Separating Impurities of Acid Gas from Hydrogen Sulfide by Using Adaptive Filter for Estimating of Claus Reaction Temperature by Neuron Networks

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Abstract - In this paper, the out coming temperature out of Claus reaction (which is used for recycling sulfur from H_2S in refineries of Gas) is estimated via adaptive linear neuron networks. In order to get to the desired results, we need to be aware of the amount of H_2S flow as well as the flow of the air. Acid gas used in the gas refinery involving in the prior reaction, has impurities such as: CO_2, H_2O, DMEA and stays null. Flow meters existing in the acid gas line movement, measure H_2S and impurities (gas flow in complete). But for estimating the temperature of reaction and controlling it, we need the real amount of gas flow. In this paper, we have been trying to show that via using adaptive filter, we can separate impurity of acid gas from H_2S.

Keywords- Adaptive filter, Claus reaction, neural networks, separate impurities.

I. Introduction

Claus process which is used nowadays is a modern process precedes the one Pioneered in 1883 based on the reaction of H_2S over a catalyst base with air (oxygen) in shape of sulfur and water.

$$2\,H_2S + O_2 \longrightarrow 2\,H_2O + S_2$$

It was difficult to get control over this exothermic reaction and the amount of sulfur recycled was low. In order to get over these difficulties, a new sort of this process was developed and put forward.

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This sketch was performed and executed as below in 1936:
1-A reaction in an exothermic type with an extra heat released on which, 1/3 H_2S and essentially %100 of all Hydrocarbon as well as all the other flammable materials are eliminated.
2- An exothermic catalytic reaction normally in which the constructed SO_2 reacts with not burning H_2S in the explosion part and turns into sulfur. The real and main reaction, happen as:

$$H_2S + 3/2O_2 \longrightarrow SO_2 + H_2O + Heat \quad (1)$$

$$2\,H_2S + SO_2 \rightleftarrows 3/nS_n + 2H_2O + Heat \quad (2)$$

As it is obvious that the second reaction is from those equilibrium ones, thus all the H_2S gas not turning to sulfur in furnace, but changing of H_2S to sulfur is kept on in the bases of catalyst. The concluded gas enjoys different concentration out of S_2, S_3, S_4, S_5, S_6, S_7, and S_8. Producer preliminary sulfur in Claus process includes untreated H_2S gas and H_2S compounds:

$$H_2S_X \leftrightarrow H_2S + (x-1)\,S$$

Non gaseous reactions are as below:

$$H_2S_X\,sol \leftrightarrow H_2S\,sol + (x-1)\,S \leftrightarrow H_2S\,gas + (x-1)\,S$$

Also some side reactions of acid gas take place which lead to form: COS, CS_2, CO, and H_2.

$$CH_4 + 2S_2 \leftrightarrow CS_2 + 2H_2S$$

$$H_2S \leftrightarrow S + H_2 \qquad CO_2 + H_2 \leftrightarrow CO + H_2O$$

$$CO + \tfrac{1}{2}S_2 \leftrightarrow COS$$

Sulfur compounds hydrolyze in catalytic converter tank partially. These days the use of neural networks and soft

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sensors in refineries have developed [1],[2]. In petrochemical plants soft sensors are designed to parallel the online analyser which is often taken off for servicing [3]. In this paper, by estimating Claus reaction temperature, the reaction in furnace will be controlled by means of adaptive neural networks. This temperature has an important role in the production of sulfur from *H_2S*. The below figure (Fig 1) shows the percentage conversion of H_2S to sulfur versus temperature in following conditions:

1. Acid gas from wellhead facilities with 3.5% mol hydrocarbon (diagram 1)
2. Acid gas from refinery treated with 7% mol hydrocarbon and 1% mol mercaptane (diagram 2)
3. Pure H_2S

Although the above diagrams show that Claus reaction is more desired in low temperatures but in furnace reaction in refinery these reaction will be controlled in temperature of above 940 ˚C , because condensing sulfur will damage equipments in lower temperatures.

