Ethanol Process HYSYS Simulation and Optimization: A Case Study of Kenana Ethanol Plant

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Abstract.

In this paper Kenana ethanol plant has been simulated by the simulator tool of Hysys. The thermodynamic properties are calculated with NTR property package models, which are available in HYSYS simulator program. Ethanol is a renewable resource of energy and is potentially cleaner alternative to fossil fuels. Also it is a very important basic chemical, widely used in different industrial sector and It is the most important and popular fuel in the current era and future as well. In new processes development, the analysis of an industrial plant through simulation may frequently indicate, beforehand, whether it is technically and economically feasible. In the case of existing plant (Kenana Ethanol), already in operation, the process simulation can help optimizing their operational conditions, obtaining products of better quality as well as reductions in energy consumption and other process losses. The main purpose of the study is to simulate and optimize the annual profit 96% ethanol plant by Aspen HYSYS 3.2. In order to simulate this process some process operational data of the ethanol plant of Kenana ethanol are used. The optimization criterion of the process is to maximize the annual profit. This study will be very helpful for the plant operators to run the factory efficiently by minimizing the process system requirement. The results show that the ethanol recovery in mass fraction was 96.35 by using HYSYS program while 92% mass fraction plant. In the stillage the ethanol was found 3.75% in case plant while 0.06% mass faction in case of HYSYS this differences attributed to un-optimized condition in plant.

Keywords: **Sugarcane, Ethanol, Aspen HYSYS, Fermentation, Simulation, Optimization.**

1. Introduction

Ethanol is a renewable resource of energy and is potentially cleaner alternative to fossil fuels. Production of ethanol is growing day by day at a great extent for its versatile application and demand. During recent years, production of ethanol by fermentation on a large scale has been of considerable interest to meet to increased demand. Fermentation is a biological process in which sugars such as glucose, fructose, and sucrose are converted into cellular energy and thereby produce ethanol and carbon dioxide as metabolic waste products.

It has long been recognized that molasses from sugar-cane or sugar provide suitable substrates for ethanol production Ruhul et al (2013).

Ethanol refers to a type of alcohol consisting of two carbon atoms, five hydrogen atoms, and one hydroxyl group. As opposed to gasoline, ethanol is a pure substance consisting of only one type of molecule: C_2H_5OH. In ethanol production, however, it is necessary to distinguish anhydrous ethanol (or anhydrous ethyl alcohol) and hydrous ethanol (or hydrous ethyl alcohol). The difference lies in the water content of the ethanol grade: while the water content of anhydrous ethanol is approximately 0.5 percent by volume the hydrous ethanol that is sold at fuel stations has water close to 5 percent by volume. In the industrial production of ethanol, the hydrous grade is the one that comes directly from the distillation tower. Producing anhydrous ethanol requires an additional processing stage that removes most of the water contained in the fuel Anon (2002).

The world is now producing a huge amount of ethanol (ethyl alcohol) through the fermentation of agricultural materials or molasses from sugar industry followed by separation of the formed ethanol by distillation process Ahmed (2013).

Ethanol is a relatively low-cost alternative fuel. It is considered to be better for the environment than gasoline. Ethanol-fueled vehicles produce lower carbon monoxide and carbon dioxide emissions, and the same or lower levels of hydrocarbon and oxides of nitrogen emissions. It burns with a smokeless blue flame that is not always visible in normal light. As the raw material of ethanol is farm based its production supports farmers and creates domestic jobs. And because ethanol is produced domestically, from domestically grown crops, it reduces dependence on oil and increases the nation's energy independence. Worldwide fuel ethanol production is increasing day by day as per demand. For all these reasons; it is a great challenge for chemical engineers to produce ethanol in low cost. Simulation analysis has become very handy tool now a day to test a process to verify its feasibility at different operating parameters. The fermentation of molasses into ethanol is one of the earliest biotechnologies employed by humanity Ruhul et al (2013).

In this present study process development to produce ethanol is main concern. And the job is done successfully by optimizing criterion of the process is to maximize the annual profit.se. The main objective of this project is to produce ethanol by a program of Hysys.

2. Methodology and Simulation

Simulation is done by HYSYS 3.2. Procedure is described below.

2.1. Fluid Package

In order to simulate the process as accurately as possible COM thermo is selected as advanced thermodynamics databank. In model phase selection NRTL was selected for liquid phase and Peng-Robinson was selected for vapour phase.

