

# Flow Analysis of Stenter Machine

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**Abstract-** The Stenter machine is used for the drying of woven and knitted fabrics. It is a very versatile and common machine in textile finishing. Almost every open width textile fabric is treated on Stenters during its textile processing. For maintaining universal use, the Stenter range is usually standing separately, not in a continuous line with other machines. Four types of processes are done on Stenter which are drying, heat setting, finishing and coating.

The Stenter machine usually consists of 8-10 chamber and each chamber contains 2-blowers, each blower provided in separate casing and each casing contains 12 nozzles, i.e. total 24 nozzles are provided in each chamber (12 facing down and 12 facing up). In each nozzle there is 48 openings, each of which are supplying the air to the fabric.

In present study, CFD analysis of fan house was carried out in three stages. In first stage, CFD analysis of Fan B with casing was done; in second stage CFD analysis Fan A with casing was done; finally, in third stage, CFD analysis of Fan B with nozzles were performed. Results were presented in terms of pressure and velocity contours. The CFD simulation results were compared with experiments and CFD results provided by M/s InspirOn engg. Pvt Ltd, Odhav, Ahmedabad, and found in good agreement.

## 1. INTRODUCTION

A mill is a factory that houses spinning and weaving machinery, typically built between 1775 and 1930 were instrumental in the growth of the machine tool industry, enabling the construction of larger cotton mills. The requirement for water helped stimulate the construction of the canal system, and the need for power the development of steam engines.

Limited companies were developed to construct the mills, which led to the trading floors of the cotton exchange of Manchester, creating a vast commercial city. The mills also generated employment and drew workers from largely rural areas, leading to the expansion of local

urban populations and the consequent need for additional housing. In response, mill towns with municipal governments were created.

The mills provided independent incomes for girls and women. Child labor was used in the mills, and the factory system led to organized labor. Poor conditions in cotton mills became the subject of exposés, and in England, the Factory Acts were written to regulate them.

The fabric mill was originally a Lancashire phenomenon that then was copied in New England and later in the southern states of America. In the 20th century, North West England lost its supremacy to the United States, then India and then China. In the 21st century, redundant mills have been accepted as part of a country's heritage. Cotton is the world's most important natural fiber. In 2007, the global yield was 25 million tons from 35 million hectares cultivated in more than 50 countries.

## 2. LITERATURE REVIEW

The Stenter range MOTEX TWIN AIR can be used for the treatment of woven and/or knitted fabrics. The Stenter itself is a very versatile and common machine in textile finishing. Almost every open width textile fabric is treated on Stenters during its textile Processing. For maintaining universal use, the Stenter range is usually standing separately, not in a continuous line with other machines. There are four type of process can be done on Stenter.

1. Drying
2. Heat Setting
3. Finishing
4. Coating.

1. Drying

The main purpose of this process is evaporating the liquid in the fabric up to certain level of residual moisture. Temperature may be reach 1200 to 1900 C

depending upon on fabric and desired degree of whiteness. Stenter Machine is used to do following process with knitted fabric this is also used to relax the fabric and to eliminate stresses and shrinkage in following process. Therefore, the fabric width is not increased very much but you give a lot of overfeed to allow relaxation in the longitudinal direction where most stress are present.

### 2. Heat Setting

In this process fabric related to thermoset material like Polyester (PES) need certain temperature to set their properties which is known as Curing temperature. This temperature range is 1800C to 2100C.

### 3. Finishing

Finishing Process is to improve surface of fabric by heating process.

### 4. Coating

Coating is the process to add some chemical in proper manner and set them on top side of fabric to improve the properties of fabric for different application.

