TEXTILE ENVIRONMENT HEALTH - A FUZZY DIAGNOSIS

Millind S. Patil*, Amir M. Shaikh, Ravindra R. Mudholkar

Department of Electronics, Shivaji University, Kolhapur (MS), INDIA-416 004

Email of Correspondence Author: mircomillind1@rediffmail.com*, neuralfuzzy.lab@gmail.com

Abstract:

Many properties like weight, tensile strength, elastic recovery etc. of textile materials vary considerably with moisture regain. This is in turn affected by the ambient Relative Humidity (RH) and Temperature (T) which contribute mainly to textile environmental conditions. Therefore the monitoring of environment at test locations either continuously or at regular intervals is necessary. Many Researches have dealt with to interpret measurement data that are frequently inconclusive. The main objectives of this paper are to perform analysis on environment condition using both Simulation and Real-time study and to design the On-line condition monitoring system with Fuzzy Logic Controller using MATLAB. The environment condition is described in terms of linguistic variables so that even unskilled personnel can handle the Textile Environmental Conditions.

Keywords:

Textile, Environmental conditions, Diagnosis, Fuzzy Logis

1. INTRODUCTION

The environmental conditions with respect to temperature and humidity play very important part in the manufacturing process of textile industry. The properties with respect to dimensions, weight, tensile strength, elastic recovery, electrical resistance, rigidity etc. of all textile fiber including natural and synthetic are influenced by moisture regain expressed in percentage. Many properties of textile materials vary considerably with moisture regain, which in turn affected by the ambient Relative Humidity (RH) and Temperature. If a dry textile material is placed in a room with a particular set of ambient environmental conditions, it absorbs moisture and in course of time attains equilibrium [1, 2]. The physical properties of textile materials affected with %RH are as follows-

1. The strength of cotton goes up
2. The strength of viscose goes down
3. The fiber elongates
4. The tendency for generation of static electricity due to friction decreases
5. The tendency of the fibers to stick together increases

DOI : 10.5121/ijfls.2012.2307

Temperature alone does not have a great effect on the fibers. However the temperature dictates the amount of moisture the air will hold in suspension and, therefore, temperature and humidity must be considered simultaneously while optimizing the environmental conditions in the textile mills [3]. Three techniques practiced in optimizing the Environment are:

1. ***Cooling and Humidification*** is a process involving reduction in Dry Bulb Temperature and increase in specific humidity.
2. ***Heating and Dehumidification*** is a process where there is an increase in Dry Bulb Temperature and reduction in specific humidity.
3. ***Heating and Humidification*** is the process where there is an increase in both Dry Bulb Temperature and specific humidity.

2. AIR CONDITIONING PROCESS FOR THE TEXTILE INDUSTRY

When air is drawn in and passed through the Air Washer, it gets saturated adiabatically. Since it is not saturated 100%, the dry bulb temperature of the saturated air will be 1^0C greater than Wet Bulb Temperature. When this air is admitted into the conditioned space, it gets heated due to the heat load of the room. During this heating process the air does not lose or gain any moisture as latent heat load is absent. The air displaces an equal amount of air in the room which is pushed outside the room. If we know the heat load of the room, we can easily calculate the rate of flow of air (G), which is the air circulation rate necessary to give the required RH as given by equation (1)

$$G = H(h_2 - h_1) \tag{1}$$

Where,

G = Mass flow rate of dry air, Kg/h
H = Total heat of air, Kcal/h
h_1 = Enthalpy of supply air, Kcal/Kg
h_2 = Enthalpy of outgoing air, Kcal/Kg

The air circulation rate is generally expressed in cubic meters per hour and not in terms of mass flow rate. $(h_2\text{-}h_1)$ can be calculated from the initial and final temperatures. Therefore

$$H = (Q/V) \times C_p \times (DB_2 - DB_1) \tag{2}$$

Where,

Q = Rate of air flow in m^3/h
C_p = Specific heat of air
V = Specific volume of air, m^3/kg
DB_1 = Supply air Dry Bulb Temperature in ^0C
DB_2 = Leaving air Dry Bulb Temperature in ^0C

However in practice, the Air Washer does not continuously supply air of 100% RH. It is considered satisfactory, if the difference between Dry Bulb Temperature and Wet Bulb

Temperature of air after the Air Washer is 1^0C. The equation (3) can be used for practical purposes.

$$(DB_2 - DB_1) = ((3.39\,H)/Q) + 0.52 \quad (3)$$

Once the RH to be maintained is decided, the quantity$(DB_2 - DB_1)$ is fixed. In other words, once the inside RH is fixed the minimum dry bulb temperature in the condition space is determined by the Wet Bulb Temperature of the outside air. It is not possible to go below this Dry Bulb Temperature unless refrigeration is used.

2.1. Need of Refrigeration

In case the Wet Bulb Temperature of outside temp is 35 degrees and if the % RH to be maintained inside the mill is 60%, then Dry Bulb Temperature of the conditioned space should be 43.5 degrees. It is not possible to reduce this temperature as long as RH is to be maintained around 60%. Under this circumstance, refrigeration process is required to bring down the Wet Bulb Temperature of the air inside, so that 60% RH can be maintained at lower Dry Bulb Temperature.

It is obvious that the mechanical behaviour of textile fiber is quite sensitive to their temperature. Besides rupture characteristics the stiffness and yielding are susceptible to the temperature variations. The appropriate humidified environment guarantees an increase in productivity and, in case of adiabatic humidification, the significant cooling of the environment takes place. These conditions furthermore guarantee a decrease in atmospheric dust. Because dust and fiber in the air are reduced as water droplets increase their weight and bring them down to the floor. This further improves the conditions of the work environment and reduces the maintenance times involved in cleaning the filters. Another benefit is that the breakage of threads requires time-consuming manual interventions in the textile processing industry. When the RH is below 50%, there is a reduction in the strength and elasticity of the threads. In contrast, increasing the RH to about 70% reduces breakages by around 40% and increases the productivity. The atomization of water directly into the room both ensures the required RH and provides adiabatic cooling due to the heat absorbed by the water when evaporating [4]. A typical application with the atomization of 100 l/h of water removes around 70 kW of heat from the air. Imprecise humidity control causes dimensional changes and makes certain processes more difficult, such as cutting the fabrics to size. Thread and fibers remain flexible help improve the process efficiency. In addition, the correct humidity level eliminates the problem of electrostatic charges, otherwise it may result into an electrical discharges and sticking of the threads. The reduction in the static electricity prevents clinging materials. However in India the climate is worm which does not demand for refrigeration. Recommended temperature and humidity values for various textile applications are given in table-1[4].

