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Development of Fabric Feel Tester Using Nozzle Extraction Principle

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Abstract
The present paper deals with development of an instrument to measure fabric handle characteristic objectively. A nozzle extraction method for objective measurement of fabric handle characteristics has been developed. The instrument measures the force exerted by the fabric being drawn out of the nozzle axially as well as on the periphery of the nozzle i.e. radials. These two forces in perpendicular directions have been used to determine the handle characteristics of fabric. Accuracy and reproducibility of the newly developed testing instrument is verified. It has been observed that the fabric extraction force and load time graph obtained from the instrument gives valuable information to draw some meaningful conclusion regarding the nature of fabric and the handle characteristics of the fabric. The preliminary test results indicate that fabric feel can be comprehensively judged from a single test from the instrument objectively. Cost and time involved in testing is also less compared to other existing instruments.

Keywords: Nozzle extraction, fabric handle, Extraction force, Radial force, Fabric feel

I. Introduction

Handle characteristics of fabric is better known as fabric handle is a characteristics of fabric defined as the subjective assessment by sense of touch. It is characterised by the subjective judgment of roughness, smoothness, harshness, pliability, thickness, etc. Judgments of fabric handle are used as a basis for evaluating quality, and thus for determining fabric value, both within the textile, clothing, and related industries and by the ultimate consumer. Studies of fabric handle may be of major commercial significance if they, for example, assist in explaining handle assessment or provide a means of its estimation based on subjective or objective measurement [1]**.**

Subjective assessment is the traditional method of describing fabric handle based on the experience and variable sensitivity of human touch [2]. In subjective assessment method materials are touched, squeezed, rubbed or otherwise handled to get feel of the materials and then quantify or rank them accordingly from the sensory reaction. In the clothing industry, professional trained handle experts sort out the fabric qualities.

On the other hand, in objective measurement, fabric sample is tested for some specific mechanical, thermal, etc. properties. These properties are then combined suitably and a single value arrived at to express the fabrics hand characteristic. Objective evaluation of the hand of apparel fabrics was first attempted by Peirce [3] as early as 1930. Fabric hand or handle characteristics of textile fabric is a complex function of human tactile sensory response towards fabric, which involves not only physical but also physiological, perceptional and social factors as explained by various researchers [3-8].

The credit for providing a feasible instrumental technique to evaluate fabric hand value goes to Kawabata [4]. The system of fabric evaluation provided by Kawabata better known as Kawabata Evaluation System (KES) comprises of a series of instruments to measure textile material properties that enable predictions of the sensory qualities perceived by human touch. Thus KES is the first of its kind to provide objective measurement of fabric hand. The principle of this system is to combine 16 mechanical properties measured by the instrument of a fabric directly to its Japanese hand preference through multivariate statistical regression analysis. Due to some serious drawbacks like Japanese hand preference and cost involved, the instrument failed to offer an adequate solution for fabric hand assessment in countries other than Japan, and there are still many other problems associated with this system as described in the papers [9-11]

The Fabric Assurance by Simple Testing (FAST) method [12] by Australian scientist also came up for evaluating handle characteristic of fabric. Both KES and FAST systems measure similar parameters using different instrumental methods.

However, although objective assessments are precise from a mechanical point of view, these methods have not been commonly used in the textile and clothing industry because of its complex nature, time and cost inolved. Even today, many companies still use subjective evaluation to assess fabric properties. The main reason for this situation is the repetitive and lengthy process of measurement, the lack of knowledge for a good interpretation of the test results and the cost of the instrument [13].

In recent past various researcher have attempted to overcome above mentioned limitations and developed a simple method which can easily measure the fabric handle value better known as ‘nozzle extraction’ method [14-16] of fabric evaluation. In this method, a specimen of fabric is extracted through a nozzle and the force generated while withdrawing a fabric specimen through the nozzle is measured. The extraction force generated due to multidirectional deformation of the fabric with respect to bending, shear, tensile, compression, friction etc. Ishtiaque et al. [17] studied a simple nozzle extraction method for measuring objectively. Their method was based on the use of a simple attachment fitted to a tensile testing machine and measures the force generated while extracting a circular fabric specimen through a nozzle. They have reported that different testing variables, like presence of supporting plate, extraction speed and shape of the specimen, have significant effect on peak extraction force, whereas the number of pass does not have any specific effect on the extraction behaviour of fabric.

In the present study, an attempt has been made to develop a simple instrument based on nozzle extraction principle on the basis of experience of the previous researchers. The focus of the said development is to minimise external influencing factors in the process of measurement. Also efforts have been made to study the reproducibility of testing, which is a major concern in textile material due to its inherent nature of variability and hence low degree of reproducibility.

II. Materials and Methods

2.1 Development of Nozzle Extraction Instrument

At present there are few instruments available for evaluating fabric handle objectively. Presently, the objective is to fabricate an instrument to measure extraction force while extracting a fabric sample through a nozzle. The outline of the basic framework required for the operations is shown fig 1 and the details of some of the important parts of the instruments are shown in the subsequent figures from fig 2 to 12. In the fig 13 a photograph of the instrument is shown. The instrument has been developed with the help of Aotutest Mechanisms Pvt. Ltd., D-51, Sector-2, Noida, U.P. – 201301.

As far as details of the construction is concern, it can be seen from the drawings that some of the details are already incorporated in the drawings itself. Apart from that here is the some more elaboration of the various parts in the constructions.

It can be seen that in the fig 1 various parts are labeled as from 1 to 12. The part no. 1 is base cabinet of the instrument. It consist of all the electrical connections, mother board of various modules the details of which given later on, main computer (CPU), etc. The dimensional details of the same are given in fig 2.

