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PERFORMANCE EVALUATION OF A CIRCULAR WEFT KNITTING MACHINE THROUGH OBSERVATION OF YARN INPUT TENSION: A CASE STUDY

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Abstract: *This paper presents a noble approach to assess the performance of a modern knitting machine through monitoring of running yarn tension during operational hours. An industrial circular weft knitting machine having positive storage feed system was observed, as a case study, in this research for its performance evaluation. A total of 16 different production runs- each for a machine running period of 30 seconds [equivalent to the time required for more than 05 revolutions of the needle bed or machine at 10.5 rev. /min.] were analyzed. Highest tension-peak value for each second was identified through MLT Wesco Yarn Tension and Rate Meter and associated PC software. Run charts were built-up with these selected tension values by a statistical software, i.e. Minitab and the p-values were checked to identify special cause variations. It was found that most of the production runs showed no non-random pattern in the tension values based on an alpha value (significance level) of 0.05, representing absence of special cause variations and thus disclosing quite satisfactory machine performance. However, the production run with non-random pattern was investigated through cause-effect diagram. The presence of astronomical data point was also evaluated. The findings here also indicated no direct machine-related cause regarding such variation or pattern in yarn input tension.*

Key words: *Knitting, Yarn Input Tension (YIT), Run Chart, Special Cause Variation, p-Value*

1. INTRODUCTION

The knowledge of how well a knitting machine is working during production is very important for a knitter. This information allows scheduling all plans and necessary actions required for improved productivity and quality in a manufacturing plant [1]. According to Catarino as cited by Catarino et al. [2] yarn input tension in a modern circular weft knitting machine can be used as a valuable resource of information concerning in particular the knitting process, and in more general term, the overall behavior of the knitting machine, since YIT directly reflects the influence of the different mechanisms involved in the production of the knitted fabric.

The analysis of yarn input tension reveals that it should be basically a fairly well-shaped sinusoidal waveform, with a frequency equivalent to the time elapsed between each loop formation [3]. However, there are all other mechanisms involved in the production of the knitted structure that will induce other harmonics and thus change the shape of the YIT waveform [3]. Nevertheless, YIT is considered as one of the most important parameters for weft knitting industry and its inspection allows the detection of several problems during production [4].

When some abnormality occurs in the knitting process it will always be reflected in the YIT [2] which is a reflection of the whole knitting process for a given yarn feeder [5]. Through the YIT waveform it is possible to identify the appearance of a fault, which is represented by a sudden increase/decrease in the force, determine eccentricities of the feeding system, which are represented with sinusoidal waveform, determine abnormalities that can degenerate in fault [1]. However, any abnormality resulting from machine performance will produce some kind of periodic behavior as almost all moving parts depend on one main engine and their movement is almost always circular [3].

The simple inspection of YIT waveform allows the detection of faults and malfunctions of knitting machines. However, the representation on graphics of the entire YIT from a feeder and inspection of YIT waveform may lead to erroneous judgment in an industrial environment as YIT fluctuates due to yarn irregularity, dust and other situations which do not constitute a fault [1]. Instead, it would be very useful to deal with any particular state of YIT (like average or peak) to evaluate the whole process of loop formation thus enabling the detection of abnormalities and possible cause diagnosis. Statistical quality tools, like run charts, may be deployed to fulfill the above purpose.

2. RUN CHART

A run chart is a graphical display of data over time or a time series chart of data. It can reveal evidence of special cause variation those creates recognizable patterns. Therefore, it may be used as a quick test of system performance.

When statistical software like Minitab is used to create a run chart, it plots individual observations in the order they were collected and draws a horizontal reference line at the median. Four basic patterns of non-randomness are detected by run chart [6], i.e. mixture, cluster, oscillating and trend, which are sometimes termed as special cause variations as shown in figure 1.

(i) (ii) (iii) (iv)

Fig. 1: *Non-random patterns as identified by a run chart-(i) Mixture (ii) Clusters (iii) Oscillation and (iv)Trend* [6]

Moreover, astronomical data points [7] are also detected on a run chart through noticeable shift from the median. Consequently, all the possible causes responsible for non-randomness may be evaluated to judge the performance of the machine.

3. METHODOLOGY

3.1 Monitoring of Knitted Fabric Production through Yarn Input Tension

The test machine is a multifeeder industrial circular knitting machine (Orizio, Johnan) of 24 gauge and 26 inch diameter. To evaluate its performance run charts were built with the help of highest tension values recorded at a particular feeder for a fixed QAP, i.e. yarn delivery setting, which occurred at each second for a machine running period of 30 seconds. YIT waveform was obtained through MLT Wesco PC software (figure 2). Advanced memory mode with zoom option of this program was used to discover secondwise graphical shape of YIT (figure 3) - thanks to Memminger-IRO.

