Development of Check up System for Picking Mechanism on Water Jet Looms

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Abstract

A check up system for picking mechanism on water jet looms is developed. This system catches the signal of water jet pressure with a pressure sensor, and detects the open-close of a damper with a clamber sensor respectively, and measures such values as water jet pressure, jetting angle and flight start angle of weft yarn etc. As these measured results, this system can find the best condition of picking mechanism for weaving.

This system is available for preventive maintenance of picking mechanism, and contributes to decrease loom stoppage and poor condition of weft flying resulting in improvement of flexible manufacturing.

1. Introduction

The speed of Water Jet Looms (WJLs) is becoming higher and higher. Some are operated over 1500 rpm at a textile machinery show, and at around 800 rpm in factories. In order to assure effective high-speed operation collectively, adjustment should be changed from conventional way by experimental feelings to more reasonable way by using measuring instruments.

The loom monitoring systems are now introduced widely in weaving factories. These are effective in improving operability of machines and in quality control of fabrics. However, they don’t offer detailed information about troubles, remedies or maintenance[11–11].

In this investigation, we aimed at developing a “Check up System for Picking Mechanism” on WJLs. This system would give various data required to diagnose running conditions or abnormal points in the picking parts of WJLs.

This paper presents the outline of the developed system and some applications.

2. Picking Mechanism and Flying of Weft Yarn

As the weft yarn is carried by water jet in WJL, sufficient flying force is necessary at an appropriate timing. About 60 percent of WJL stoppage is caused by poor flying of yarns.

In weft feeding, first, a plunger is pulled out of a plunger pump by the rotation of a pump cam. Water accumulated in a water tank is sucked into a cylinder.

Second, by so doing, a pump spring is compressed and the pump cam reaches the maximum lift and completes suction. Soon after, by the force of the compressed pump

<table>
<thead>
<tr>
<th>Poor flying</th>
<th>Picking condition</th>
<th>Adjustment of Picking mechanism</th>
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</thead>
<tbody>
<tr>
<td>Miss-stop</td>
<td>Water pressure</td>
<td>● Spring constant of pump spring&lt;br&gt; ● Initial displacement of spring&lt;br&gt; ● Exit area of nozzle</td>
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<tr>
<td>Tip trouble</td>
<td>Water volume</td>
<td>● Diameter of cylinder&lt;br&gt; ● Stroke of plunger</td>
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<td>Short pick</td>
<td>Jet timing</td>
<td>● Position of pump cam</td>
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<td>Loose pick</td>
<td>Jet direction</td>
<td>● Direction of nozzle</td>
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<td>etc.</td>
<td>Concentration</td>
<td>● Shape of nozzle</td>
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<tr>
<td>II</td>
<td>Flying start timing&lt;br&gt;Flying finish timing&lt;br&gt;Tension</td>
<td>● Position of first clamp cam&lt;br&gt; ● Position of second clamp cam&lt;br&gt; ● Measuring and storage parts</td>
</tr>
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</table>

I : for water jet, II : for weft yarn
spring, water in the cylinder is pressed and jetted from a nozzle. Then, a clamer opens and the filling yarn measured and stored is ejected and inserted into the shed.

The poor flying of wefts will be related to conditions and adjustment as shown in Table 1. Trouble such as miss-stop or tip trouble occurs due to complex combination of water pressure and water volume etc. Also, the disorder in the pump or the nozzle induces the change of the picking condition.

Figure 1 shows the variation of the weft tip position measured at 34.8 msec after jetted when the initial displacement of the pump spring is changed in three levels. The vertical axis indicates the distance from the nozzle. A circular symbol indicates the average position of fifteen measurements. The left side circle shows the first pick from No.1 nozzle. The second circle shows the second pick from No.1 nozzle. The third circle does the first pick from No.2 nozzle, the fourth the second from No.2 nozzle, respectively for each spring displacement. Each arrow length indicates the standard deviation ± σ. It is worth while to note that the tip position and the standard deviation always vary, and so does the running condition of the picking mechanism.

3. Requirement of System

Requirements of the check up system are determined as follows.

It is capable of measuring directly or indirectly water pressure, water volume, jetting timing and start timing etc. Namely, signals of water pressure and the clamer as shown in Fig.2 should be input at every degree of the crank angle, and following 7 terms can be measured for every pick.

