important tool in solving measuring problems of distillation process. Exemples are phase exchange, vaporization, chemical conversion of components;
- Despite the variety of methods and instruments, frequently not all the information required can be provide by on-line process sensor systems. For technical or economic reasons, information gatherig may only be possible off-line by analitical laboratories with their specific methods;
- There are still a number of unknowns ramaining has not yet been reached. For instance, the best way o corelate the vapour phase mass transfer coefficient; the machanisms determining the amount of interfacial area available for mass transfer; the contribution of the liquid phase mass transfer resistance; and last but not the least the influence of two phase flow regime.

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