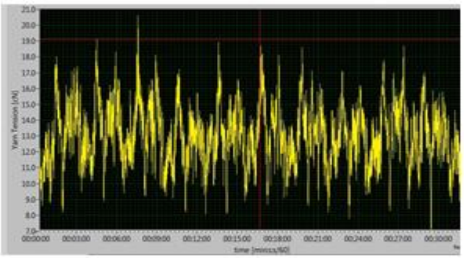

Fig.2: *A typical YIT wave form (for 30 sec)*

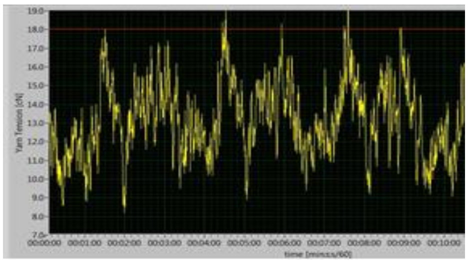

Fig. 3: *A typical YIT wave form (for 10 sec)*

A total of 16 production runs producing plain jersey fabrics with spun polyester and cotton yarns were evaluated. Two different counts (as measured experimentally) were used for each type of yarn at four different cam setting points. All other machine settings were kept constant. The machine rpm of 10.5 indicates more than 5 revolutions of the needle bed in the chosen run time. Average temperature and relative humidity recorded during the experimental hours were around 29°C and 67% respectively.

3.2 Interpretation of Run Charts

Tension values for each process were plotted through run charts in the order that they were collected. The run chart built through Minitab (version 17.1.0) also calculates p-values for different special cause variations. These are presented in table 1. The p-value is a probability that measures the evidence against the null hypothesis. The null hypothesis is that there exists no non-randomness pattern in the data. A p-value that is less than the specified level of significance indicates a tendency for non-randomness or special cause variation. Usually a significance level (denoted as α or alpha) of 0.05 works well. A significance level of 0.05 indicates a 5% risk of concluding that a nonrandom pattern exists when the data are actually randomly distributed. If the p-value is less than or equal to the significance level, the null hypothesis can be rejected and it can be concluded that the data are not randomly distributed [8].

Table 1: *Summarized results for different run charts obtained through Minitab software*

Run No.	Yarn	Cam setting Point	p-value for clustering	p-value for mixtures	p-value for trends	p-value for oscillation	Special Cause Variation/Non Randomness type (If any)	Presence of astronomical data point (if any)
01	23.62 Tex Spun Polyester	0.7	0.500	0.500	0.974	0.026	Oscillation	--
02	23.62 Tex Spun Polyester	0.6	0.874	0.126	0.559	0.441	--	--
03	23.62 Tex Spun Polyester	0.5	0.771	0.229	0.228	0.772	--	--
04	23.62 Tex Spun Polyester	0.4	0.771	0.229	0.383	0.617	--	Yes
05	20.36 Tex Spun Polyester	0.7	0.500	0.500	0.559	0.441	--	--
06	20.36 Tex Spun Polyester	0.6	0.655	0.345	0.559	0.441	--	--
07	20.36 Tex Spun Polyester	0.5	0.645	0.355	0.117	0.883	--	--
08	20.36 Tex Spun Polyester	0.4	0.510	0.490	0.383	0.617	--	--

09	19.92 Tex Cotton	0.7	0.931	0.069	0.383	0.617	--	--
10	19.92 Tex Cotton	0.6	0.229	0.771	0.724	0.276	--	--
11	19.92 Tex Cotton	0.5	0.936	0.064	0.383	0.617	--	--
12	19.92 Tex Cotton	0.4	0.645	0.355	0.383	0.617	--	--
13	15.22 Tex Cotton	0.7	0.500	0.500	0.383	0.617	--	--
14	15.22 Tex Cotton	0.6	0.931	0.069	0.383	0.617	--	--
15	15.22 Tex Cotton	0.5	0.510	0.490	0.724	0.276	--	--
16	15.22 Tex Cotton	0.4	0.229	0.771	0.228	0.772	--	--

4. RESULTS AND DISCUSSION

Production Run No. 2-3 & 5-16

Here in every case the p-values for clustering, mixtures, trends and oscillation are all greater than α-value of 0.05. So, presence of special cause variation or non-randomness is absent for these production runs.

Production Run No. 1

The p-value for oscillation is less than α-value of 0.05, indicating that the process is not steady. It can be found in figures 4 & 5.

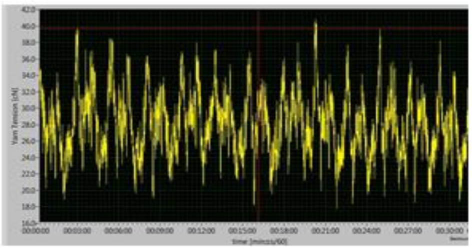

Fig. 4: *YIT waveform obtained for knitting production with 23.62 Tex Spun Polyester at cam setting 0.7*