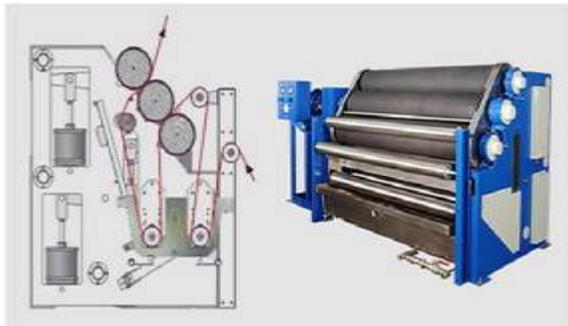


Fig. 2.0.1: Entry of section of stenter

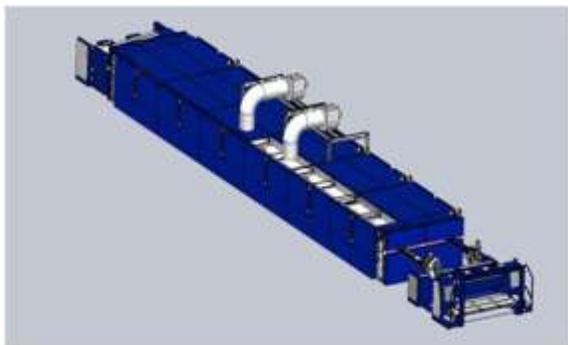


Fig. 2.0.2: Outlet of stenter machine

## 3. DRYING TECHNOLOGY

### Microwave Drying for Textile

Datta and Ramaswamy gives brief introduction about Microwave heating that, Microwave heating is a very promising technology which has been finding new applications in industry. It is a technology which can replace conventional heating. We would like to describe our new microwave industrial applicator used for drying textiles in manufacturing. In this drying process, a very thin layer of textile material does not have a very well-defined position in the applicator. Also, the complex permittivity of dried textile is not constant during the procedure. Its value changes in time with respect to the decreasing moisture content.

And also, Datta and Ramaswamy presents an overview of the microwave drying technology as well as it reviews the recent developments in microwave assisted drying technologies and future R&D needs in India. Recently, microwave convective and microwave vacuum drying techniques have been investigated as potential methods for obtaining high quality dehydrated food products. Microwave drying is rapid, uniform and energy efficient compared to conventional hot air drying as the microwaves penetrate to the interior of the food causing water to get heated within the food. This results in a greatly increased vapor pressure differential between the center and surface of the product, allowing rapid removal of moisture from the food.

Microwaves are electromagnetic waves having wavelength (peak to peak distance) varying from 1millimeter to 1 meter. Frequency of these microwaves lies between 0.3 GHz and 3 GHz. Microwaves have greater frequency than radio waves so they can be more tightly concentrated. Microwaves propagate through air and space at about the speed of light. Microwaves can also be considered as electromagnetic force fields for better understanding of working of microwave oven. Microwaves interfere inside the microwave oven to produce high and low energy pockets. Application of microwave energy to dry food materials is a good approach for coping with certain drawbacks of conventional drying. Microwaves penetrate to interior of the food causing water to get heated within food. This results in a greatly increased vapor pressure differential between the center and surface of the product, allowing fast transfer of moisture out of the food. Hence, microwave drying is rapid, more

uniform and energy efficient compared to conventional hot air drying. The problems in microwave drying, however, include product damage caused by excessive heating due to poorly controlled heat and mass transfer.

Table 3.1: Comparison of pulse combustion with other drying process

Fig. 3.1: Microwave heating Process

Process Parameters	Steady State	Pulse
Combustion intensity	100-1000	10000-50000
E-cadency of burning	80-96	90-99
Loss due chemical under burning (%)	0-3	0-1
Loss due mechanical under burning (%)	0-15	0-5
Temperature level(K)	2000-2500	1500-2000
Co concentration (%)	0-2	0-1
NOx concentration(mg/m <sup>3</sup> )	100-7000	20-70
Convective Heat transfer coincident(W/m <sup>2</sup> k)	50-100	100-500
Time of reaction(s)	1-10	.01-.5

#### 4. METHODOLOGY OF WORK

##### 4.1. Work

The work done is given by Euler's Equation

$$\omega = U_2 V_{\omega 2} - U_1 V_{\omega 1}$$

It is reasonable to assume zero whirl at the entry.

This condition gives

$$\alpha_1 = 90^\circ, V_{\omega 1} = 0 \text{ And hence } U_1 V_{\omega 1} = 0$$

Therefore, we can write,

$$V_1 = V_{f1} = V_{f2} = U_1 \tan \beta_1$$

Equation gives

$$\omega = U_2 V_{\omega 2} = U_2 (V_{\omega 2} / U_2)$$

For any of the exit velocity triangles

$$U_2 - V_{\omega 2} = V_{f2} \cot \beta_2$$

$$(V_{\omega 2} / U_2) = [1 - (V_{f2} \cot \beta_2 / U_2)]$$

$$\omega = U_2 [1 - \phi \cot \beta_2]$$

Where  $\phi = (V_{f2} / U_2)$  is known as flow coincident

Head developed in meters of air  $H_a = (V_{\omega} U_2 / g)$

Equivalent head in meters of water  $H_{\omega} = (\rho_a H_a / \rho_{\omega})$

Where  $\rho_a$  and  $\rho_{\omega}$  are the densities of air and water respectively.