- \( P_1 \) : Peak water pressure (maximum water pressure)
- \( P_2 \) : Water pressure at clamer opening
  (water pressure when the clamer begins to open)
- \( A \) : Momentum (area of water pressure signal)
- \( \theta_1 \) : Start angle of jet
  (crank angle when water pressure begins to rise)
- \( \theta_2 \) : Jetting angle (angle while water pressure rises and goes down)
- \( \theta_3 \) : Start angle of clamer opening
  (crank angle when clamer begins to open)
- \( \theta_4 \) : Work angle of clamer (angle during clamer is open)

In addition, the maximum number of picks measured is assumed 2,000. Unsteadiness of the picking mechanism, such as shown in Fig. 1, is estimated by these data. By statistical process, those values of average, maximum, minimum, and standard deviation are obtained, together with each histogram.

To compare normal running with abnormal running just before stoppage, the system can continuously measure until WJL stops, and can analyse 2000 picks before stoppage.

The system can be applied to both one-color and two-color WJLs, and to each nozzle and each pick in two-color WJLs.

4. System Structure

Figure 3 shows our system, and Fig. 4 its block diagram. Two pressure sensors (1–1, 1–2) are set just
before each nozzle entrance, and two proximity switches (4-1, 4-2) are set above each clamper in two-color WJL by special adapters (cf. Fig. 5). Signals from two pressure sensors are sent to computer (7) through each amplifier (2-1, 2-2) and A/D converter (3). Signals from proximity switches and timing sensor (5) are sent to computer (7) through interrupt controller (6) prior to other singles. Crank angle indicated by angle controller (9) is also sent to computer (7). These signals during one pick are, after sent to computer (7), stored in data memory (8) orderly. If running sensor (10) senses the loom stoppage, or if the number of picks measured reaches a set number, computer (7) stops reading these signals. Then computer (7) calculates these data stored in data memory (8) through keyboard (12) operation. The calculated result is shown on CRT (15) through CRT controller (14) or is output to a printer through I/O controller.

The specification of the system is as follows:

- Pressure sensor: strain gauge pressure transducer, capacity 50kgf/cm²
- Clamper sensor: linear proximity switch, response 10kHz
- Timing sensor: making use of timing switch for weft feeler on WJL
- Running sensor: making use of magnetic switch for main motor on WJL
- Amplifier: direct current amplifier, bridge voltage of 2.5V, amplification of 1102200, low-pass filter 500 Hz
- A/D converter: 8 ch., 12 bit, processing speed 2.5 µsec
- Interrupt controller: 16 ch., Z80CTC
- CRT controller: monochrome-full-graphics (512 X 256 dots)
- CPU: Z80A (4MHz)
- Data memory: 1M byte DRAM
- Angle controller: timer interrupt by Z80CTC
- I/O controller: Z80PIO
- CRT: 12 inch green display
- Key board: 16 keys (non-decode)
- Printer: 10 inch impact-dot-matrix

5. Data Reading and Processing

Figure 6 shows a flow-chart of the main program.
CRT will display the first screen as shown in Fig. 7 when the main switch is turned on. Initializing can be done through this screen.

Setting procedures are as shown below.

0 ピックス (Number of picks): Number of picks measured is set in the range of 1~2,000. If the set number is 2,000, the system reads data endlessly until WJL stops. Then the system analyzes 2,000 picks reversely before the loom has stopped.

1 スイアツトリコミクシクインカクド (Start angle of water pressure to be measured): This start angle is set in the range of 80~230°.

2 フィーラートリコミクシクインカクド (Start angle of feeler signal to be measured): This start angle is set in the range of 90~230°. At present, this function isn’t used. It will be used to measure the condition of weft flying.

3 タイミングニュウリョクカクド (Input angle of timing): Angle when the signal from timing sensor is input can be set in the range of 1~320°.

4 1 ノズル OR 2 ノズル (1 nozzle or 2 nozzles): One-color WJL is set to 1 and two-color WJL is set to 2. Setting in the range of 3~8 will be used for the following analysis on two nozzle WJL.

5 : For analyzing the first pick of No.1 nozzle.
6 : For analyzing the second pick of No.1 nozzle.
7 : For analyzing the first pick of No.2 nozzle.
8 : For analyzing the second pick of No.2 nozzle.
9 : For analyzing No.1 nozzle only.
10 : For analyzing No.2 nozzle only.

5 スイアツフルスケール (Maximum scale of water pressure): Maximum scale of water pressure is set in the range of 10~100 kgf/cm².

After initial setting is completed, Key [6] is pushed in. Then the data read-in program shown in Fig.8 will be actuated in the following steps.