Table-1: Recommended temperature and humidity values

Material	Application	Air Temperature (°C)	RH (%)
Cotton	-	20 to 25	60 to 70
Wool	Carding/Combi	20 to 25	65 to 80
	Ring Spinning	20 to 25	55 to 60
	Weaving	22 to 25	55 to 65
Linen	Carding	20 to 25	50 to 60
	Spinning	20 to 25	60 to 70
	Weaving	20 to 25	70 to 75
Perlon/Nylon	-	25 to 27	65 to 70
Ribbons	-	22 to 25	70 to 75
Knitwear	-	20 to 25	50 to 60
Carpets	-	20 to 25	65 to 70

2.2. Fuzzy Conditioning Approach

Moisture in atmosphere has a great impact on the physical properties of textile fibers and yarns. RH and temperature will decide the amount of moisture in the atmosphere. High RH in different departments of spinning is not desirable. It will result in major problems. But on the other hand, a high degree of moisture improves the physical properties of yarn and help increase the process efficiency in the Textile Industry. Moreover it helps the yarn to attain the standard moisture regain value of the fiber. Yarns sold with lower moisture content than the standard value will result in monetary loss [5]. Therefore the aim of conditioning is to provide an economical contrivance for providing the necessary moisture in a short time in order to achieve a long lasting improvement in the product quality.

In these days there is a dramatic change in the production level of weaving and knitting machines, because of the sophisticated manufacturing techniques. Yarn quality required to run on these machines is extremely high. In order to satisfy these demands without altering the raw material, it was decided to exploit the physical properties inherent in the cotton fibers. Cotton fiber is hygroscopic material and has the ability to absorb water in the form of steam. It is quite evident that the hygroscopic property of cotton fibers depends on the RH. Higher the humidity more is the moisture absorption. The increase in the relative atmospheric humidity causes a rise in the moisture content of the cotton fiber however non-lineally. The RH affects the properties of the fiber via the moisture content of the cotton fiber. The fiber strength and elasticity increase proportionately with the increase in humidity. If the water content of the cotton fiber goes high, the fiber swells, resulting in higher fiber to fiber friction in the twisted yarn structure. This positive alteration in the properties of the fiber will again have a positive effect on the strength and elasticity of the yarn and hence on the final product. Based on the past investigations on the Temperature and RH in the textile mills some recommendation have been made as follows-

1) Currently textile conservators tend to advise ranges for temperature (60-70 ^{0}F / 15-20^{0}C) and RH (40-60%) rather than single target figures. Slow, seasonal change is recommended to transition between seasonal ranges.
2) Textiles are often part of composite artifact where heterogeneous material conditions are involved with variety of process techniques. The specific homogeneous subgroups of textiles may benefit from imprecisely defined narrow ranges for temperature and RH and permit these recommendations suggest the feasibility of Fuzzy Logically implementable control strategies.

While devising the Fuzzy Inference System for Environment Condition Monitoring and Control the factors taken into consideration are as follows-

2.2.1. Relationship Between Temperature And Rh

1. For a fixed amount of moisture in a fixed space, higher the temperature more the water the air can hold, so the RH will be reduced as the temperature rises. For a fixed amount of moisture in a fixed space, the lower the temperature, the less moisture the air can hold; the humidity relative to its capacity to hold moisture is increased, so the RH will rise.
2. Natural fiber absorbs moisture quickly and desorbs moisture slowly. Generally absorption to equilibrium occurs within hours and desorption to a lower RH equilibrium takes weeks under normal conditions. In other words, natural fibers act as their own *buffers* to changes in RH.
3. Natural fibers approaching equilibrium with RH exhibit a hysteresis effect. The amount of moisture in the fiber at the equilibrium point will be different depending upon whether equilibrium is approached from a point above it or below. Typically the moisture content of the fiber at the point of equilibrium will be higher when the fiber has previously been wet (100%) and lower when the fiber has been bone dry (0%).

2.2.2. Responsiveness Of Textile Materials To Changes In Temperature And Rh

1. Fibers gain or lose moisture to the environment.
2. A rapid cycle of high and low humidity causes the most damage over time. The risk of damage is greater with short and extreme cycles. Slow, seasonal change within recommended ranges is acceptable.
3. Severely degraded textiles are at greater risk of damage from low RH than less degraded textiles.
4. Changes in RH can cause changes in the dimension and shape of the textile/fiber and can catalyze the chemical reactions causing the damage.
5. Higher temperatures speed up the rates of deterioration by adding energy to accelerate chemical reactions.

2.2.3. Responsiveness Of Associated Materials To Changes In Temperature And Rh

1. Associated materials that are part of a textile (e.g. paint, embroidery, beads, machinery parts, accessories etc) may respond at different rates to changes in temperature and RH.
2. Mounts and stabilization materials associated with textiles may respond at different rates to changes in temperature and RH. When a textile is restrained either externally or internally wide fluctuations in RH that cause significant shrinkage of the textile are likely to cause irreversible damage.
3. Hygroscopic storage materials buffer the textiles stored within them from changes in RH.

2.2.4. Role of temperature and RH on other conditions

1. At about 68^0F (20^0C), RH above 65% and lack of air circulation are likely to promote mold growth. However, if mold growth is already established, or if a textile has a high equilibrium moisture content, then growth can occur even at lower RH.
2. RH above 65% provides an environment hospitable to most insect pests.
3. High temperatures and/or high RH can accelerate chemical reactions. If textiles are in contact with materials that are incompatible in terms of their respective pH values undesirable reactions may occur, especially in the presence of high temperature or RH.

2.3. Environmental Parameter Sensing Scheme

The overall schematic of Environmental Parameter Sensing in Textile Industry is shown in fig.1. This is simple and complete solution for controlling humidity and cooling the air in a textile factory. The pressurized water is atomized into very fine droplets and introduced into the air, which are absorbed thereby humidifying and cooling the environment. *Humidity probe* can be installed up to 200 meters away from the humi-fog station *Atomizer with fans* is atomizing nozzles and tangential fan that creates a flow of air to carry the droplets. *Humi-fog station* contains the Electronic Controller that manages the humidification system automatically, and the volumetric pump that delivers water at high pressure to create a very fine spray. The system may be have connectivity with optional supervisor i.e. computer equipped with the database management, serial communication and navigation software.