Assuming that the flow fully obeys the geometry of the impeller blades, the specific work done in an isentropic process is given by

$$\Delta h_0 = U_2 (1 - \cot \beta_2)$$

Power required to drive fan is

$$P = m(\Delta h_0) = m U_2 V_{\omega 2} = m U_2^2 (1 - \cot \beta_2) = m C_p (\Delta T_0)$$

The static pressure rise through the impeller is due to the change in centrifugal energy and the diffusion of relative velocity component. Therefore, it can be written as

$$P_2 - P_1 = (\Delta p) = \frac{1}{2} \rho (U_2^2 - U_1^2) + \frac{1}{2} (V_{2r1}^2 - V_{2r2}^2) \\ (\Delta p_0) = \frac{1}{2} \rho (U_2^2 - U_1^2) + \frac{1}{2} (V_{2r1}^2 - V_{2r2}^2) + \frac{1}{2} \rho (V_2^2 - V_1^2)$$

The stagnation pressure rise through the stage can also be obtained as

$$(\Delta p_0) = (\Delta p) + \frac{1}{2} \rho (V_1^2 - V_2^2)$$

From any of the outlet velocity triangles

$$V_2 / \sin \beta_2 = U_2 / \sin \{\pi - (\alpha_2 + \beta_2)\}$$

$$V_2 / \sin \beta_2 = U_2 / \sin (\alpha_2 + \beta_2)$$

$$V_{\omega 2} = V_2 \cos \alpha_2 = U_2 \sin \beta_2 \cos \alpha_2 / \sin (\alpha_2 + \beta_2)$$

$$V_{\omega 2} / U_2 = (\sin \beta_2 \cos \alpha_2) / (\sin \alpha_2 \cos \beta_2 + \cos \alpha_2 \sin \beta_2)$$

$$V_{\omega 2} / U_2 = (\tan \beta_2) / (\tan \alpha_2 + \tan \beta_2)$$

$$\omega = U_2^2 (\tan \beta_2 / \tan \alpha_2 + \tan \beta_2)$$

##### 4.2. Efficiency

On account of losses, the isentropic work is less than the actual work  $1/\rho (\Delta p_0)$  is less than actual work

Therefore, the stage efficiency is defined by

$$\eta_s = (\Delta p_0) / \rho U_2 V_{\omega 2}$$

##### 4.3. Number of Blades

Too few blades are unable to fully impose their geometry on the flow, whereas too many of them restrict the flow passage and lead to higher losses. Most of the efforts to determine the optimum number of blades have resulted in only empirical relations given below

$$n = [8.5 \sin \beta_2 / 1 - (D_1 / D_2)]$$

$$n = 6.5 (D_2 + D_1 / D_2 - D_1) \sin \frac{1}{2} (\beta_1 + \beta_2)$$

#### 5. CFD ANALYSIS OF FAN HOUSE OF STENTER MACHINE

##### 5.1. Structure of CFD code

CFD codes are structured around the numerical algorithms that can tackle fluid flow problems. All commercial CFD packages include sophisticated user interfaces to input problem parameters and to examine the results. Hence all codes contain three main elements: (i) a pre-processor, (ii) a solver and (iii) a post-processor. The function of each of these

elements is briefly described, within the context of a CFD code.

Pre-processor:

Pre-processing consists of the input of a flow problem to a CFD program by means of an operator-friendly interface and the subsequent transformation of this input into a form suitable for use by the solver. The user activities at the pre-processing stage involve:

- Definition of the geometry of the region of interest: the computational domain
- Grid generation - the sub-division of the domain into a number of smaller, nonoverlapping sub-domains
- Selection of the physical and chemical phenomena that need to be modeled.
- Definition of fluid properties
- Specification of appropriate boundary conditions at cells which coincide with or touch the domain boundary

Solver:

There are three distinct streams of numerical solution techniques: finite difference, finite element and spectral methods. In outline the numerical methods that form the basis of the solver perform the following steps:

- Integration of the governing equations of fluid flow over all the control volumes of the domain
- Discretization - conversion of the resulting integral equations into a system of algebraic equations
- Solution of the algebraic equations by an iterative method

Post-processor:

As in pre-processing a huge amount of development work has recently taken place in the post-processing field. Flowing to the increased popularity of engineering work stations, many of which have outstanding graphics capabilities, the leading CFD packages are flow equipped with versatile data visualization tools. These include:

- Domain geometry and grid display
- Vector plots
- Line and shaded contour plots
- 2D and 3D surface plots

