WMSCI 2006

The 10th World Multi-Conference on Systemics, Cybernetics and Informatics

July 16-19, 2006 ~ Orlando, Florida, USA

Jointly with
The 12th International Conference on
Information Systems Analysis and Synthesis: ISAS 2006

PROCEEDINGS

Volume IV

Edited by

Nagib Callaos
Katsuhisa Horimoto
Takemi Fujikawa
Jesse Bemley
Andreas Tolk
Jaw-Sin Su
Jeremy Porteus

IIIS

Organized by
International Institute of Informatics and Systemics
Member of the International Federation of Systems Research (IFSR)

Direct Measurement of Yarn Mass with 1mm Accuracy Using Capacitive Sensors

Vitor CARVALHO[1], João MONTEIRO[1], Rosa VASCONCELOS[2] and Filomena O. SOARES[1]

[1] Dept. of Industrial Electronics, [2] Dept. of Textile Engineering
Minho University
Guimarães, 4800-058, Portugal

ABSTRACT

In Textile production, measurement of yarn mass in 1 mm range is of utmost importance to evaluate evenness correctly, as several irregularities occur in 1mm to 4 mm yarn length. Direct measurements in the 1mm range are not available in commercial equipments: yarn analysis is based on samples of 8mm. This paper presents a system which enables direct mass measurement in the 1mm range based on parallel capacitive sensors and signal processing techniques for detection of periodical errors. Results point out that evaluation of yarn mass, with this approach, is feasible in 1 mm range, allowing on-line measurement (1 mm yarn mass) in a spinning frame for real-time control. Spite low signal to noise ratio (SNR) it is possible to measure small variations of yarn mass (note that there is a typical capacity variation of 2,08E-17 F for 57 tex - 0,057 g/m of yarn). As a spin-off of this project, a new low-cost system was prepared for use in knitting flat machines to control yarn break and bobbin end. On-line quality classification is also feasible with the developed system.

Keywords: Yarn Evenness, Capacitive Sensor, Signal processing.

1. INTRODUCTION

The quality of any textile product is strongly influenced by its components, e.g., fibres and yarns. These must be manipulated in bulk and the resulting structures have many varying characteristics, which ultimately depend on variation in mass per unit length. It is thus important to find out linear density variations and irregularity, to predict yarn property effects on production and final appearance of fabric.

For detection of such irregularities, electronic capacitance testers are still applied nowadays as a convenient and a reliable method of testing irregularity (determination of mass variation). The system signals when a measured mass value is greater or lower than pre-defined thresholds. These thresholds are related to yarn mass average value and allow detection of imperfections (thick points, thin points or neps) [1].

Yarn mass evaluated in the 1 mm range is of utmost importance to a correct detection of defects, identification of periodical errors in wavelengths that start at 2mm, which enable in some cases characterization of fiber constitution of analyzed yarn and to perform an accurate classification of quality [2, 3]. This paper presents a new system for direct measurement of 1mm yarn mass using a capacitive sensor.

2. TEXTILE PARAMETERS

Some of the most important parameters to identify specifications for yarn quality are linear density, structural features and fiber content. The combination of different numbers of fibers per cross section with varying forces binding them together due to twist variation, leads to unlike yarn properties. An example of yarn configuration is shown in Figure 1.

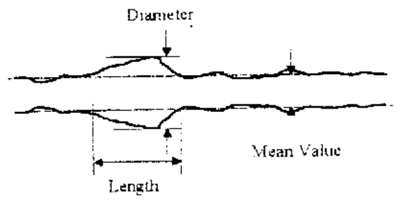

Fig. 1 – Example of yarn configuration

Electronic capacitance testers are established as an appropriate method to obtain yarn mass irregularity [4]. Basic requirement of this type of unevenness tester is that the output of measuring circuit is directly proportional to linear density of that part of strand within the capacitor; the relationship between capacitance and mass of fiber between sensor plates must be linear; changes of capacitance brought about by variation of total fiber cross-sectional area between plates enables automatic indication of mean absolute deviation (U%) and coefficient of variation (CV%) [5]. In mathematical form U is defined (as a percentage) by Eq. (1).

$$U = \frac{100}{\bar{x}T}\int_0^T |x_i - \bar{x}|\,dt \qquad (1)$$

where, x_i - instantaneous value of the mass;
$\bar{x}$ - mean;
T- evaluation time.