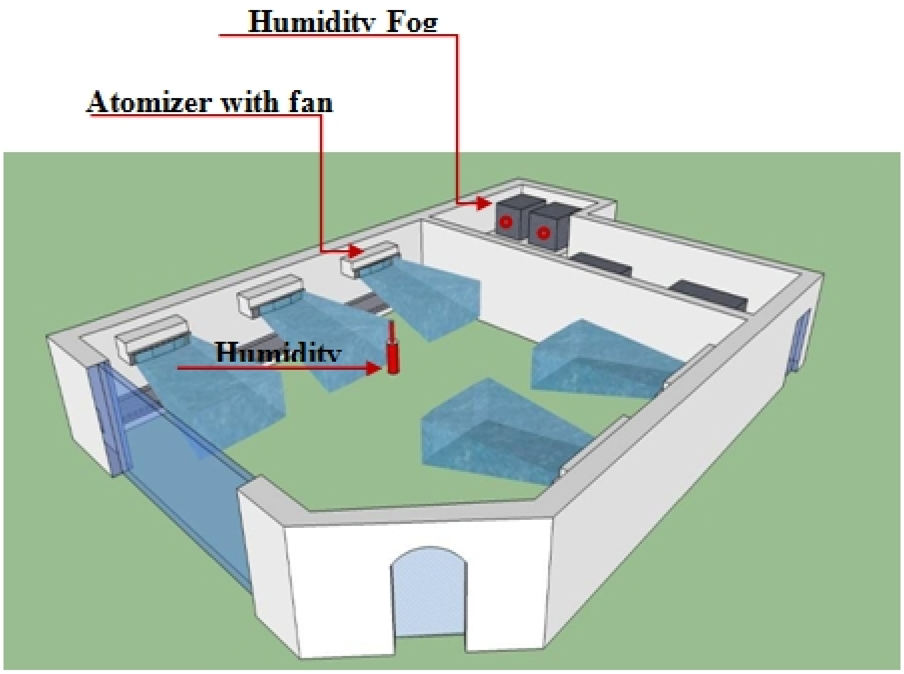

Fig. 1: Environmental parameter sensing scheme

2.3.1. Air Washer System

Clean air that is free from dirt, debris, fibers and closely maintained to desired limits of temperature and humidity is a vital necessity to the Textile Industry. Because of this need, the Textile Industry is one of the largest industrial users of air washing equipment. The use of air-washing equipment in the Textile Industry is more difficult to understand than in most other industries since there are so many different textile processes and different combinations of these processes that present in one plant. Air washers are utilized throughout the various processes in cotton mills where raw cotton is processed into woven cotton fabric. Air moving devices are always divided into two groups- one for Return Air and other for Supply Air. The return air fans return the air to the plant room from where it may circulated or exhausted in the mill, while the supply air fans supply air to the mill from the plant room. Air washer is a device for intimately mixing water and air. The intimate contact between these two elements is best brought about for this application by drawing air through a spray chamber in which atomized water is kept in transit.

3. FIS FOR ENVIRONMENT CONDITION DETERMINATION

The Fuzzy Inference Scheme employed in Temperature and Humidity is based on the individual rule firing where contribution of each rule is evaluated and overall decision is derived. The current values of temperature and humidity are provided to the FIS of Environment Condition Monitoring System, which derives the output of the current environment condition with the help of the Rulebase and the database of FIS. The FIS of Environment Condition Determination is shown in Fig. 2. Membership functions represent the meaning of linguistic values of Temperature and Humidity and Labels of the fuzzy sets represent the linguistic values of variables. Fig. 3 shows the membership functions of the input variables: Temperature, Humidity and the output variable: Environment condition.

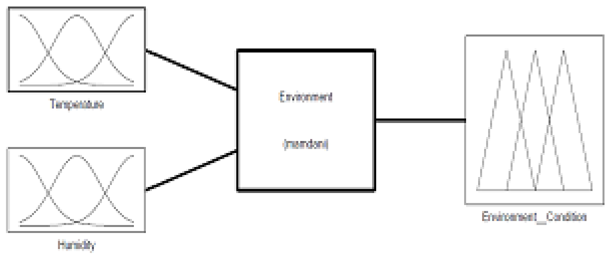

Fig. 2: FIS of Environment

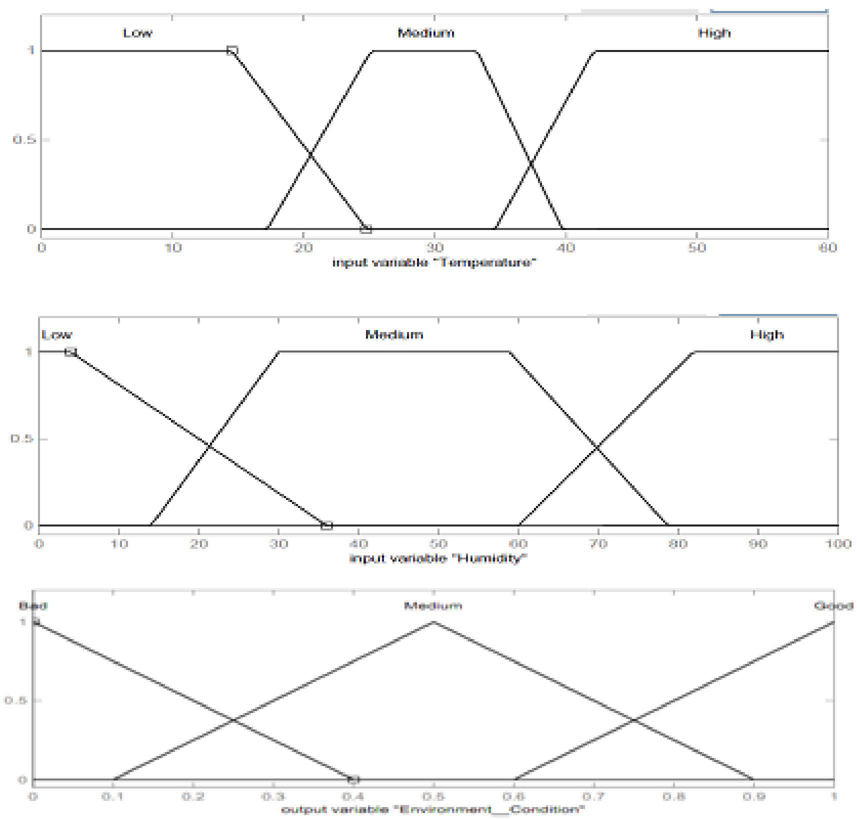

Fig. 3: Membership functions of Temperature, Humidity and Environment Condition

3.1. Fuzzy Rule Base

Inference rules were developed which relate the two inputs to the output. They are summarized in the Table 2. As seen from the table, there are nine rules. For example, if the temperature is 'Medium' and humidity is also 'Medium' then the Environment_condition is 'Good'.