2.2. Process Description:

The following diagram shows the ethanol process was worked on. In Kenana ethanol plant it is important to recognize that this is suggested as a good way to make ethanol. The design has been formulated to demonstrate many key aspects of

Hysys, without getting overwhelmed by detail

3. Results and Discussion

Simulation work is done to optimize different parameter of process to obtain maximum products. The calculation method for distillation in HYSYS is done to a high standard in accordance with the matrix method. A quick convergence and short simulation time is therefore guaranteed. In most cases, the user need not be concerned with the details of the internal calculation, this is done automatically by HYSYS, and the following six basic steps are used to run a flow sheet simulation in HYSYS are: [Hyprotech Company, "HYSYS® 3.2 Simulation Basis Manual", 2003]

1. Selecting components.
2. Selecting thermodynamics options.
3. Creating a flow sheet.
4. Defining the feed streams.
5. Input equipment parameters.
6. Running the simulation and reviewing the results.

In this study a series of results are presented showing the comparative studies between Kenana ethanol production plants and HYSYS as a powerful engineering simulation tool under the same conditions. Full pilot plant was constructed by using Hysys program and all the results are shown below.

Effects of parameters, such as the temperature, pressure, flow rate, composition on overall ethanol (Beer from fermenter) recovery were studied as shown in Table 1 and Figure 2.

Table1: Beer from fermenter

Flow rate	4818.7 kg mol/hr
Temperature	97.5^{0}C
Pressure	101.325 kpa
Composition	7.1%ethanol