The irregularity U is proportional to the amount of mass variation around average value and is independent of evaluating time or tested material length if the material has a homogeneously distributed mass variation. Standard deviation CV also measures mass variation, and usually has (homogenous fiber composition) a relation with U (CV=1.25U). The standard deviation is equal to mean value as presented in Eq. (2).

$$CV = \frac{100}{\bar{x}} \sqrt{\frac{1}{T} \int_0^T (x_i - \bar{x})^2 dt} \qquad (2)$$

Irregularity U% and CV% can be described graphically according to Figure 2 [5].

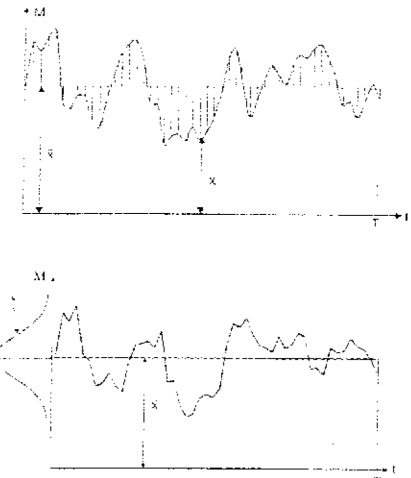

Fig. 2 – Graphical representation of U and CV

Apart from these yarn irregularities, it is important to provide data on number and type of 'imperfections', to produce a high quality yarn. These are commonly named faults and are of three kinds (Figure 3):

- Thin places - a decrease (50%) in the mass during a short length of about 4 mm;
- Thick places - an increase in the mass, usually lower than 200% and longer than 4 mm;
- NEP's - huge mass of yarn in a short length, typically from 1 to 4 mm.

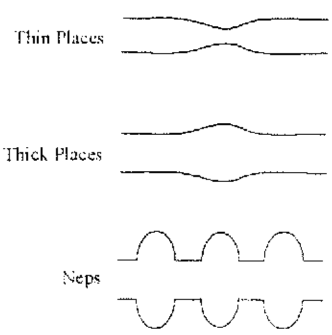

Fig. 3 - Types of yarn faults

Number of faults and mass measurements (U and CV) enable a quality rating of product. An accurate measurement of these properties is of major importance [6].

Periodical Errors

Analysis of yarn irregularity, which is known to contain a random component and eventually a periodic component may be carried out with a frequency analyzer (spectrogram graphic) that performs harmonic analysis of periodic yarn irregularities. In spectrogram, ordinates represent proportions of irregularity associated with wavelengths represented by abscissa. For a strand with fibers of uniform length, curve is given by Eq. (3) [7]

$$S(\log\lambda) = K \frac{\sin\frac{\pi l}{\lambda}}{\sqrt{\frac{\pi l}{\lambda}}} \qquad (3)$$

where, $S(\log\lambda)$ is the amplitude of spectrum corresponding to wavelength λ plotted as abscissa and K is defined by Eq. (4).

$$K = \frac{1}{\sqrt{\pi n}} \qquad (4)$$

where: l - fiber length;
λ - wavelength.

Maximum of ideal spectrum lays at about 2.3-2.7 the mean fiber length. Chimneys protruding above smooth course of spectrogram indicate regular periodic variations in yarn, and their importance is proportional to ratio of height of chimney to height of underlying curve at that point. Their wavelength is read off scale and processing details such as drafts, roller diameters among others, may enable deduction of mechanical cause of unwanted period. Figure 4 shows a typical spectrogram from commercial equipment based on an 8mm capacitive sensor.

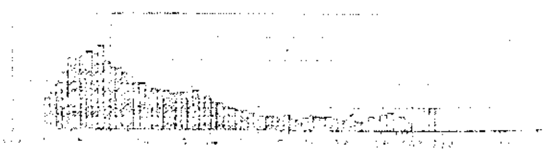

Fig. 4 Typical spectrogram from a commercial equipment

Observing figure 4, two main errors can be identified, one between 5 and 10 cm and other between 50 cm and 1 meter.