		Temperature		
		LOW	MEDIUM	HIGH
Humidity	LOW	***Bad***	***Bad***	***Bad***
	MEDIUM	***Bad***	***Good***	***Bad***
	HIGH	***Bad***	***Medium***	***Bad***

The rule base can further be made small as follows-

1. **IF** *Temperature* or *Humidity* is *LOW* **THEN** *Environment_condition* is **Bad**
2. **IF** *Temperature* or *Humidity* is *MEDIUM* **THEN** *Environment_condition* is **Good**
3. **IF** *Temperature* is *MEDIUM* and *Humidity* is *HIGH* **THEN** *Environment_condition is* ***edium***
4. **IF** *Temperature* is *HIGH* **THEN** *Environment_condition* is **Bad**

4. ENVIRONMENT CONDITION MODELING

Fig 4 shows the Environment Condition determination Simulink model for the testing of the system performance by providing the different type of inputs. The model is designed to view the resultant output of FIS while provided with the constant Temperature and variable Humidity, so that system can thoroughly tested. Different Simulink models are designed to simulate the

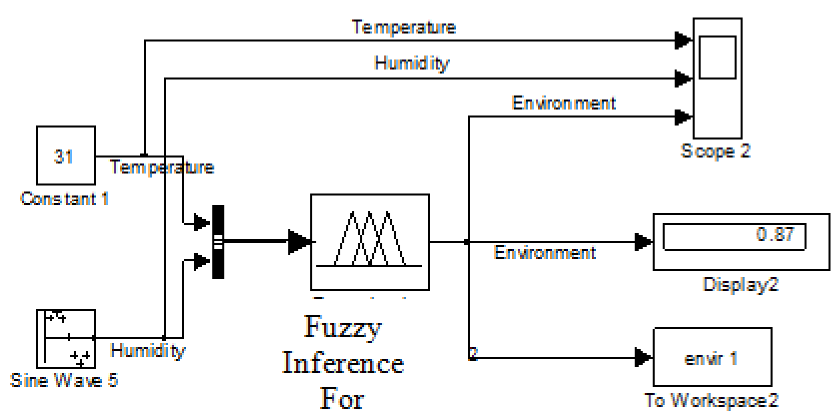

Fig. 4: Simulink Model for Environment condition determination with constant temperature

Environment conditions of textile industry. The fig. 5 shows model with constant Humidity and variable Temperature. And the fig. 6 shows model with variable Temperature and Humidity.

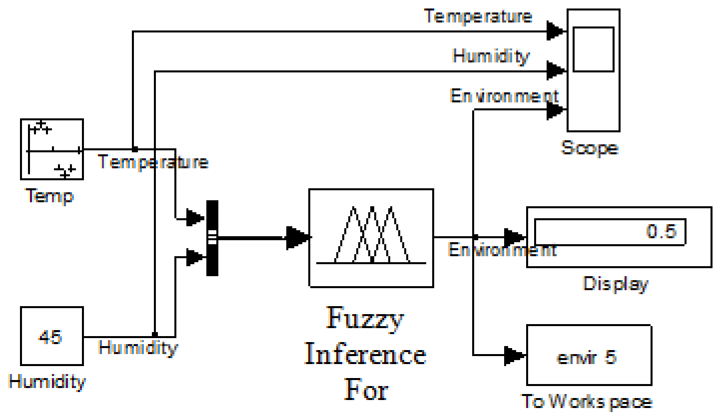

Fig. 5: Simulink Model for Environment Condition determination with constant Humidity

Having number of models with slight variation in output parameter makes it handy to retune and re-simulate them to get the best appropriate model which closely matches the expected real-time results. For simulation purpose the inputs of Temperature and Humidity were provided simultaneously to the different models. To make and achieve all possible simulation conditions the both input were made of as sine wave inputs with different frequencies. The expected results were analyzed with different variation

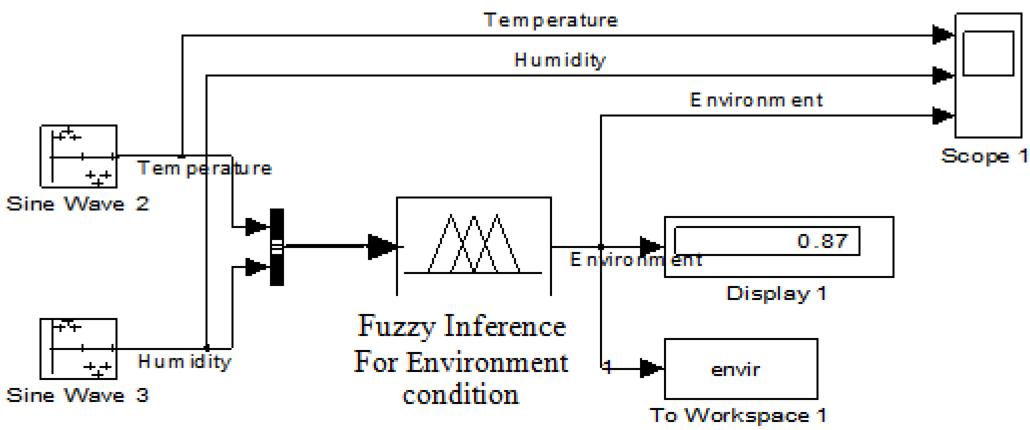

Fig. 6: Simulink Model for Environment condition determination with variable input

