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Twin optical sensor based instrument for the measurement of weft velocity in air-jet weaving

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ABSTRACT

A previous paper described the effectiveness and application advantages provided by a single opto-electronic sensor based instrument for weft velocity measurement in air-jet weaving. Consideration of further refinement of the instrument, particularly for improving the smoothness of the weft velocity curve obtained by using it, indicated possible advantages of developing it as a twin sensor based design. This would enable two time related data streams and their analysis by use of the cross-correlation technique, which would primarily help in reducing errors of weft velocity determination due to possible variation of the uniformity of center distance between yarn markings. This paper reports on the evaluation of the performance of the modified instrument which was found to be superior to that of the single sensor based device. More significantly, given the ease with which a large number of repetitive measurements can be made using it, this development also led to the very useful outcome that it enables obtaining a close estimate of the 'true' weft velocity curve for a given set of weft insertion settings. The overall size of the modified sensor has remained the same as before, so mounting it on the weaving machine is just as simple as before.

1. Introduction

The effectiveness and advantages of using optical sensing for the measurement of the velocity curve (velocity vs. time) of the weft yarn in air-jet weft insertion was described in a previous paper [1]. Primarily the development was the result of an effort to develop a suitable instrument which could be used to verify the accuracy of the weft velocity curve computed by a computer simulation program to model weft insertion on an air-jet weaving machine, by comparing it with the actual weft velocity curve obtained on the weaving machine at the settings concerned. The instrument can also be used for verifying the accuracy of weaving machine settings according to those recommended by the machine manufacturer. The impetus for the initial development arose due to the fact that there was no commercially available, simple yet accurate and easy to use instrument intended for this purpose. The compact lightweight yarn position sensor realized can be conveniently mounted on the sley of the weaving machine without affecting the normal weft insertion process.

The sensor requires the weft yarn to carry dark markings at equal intervals along it, to enable detection of its movement by optical sensing during weft insertion. The marks are of negligible mass and have no effect on the properties of the weft yarn, and hence have no influence on the insertion process. Such marking of the weft is not objectionable under experimental weaving conditions. During a measurement, the instrument provides a continuous electrical signal output, which can be data logged at a high sampling rate (500 kS/s or more). The instrument was found to be particularly advantageous in its ability to measure a large number of successive weft insertions (50–100 and possibly more) automatically in one continuous measurement, thereby minimizing measurement time, operator involvement and effort, and weft consumption. Since the measurement provides individual data files on each separate insertion, the data analysis can be carried out conveniently and relatively rapidly. However, the need to use marked weft does not make it possible to use the instrument for continuous process optimization under normal weaving conditions.

While the velocity curve obtained using the optical sensor on a single weft insertion is much better than that obtained by the stroboscopic method described previously [1], the need to refine the sensor for a superior (smoother) weft insertion profile was strongly felt. With the previous single sensor based instrument, the weft velocity calculation is carried out on the assumption of the constancy of distance between the mid points of successive yarn markings. However some variation of the center distance between successive printed marks made on the weft yarn is unavoidable, which can cause some weft velocity measurement inaccuracies. In this regard, the use of a twin-sensor yarn movement detector was

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seen to be particularly advantageous, since that will produce two time related data streams, which can be analyzed for their time relationship using the cross-correlation technique. This method enables calculating weft velocity based on the length of time each yarn mark takes to move over the fixed distance between the two optical sensors.

2. Weft insertion system on an air-jet weaving machine

Fig. 1 is a schematic diagram of the weft insertion system of a typical air-jet weaving machine, the Sulzer L-5100 as used in this work.

Since the above weft insertion system was described in some detail previously [1], it would be sufficient to indicate here that the weft yarn is supplied from a conical package through a weft accumulator (prewinder), and blown into the open warp shed by the main nozzle at the start of a weft insertion cycle. The relay nozzle groups blow in a sequential manner under program control to keep the weft moving till it reaches the far end of the reed [2,3]. In the weaving machine concerned, the reed width is 1.72 m. The weaving speed is 510 picks/min. Weft insertion begins at 75° of the main shaft angle, when the yarn stopper opens. Each complete insertion operation lasts approximately 52 ms. The compact optical weft movement sensor is mounted on the sley, just before the entrance to the main nozzle. Fig. 2 is a typical weft insertion velocity curve of a weft insertion obtained by monitoring the weft at the entrance to the main nozzle using the previous, single sensor based instrument [1]. The single horizontal line and the rectangular boxes indicate the blowing duration of the main nozzle and the relay nozzle groups respectively. The yarn markings were each 5 mm long, and successive marks were at a mean spacing of 55 mm. The weft velocity graph was obtained by joining successive weft velocity values calculated at the corresponding shaft angle positions. The zig-zag nature of the calculated weft velocity curve could be caused by several factors. Some variation of the uniformity of successive inter-mark distances on the weft is one of these. The turbulent nature of the air flow produced by the air nozzles and the resulting small deviations from straightness in the weft observed during its flight, which cause intermittent tangential contact of the weft with the reed tunnel, could be another reason.