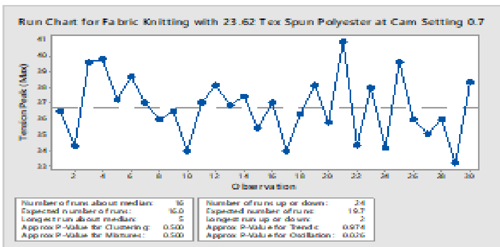

Fig. 5: *Run chart for production run no.01(30 sec)*

Fluctuation in maximum yarn input tension may be attributed to periodic variation of yarn delivery rate from the feed wheel. The cause-effect diagram (figure 6) for oscillation in yarn tension on a knitting machine may be depicted as:

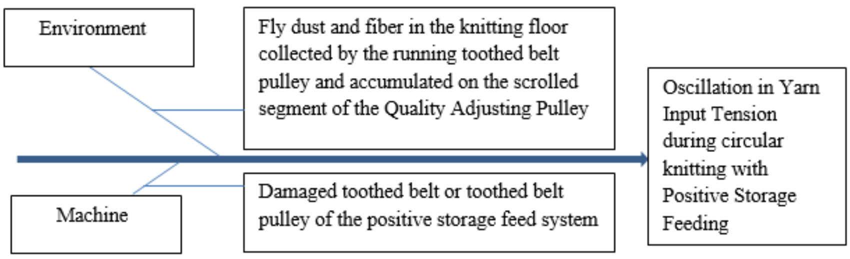

Fig. 6: *A cause-effect diagram for oscillating yarn input tension in a circular weft knitting machine with positive storage feeding*

In this particular case it was found that fluff deposition around the scrolled segments of quality pulley (figures 7 & 8) built non-uniform diameter, which in turn introduced some kind of periodic variation in yarn delivery from the feed wheel.

Fig. 7: *Quality Adjusting Pulley (QAP)-Top view*

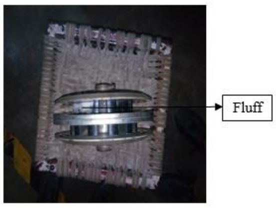

Fig. 8: *Fluff deposition inside QAP*

As the machine speed and cam setting remained same, such variation in yarn delivery resulted oscillation in tension peaks.

Production Run No. 4

Here the p-values for clustering, mixtures, trends and oscillation are all greater than α-value of 0.05. So, presence of special cause variation or non-randomness is absent here. However, observation no. 19 may be judged as an astronomical data point. It seems to be fleeting -a one-time occurrence of a special cause (figures 9 & 10)

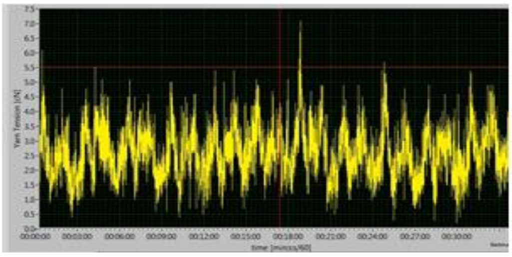

Figure 9: *YIT waveform obtained for knitting with 23.62 Tex Spun Polyester at cam setting 0.4*

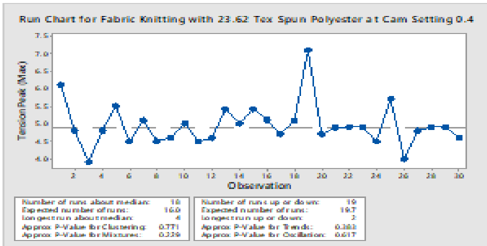

Figure 10: *Run chart for production run no.04 (1st 30 sec)*

To find out whether it comes back again or not - another run chart (figure 11), built with tension peak values for next 30 seconds, was examined.

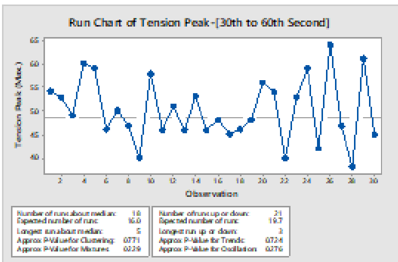

Figure 11: *Run chart for production run no. 04 (31st to 60th second)*

On the 2nd run chart built for fabric knitting with 23.62 Tex spun polyester at cam setting 0.4, the presence of any astronomical data point is not prominent. So, the sudden large shift of tension peak value at a particular observation on figure 5 was caused by a fleeting special cause -it was there and then it was gone.

5. CONCLUSION

The monitoring of performance of an industrial knitting machine is crucial for order planning and scheduling from both production and quality related aspects. Performance evaluation is also significant to find out any flaw of the running machine. In this research work an industrial knitting machine of an export-oriented knitting factory of Bangladesh was selected for its performance evaluation. The aim was mainly concentrated on discovering machine related flaws that could hamper its performance, ultimately the process performance. It was found that non-random patterns were absent in more than 85% of the evaluated production runs based on an alpha level (significance level) of 0.05. However the production run with special cause variation was due to environmental rather than machine related cause. Astronomical data point observed in another production run was of fleeting nature rather than periodical. Therefore the said knitting machine was quite flawless during the experimental production hours. Additionally IMR charts (Individuals-Moving Range Charts) may be consulted to get the complete information on the behavior of the overall processes.

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