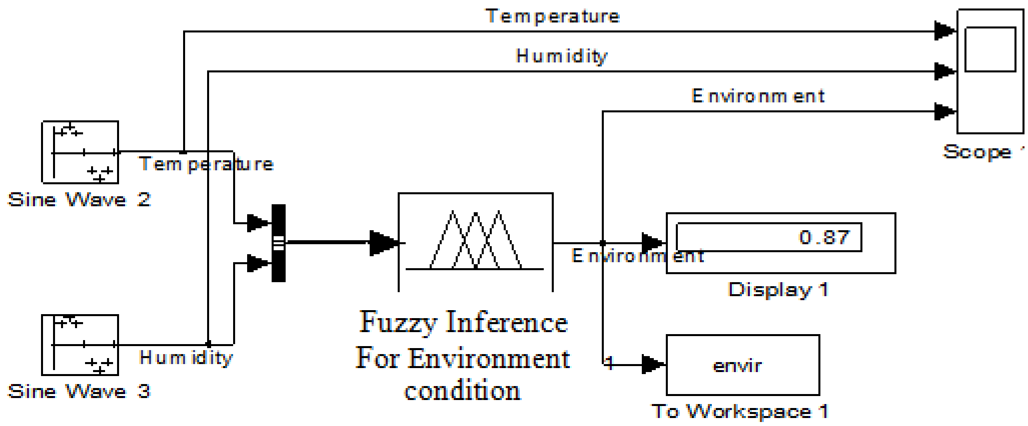

Fig. 6: Simulink Model for Environment condition determination with variable input

in frequencies and amplitude of the Temperature and Humidity so that full range of output could be achieved.

4.1. Rule Viewer

The rule viewer of environment condition is shown in Fig. 7. The nine rules are developed for FIS of environment condition. Different conditions were generated manually in the rule view and for simultaneous evaluation have been designed and analyzed. Fig. 7 shows the rule 8 and rule 9 are fired and environment condition is 'Good' for temperature medium and humidity also 'Medium'. For medium temperature and high humidity the environment condition is 'Medium'. For other cases the environment condition is 'Bad' which can be viewed from rule viewer of MATLAB toolbox.

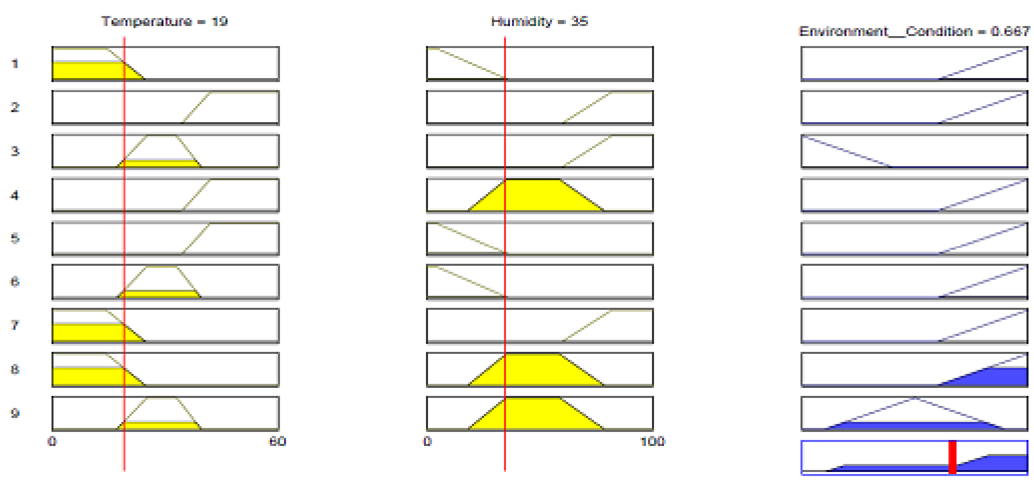

Fig. 7: Rule Viewer of Environment Condition

5. HARDWARE IMPLEMENTATION

Fig. 8 shows the experimental setup for Environment Condition monitoring and Fig. 9 shows the circuit diagram of Environment Data Collector. This circuit includes the microcontroller board with Temperature sensor and humidity sensor. The signal conditioning is an amplifier built around op-amp LM358. The temperature of the environment was measured with an LM-35 sensor. The LM-35 sensor is a linear component that can produce 10 mV/$1^{0}C$ [7]. The temperature signal was magnified and transferred to inbuilt ADC of microcontroller. The humidity sensor SY-HS 220 is used for humidity measurement [8].