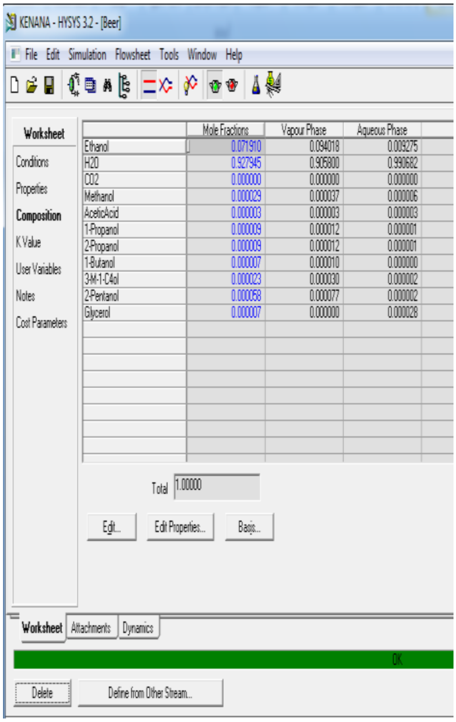

Figure 2 **Beer from fermenter**

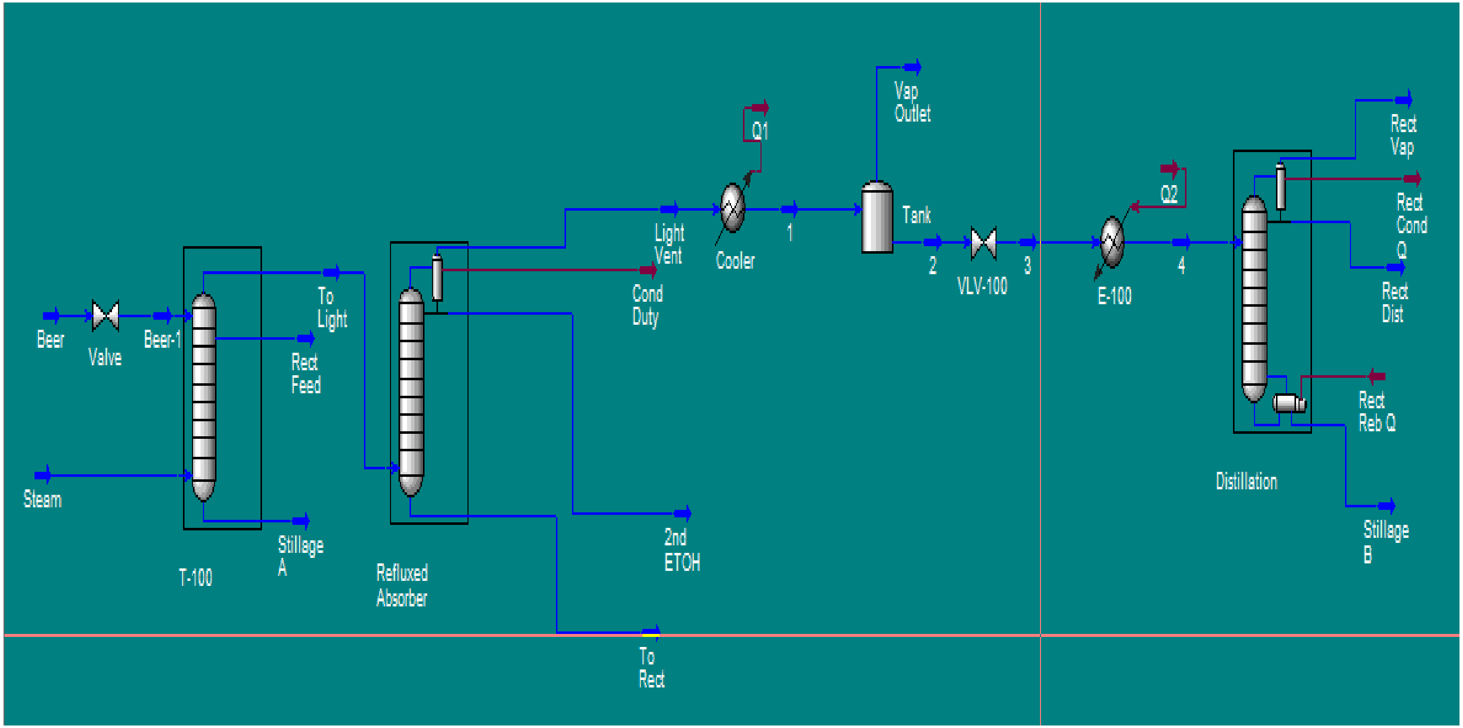

Figure 1 HYSYS worksheet

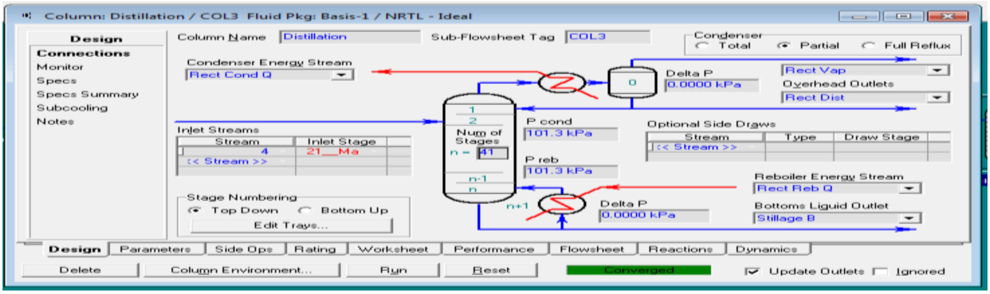

Figure 3 **rect vapour and stillage**

Table 4: **rect vapour (material balance)**

HYPROTECH — TEAM LND, CANADA
Case Name: D:\ETHANOL BY HYSYS\KENANA.HSC
Unit Set: SI
Date/Time: Thu Dec 24 17:23:16 2009

Material Stream: Rect Vap (continued)
Fluid Package: Basis-1
Property Package: NRTL - Ideal

COMPOSITION

Overall Phase — Vapour Fraction 1.0000

COMPONENTS	MOLAR FLOW (kgmole/h)	MOLE FRACTION	MASS FLOW (kg/h)	MASS FRACTION	LIQUID VOLUME FLOW (m3/h)	LIQUID VOLUME FRACTION
Ethanol	7.7484	0.9123	356.9691	0.9635	0.4485	0.9706
H2O	0.7399	0.0871	13.3289	0.0360	0.0134	0.0289
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methanol	0.0046	0.0005	0.1458	0.0004	0.0002	0.0004
AceticAcid	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1-Propanol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2-Propanol	0.0009	0.0001	0.0528	0.0001	0.0001	0.0001
1-Butanol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3-M-1-C4ol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2-Pentanol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Glycerol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	8.4937	1.0000	370.4966	1.0000	0.4621	1.0000

Table 5: **Stillage B (material balance)**

HYPROTECH — TEAM LND, Calgary, Alberta, CANADA
Case Name: D:\ETHANOL BY HYSYS\KENANA.HSC
Unit Set: SI
Date/Time: Thu Dec 24 17:32:09 2009

