An apparatus for measuring the sub-nozzle efficiency of air-jet weaving machine

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A simple apparatus for measuring the efficiency of sub-nozzle has been developed by checking the air velocity at the nozzle outlet at the predetermined pressure. The testing set-up can also be used for the comparison of different types of nozzles, either main or sub-nozzles. It is observed that sub-nozzle with 19 holes gives less air velocity than that of one circular hole sub-nozzle. This is because of the possible contamination due to which the holes of used sub-nozzles get blocked and remain not so smooth, thus giving less air velocity, and hence the lower efficiency. Based on the above, continuous measuring of sub-nozzle efficiency has become a necessity. The design of the suggested apparatus is simple and reliable.

Keywords: Air-jet weaving, Sub-nozzle efficiency, Weaving

Fig. 1—Some common sub-nozzles

An air-jet loom inserts the weft into the warp by using high pressure air-jet thrust force and skin friction force along the yarn. The air-jet loom is popular in weaving industries because of its high productivity, convenient controllability, and for wide variety of fabrics such as silk, cotton, wool, and spun textures. The air-jet loom is also capable of texturing spun or cellulose filament fabrics which cannot be woven by water-jet looms.

Due to substantial consumption of air and compressor electricity, the increased manufacturing cost is one of the air-jet loom's disadvantages. Main nozzle shape, exit shape of sub-nozzles, response time of the solenoid valve, body shape, sub-nozzle locations, and control methods have been studied intensively to reduce air consumption in air-jet looms.

Energy saving is the most important among the various technical aspects related to air-jet loom. Several studies have been published on the improvement in performance of sub-nozzle, stressing on the efficiency of sub-nozzle which plays an important role in weft insertion process. The compressor that produces the compressed air consumes 60-80% of the electric power required for air-jet loom weaving. Reduction in air consumption has therefore been of a major concern. Air-jet loom machine maker tries to improve the design of the nozzle and reed that makes air flow speed sufficient to insert the filling. As a result, air consumption is reduced by about 10-20% (ref. 3).

The purpose of this investigation is to measure the sub-nozzle efficiency with a simple method to save the energy lost in air-jet loom in the case of using a defective sub-nozzle. Hence, in this study, a new apparatus has been designed to measure the sub-nozzle efficiency during the processing in the air-jet loom.

Design of Sub-nozzle

Groups of sub-nozzles are located across the whole width. Each group jets compressed air in a specific order to feed the filling tip to the right end of the fabric. The compressed air is supplied from the compressor, its pressure is adjusted by the regulators for the main nozzle and the sub-nozzles, and sub-nozzles are arranged in groups of 4 or 5 nozzles. An electro-magnetic valve is attached to each group and the sub-nozzles of the same group jet simultaneously. Arrangement and design of sub-nozzle has a great effect on the weft insertion at low pressure. Figure 1 shows some designs of common sub-nozzles.

Sub-nozzle is one of the most important elements in air-jet loom which makes the weft yarn straight during the weft insertion and keeps the velocity of weft yarn insertion constant. An air-jet loom requires 40-100 m$^3$/h of compressed air with about 0.6 MPa of

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air pressure for weaving fabric, depending on the yarn type, fabric type and loom speed. There are different sub-nozzle designs with rectangular hole, circular hole, elliptical hole, multi holes, two vertical holes, and tapered hole. It has been found that sub-nozzle with multi holes (19 holes) gives blowing angle stable at different pressure levels with 15% higher weft yarn insertion speed than single hole.

In the case of using sub-nozzle with 2 vertical holes, no guide bar is used. Sub-nozzle with 16 holes gives up to 5 times longer life time, up to 20% air saving, and no warp marks in the final fabric.

Tsudakoma Co. patented a new design of the sub-nozzle in which the interior is wider at one end than the other (Fig. 2). The nozzle’s pulling force is increased by 30%, and air consumption of the main nozzle is reduced by 10% in comparison to the cylindrical nozzle. In addition, the sub-nozzles use almost all of the air consumption in the air-jet loom because of their number. The part around the jetting outlet of the new sub-nozzle is hollowed, and the flow speed is increased by 10%. Because the filling does not touch the edge of the jetting outlet, damage to the filling is lowered.