Placement of load cell for radial force measurement was an important issue. Load cells should be placed in such a way, while extracting fabric, as mentioned above, there should be minimum influence of external force. To measure the radial force the nozzle is slit through the centre so that left and right radial force can be measured. The split nozzle is placed at the centre and supported by a cantilever mechanism. The base of that cantilever is on the top of the base cabinet as shown in the fig 3. The details of the split nozzle is given later on in the sequence.

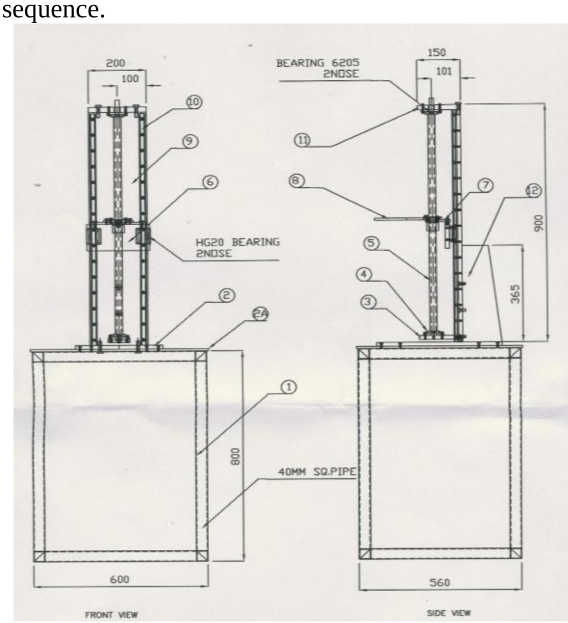

Fig 1. Line Diagram of the Instrument

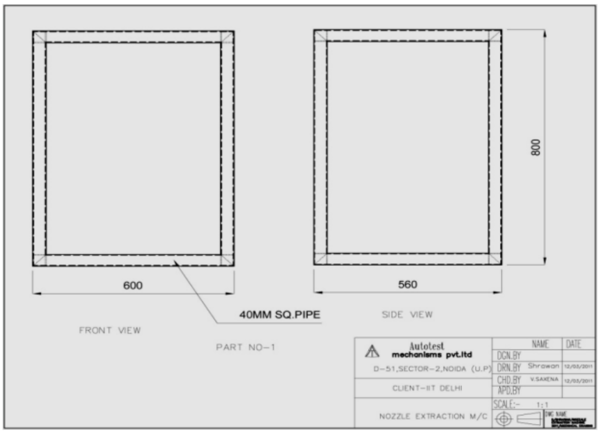

Fig 2: Base cabinet of the instrument

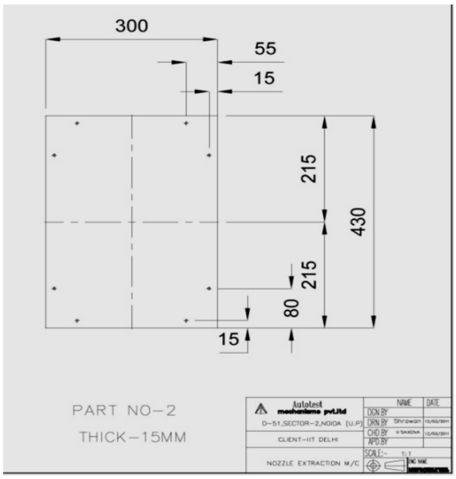

Fig 3: Load cell support base dimensions

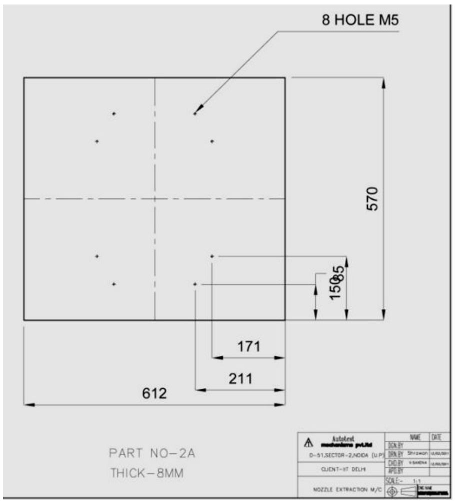

Fig 4 : Cabinet top and vertical stand base dimensions

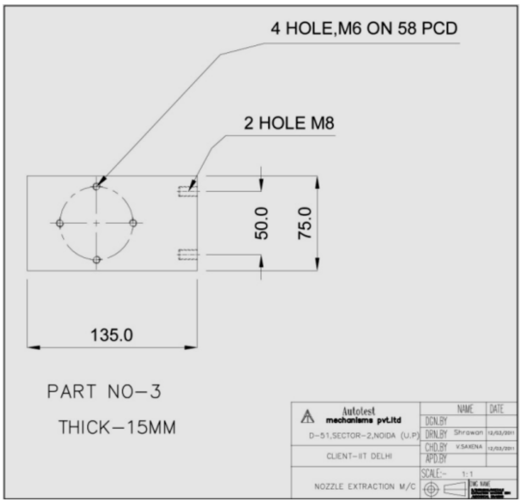

Fig 5: Vertical threaded bar stand base dimensions

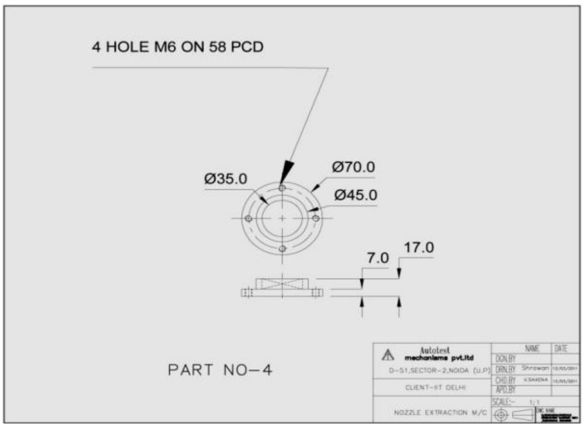

Fig 6: Vertical threaded bar stand base bolt dimensions

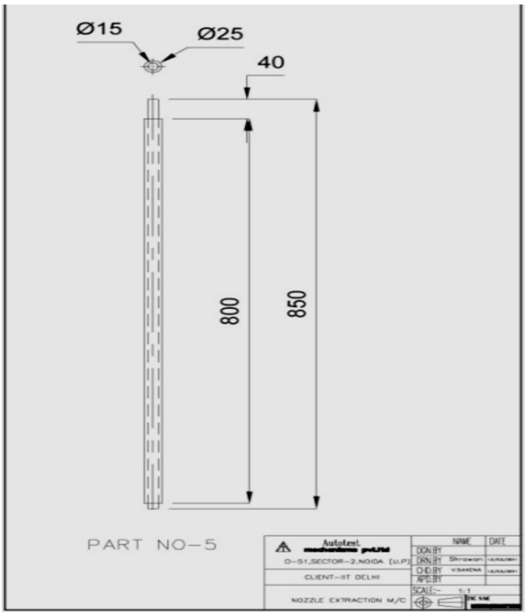

Fig 7: Threaded bar on which movable fabric holder mounted

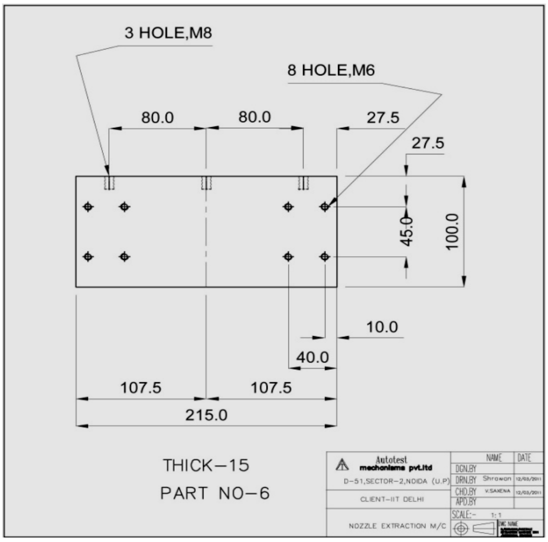

Fig 8: Clamp holder mounting dimensions

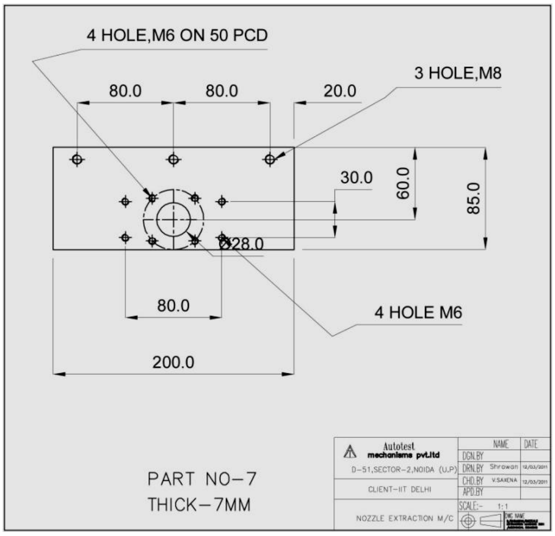

Fig 9: Clamp holder support bolt dimensions and positions

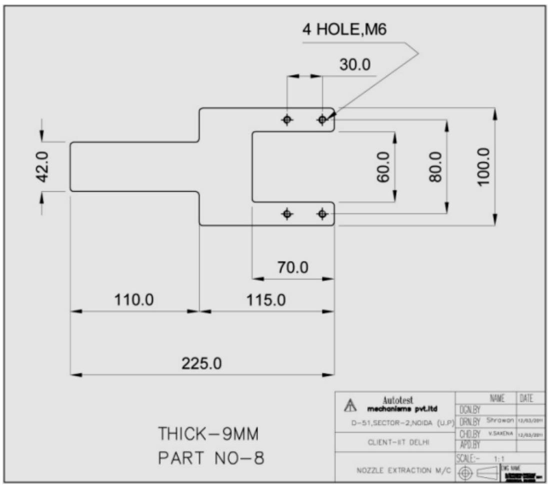

Fig 10: Cantilever support for clamp

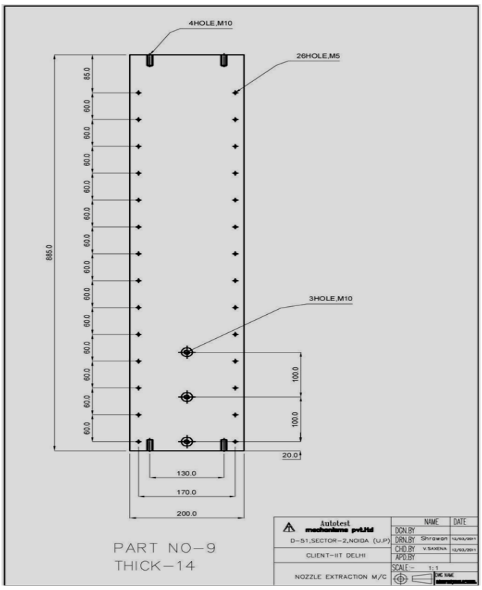

Fig 11: Side support of moving clamp

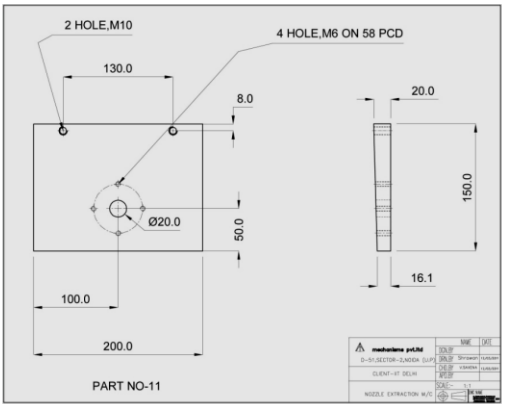

Fig 12: Computer display unit mounting

Fig 13: A photograph of the Instrument