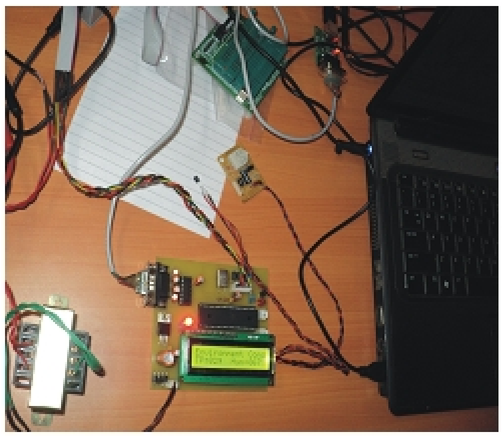

Fig. 8: Photograph of Experimental Setup of Environment Condition

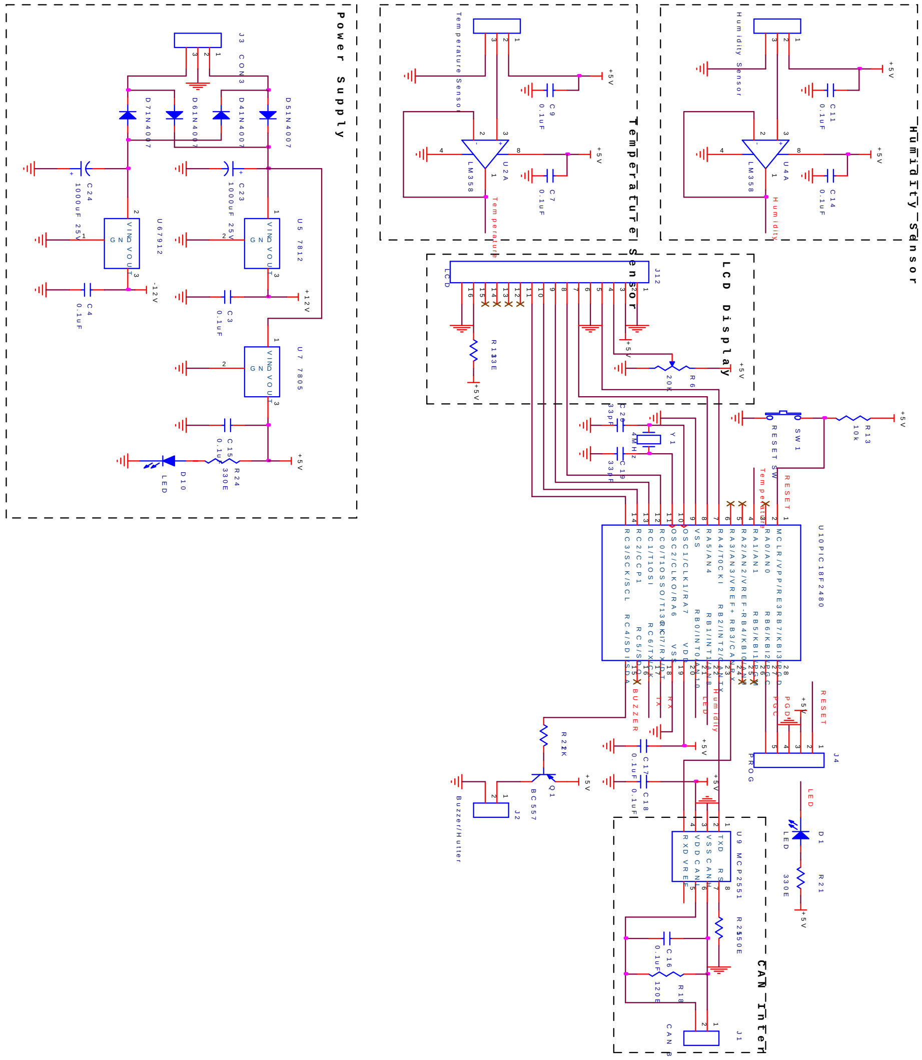

Fig 9: Circuit Diagram of Environment Data Collector

6. RESULTS AND CONCLUSIONS

6.1. Simulation Results of Environment Condition Modeling

Good quality production of cloth recommends that temperature should be medium and the humidity should be high enough. Fig. 10 shows the Simulink model for Environment Condition Determination with constant temperature. The temperature is set in Medium range and the Humidity is kept variable. The number of sets of data pertaining to temperature and humidity are applied to Fuzzy Logic Inference module that develops output to indicate the status of 'Environmental Condition'. For high humidity if the temperature is medium or low then the output 'Environmental Condition' is 'Good', but if the temperature is also high the 'Environmental Condition' turns out to be 'Bad'. According to the knowledge reciprocated in the rule base the environment condition transits from 'Good' to 'Bad' and vice versa encompassing the all possible conditions of environment as illustrated in waveforms shown in fig. 11.Simulink Model for Environment Condition determination with constant Humidity with temperature variable and output results are shown in Fig. 12 and Fig.13.

Similar Simulink Model for Environment Condition determination with both Humidity and temperature variable encompassing all possible environmental conditions and subsequent output results are shown in Fig.14 and Fig.15.

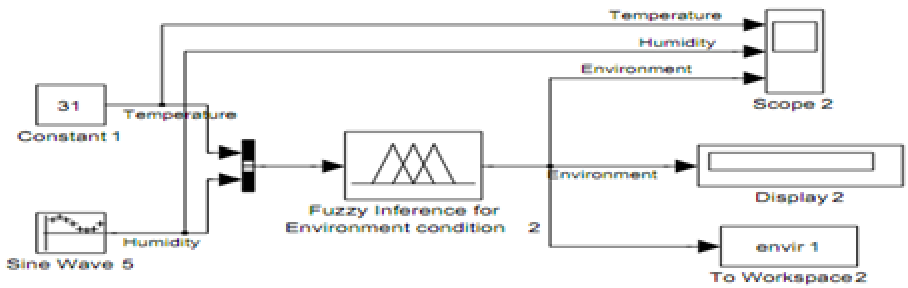

Fig. 10: Simulink Model for Environment condition determination with constant temperature

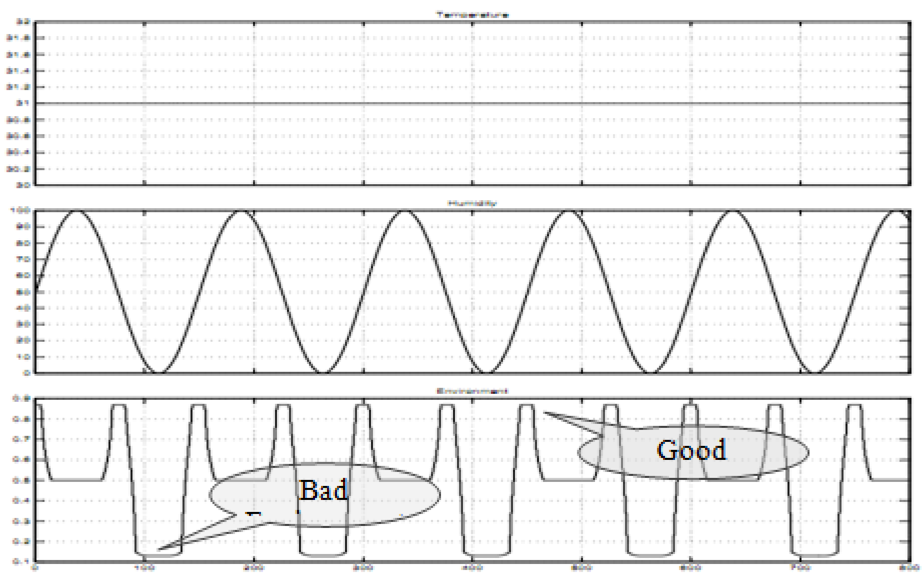

Fig. 11: Simulation results with Temperature constant for Environment determination