Material Stream: Stillage B (continued)
Fluid Package: Basis-1
Property Package: NRTL - Ideal

COMPOSITION

Overall Phase — Vapour Fraction 0.0000

COMPONENTS	MOLAR FLOW (kgmole/h)	MOLE FRACTION	MASS FLOW (kg/h)	MASS FRACTION	LIQUID VOLUME FLOW (m3/h)	LIQUID VOLUME FRACTION
Ethanol	0.1274	0.0006	5.8694	0.0016	0.0074	0.0020
H2O	203.7849	0.9972	3671.2053	0.9884	3.6786	0.9858
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methanol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AceticAcid	0.0031	0.0000	0.1836	0.0000	0.0002	0.0000
1-Propanol	0.0424	0.0002	2.5484	0.0007	0.0032	0.0008
2-Propanol	0.0004	0.0000	0.0246	0.0000	0.0000	0.0000
1-Butanol	0.0330	0.0002	2.4456	0.0007	0.0030	0.0008
3-M-1-C4ol	0.0987	0.0005	8.7027	0.0023	0.0106	0.0028
2-Pentanol	0.2661	0.0013	23.4561	0.0063	0.0288	0.0077
Glycerol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	204.3560	1.0000	3714.4357	1.0000	3.7318	1.0000

4. Conclusions

Figure 3 illustrates the ethanol produced under the same conditions. In these results a clear difference is shown between processing and simulation program concerning ethanol production in rectifying section and stillage. The ethanol recovery in mass fraction was 96.35 by using Hysys program (Table 4) while 92% mass fraction in case of Kenana ethanol plant. In the stillage, the ethanol was found 3.75% in case plant while 0.06% mass faction in case of Hysys as shown in (Table 5) this attributed un-optimized condition.

In conclusion, this study is achieved Kenana ethanol process simulation and optimization by using Aspen HYSYS. By doing this simulation project, the main features of industrial production of ethanol were represented in a Process Flow Diagram. Satisfactory results are obtained in optimizing the process, keeping in mind the fact that the profit maximization is done in a rather simple way. On the whole, using this simulation approach will be helpful for the process plant to optimize the annual profit

مستخلص:

في هذه الورقة تمت محاكاة مصنع كنانة للإيثانول باستخدام أدوات المحاكاة للهيسس(Hysys). الخوص الديناميكية تم حسابها باستخدام حزمة نموذج NTR وهي موجودة في برنامج المحاكاة الهيسس. الايثانول هو مصدر طاقة متجدد ونظيفة بديل لطاقة البترول. و أيضا مصدر أساسي للمواد الكيميائية ويستخدم بصورة واسعة في قطاعات صناعية مختلفة وأيضا مصدر هام وشائع للوقود في العصر الحالي والمستقبلي. في التطورات الصناعية الجيدة، تحليل الوحدات الصناعية عن طريق المحاكاة هو دليل يوضح مقدما مدي جدوى الوحدة تقنيا و اقتصاديا. في حالة الوحدات الموجود مسبقا تحت التشغيل مثل مصنع كنانة للإيثانول الموجود أصلا عملية المحاكاة في هذه الحالة تساعد في ضبط الظروف التشغيلية للمصنع التي تحقق منتج ذو جودة أفضل مع خفض في الطاقة المستهلكة والفواقد التصنيعية الأخرى. الهدف الأساسي من هذه الدراسة هي محاكاة و ضبط وحدة لإنتاج الايثانول بتركيز 96 % باستخدام برنامج الهيسس. لمحاكاة مثل هذه العملية تم استخدام بعض بيانات الظروف التشغيلية لمصنع كنانة للإيثانول. الضبط المعياري لهذه العملية هي لتعظيم الربح السنوي. أهمية الدراسة تساعد مشغلي الوحدة في تسيير و ضبط كفاءة المصنع و ذلك بتخفيض متطلبات عملية النظام. أظهرت النتائج إن الايثانول المستخلص بالكتلة الوزنية بواسطة البرنامج (Hysys)هي 96.35% بينما 92% في حالة مصنع الايثانول. المتبقي وجد إن نسبة الايثانول 3.75 % نسبة وزنية في حالة المصنع بينما 0.06 نسبة وزنية في حالة برنامج الهيسس. هذه الفروقات تعزي لعدم ضبط الظروف للعملية.

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