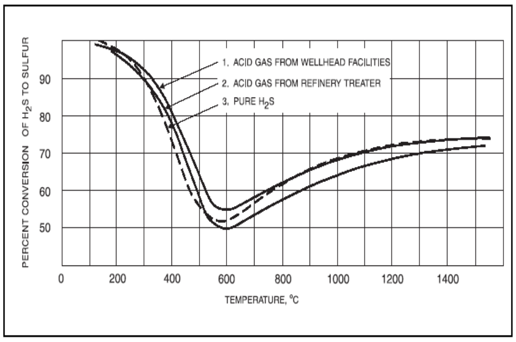

Fig 1. The percentage conversion of H_2S to sulfur versus temperature

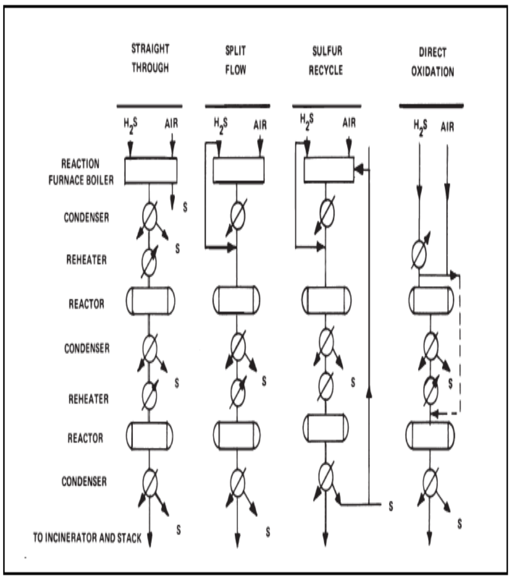

Fig 2. Various types of Claus reaction that be used in gas refineries

For preventing these problems, the other process gases will be controlled in temperature above dew point of sulfur. Converting *H_2S* to sulfur takes place in a reaction furnace (usually performs at temperature of above 940 ˚C) which is followed by a convertor in the presence of catalyst bed at temperature below 341 ˚C.

II. Reaction Furnace

To perform Claus reaction in furnace;

1- Entering fuel gas burn with compressed air and cause rising in temperature to reach 940 c (required temperature for burning H_2S in reaction furnace)

2- Gradually opening of preheated acid gas lines.

3- Fuel gas line blockage slowly until no fuel gas flows through line.

4- Claus reaction occurs and sulfur is separated from H_2S.

5- After the Claus reaction is being accomplished, in order to separate sulfur gas produced in the furnace, the temperature of hot gases released should be reduced to come to liquid form of sulfur. This action happens through the exchange of temperature between hot gases and water in the waste heat

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boiler. (Mentioned boiler is a shell & tube type which water is passed thorough shell and hot gases are flowing in tubes. Sulfur will be liquefied and water is evaporated and produces medium pressure steam for using in other units.)

III. Adaptive Neuron Networks for Estimating of Claus Reaction Temperature

We use adaptive linear neuron networks for estimating resulted heat of Claus reaction (Fig 3).

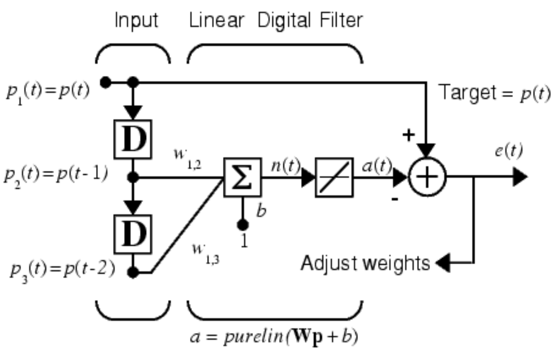

Fig 3. a(t) is approximation to p(t)

$$a = purelin(n) = purelin(wp + b) = wp + b$$

Here p_q is an input to the network, and t_q is the corresponding target output. As each input is applied to the network, the network output is compared to the target. The error is calculated as the difference between the target output and the network output. We want to minimize the average of the sum of these errors.

$$mse = \frac{1}{Q}\sum_{k=1}^{Q} e(k)^2 = \frac{1}{Q}\sum_{k=1}^{Q}(t(k) - a(k))^2$$

The LMS algorithm adjusts the weights and biases of the *ADALINE* so as to minimize this mean square error. Adaptive networks will use the LMS algorithm or Windrow-Hoff learning algorithm based on an approximate steepest descent procedure. [4]

$$w(k+1) = w(k) + 2\alpha e(k)p^T(k)$$

$$b(k+1) = b(k) + 2\alpha e(k)$$

Our input for this network is acid gas flow rate and compressed air flow rate. Targets are inner temperature of furnace and shell temperature of furnace. Acid gas used in the gas refinery involving in the prior reaction, has impurities such as: CO_2, H_2O, DMEA and stays null. Flow meters existing in the acid gas line movement, measure H_2S and impurities (gas flow in complete). But for estimating the temperature of reaction and controlling it, we need the real amount of Gas flow. In this paper, we have been trying to show that via using adaptive filter, we can separate impurity of acid gas from H_2S.

