# Parametric Design and Modeling of Semi Kestner Evaporator for a Sugar Mill

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***Abstract :*** *A sugar mill comprises of various equipment like heat exchangers, pressure vessels, boilers, and other process equipment. Each equipment contains a number of parts, and their sub-assemblies. These equipment are designed and modeled according to the capacity of the sugar mill i.e. TCD (Tons Crushed per Day). For different TCDs, the 3D model, design and drawings have to be made by changing dimensions of parts and assembly constraints respectively. This is repetitive, time consuming and it requires software skills for 3D modeling and drafting. By using parametric modeling, the task of redesigning equipment for different plant capacities can be made efficient because basic features and relations between them are constant for a specific equipment. In this paper, commercially available software like Solid Edge ST10 and MS Office Excel are used for 3D Parametric Modeling to generate 3D models and manufacturing drawings for **Semi Kestner Evaporator** based on plant capacity. Advantages of parametric modeling in terms of time saving are quantified and analyzed, and future course of action is suggested.*

***Keywords –*** *Modeling and Drafting, Process Equipment, Redesigning, Sugar Mill, 3D Parametric Modeling*

## I. INTRODUCTION

The sugar industry is third largest industry in India. A sugar mill is a factory that processes sugar cane or sugar beet to produce raw or white sugar and wastes like molasses, bagasse etc. More than 60% of the world's sugar production is from sugar cane; the balance is from sugar beet. Sugar manufacturing is highly seasonal industry, with season lengths of about 6 to 18 weeks for beets and 20 to 32 weeks for cane. The sugar cane production process flow diagram is as follows:
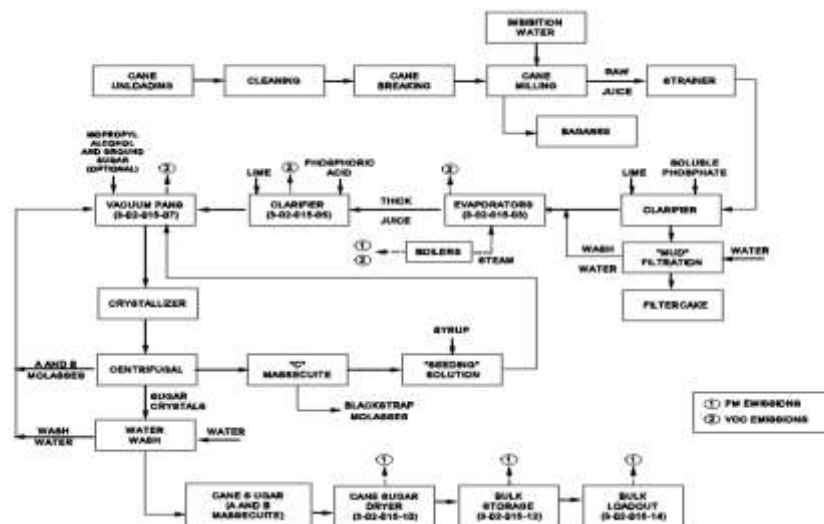


**Fig.1**.Process Flow Diagram For cane sugar Production Plant [9]

Cane is transported to the mill for extraction of juice using cane conveying equipment, and prepared using cane preparatory equipment like knives, fibrizers, cane cutters etc. The milling process uses heavy rollers to extract juice from the prepared cane. The output of the mill is juice and waste i.e. bagasse. Then juice is strained to remove the large particles and then clarified. Clarified juice goes to the evaporators without any additional treatment. Evaporation is performed in two stages: initially in an evaporator station to concentrate the juice and then in vacuum pans to crystalize the sugar. Following evaporation, the syrup is clarified. From the clarifier, the syrup goes to the vacuum pans for crystallization. Crystallization of the sugar starts in the vacuum pans; whose function is to produce sugar crystals from the syrup. After cooling, the cane sugar is transferred to packing bins and then sent to bulk storage.

In this paper, the process equipment like evaporator is chosen for parametric modeling. As discussed above, the evaporation is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid. There are five types of evaporator according to their arrangement are: 1.Falling film Evaporators 2.Rising film Evaporators 3.Forced Circulation Evaporators 4.Plate Evaporators 5.Thermal and Mechanical Vapor Recompression. In this paper, semi rising film evaporator is considered for parametric modeling. Semi Rising Film Evaporator, also known as the Semi Kestner Evaporator, is widely used in sugar industries for making concentrated solution of cane juice which consists of 65% solids and 35% water.