3. HARDWARE OVERVIEW

First step of work consisted in using an experimental apparatus (Uster Tester I) based on a commercial 8 mm capacitive sensor and a Labview data acquisition system to achieve yarn evenness. After validation of results obtained with this experimental rig with ones obtained with a more recent device, Uster Tester III equipment, the research objective is to extract 1 mm mass values, using measurements of 8 mm length sensor. Using signal processing techniques, sequential samples of mass signal are then acquired in such a way that length interval is in 1mm range [8]. Mathematical study allowed extracting 1 mm mass values, using measurements from an 8 mm length sensor, acquired with a sample rate proportional to 1 mm yarn length.

In order to analyze the influence of measurement length (portions of 1 to 8 mm) in evaluation of yarn evenness, a statistical study was carried out. The Scheffe method was used for pair wise comparisons of means. Pairs of means that were significantly different at 0.05 levels were those obtained in comparison with 1 mm range [9].

Commercial capacitive sensors with parallel plates with 1 mm length could not be found. Instead, a 1 mm diameter cylindrical sensor was tested. Measurement instrument was tuned to get maximum resolution. For that, yarn should be close to sensor, and specific and carefully designed electronic conditioning circuit was needed. In this case, acceptable results were obtained. However, due to yarn oscillations in industrial spinning frames, this kind of sensor could not be accepted [10].

A capacitive sensor with parallel plates and its electronic conditioning circuit were developed allowing 4 mm yarn mass reliable measurements [11]. Based on knowledge acquired with results obtained with the 4 mm length sensor, a linear 1mm length sensor could be developed.

Regarding accuracy, a theoretical study was undertaken to quantify capacity variations due to difference in dielectric constant corresponding to analysis with/without cotton yarn between plates. An estimated variation of 2,08E-17 F was considered for a 57 tex (0,057 g/m) yarn. Although it is possible, with this equipment, to detect small variations, some difficulties in terms of signal to noise ratio (SNR) were still present. These small variations of capacity were translated in variations of μV tension, resulting in a very small SNR.

In order to reduce the noise, some attempts were made using traditional filters, with relative success, as noise had its main component at 50Hz range. To overcome SNR problems a study on influence of electromagnetic radiation was carried out, using two identical sensors, in a differential configuration, with different distances between plates (Figure 5).

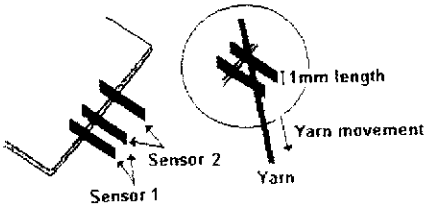

Fig. 5 - Representation of the two sensors

With this technique it was possible to use the same equipment for different yarn diameters. Furthermore, the use of differential set-up improved the electronic circuit performance, making it more robust to temperature and air humidity variations, which are particularly important in textile industries. This system is to be used for ring spinning frames on-line control in order to evaluate yarn evenness produced. Presently, in spinning mills, this kind of evaluation is made off-line in laboratory using a small amount of yarn. Tests made with this system show good performance in laboratory environment. The experimental set-up used consists on a PC with Labview data acquisition system (National Instruments) together with two sensors and electronics. Figure 6 shows system schematic diagram used in project development.

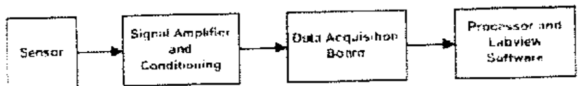

Fig. 6 - System flow chart

In order to have two capacitors with a common electrode, three metallic conductors placed in parallel were used in system design. Air and yarn make up capacitor dielectric. Integrated circuit (IC) MS3110 from Microsensors© implements functions regarding transducer, amplification and signal conditioning. This is a specific IC for capacitive sensors and has the following characteristics (Figure 7):

- Capacitance resolution up to 4.0 aF/rtHz;
- Single Variable or Dual differential variable;
- On-chip dummy capacitor for quasi-differential operation and initial adjustment;
- Gain and DC offset trim;
- Programmable bandwidth adjustment 0.5 to 8 kHz;
- 2.25 V DC output for ADC reference/ratiometric operation;
- Single supply;
- On-chip EEPROM for storage of settings.