IV. Separating Impurities of Acid Gas from H_2S by Using Adaptive Filter

In a gas refinery, contents of acid gas lines will be sampled by laboratorial for obtaining the exact percent of H_2S (percent of H_2S by analyzing acid gas sample) , but this in addition to lowering safety and rising cost, has hardware problems such as sensor coming out of calibration and indicate some incorrect value . In this paper, we separate impurities of acid gas from H_2S by using adaptive filter [5], [6] (Fig 4) and by this method, the actual flow rate of H_2S is obtained. We obtain a sample of the imparity (by laboratory) and apply it as the input to the adaptive filter. Here we adaptively train the neural linear network to predict the combined H_2S / imparity gas m from an imparity gas n. Notice that the imparity gas n does not tell the adaptive network anything about the H_2S gas contained in m. However, the imparity gas n. does give the network information it can use to predict the imparity's contribution to the H_2S / imparity gas m. The network will do its best to adaptively output m. In this case, the network can only predict the imparity interference in the H_2S / imparity gas m. The network error e is equal to m, the H_2S / imparity gas, minus the predicted Contaminating imparity gas.

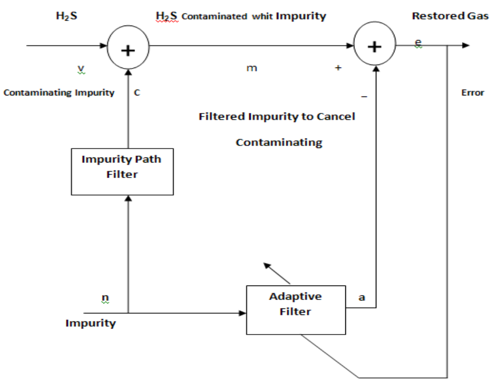

Fig 4. Adaptive Filter Adjusts to Minimize Error. This removes the impurity from contaminated gas, leaving the H_2S as the "error".

Thus, e contains only the H_2S our linear adaptive network adaptively learns to cancel the imparity gas. Note, in closing, that such adaptive imparity canceling generally does a better job than a classical filter because the imparity here is subtracted from rather than filtered out of the gas m.

V. Control Claus Reaction

Acid gas flow and air flow adjusting control valves, Claus reaction being controlled in basis of furnace temperature and H_2S/ SO_2 ratio in sulphur recovery unit egress (set point of this ratio is 2). We estimate furnace temperature by using neural network and control Claus reaction by using a PID controller which is implemented on a PLC (Fig 5) [7].

VI. Conclusion

This research was carried out in a gas refinery plant and we could separate the impurity of acid gas from H_2S using adaptive filter. After that we could estimate the temperature of furnace using neural networks and could control the Claus reaction. This temperature has an important role in the production of sulfur from H_2S. Using analyzer for separating the impurities and also using sensor for distinguishing the temperature of reaction not only cost much but also have hardware problems which are dangerous because of having H_2S as a fatal poisonous gas. We could get rid of this deficiency using adaptive filter and adaptive linear neuron networks.

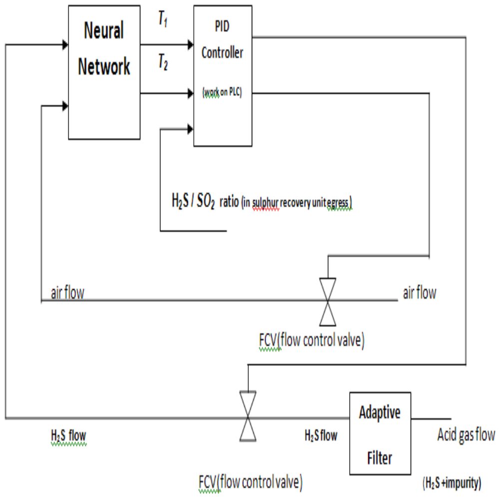

Fig 5. Acid gas and air flow adjusting control valves, Claus reaction be control in basis of furnace temperature and H_2S / SO_2 ratio in sulphur recovery unit egress. Adaptive filter separate impurities of acid gas from H_2S.

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