Various researchers define parametric modeling and design in their own way. In our view, the term parametric design is defined as the generation of geometry from the definition of initial parameters and the design of the formal relations they keep with each other. Parametric model can be defined as the model whose actual shape is a function of a given set of parameters and constraints upon them. Parametric modeling is a well-developed technology to utilize previous design to develop a new design by varying parameters. Parametric modeling has made product development quick and efficient. Previous work was done in the parametric design and modeling of simple parts and small assemblies like Oldham coupling etc., but no work was done in the field of sugar mill equipment which consists of large number of parts and their subassemblies with various assembly constraints between them. This paper contributes to the parametric design and modelling of a semi kestner type evaporator for a sugar mill.

For generation of part model of shell (calandria) for semi kestner, parameters required are inner diameter, outer diameter, thickness, and height. All these parameters vary with the change in the value of plant capacity in tonnes of sugar cane crushed per day (TCD). These changes in the equipment design can be made by MS-Excel and Solid Edge ST10 integration using parametric modeling. This kind of integration results in the automation in 3D modeling and the design of equipment.

## II. STEPS FOR PARAMETRIC DESIGN AND MODELING

Solid Edge ST10 is a powerful 3D modeling, drafting and piping design generation tool. It is commonly used in industries for 3D modeling of equipment, piping design and 2D drafting of 3D model. Solid Edge is also used for 2D drafting to validate the model with AutoCAD drawing of the same. Solid Edge software can directly modify and regenerate the part model and assembly according to the user input in the Excel sheet because there is integration of MS Excel and Solid Edge software to perform parametric modeling.

**Step 1: - Generation of 3D Model from 2D sketch.**

A 3D model of the semi-kestner with all features with dimensions and proper constraints have been generated as below figure 2. While modelling the semi kestner for the first time, we have to satisfy the 2D and 3D geometry constraints. Without maintaining the 2D and 3D constraints we can not proceed for parametric modelling. This model can be called as the universal model and it is the model that has to vary with dimensions and constraints in Excel sheet data. This file is then saved.
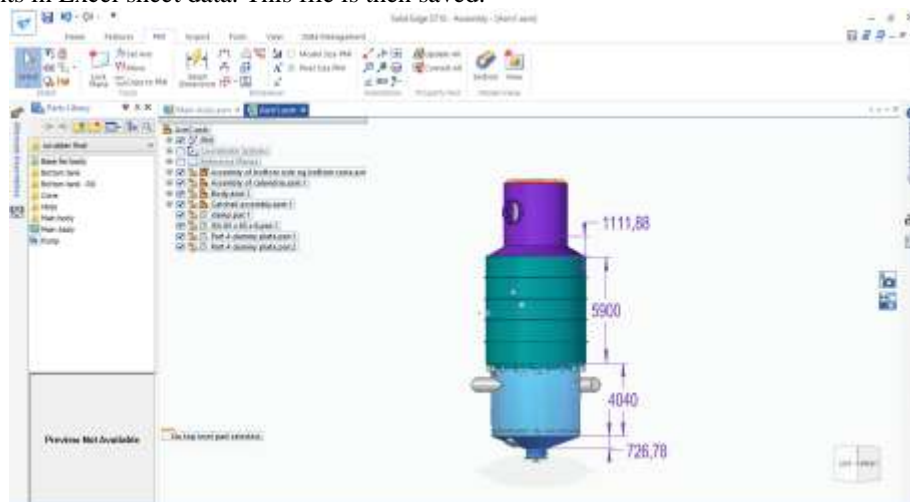


**Fig.2.** Generation of 3D Model of Semi-Kestner

**Step 2:- Generation of an Excel Sheet**

An excel sheet with all the parameters (Dimensions and Constraints) is generated as shown in the fig.2. The excel sheet consists of all the values of required dimensions. This is done by applying formulae used in the design calculations for semi-kestner. The Excel sheet also contains the value of constraints between the parts and these also vary with the change in the value of the plant capacity.

| Descriptions | Symbol | Value | Unit | | | | |
|---|---|---|---|---|---|---|---|
| Tp (Tube plate thik) | tp | 32 | | input | | | |
| Thik of Shell | Ts | 16 | | | | | |
| Thik of Calendria | Tcal | 16 | | **Heating surface Calculations** | | | |
| top cone | Tc | 16 | | | | | |
| bottom | Tb | 22 | | Working Hours | | 22 | Hrs |
| catch-all | Tca | 16 | | TCH | | 160 | |
| Catchall internals | Tcal | 12 | | Steam Consumption rate on cane (32 to 50) | | 42 | |
| Heating Surface | H.S. | 2500 | m² | capacity of boiler | | 68 | TPH |
| Tube OD | d | 42 | mm | Actual capacity of boiler | | 91 | TPH |
| Thik of tube | Tt | 1.2 | | Evapocation rate (26 to 32) | | 27 | Kg/m²/hr |
| Effective length of tube | Le | 4026 | mm | Heating Surface | | 2518.52 | m² |
| Area of single tube | A | 530949 | mm² | say | | 2500 | |
| Total no. of tubes | N | 4708.55 | | 4935.29 | | | |
| Ligment | Pt | 18 | mm | | | | |
| Dia. Of Tube plate | Dc | 4987.05 | mm | **Nozzle Pos on Calendria** | | | |
| | Say | 4900 | mm | | | | |
| I.D. of calandria | | 4900 | mm | Dist bet equilizing conn and top | | 900 | mm |
| Height of Calandria | H | 4390 | mm | Dist bet spring loaded safety valve and top | | 950 | mm |
| Distance between top of shell and tube plate | dst | 50 | mm | | | | |