In an ideal case, flow through a perfect nozzle would be reversible, i.e. without heat transfer, frictional effects, and shocks, and will therefore be isentropic. During the weaving process or loom maintenance the holes in the sub-nozzles are subjected to be blocked partially. A nozzle inspector needs to be sure that the right value of air velocity will come at the pre-determined pressure. The TR-7700 Nozzle Inspector is a maintenance tool for insuring higher efficiency of air-jet loom performance by setting sub-nozzles as per the visual data gathered on loom. Variations in nozzle angles and air flow details can be compared between different sub-nozzles on the same or different looms, and this information can be used to correct these discrepancies. The sub-nozzle should be cleaned frequently. Supersonic sub-nozzle cleaner washes away the minutest dirt.

**Proposed Instruments to Measure Sub-nozzle and Main Nozzle Efficiency**

**Apparatus design**—Figure 3 shows a schematic diagram of the apparatus used for measuring the efficiency of both sub-nozzle and main nozzle. The compressed air was supplied through a pressure gauge from the compressor, air receiver, and flow meter using a separate air valve for each of sub-nozzle or main nozzle to operate main nozzle or sub-nozzle individually during the test; the sub-nozzle and main nozzle were set with the special attachments so that they can be changed easily.

To measure the efficiency of sub-nozzle and main nozzle, an apparatus was constructed using a scaled glass tunnel which is held by a special attachment. In this case, when the air is connected to the nozzle, the height of the plastic ball determines the air flow rate. The value of the ball height defines the condition of the nozzle and, hence its efficiency.

In the case of measuring the efficiency of sub-nozzle, a ball weighting 17.3g was used, while in the case of measuring main nozzle, a ball was weighting 60g because the air flow coming of the main nozzle is higher than that of the sub-nozzle.

**Design parameters of the apparatus**—There are different sub-nozzles with different shapes and hence, the air velocity distribution from the sub-nozzles also differs. The position of the sub-nozzle in the apparatus should be changed according to the angle of the confection of the air stream coming from the sub-nozzle to enter the edge of the glass tube. The following
equations are used to determine the position of sub-nozzle in the apparatus:

\[ D = D_{\text{ball}} + 4 \text{ mm} \]  
\[ L = \left(\frac{D}{2}\right) / (\tan \theta/2) \]  

where \( D_{\text{ball}} \) is the diameter of ball; \( D \), the diameter of glass tunnel; \( L \), the distance between nozzle opening and opening of glass tunnel; and \( \theta \), the angle of the confection of air stream coming from nozzle.

For measuring the main nozzle efficiency, the main nozzle is set in the centre of the glass tunnel while the main nozzle tip in the same level with the lower edge of the glass tunnel. The procedure for measuring the nozzle is as follows: adjust the position of the sub-nozzle and the pressure gauge on the required air pressure, open the air-jet valve, put the ball in the air stream inside the glass tunnel and read the ball height from the scale on glass tunnel. Most efficient sub-nozzle is indicated by the higher ball position.

In air-jet loom, one of the main requirements is to measure the efficiency of the sub-nozzle and main nozzle after the maintenance to assure the required air velocity at a pre determined pressure. In this study, three different types of sub-nozzles have been used on the weaving machines in a modern weaving mill with the designed apparatus. Several types of sub-nozzles, such as 19 holes and with one circular hole (either straight or inclined stem) as well as main nozzle have been inspected.

In a weaving mill random samples of sub-nozzles were tested on the designed apparatus. The average values of the floating ball height (H) at different air pressures are shown in Fig. 4. It is found that 19 holes sub-nozzle gives less efficiency than the single hole either straight or inclined. This is due to the air resistance in the small diameter holes and because of the contamination of the air which blocks the nozzle holes, and thus it requires higher pressure to reach the optimum air velocity than in case of one circular hole nozzle.

Figure 5 illustrates the testing results of the main group nozzle at the different air pressure values. This indicates that the height of ball increases with the increase in air pressure. In all measured cases, the value of the mean ball height varies within ± 5% , which is acceptable range in practice.

The design of the suggested apparatus is simple and reliable and hence weaving mills can use it to inspect the nozzle’s efficiency on the weaving machine, especially after the maintenance or when new nozzles are supplied.

![Fig. 4— Comparison between different types of sub-nozzles at different values of the air pressure](image1)

![Fig. 5— Effect of air pressure on the measuring ball height in the case of testing main nozzle](image2)

**References**

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