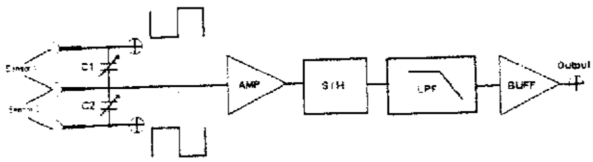

Fig. 7 - MS3110 electric diagram

Sensor capacitance variations are converted into a voltage signal and amplified. A second order low pass filter attenuates high frequency interferences, which come from internal oscillator and from other external noise sources. Filtered signal is then amplified using an output buffer. Then, MS3110 output voltage is filtered and converted to a digital signal with an ADC incorporated in data acquisition board (6024E from National Instruments). The acquired signal is monitored in a PC using specific developed software based on National Instruments, Labview. This software allows data storage, manipulation and processing for analysis and evaluation of results.

Figure 8 shows some print screens of results obtained with the software developed, namely acquired signal:

yarn mass in right top and in left corner the values obtained for U% and CV%. In bottom, spectral analysis based on Fast Fourier Transform algorithm (FFT) is presented.

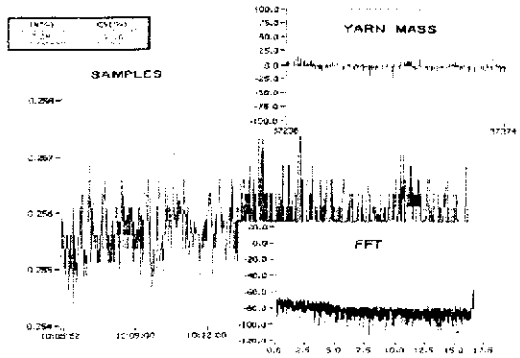

Fig. 8 - Control panel software components

To allow an industrial use of system there is a need for several sensors and processor linked over an industrial network. A new system based on microcontrollers (RISC technology) that allows the use of advanced Digital Signal Processing algorithms and distributed real time control is under development. The central unit monitors events (such as broken ends, neps, bobbin ends), report production data and updates control algorithms. Final result is an alert display that signals events, for example, lamps indicating that a position needs the presence of an operator.

4. SOFTWARE OVERVIEW

First attempt to extract 1 mm mass values was implemented offline with post-processing algorithms. This method is based on measurements of 8 mm length sensor acquired in real time, with a sample rate proportional to 1 mm yarn length. Figure 9 displays, graphically, the method employed in order to obtain this measurement.

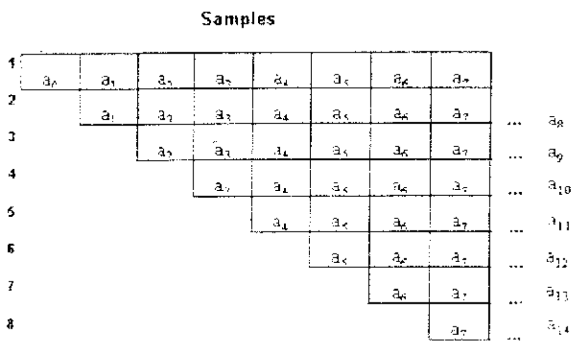

Fig. 9 - Method used in the determination of mass in 1 mm yarn length

Sequential samples of mass signal are acquired in such a way that length interval is in 1mm range. With this approach, each new sample includes a new segment with 1 mm length. To evaluate value of this new segment, it is necessary to know previous samples in 1mm range, using the following approach.

$$a_i = \sum_{j=i-7}^{i} a_j - \sum_{k=i-8}^{i-1} a_k + a_{i-8} \quad (5)$$

where a_i are values in 1mm-range. As sums are values of each acquired sample with 8mm sensor, there is only need to know previous values of a. To achieve this, during calibration, signal acquired from sensor has no material. These signals are presented in Figure 10

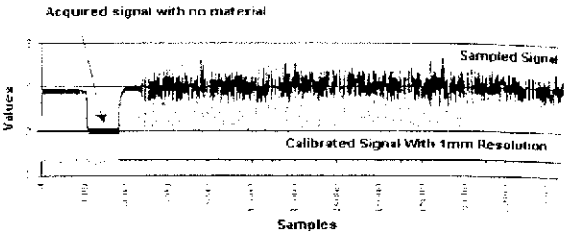

Fig. 10- Acquired signal with an 8mm sensor and the evaluated signal with 1mm length resolution

Values acquired from sensor allow evaluation of mass in 1mm range if we consider values acquired when there is no material (yarn) between plates of sensor. Values during this period present some small variation that is due to noise. However, its peek-to-peek value is small if compared with variation due to yarn. Results are saved on a file for offline analysis, namely quantification of yarn faults: U%, CV% and number of points that are outside of a previously defined threshold. For instance, if a sample corresponds to a value of 150%, number of thick points with a 50% threshold is incremented. Two consecutive samples with values more than 150% are quantified as only one fault.