**Fig.3.** Excel sheet for Parametric Modeling

**Step 3: - Linking of Solid Edge ST10 to Excel**

The parameters in the Excel sheet are linked to the same parameters of the part in the model modeled in the Solid Edge Software. For the linkage, in Solid Edge software, open the part model, go to "Tool" command and then go to option "Variables". Copy the value of parameter in the Excel sheet and then paste it into the table opened in the Solid Edge software in front of the value of same parameter in the formula column.
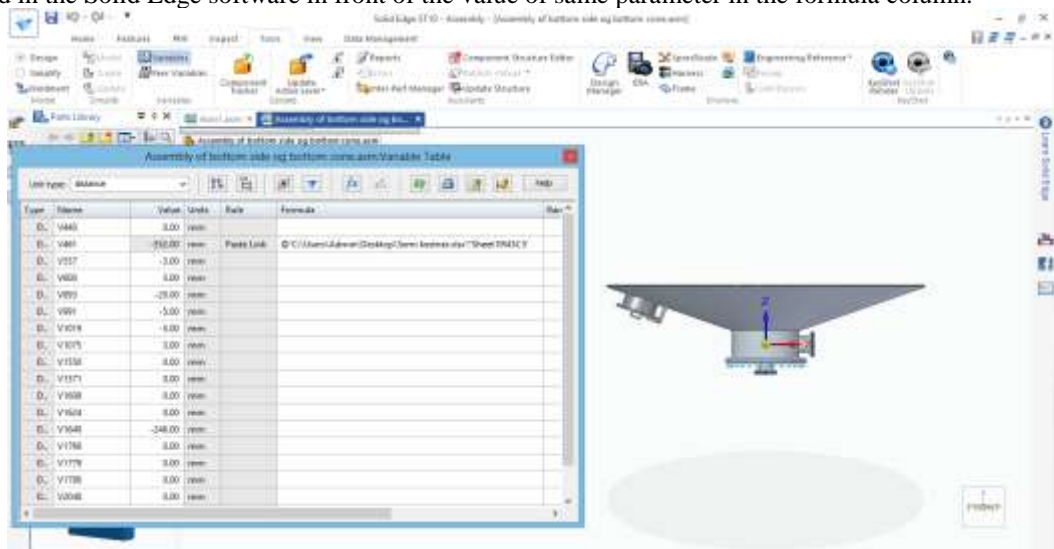


**Fig.4.** Linkage of Solid Edge to Excel sheet

**Step 4: - Drafting of 3D model**

Drafting of the model can be done Solid Edge software itself by the module "Draft of Active Model" in the Solid Edge software. Automatic generation is done in the draft as the 3D model changed by parametric modeling technique by the option "Update Views" in the Drafting Environment.
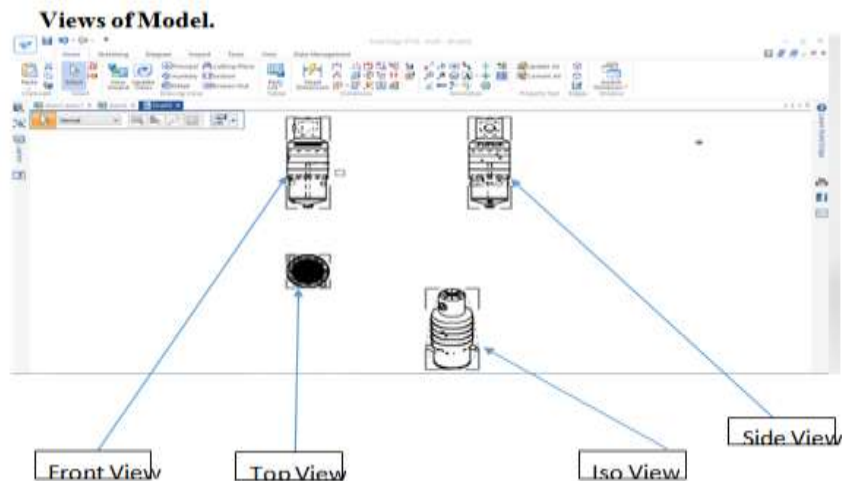