3. Methods of measuring the velocity of a moving yarn

Many researchers have used different techniques for measuring yarn velocity. A recent fluidic sensor developed by Tesar [4,5] for the measurement of weft velocity in air-jet weaving is based on sensing the pressure difference across the sensor due to the viscous drag between the moving yarn and the surrounding air. The use of sensing yarn irregularities for the measurement of yarn velocity has been reported by Pijls [6]. He used the noise signal developed in response to yarn irregularities and compared it with a reference signal of a known velocity yarn in order to get an estimate of the velocity of the measured yarn. The measurement is based on the principle that each yarn signal has its own components of noise which is proportional to yarn velocity. The cross-correlation approach for velocity measurement has been used in textile processes particularly in measuring yarn velocities. Alther [7] reported the use of a yarn velocity meter based on this technique for measuring weft insertion velocity on an air-jet weaving machine, based on sensing the pattern of random static electric charges normally found on yarns using electrodes. However the wide variation of the amplitude of natural static charges tends to cause considerable measurement difficulties. The cross-correlation technique was used also by Featherstone et al. [8] to measure the velocity of a yarn in the false twist texturing process by measuring the random pattern of naturally arising electrostatic charges along the yarn as a marker signal, detected by two non-contacting electrodes connected to charge-to-voltage converters. Dodds and Convey [9] reported another application of the cross-correlation function to measure yarn velocity in the cone winding process in spinning industry and to measure the mass flow rate of textile materials. The measurement was carried out using an electronic hardware correlator with signal detection by an electro-optical detector.

4. Twin sensor weft velocity measuring instrument

The basic configuration of the twin optical sensor based weft movement sensor is similar to that of the previous single sensor based instrument except that it incorporates two identical in-line optical yarn sensors separated by a small distance. The provision of two sensing points on the optical yarn sensor, which are separated by a suitable distance results in an arrangement whereby the detection of each mark on the yarn is observed at each sensing point with a time delay dependent of the mean weft velocity during that short interval. Since the weft velocity varies during its flight, the time interval between the sightings of a given mark by the two sensors will vary according to the variation of weft velocity.

Fig. 3 shows the basic construction of the twin optical sensor based arrangement. The distance between the sensors is nominally 10 mm but its effective value has been determined by calibration. Each sensor has its own LED based yarn illumination. The twin sensor construction has the same overall dimensions as the single sensor based device, so mounting it on the weaving machine sley causes no problems. The response speed of the photodiodes together with that of the signal amplifier circuits is fast enough to make any time lag effects of the variation of weft velocity on the measured signal amplitude to be negligible.

Since the center distance between yarn marks is 55 mm, the time interval between sightings of a mark by the two sensors is of the order of 2 ms. Hence some 1300 data points are recorded by the data acquisition device during the passage of a single yarn mark past the two sensors at a mean velocity of 27.5 m/s. Over successive observations this number will vary in response to the instantaneous weft velocity.

5. Calibration of the inter-sensor distance:

As with the single sensor based instrument, the twin sensor design also requires black marks at a suitable center distance along the weft yarn to detect its movement. The twin sensor design measures the time taken by a given mark to move past the two sensors. Provided the effective distance between the two sensors is known, then the velocity of the weft during that time interval can be simply calculated. What this means is that the actual distance between successive marks on the yarn is no longer important. However to keep the averaging effect of the inter-mark distance on the velocity calculation the same, it is useful to keep these spaces closely the same. Since it is now the actual center distance between the two sensors which is important in determining the weft velocity curve, it is necessary to calibrate the instrument to determine this parameter. This calibration can be carried out by moving a linear scale with fine transverse lines, under the sensor heads, at an appropriate constant velocity. However it is very difficult to realize such an arrangement, so the best practicable method of doing this was found to be the use of a rotating circular disc, carrying a set of equally spaced lines along its circumference. A steel disc, having a suitable diameter and of adequate thickness was accurately mounted on an electric motor so that it could be rotated at a constant speed without any vibration. A 10 mm wide white paper tape carrying transverse black lines was glued on the edge of the disc. The twin sensor head was (connected