It is also possible to calculate mean values from eight consecutive samples, which corresponds to a sample of 8mm yarn length. These values, as well as quantification of yarn faults based on them, make possible comparison with conventional equipment that uses 8mm capacitive sensors.

Second step in the software development task is on-line and real time yarn analysis based on a 1mm sensor

After calibration (acquired signal without yarn) data acquisition system runs with a pre-defined sample rate. Statistical parameters are calculated as well as Fast Fourier Transform using a Hanning window, Fast Walsh Hadamard Transform and Fast Impulse Frequency Determination. FFT is used for detection of sinusoidal errors (most common), FWHT for detection of rectangular errors and FDFI for detection of impulse errors [2, 3]. This evaluation is very important for periodical faults detection, responsible for defects on fabrics.

As the signal is not fully periodic and the sample rate is not guaranteed to be a multiple of sample period, the use of windows does not solve problem. A method to solve this problem was using energy bands, i.e., neighbor spectral components are grouped in the same band. With this method, small speed variations in traction mechanism are solved. Results are displayed in a bar chart corresponding to each bar average energy of harmonics in the interval. This periodogram graphic loses some resolution but eases result analysis as well as allows a quicker identification of periodic faults. At present it is implemented the statistical parameter Deviation Rate (DR %) that gives information about the yarn fault length. DR% is calculated as sum of fault yarn lengths divided by the overall yarn length analyzed. Another parameter also determined is Integral Deviation Rate (IDR %) that provides data of the amount of mass that is above or lower a pre-defined mass threshold. IDR (%) for a threshold of 0% provides same information that U (%) [12].

5. RESULTS

With yarn mass evaluated signal it is possible to calculate evenness values, which is of utmost importance to extract information regarding yarn quality. Several tests were performed with different bobbins (from open end spinning system, ring spinning system and filament type fibers) in order to detect the influence of linear mass.

Table 1 displays U% and CV% values in several yarn samples.

Table 1 - U% and CV% values

Fiber	Yarn Mass (tex)	U (%)	CV%
Cotton	57	14.96	18.69
Cotton	25	12.7	15.88
Cotton	37	11.28	14.09
Cotton	20	14.04	17.55
Cotton	20	21.35	26.68
Cotton	30	12.85	16.06
Polyamide	76.5	7.28	9.10

In order to evaluate yarn faults, previously defined as a mass decrease (50% during a short length thin places), an increase in mass (usually lower than 200% thick places) and a huge mass of yarn (in a short length NEPs), different thresholds were considered. Results show that a short difference in irregularity threshold produces a strong change in the number of irregularities. These results are displayed in Table 2.

Nevertheless, note that neither thin places can be obtained in a 182% threshold nor neps in less than 182% range. The primary goal of the project was to analyze only cotton yarns, but in order to expand system application field some tests were made to detect Lycra yarns with small linear mass (less than 6 tex, g/km). Although Lycra has a higher dielectric constant, its small linear mass prevents good performance of system. At the moment, research work focuses on an adaptation of the developed system that enables the detection of Lycra yarns and all types of yarn with less than 6 tex.

Table 2 Yarn faults in several yarn samples

Fiber	Yarn Mass (tex)	Thresholds (%)	Thin places (1000 m)	Thick places (1000 m)	Neps (1000 m)
Cotton	57	182	-	0	2
		60	0	17	-
		40	7	47	-
		20	104	147	-
Cotton	25	182	-	0	0
		60	0	4	-
		40	12	13	-
		20	208	105	-
Cotton	37	182	-	6	0
		60	0	1	-
		40	1	10	-
		20	131	102	-
Cotton	20	182	-	0	0
		60	0	6	-
		40	34	31	-
		20	281	161	
Cotton	20	182	-	0	12
		60	2	22	-
		40	109	42	-
		20	358	106	-
Cotton	30	182	-	0	0
		60	0	5	-
		40	10	20	-
		20	274	146	-
Polyamide	76.5	182	-	0	0
		60	0	0	-
		40	0	2	-
		20	59	27	-

6. CONCLUSIONS AND FUTURE WORK

With the developed system the determination of all faults is performed correctly, especially neps, which occur in lengths between 1mm and 4 mm and are not measured directly (estimation techniques) considering commercial solutions.