The next task was to measure the force while it is being extracted. We need to measure the force in two directions, one in the direction of extraction (which will give us the extraction force) and second in the radial direction i.e. the force exerted by the sample on the nozzle while it is being extracted. To measure the extraction force, we attached a load cell above the clamp, bolting the clamp on its one side and the moving panel on the other. So as drive moves the panel in the upward direction, the load cell, attached to the clamp moves up and the fabric while being extracted exerts a pull force on the clamp. This force is captured by the load cell attached to the clamp and we are thus able to measure the extraction force as given in fig 14.

Fig 14: Load cell attached to clamp

To measure the radial force exerted on the nozzle by the fabric, we designed a split nozzle. To make this nozzle, we took a steel square block and a nozzle is prepared and then split it into exactly two halves. Designing of the nozzle was a big task. Nozzle should be such that it will have minimum interference of external force. Also it was kept in mind that throughout the movement of the fabric through the nozzle also there should be minimum interference of any external force or obstruction.

It can be seen from the design that the dimension of the nozzle is decided to get the uniform bending of 60° covering the full radius of a circle i.e. 360°. To study the effect of diameter it was decided to construct nozzle with different diameters. It was also thought of that for various nozzles the fundamental principle and type of bending should be kept constant. Therefore as mentioned above about the