① One-color or two-color is detected. In case of two-color, data are read in from the first pick of No.1 nozzle, synchronizing with WJL.

② Data of one pick are read. Data read-in can be stopped by pushing Key [5], and the second screen will be displayed for data analysis. Data read-in is stopped also when the sensor detects loom stop, and the second screen will be displayed.

③ After data of one pick are read in, they are stored in memory. Counter I is added by 1.

④ When the first screen is set as shown below;

Pick No. N=2000
D>1999

data are endlessly read.

Then, counter should be reset before data of the next pick are read.
In case of \( N \leq 1999 \) and \( I > N \), the second screen will be displayed. Data on next pick will be read when \( I \leq N \).

After data are completely read, CRT will display the second screen as shown in Fig.9. Select the required item to be analyzed by Key operation of \([0] \sim [6]\). The results will be displayed on CRT along with histogram.

Figures 10 \sim 16 show examples of measurements. In these measurements, Nylon Taffeta (warp and weft; 70 deniers) is woven for 20 consecutive days on one-color WJL under excellent conditions (machine stoppage; 4 times, operability; over 99.9%).

Symbols used in the figures indicate as follows.

- \( E(x) \): Average value
- \( \text{MAX} \): Maximum value
- \( \text{MIN} \): Minimum value
- \( S \): Standard deviation
- \( T \): Analyzed pick number

Figures in bracket \( (\ ) \) for \( \text{MAX} \) and \( \text{MIN} \) indicate the pick numbers when the max. and the min. values are obtained after data reading is started. Water pressure waveform can be displayed on CRT by inputting \([7]\) and the required number of picks up to 2,000 (Figs. 21 and 22).
6. Application of System

Application of the developed system was examined in a factory to check the actual performance.

6.1 Application 1

Figure 17 is a result on one-color WJL (reed width; 210cm, rotation speed; 395rpm). It shows excessive deviation in peak water pressure caused by abrasion on the pump drive system for the picking mechanism. This trouble was improved by changing parts between the pump cam and the plunger.
6.2 Application 2
Figure 18 shows a trouble which may easily occur with two-color WJL (reed width: 150cm, rotation speed: 424rpm). The two peaks are caused by insufficient adjustment of damper inner structures. It occurs when there is a difference between the start angles of clamp opening of No.1 and No.2 nozzles.

6.3 Application 3
In this case, two-color WJL tested has two nozzles of different structures. One is an ordinary type (Fig. 19(a)), but the other has a metal stabilizer to improve the concentration of water jet (Fig. 19(b)). Fig. 20 shows a clear difference in the peak water pressures between the two. There are also similar differences in water pressure of clamp opening, in momentum and jetting angle. Figs. 21 and 22 indicate water pressure waveforms of two nozzles.

6.4 Application 4
This application is to investigate the relationship among the adjustments for poor weft flying, picking condition and picking mechanism. In other words, defective yarn inserting can be reduced by adjusting the picking mechanism.

Twenty units of the same WJLs for Polyester Taffeta

(a) No.1 nozzle without stabilizer
(b) No.2 nozzle with stabilizer

Fig. 19 Inner structur of nozzle body
(warp of 50 deniers and weft of 75) were used. Each WJL had a reed width of 145 cm and average speed of 500 rpm. Every picking condition was measured by our system. The number of loom stoppages due to miss-stop and tip trouble was also checked for each WJL when operated for 20 days continuously. The adjusting conditions (initial displacement of pump spring, stroke of plunger, angle of pump cam and angle of clamp cam in Table 1) were examined. Tabel 2 indicates the results of measurements and investigation. In Table 2, the maximum and the minimum values were ignored because they had high correlation coefficient to average or deviation value.

Table 3 shows calculated correlation coefficients concerning these data, the underlined values in which were significant at 5% level. Table 3 indicates as follows.