**Fig.5.**Drafting of 3D Model

**Step 5:- Technique for Modifying and Regenerating the Model**

The parameters (Dimensions and Constraints) in the Excel-sheet is then changed according to variation in the value of the mill capacities. Here if we change the value of "TCD", the values of all other parameters (dimensions and constraints) will be calculated according to the design formulae and modified in the Excel sheet and simultaneously in the Solid Edge Software. In this way the 3D model and drafting of model is redesigned and regenerated.

| Descriptions | Symbol | Value | Unit | | | |
|---|---|---|---|---|---|---|
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| Thik of Shell | Ts | 16 | | | | |
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| top cone | Tc | 16 | | | | |
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| Catchall internals | Tcal | 12 | | Steam Consumption rate on cane (32 to 50) | 42 | |
| Heating Surface | H.S. | 3000 | m² | capacity of boiler | 77 | TPH |
| Tube OD | d | 42 | mm | Actual capacity of boiler | 103 | TPH |
| Thik of tube | Tt | 1.2 | | Evaporation rate (26 to 32) | 27 | Kg/m²/hr |
| Effective length of tube | Le | 4026 | mm | Heating Surface | 2851.85 | m² |
| Area of single tube | A | 530949 | mm² | say | 2500 | |
| Total no. of tubes | N | 5650.26 | | 5922.35 | | |
| Ligment | Pt | 18 | mm | | | |
| Dia. Of Tube plate | Dc | 5446.81 | mm | **Nozzle Pos on Calendria** | | |
| | Say | 5500 | mm | | | |
| I.D. of calandria | | 5500 | mm | Dist bet equilizing conn and top | 900 | mm |
| Height of Calendria | H | 4390 | mm | Dist bet spring loaded safety valve and top | 950 | mm |
| Distance between top of shell and tube plate | dst | 50 | mm | | | |

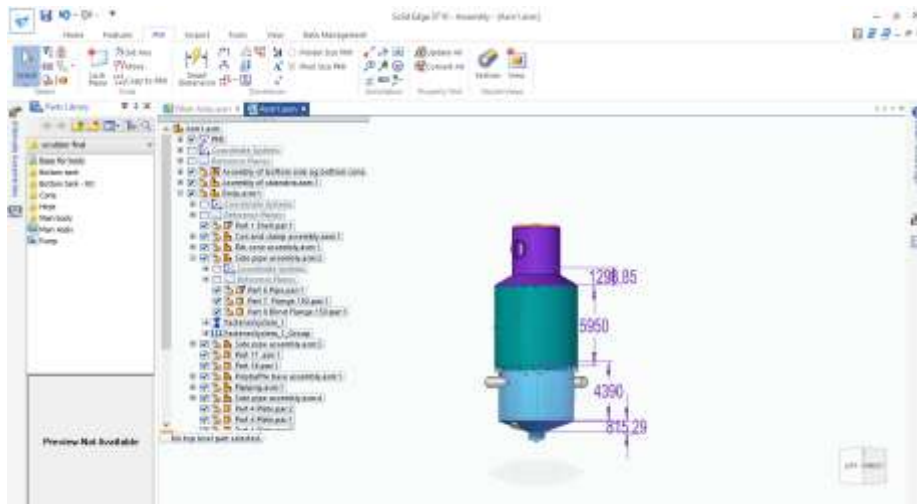**Fig.6.** Modified Excel sheet after adding TCD = 4000



**Fig.7.** "Regeneration of Model for 4000 TCD as Per Excel sheet"

## III. CONCLUSION

Parametric design and modelling speeds up the design and modelling process. Automatic generation of 3D model of various equipment for different plant capacities can be made possible. Usually the time required for preparation of 3D model of equipment for various capacities in the industry was approximately 10 to 15 days. But by implementing parametric modelling technique it requires only 1 to 2 days. Production lead time also decreases due to quick preparation of the model of equipment for required capacity of plant. The design, modelling and drafting efficiency increases due to parametric modelling. The addition of new parts in the assembly is also admissible, without changing relation in the model and data of excel sheet. Due to parametric modelling, one person can perform design, modelling and drafting. So, it is beneficial to firms in terms of manpower efficiency. The limitation of parametric modelling is that it is a profitable and efficient way of design and redesign of model which consists of constant relationship between dimensions and assembly constraints only. Also, manufacturing drawings are not generated automatically. For that, we have to open each part model in draft environment of solid edge software. Automatic generation of manufacturing drawings is the future scope of work and is recommended of further research.

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