initial bending at the bottom of nozzle at 60°, the bottom opening i.e. diameter at the bottom of the nozzle kept constant at 60mm for all the nozzles, whereas the top diameter from where the final exit of the fabric takes place varied from 20mm to 30mm at an interval of 5mm. Dimensions of the nozzles are given in the fig 15 to 17. All the nozzles were made up of stainless steel and chrome plated to minimize the frictional force between the fabric and the metal while it is being extracted. It was also thought of to study the effect of surface characteristics on fabric one nozzle is manufactured of nylon and another nozzle is made up of stainless steel with corrugated surface.

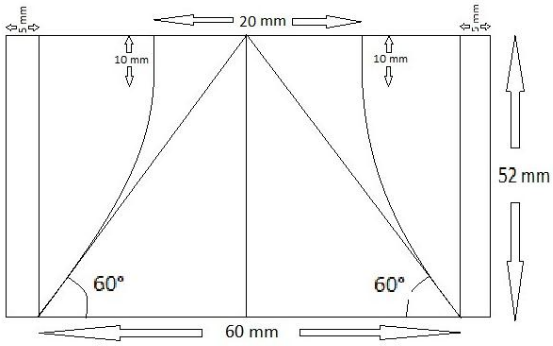

Fig 15: Nozzle with 20 mm top diameter

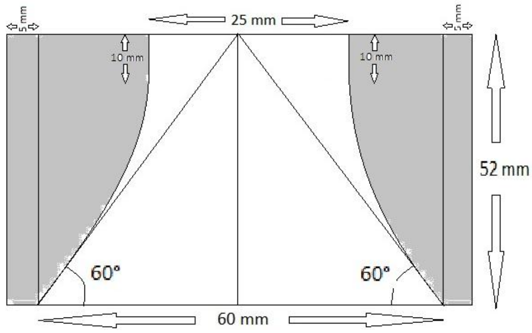

Fig 16: Nozzle with 25 mm top diameter

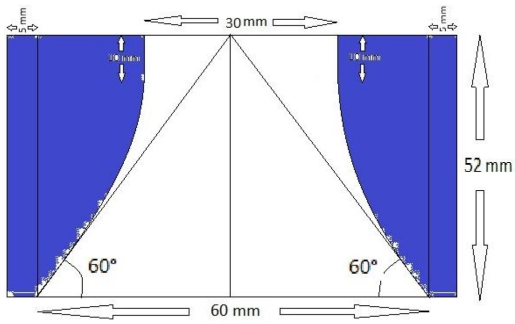

Fig 17: Nozzle with 30 mm top diameter

Once the nozzle is ready with the dimensions mentioned above it was slit in to two pieces. Then we mounted these halves on the base plate with the help of a metal piece and two load cells in the cantilever arrangements as mentioned above in the instrument drawing panels. The load cells were connected to the back of these halves and the halves were mounted such that they form a closed nozzle loop when joined as seen in the sketch from fig 15 to 17. This kind of a nozzle would provide us radial force exerted on the nozzle by the fabric in two directions, thus averaging out any variations owing to orientation of the samples while mounting. The photographs of the nozzle are given fig 18 and in fig 19 radial load cells mounted with nozzle are shown.