<table>
<thead>
<tr>
<th>Measured and investigated items</th>
<th>Average</th>
<th>S.D.</th>
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<tbody>
<tr>
<td>P1: Peak water pressure</td>
<td>E(x)</td>
<td>16.491</td>
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<td></td>
<td>S</td>
<td>0.477</td>
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<tr>
<td>P2: Water pressure of clapper opening</td>
<td>E(x)</td>
<td>15.372</td>
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<td></td>
<td>S</td>
<td>0.322</td>
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<tr>
<td>A: Momentum</td>
<td>E(x)</td>
<td>108.838</td>
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<td>S</td>
<td>1.122</td>
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<td>I:</td>
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<td>i1: Jet start angle</td>
<td>E(x)</td>
<td>104.790</td>
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<td>S</td>
<td>1.422</td>
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<td>i2: Jetting angle</td>
<td>E(x)</td>
<td>61.927</td>
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<td>1.071</td>
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<td>i3: Start angle of clapper opening</td>
<td>E(x)</td>
<td>118.868</td>
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<td>S</td>
<td>1.275</td>
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<td>i4: Work angle of clapper</td>
<td>E(x)</td>
<td>126.548</td>
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<td>S</td>
<td>1.512</td>
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| a | Initial displacement (dimension P) | 19.925 | 3.572 |
| b | Stroke of plunger | 14.050 | 1.284 |
| c | Jet start angle | 93.950 | 3.640 |
| d | Flying start angle | 111.600 | 2.035 |
| e | Flying finish angle | 250.600 | 3.308 |

I: Picking condition, II: Adjusting condition, III: Poor flying

Table 3 Correlation matrix of Table 2

<table>
<thead>
<tr>
<th>X_1</th>
<th>X_2</th>
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<th>X_22</th>
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<td>X_0</td>
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<td>P2: Water pressure of clapper opening</td>
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<td>i3: Start angle of clapper opening</td>
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<td>i4: Work angle of clapper</td>
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Table 2 Data of twenty WJLs

Table 3 Correlation matrix of Table 2

Journal of the Textile Machinery Society of Japan
① Relation among to picking conditions

• The peak water pressure is related to the water pressure of clamping opening and the momentum.
• The momentum is related to the jetting angle besides the peak water pressure.
• The jet start angle is related to the start angle of clamping opening.

② Relation between the picking condition and the loom stoppage

Number of miss-stops increases in proportion to the deviation of the peak water pressure or the jet start angle.

③ Relation between the adjusting condition and the loom stoppage

Number of tip troubles increases if the initial displacement of the spring decreases.

Then, multiple regression analysis of backward elimination\(^5\) was used to estimate the number of loom stoppages from the picking condition by putting the picking condition as explanatory variable \((X_i)\) and the number of loom stoppages as criterion variable \((Y)\). Two multiple regression equations are obtained as follow, which have multiple correlation coefficients of 0.8808 and 0.8346 respectively, in which \(Y_1\) is the number of miss-stops, and \(Y_2\) is the number of tip troubles and \(X_i\) refers to Table 3:

\[
Y_1 = -2.754X_{31} + 2.219X_{51} - 9.966X_{91} + 8.859X_{11} + 34.653X_{12} + 14.233X_{22} + 0.231X_{21} + 8.336X_{62} - 0.503 \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots (1)
\]

\[
Y_2 = -15.153X_{11} - 12.948X_{01} - 0.471X_{61} - 12.380X_{42} + 20.716X_{32} + 0.350X_{21} + 11.133X_{02} - 3.978X_{62} + 0.120 \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots (2)
\]

where the explanatory variables in the right sides of the formulas are arranged in the order in which the standard partial regression coefficients are from large to small.

Equations (1) and (2) would give the results as follows:
(1) The number of miss-stops will decrease, if the jet start angle is late, and the start angle of clamping opening is fast, and the peak water pressure is high and the water pressure of clamping opening is low.

(2) The number of tip troubles will decrease, if the water pressure of clamping opening is low, and the peak water pressure is high, and the work angle of clamping is large and the deviation of jetting angle is small.

However, eqs. (1) and (2) are so complicated that they are applicable only when yarns and looms are fixed. The multiple regression analysis was tried in vain for many looms with different yarns. Therefore it would be necessary to reconsider the selection of explanatory variables.

7. Conclusion

By using the system developed by us in a weaving factory, it is found that the present system works well as initially expected. To get more exact diagnosis on WJL, much more data as described are needed. By such data, preventive maintenance would be possible, together with low production cost. Production efficiency would increase if setup time in large-variety/small-lot production is minimized by the present system.

However, this system has some problems such as incapable of assuring good timing when the yarn condition changes from free flight to compulsory flight.

Acknowledgements

The authors gratefully acknowledge the support of Yoshikazu Yamashita, Seiichi Yano (Yano Laboratory Co.), Yuji Hama (Tsudakoma Corp.), Masaya Nishihira (Takio Syokufu Co., Ltd.), Ichirou Zinbo (Kamimura Co., Ltd.) and Kouzou Yamada (Yamacho Co., Ltd.).

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