- Particle tracking
- View manipulation (translation, rotation, scaling etc.)
- Color postscript output

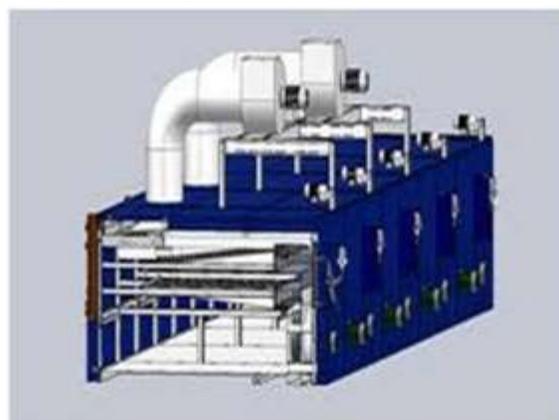
## 5.2. Typical Steps of CFD Stimulation in Software

The typical steps of solving the problem using CFD software are under:

1. Create the geometry model and mesh it.
2. Start the appropriate solver for 2D or 3D modeling.
3. Import the grid and check it.
4. Select the solver formulation
5. Chose the basic equation to solve: laminar or turbulent (or in viscid), chemical species or reaction, heat transfer models, etc. Also identify additional models needed: fans, heat exchangers, porous media, etc.
6. Specify the material properties.
7. Specify the boundary properties.
8. Adjust the solution control parameter.
9. Initialize the flow field.
10. Calculate a solution.
11. Examine the results.
12. Save the results.
13. If necessary, refine the grid or consider revisions to the numerical or physical.

Some simplifying assumptions are required before applying the conventional Navier-Stokes and Energy equations to the model. The major assumptions are:

1. Steady state flow and heat transfer,
2. Incompressible fluid,
3. Laminar flow,
4. Uniform wall heat flux,
5. Constant solid and fluid properties (thermo physical properties)



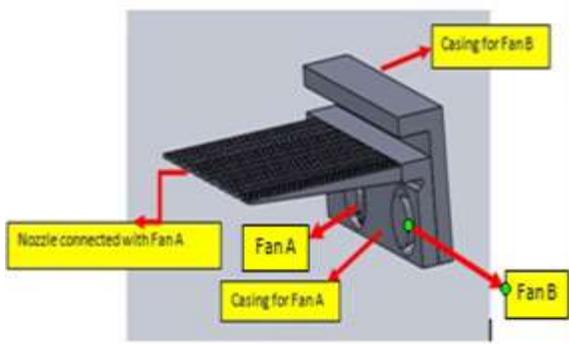


Fig. 5.1: Section view of stenter and arrangement of Fan A and Fan B

## 6. CONCLUSIONS AND FUTURE WORK

### 6.1. Conclusions

The Stenter machine is used for the drying of woven and knitted fabrics. Four type of process are done on Stenter which are drying, heat setting, finishing and coating. The Stenter machine usually consists of 8-10 chamber and each chamber contains 2-blowers, each blower provided in separate casing and each casing contains 12 nozzles, i.e. total 24 nozzles are provided in each chamber (12 facing down and 12 facing up). In each nozzle there is 48 openings, each of which are supplying the air to the fabric.

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#### 1. Stage 1: CFD analysis of Fan B with casing

- At casing outlet non-uniform distribution of air was found which may be due to unsymmetrical position of Fan in the casing,
- Head generated, power input and efficiency of Fan B with casing were found to be 70.5 mm water column, 4.2 kW and 50% respectively.

#### 2. Stage 2: CFD analysis of Fan A with casing

- The methodology adopted in this case was similar to stage-1.
- In this case also non-uniform distribution of air was observed at casing outlet.

#### 3. Stage 3: CFD analysis of Fan A with nozzles

- From analysis, the velocity at inlet and outlet of nozzle were found to be 10 m/sec and 38-40 m/sec respectively.
- The corresponding experimental values provided by IEPL were 7.1 m/sec and 24-28 m/sec respectively, which shows quiet good agreement of the results.

### 6.2. Future Work

- To study the effects of various modifications on fan house performance such as: by considering symmetric position of the blower, by changing the type of blower (radial/ forward), by considering the volute profile of casing etc.
- To study the effects of various modifications on nozzle performance viz. shape, pitch, size and location of nozzle openings.
- CFD analysis of complete assembly (i.e. air blower with duct passage and nozzle) in view of optimization of the Stenter machine.

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