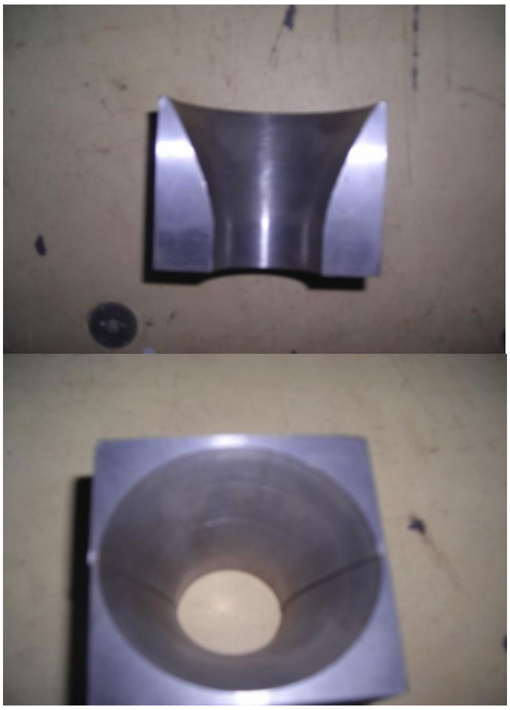

Fig. 18: Photograph of nozzle

Next very important task was to design fabric holder or clamp to hold the fabric pull out through the nozzle. The considerations was that the holder should be such that it will have minimum impact on three dimensional deformation of fabric while passing through the nozzle, at the same time there should not be any slippage throughout the test conducted. If there is any slippage during the test it will be a disastrous. Based on these considerations few designs were thought off, trials were carried out and arrived at the final design as shown in the figure 20.

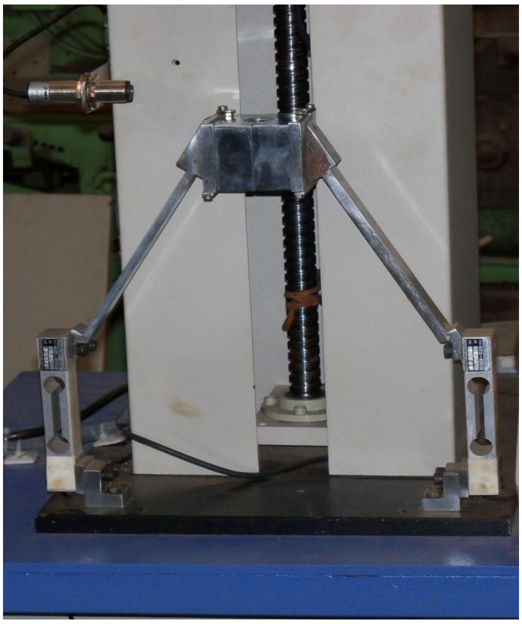

Fig 19: Radial load cell

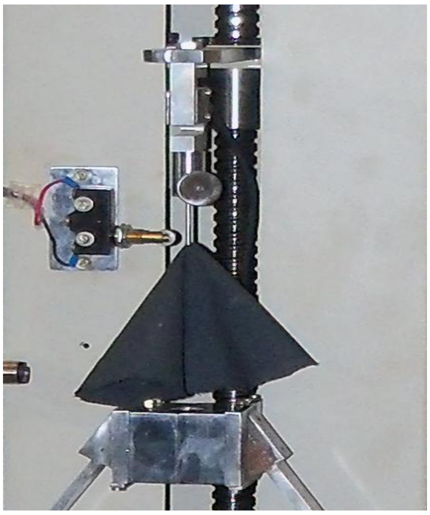

Fig 20: Fabric holder

Estimation of required traverse and the rate of traverse of the clamp are very important in this context. Initially it was proposed to use of pneumatic cylinders for the movement of the clamps, but faced with certain shortcomings of the pneumatic cylinder. It was not possible to regulate the speed with which the clamp would move while extracting the fabric from the nozzle. This was essential for the design, as it was preferred having a design that would have the liberty to change the extraction speed thus open another window of correlating the extraction forces at various speeds with the other properties of the fabric. Therefore, switched to another system and finally the mechanism adopted was a gear drive motor which moves the clamp up and down, along a guide, which is held by two C channels on both sides to prevent any alignment issues as shown in fig 1. With the gear motor drive, it was possible to regulate the speed of the clamp, ranging from 1mm/min to 200mm/min, thus lining up another variable which can be varied to check for optimum correlation as shown in fig 21.

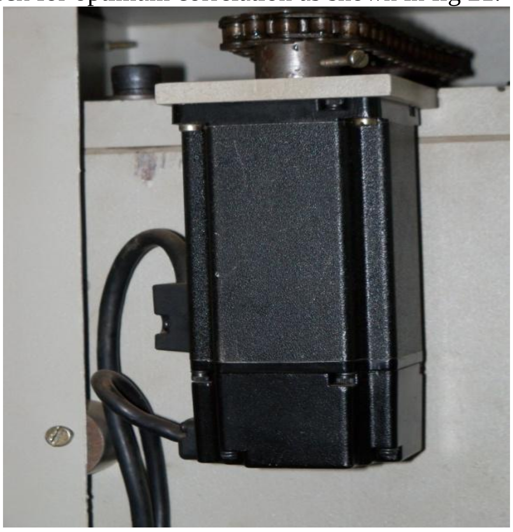

Fig 21: Motor

The next task was to convert the analog signal generated by the load cells to a digital from. LabJack device, model U3-HV used for this purpose. Fundamentally, it is a process of converting analog signal to electrical signal and then electrical signal to digital form by an analog to digital card. Therefore, in the whole process power supply is very important. Any small amount of power fluctuation will give error in reading. As envisage it was found that when the power supply was given from an ordinary line conditioner there is lot of spikes in the load cell reading. Therefore, we had to arrange a suitable high quality switched-mode power supply (SMPS) to overcome the problem.

LabJacks are USB/Ethernet based measurement and automation devices which provide analog inputs/outputs, digital inputs/outputs, and more. They serve as an inexpensive and easy to use interface between computers and the physical world. Read the output of sensors which measure voltage, current, power, temperature, humidity, wind speed, force, pressure, strain, acceleration, RPM, light intensity, sound intensity, gas concentration, position, and many more. A LabJack brings this data into a PC where it can be stored and processed as desired. Control things like motors, lights, solenoids, relays, valves, and more.