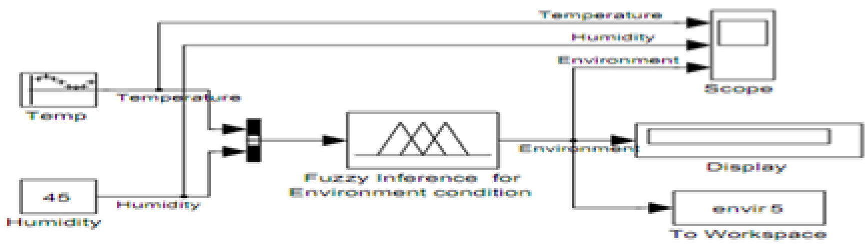

Fig. 12: Simulink Model for Environment Condition determination with constant Humidity

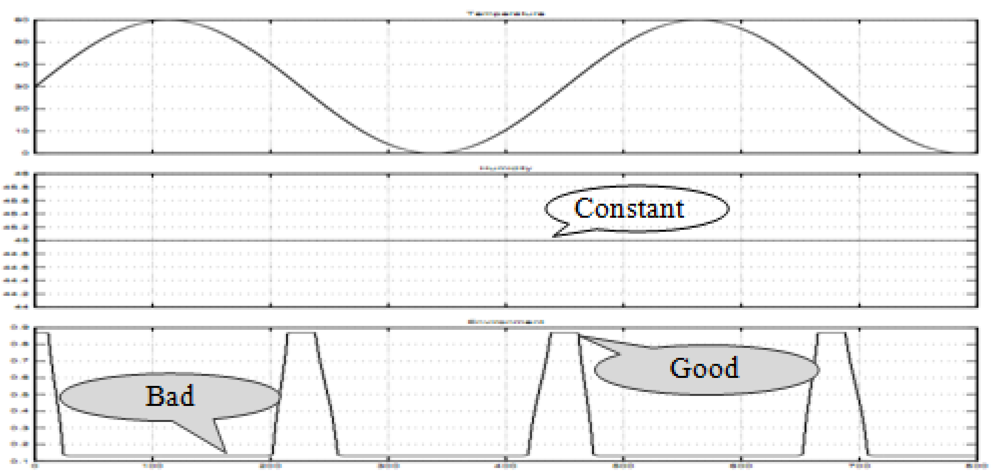

Fig. 13: Simulation results with Humidity constant for Environment determination

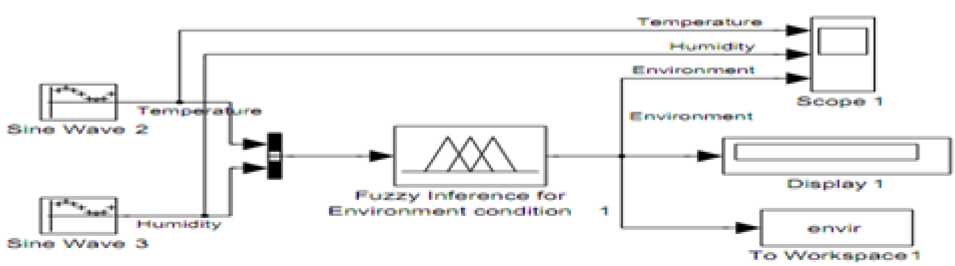

Fig. 14: Simulink Model for Environment condition determination with variable input

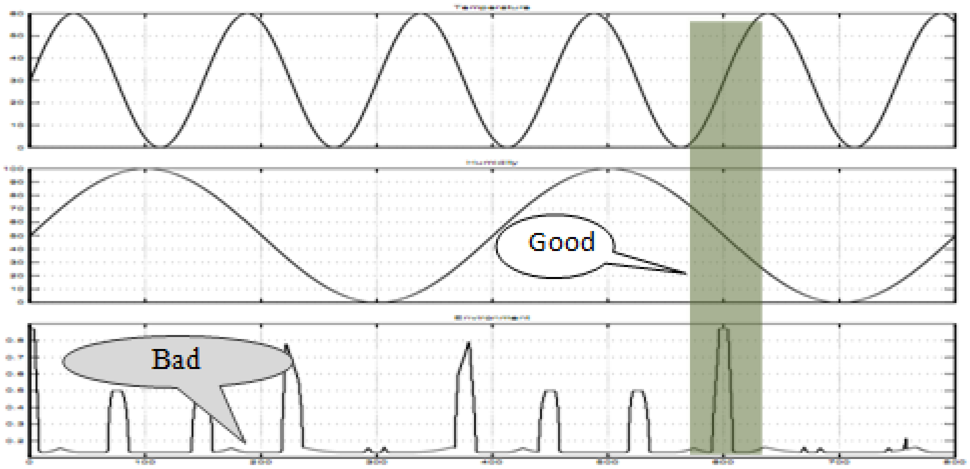

Fig. 15: Modeling Results for Environment determination with Variable Environment Parameters

6.2. FIS Results with Real time Data for Weaving Section

After simulation of the FIS with simulation model and getting the satisfactory results the FIS was presented with the real time data captured from different units of the Textile Industry. The data provided by the Central Node is captured from the PC serial port and stored in the MATLAB's workspace as a variable for the evaluation purpose. The data is then presented to the Environment Simulink model to generate the Environment condition output implicated by the FIS. Figures 16, 17 and 18 show the result in the form of Environment Condition at different nodes under various conditions.

Fig. 18 shows the all possible conditions of Environment health those are forcefully generated to test the functionality and reliability of the system with the real time implementation.