Periodical errors, with wavelengths inferior to 2 cm are determined allowing measurement of fiber yarn length in cotton; quality classification accuracy is also increased. However, large scale tests are needed to allow a total correlation of results with those obtained by commercial solutions.

System under development should integrate yarn mass measurements based on capacitive sensors (as presented) and yarn hairiness measurements based on optical sensors. A solution including image processing is also being considered.

The main objective of the project is to perform on-line measurements of 1mm in a spinning frame and using feedback control to obtain a certain yarn with specified characteristics defined by the operator.

7. ACKNOWLEDGEMENT

The authors are grateful to Portuguese Foundation (FCT) scholarship (BD/ 19028/ 2004).

8. REFERENCES

[1] J. L. Monteiro and C. M. Couto, **Pulse Frequency Calculation and Estimation in Yarn Evenness Analysis.** Proceedings of the 21st Annual Conference of the IEEE Industrial Electronics Society - IECON' 95, Orland, November 1995; Ed. IEEE Press, IEEE Catalogue Number 95CH35868, ISBN 0-7803-3026-9, pp. 985-989.

[2] V. Carvalho, **Parametrização de Fio Têxtil Baseada de Massa**, Msc. Dissertation, Minho University, 2004.

[3] V. Carvalho, J.L. Monteiro, R. Vasconcelos, F. O. Soares, **Yarn Mass Analysis with 1mm Capacitive Sensors**, ISIE'2004, 4-7 Maio de 2004, Ajjacio, França, ISBN 0-7803-8305-2, p.633-638.

[4] J. L. Monteiro and C. M. Couto, **High Resolution Capacitive Sensors for High Speed Yarn Evenness Analysis**, Proceedings of the ICRAM'95 -, Istanbul, August 1995; Ed. Unesco Bogaziçi University, ISBN 975-518-063-X, pp. 824-829.

[5] R. Furter, **Evenness Testing in Yarn Production: Part I**, Manual of Textile Technology, Ed. K. Douglas, 1982.

[6] R.M. Vasconcelos and M. Lima, **Comparative Study of Yarn Regularity Using Capacitive and Optical methods**, 1997 Fall General Conference Fiber Society, October 1997, Knoxville, Tennessee, USA.

[7] B.C. Goswami, J.G. Martindle and F.L. Scardino, **Textile Yarns, Technology, Structure and Applications**, John Wiley and Sons, 1977.

[8] S. Monteiro, R.M. Vasconcelos, F. O. Soares and J. L. Monteiro, **Yarn Evenness Control in 1 mm Range.** Proceedings of Controlo 2000, Universidade Minho, 4-6 October 2000, ISBN 972-98603-0-0.

[9] F. O. Soares, R.M. Vasconcelos, J. L. Monteiro, **Influence of Measurement Length in Yarn Evenness Control**, Control and Applications 2001, IASTED Conference, Banff, Canada, 27-29 June 2001, ISBN 0-88986-285-0, pp215-219.

[10] J. G. Pinto, R.M. Vasconcelos, F. O. Soares, J. L. Monteiro, **High Resolution Yarn Mass Measurement**, Conference Information Technology in Mechatronics, Istambul, Turkey, 1-3 October, 2001, ISBN 975-518-171-1, pp425-430.

[11] L. Baxter, **Capacitive Sensors: Design and Applications**, IEEE Press, NJ, 1997.

[12] V. Carvalho, J.G. Pinto, J.L. Monteiro, R. Vasconcelos, F. O. Soares, **Yarn Parameterization Based on Mass Analysis**, Sensors and Actuators A: Physical Volume 115, Issues 2-3, 21 September 2004, pp.540-548.

WMSCI-2006

COPYRIGHT

The papers of this book comprise the proceedings of the conference mentioned on the title and the cover page. They reflect the authors' opinions and, with the purpose of timely disseminations, are published as presented and without change. Their inclusion in these proceedings does no necessarily constitute endorsement by the editors.

ISBN: 980-6560-65-5 (Collection)
980-6560-69-8 (Volume IV)
If83120060042182