In our case the load cells used are of beam type. Generally a load cell is a transducer that is used to convert a force into electrical signal. This conversion is indirect and happens in two stages. Through a mechanical arrangement, the force being sensed by way of deforms of a strain gauge. The strain gauge measures the deformation (strain) as an electrical signal, because the strain changes the effective electrical resistance of the wire. A load cell usually consists of four strain gauges in a Wheatstone bridge configuration. Load cells of one strain gauge (quarter bridge) or two strain gauges (half bridge) are also available. The electrical signal output is typically in the order of a few millivolts and requires amplification by an instrumentation amplifier before it can be used. The output of the transducer is plugged into an algorithm to calculate the force applied to the transducer. The LabJack module is used to manage all this input/output signals.

There are different data acquisition modules of LabJack like U3, U6, UE9, U12 are available. Initially we tried with U12 and later on upgraded with U3 module with high voltage option. The U3 is newer than the U12, and in general is faster, more flexible, and less expensive. The U3 is about half the size of the U12. The enclosure can be mounted using a couple screws or DIN rail, whereas the U12 enclosure has no mounting options. Command/response functions on the U3 are typically 5-20 times faster than on the U12. The U3 has up to 16 analog inputs compared to 8 on the U12. Any channel can be measured differentially versus any other channel. Accuracy specs are better than the U12.

The U3-LV has single-ended ranges of 0-2.4 or 0-3.6 volts, and a differential range of ±2.4 volts (pseudobipolar only). The U3-HV has 12 flexible I/O capable of those same low-voltage ranges, and 4 high-voltage analog inputs with a range of ±10 volts or -10/+20 volts. The U12 has a ±10 volt single-ended input range, and differential input ranges varying from ±20 volts to ±1 volt (all true bipolar). The circuitry used by the U12 to provide those high bipolar ranges is simple and inexpensive, but has drawbacks including relatively poor input impedance and errors which are different on every channel. There are many devices on the market now that have copied the same circuitry from the U12 and have the same drawbacks.

The U3 supports input streaming with a max rate of up to 50,000 samples/second, compared to 1200 samples/second for the U12. The U3 achieves the full 12-bit resolution up to 2500 samples/second, and then as speed increases the effective resolution drops to about 10 bits due to noise. The U3 has two 10-bit digital to analog convertors (DAC) as does the U12. The DACs on the U3 are derived from a regulated voltage, whereas the U12 DACs are derived from the power supply, so the U3 DACs will be more stable. The digital I/O on the U3 use 3.3 volt logic, and are 5 volt tolerant. The U12 has 5 volt logic. The U3 can have up to 2 timers and 2 counters. The timers have various functionality including period timing, duty cycle timing, quadrature input, pulse counting, or pulse-width modulation (PWM) output. The U12 has 1 counter and no timers. The U3 has master support for serial peripheral interface (SPI), inter-integrated circuit known as I2C, and asynchronous serial protocols. The U12 does not support I2C, but does have some SPI and asynchronous support. The U3 is supported on Windows, Linux, Mac OS X, and PocketPC. The U12 has full support for Windows, limited support for Linux, and limited public support for the Mac. On Windows, the U3 uses the flexible driver which also works with the UE9. There is a specific separate driver for the U12.

Some of the exclusive special features of **U3** are listed below.

Features of LV (Low-Voltage) Version:

- 16 Flexible I/O (Digital Input, Digital Output, or Analog Input)
- Up to 2 Timers (Pulse Timing, PWM Output, Quadrature Input, ...)
- Up to 2 Counters (32-Bits Each)
- 4 Additional Digital I/O

- Up to 16 12-bit Analog Inputs (0-2.4 V or 0-3.6 V, SE or Diff.)
- 2 Analog Outputs (10-Bit, 0-5 volts)
- Supports SPI, I2C, and Asynchronous Serial Protocols (Master Only)
- Supports Software or Hardware Timed Acquisition
- Maximum Input Stream Rate of 2.5-50 kHz (Depending on Resolution)
- Capable of Command/Response Times Less Than 1 Millisecond
- Built-In Screw Terminals for Some Signals
- OEM Version Available
- USB 2.0/1.1 Full Speed Interface
- Powered by USB Cable
- Drivers Available for Windows, Linux, Mac and Pocket PC
- Examples Available for C/C++, VB, LabVIEW, Java, and More
- Includes USB Cable and Screwdriver
- Free Firmware Upgrades
- Enclosure Size Approximately 3" x 4.5" x 1.2" (75mm x 115mm x 30mm)
- Rated for Industrial Temperature Range (-40 to +85 Degrees C)

Differences with the HV (High-Voltage) Version:

- ✓ First 4 Flexible I/O are Changed to Dedicated HV Analog Inputs.
- ✓ 4 HV Inputs have ±10 Volt or -10/+20 Volt Range.
- ✓ 12 LV Inputs (Flexible I/O) Still Available, for 16 Total Analog Inputs.

Flexible I/O:

The first 16 I/O lines (FIO and EIO ports) on the LabJack U3-LV can be individually configured as digital input, digital output, or analog input. In addition, up to 2 of these lines can be configured as timers, and up to 2 of these lines can be configured as counters. On the U3-HV, the first 4 flexible I/O are replaced with dedicated high-voltage analog inputs.

The first 8 flexible I/O lines (FIO0-FIO7) appear on built-in screw terminals. The other 8 flexible I/O lines (EIO0-EIO7) are available on the DB15 connector.

Analog Inputs:

The LabJack U3 has up to 16 analog inputs available on the flexible I/O lines. Single-ended measurements can be taken of any line compared to ground, or differential measurements can be taken of any line to any other line.