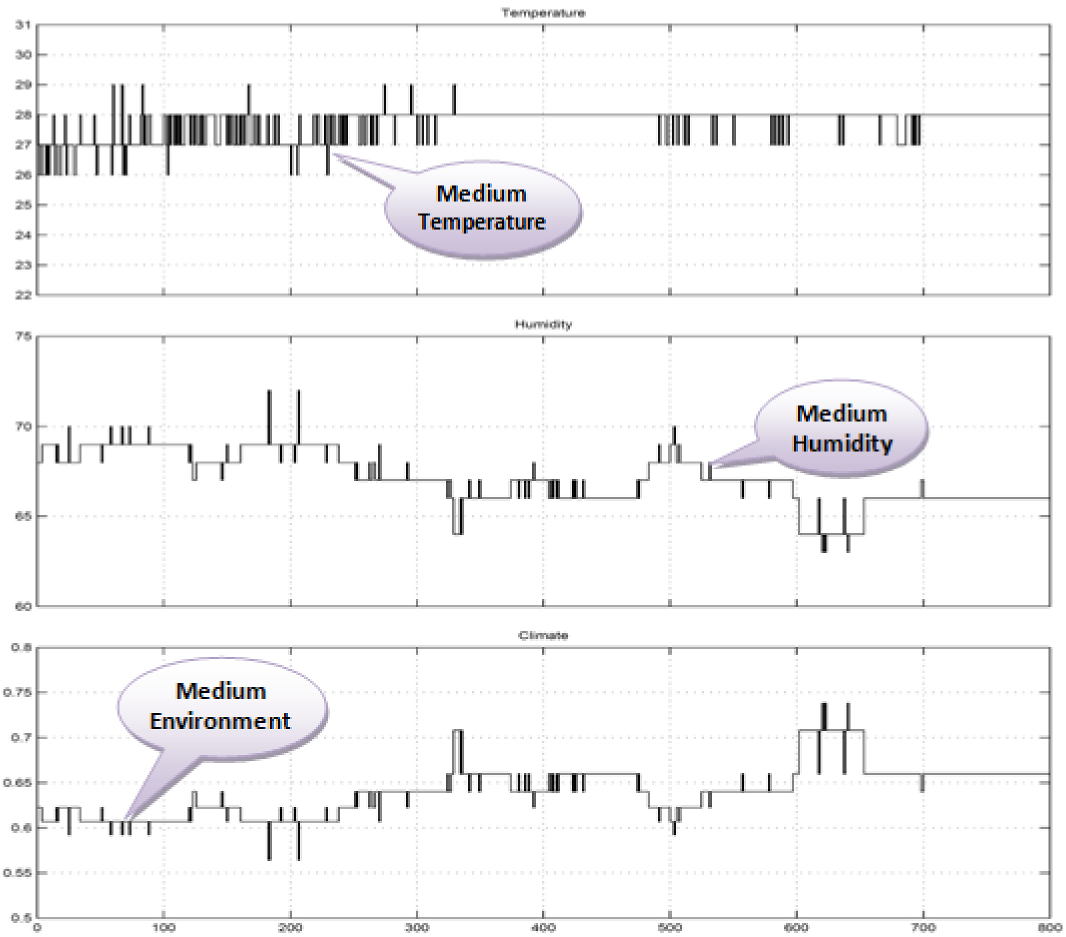

Fig. 16: Simulation Results of the Environment Condition Determination Model with Real-time data input Set 1

The Green band shows the healthy operating conditions, whereas the Red band shows the worst case conditions which are emulated by closing the ventilator and turning off the exhaust fans of the machine operating area and blocking the inside air circulation completely.

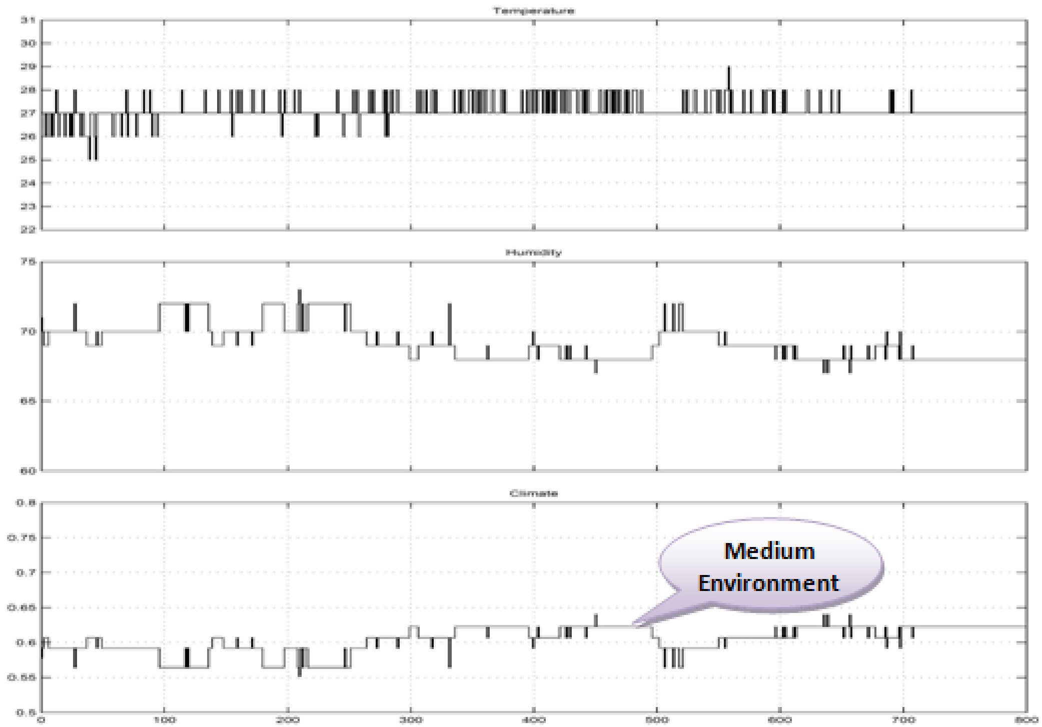

Fig. 17: Simulation Results of the Environment Condition Determination Model with Real-time data input Set 2

REFERENCES

[1.] Woo S. S., Shalev, I. and Barker, L., "Heat and moisture transfer through nonwoven fabrics, Part II: Moisture diffusivity", Text. Res. J., 64 (4), 190-197 (1994).

[2] Collier, Ann M, A Handbook of Textiles, Pergamon Press, pp. 258, ISBN 0080180574, 0080180566, 1970.

[3] Matsumara and Ihizuka Y, The effect of temperature on development of Bombyx mori L. Rep. Nagano Seri. Experimental Station, Jpn: 1929.

[4] Brooker, D.B., Bakker Arkema, F.W. and Hall, C.W., Moist air properties, pp. 24-48. Drying Cereal Grains. 2nd ed. Avi Publ. Co., Westport, CT., 1975.

[5] Prade H. and Negoita C. V, Fuzzy Logic in Knowledge Engineering. Verlag Tuv Rheinland, Koln., 1986.

[6] Misza Kalechman, Practical MATLAB Applications for Engineers - CRC Press.

[7] National Semiconductor, LM35 Temperature Sensor Datasheet.

[8] Humidity Sensor Module SY-HS-220 Datasheet.

[9] Getting started with Matlab – The MathworksTM