Analog input resolution is 12-bits. The range of single-ended low-voltage analog inputs on the U3-LV is typically 0-2.4 volts or 0-3.6 volts, and the range of differential analog inputs is typically ±2.4 volts (pseudobipolar only). For valid measurements, the voltage on every analog input pin, with respect to ground, must be within -0.3 to +3.6 volts.

On the U3-HV, the first 4 flexible I/O are replaced with dedicated high-voltage analog inputs. The input range of these channels is ±10 volts or -10/+20 volts. The remaining 12 flexible I/O are still available as described above, so the U3-HV has 4 high-voltage analog inputs and up to 12 low-voltage analog inputs.

Command/response (software timed) analog input reads typically take 0.6-4.0 ms depending on number of channels and communication configuration. Hardware timed input streaming has a maximum rate that varies with resolution from 2.5 ksamples/s at 12-bits to 50 ksamples/s at about 10-bits.

Analog Outputs:

The LabJack U3 has 2 analog outputs (DAC0 and DAC1) that are available on the screw terminals. Each analog output can be set to a voltage between 0 and 5 volts with 10-bits of resolution.

The analog outputs are updated in command/response mode, with a typical update time of 0.6-4.0 ms depending on communication configuration. The analog outputs have filters with a 3 dB cutoff around 16 Hz, limiting the frequency of output waveforms to less than that.

Digital I/O:

The LabJack U3 has up to 20 digital I/O channels. 16 are available from the flexible I/O lines, and 4 dedicated digital I/O (CIO0-CIO3) are available on the DB15 connector. Each digital line can be individually configured as input, output-high, or output-low. The digital I/O use 3.3 volt logic and are 5 volt tolerant.
Command/response (software timed) reads/writes typically take 0.6-4.0 ms depending on communication configuration. The first 16 digital inputs can also be read in a hardware timed input stream where all 16 inputs count as a single stream channel.

Timers:

Up to 2 flexible I/O lines can be configured as timers. The timers are very flexible, providing options such as PWM output, pulse/period timing, pulse counting, and quadrature input.

Counters:

Up to 2 flexible I/O lines can be configured as 32-bit counters.

I/O Protection:

All I/O lines on the U3 are protected against minor over voltages. The FIO lines can withstand continuous voltages of up to ±10 volts, while the EIO/CIO lines withstand continuous voltages of up to ±6 volts.

High Channel Count Applications:

By using USB hubs, many LabJacks can be interfaced to a single PC, providing an inexpensive solution for high channel count applications.

OEM Version:

The U3-LV-OEM or U3-HV-OEM includes the board only without the enclosure and without most through-hole components. See Section 2.12 of the U3 User's Guide for more information.

The electrical interfaces diagrams of the instrument with LabJack are shown in the following fig 20 to 23 as mentioned above. The input output voltage ranges also shown in the said diagrams. Also power factors are mentioned in many places as required.

The details of electrical diagrams are shown in fig 22 to 25. In the subsequent three figure i.e. fig 26, 27 & 28 actual photographs of main board, LabJack U3-HV and A2D card interface with LabJack respectively are shown.

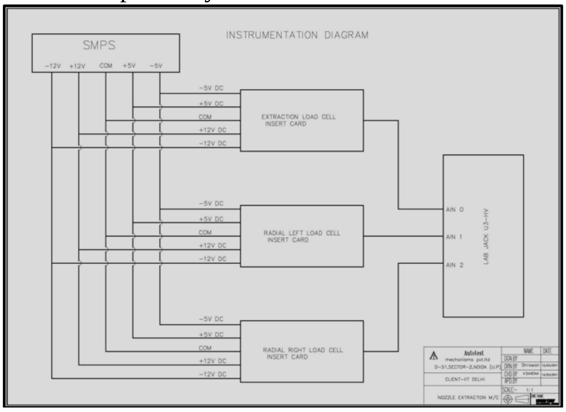

Fig 22: Complete electrical interface diagram

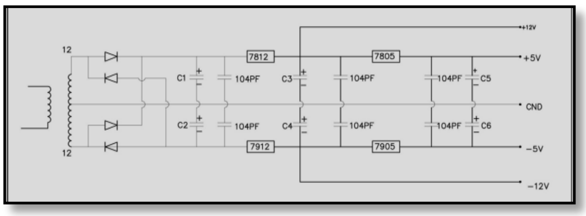

Fig 23: Electrical diagram for SMPS power distribution

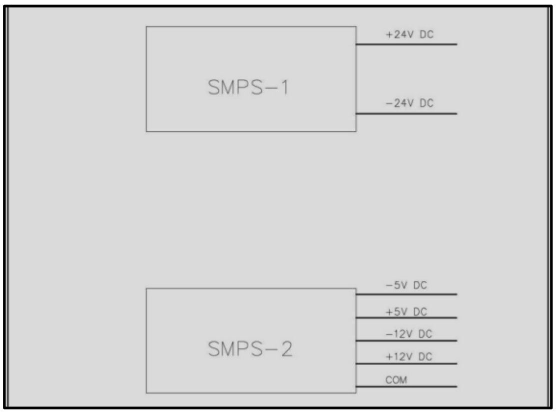

Fig 24: Electrical diagram for SMPS power input/output

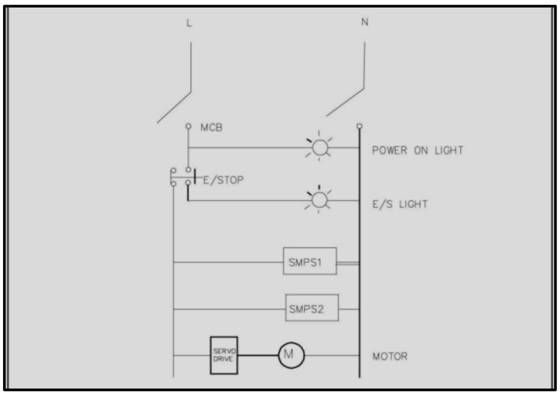

Fig 25: Electrical diagram for power system

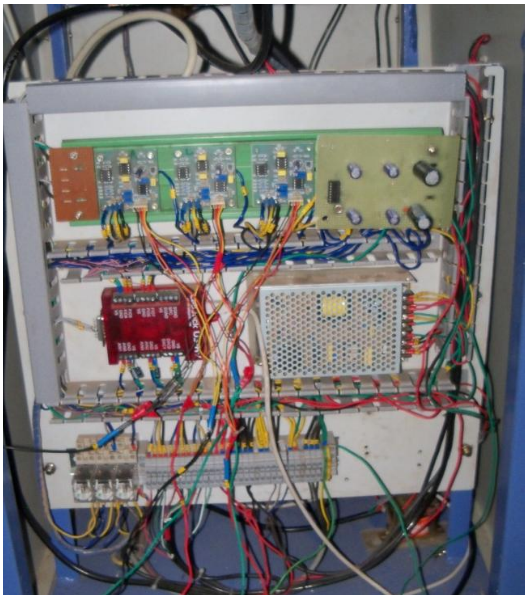

Fig 26: Main board connections

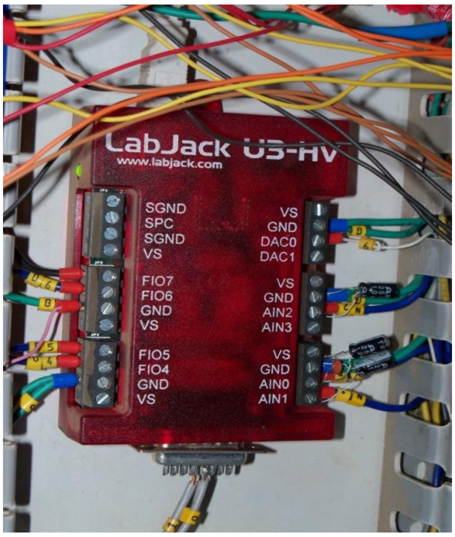

Fig 27: LabJack U3-HV


Fig 28: Analog to digital card interface with LabJack

Instrument has been designed so that all the function and operations are controlled through commands from a computer. The computer interface is simple yet effective in fulfilling all the basic requirements of our testing and validation procedure. The user interface has been designed in Visual Basic and the functions incorporated in such a way it becomes user friendly. As we press start button, the system would ask for the extraction speed and the test time we would like to put. But as such the last data fed is automatically stored in the memory. Therefore, if we continue with the same data it will be savings of time. All this options are programmable in the visual basic program easily.

The output format and the samples of testing are also programmable. All the data is also stored in a data sheet (Microsoft Excel) automatically. Therefore, one can use the data later on as required. The only hitch in this aspect is the data sheet records the data in cumulative fashion. The latest test data is just appended at the bottom of the last data, so one has to be very careful about the corresponding test data.

The platform i.e. operating system compatibility of the system is also wonderful. It supports Windows, Linux, Mac OS X, and PocketPC. In this case we have connected the machine with a dedicated standby desktop personal computer with windows platform for hassle free operations.

One of the typical actual command prompt menus is shown hereunder in the figure 29. It can be seen that the command prompt has many user interface options like opening an existing file, print a file, saving of the current test results, taking down the jaw, starting of the test, stopping it manually if required, etc icons.

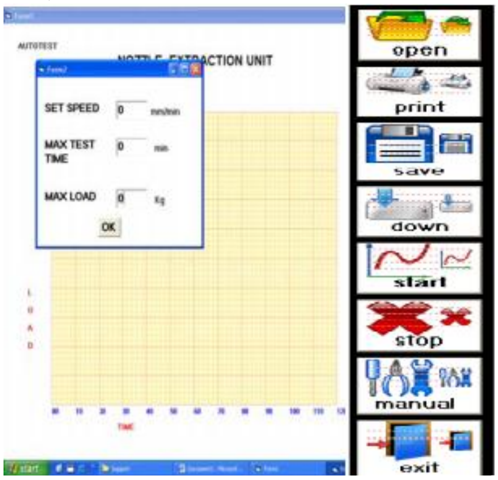

Fig 29. Dialog box with command prompt

As mentioned above the default menu option saves the last data fed automatically. If one wants to change the data it can be done. Once feeding these variables is done, the test would start on clicking the start button or icon and the clamp would start moving upward. As it does so, the three load cells measure the force being exerted upon their respective parts and is thus taken by the software. These values are then used to plot individual graphs i.e. force exerted vs. time. Thus we obtain three different graphs for three different load cells, which are given different colour coding so as to assist in identification of different forces as given in fig 30.

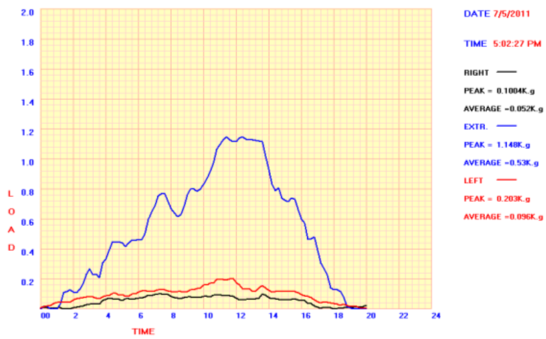

Fig 30: Output Graph

III. CONCLUSION

The computerized fabric feel tester (nozzle extraction principle) has been developed to study the fabric feel through measuring extraction force. The newly developed instrument is having many features that may be useful to study and arrived at fabric feel factor in due course of time. Elaborative study will be conducted soon to validate the instrument and study various parameters related to it and will be reported soon.

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