An Automatic Adjustment System for VCR Magnetic Heads on Cylinder Units

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To eliminate the requirement for skilled workers in Video cassette recorder (VCR) cylinder assembly lines, an automatic adjustment system for VCR magnetic heads on a rotating cylinder unit has been newly developed. The reconstructed image quality is strongly affected by magnetic head setting errors, such as;
(1) Setting angle error for two symmetrically positioned head.
(2) Rotational angle error for every individual head, in regard to a setting screw axis.
(3) Error in the distances head tips protrude from a cylinder edge.
The pertinent technical features for the system are high speed and highly accurate image processing algorithms, to determine head positions using interferometric head images and very precise mechanisms and algorithms to adjust head positions, even when head slipping and elastic deformations occur.
Adjustment speed for the system is 30 sec/unit. One machine corresponds to three skilled operators in total productivity.

1. INTRODUCTION

There are many manual adjustment jobs in factories, especially in assembly lines. For example, magnetic alignment of an electron gun and electron beam for color display tubes. Basically, adjustment jobs are done for absorption or control of errors in assembled parts or components. So, there are many factors governing these adjustments, for example, parts accuracy, assembled accuracy or how to set the adjustment references. In general, these skilled assembly work causes a bottle neck in a flexible manufacturing system in factories.

Important VCR features are picture quality and compatibility between sets. In a VCR system, magnetic tape runs on a tape guide and a cylinder unit, with magnetic heads, rotates to read signals from and write signals onto tapes. Therefore, key VCR set mechanisms are a tape running guide and a cylinder unit with magnetic heads. On the top of the magnetic head, there is a gap 0.5 μ m wide and nearly 30 μ m long. The gap position is used as a reference for these adjustments.

In replaying, the tape and the heads on the cylinder unit move in a mutually appropriate configuration and the narrow gap must trace the track very precisely. So, setting the accuracy for heads on a rotating cylinder is a very important factor for VCR sets.

On the other hand, in conventional assembly lines, these magnetic heads are set manually on a cylinder unit by skilled operators, while observing optically enlarged head images on monitor displays. So, these tasks are tedious, slow, unreliable and require well trained and skilled operators.

Considering this background, the authors have developed an automatic adjustment system for VCR magnetic heads on cylinder units.

2. ADJUSTMENT SPECIFICATIONS

Extremely important head position error are ;
1) Setting angle error for two symmetrically oppositely positioned (180 degree) heads.
2) Rotational angle error for every individual head, in regard to a setting screw axis.
3) Error in the distances head tips protrude from the cylinder edge.
These items and specifications are shown in Fig. 1 and are listed in Table I.

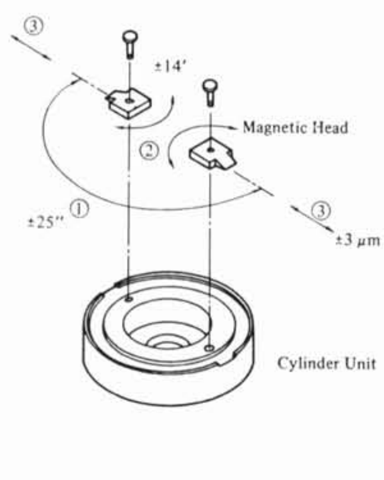

Fig. 1 Head Assembly

Table I. Adjustment Specifications

	Protruded Distance (μm)	Rotational Error (minutes of arc)	Setting Angle Error (seconds of arc)
Specification	±3.0	±14.0	±25.0

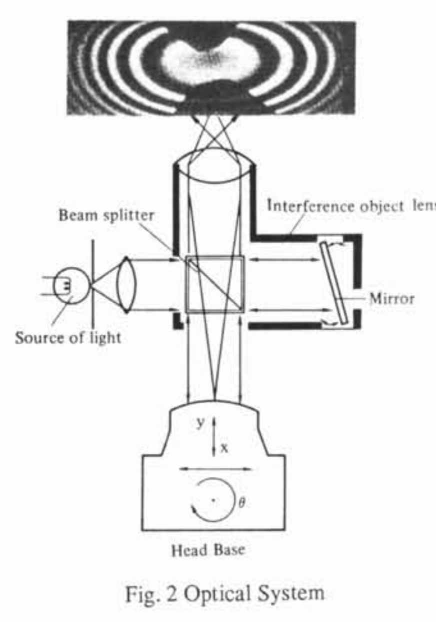

Fig. 2 Optical System

3. SYSTEM CONFIGURATION

3.1 Optical system

In this system, the head gap position is detected by an optical system with a reference plane, as shown in Fig. 2, and is accurately calculated by image processing computers. Two images of the head (with/without interferometric fringes) are used to calculate head position errors. The head image with fringes, using the optical system, are also shown in Fig. 2.

3.2 Image processing

MC68000 CPU (OS-9/68000) is used as the host computer. Two image processing computers (Tospix-i) are connected to the host computer by bus. Tospix-i is Toshiba's low cost, compact image processing computer for industrial applications. Speedy image processing (for example, projection, filtering, region labeling) is accomplished within 31.5ms for a picture frame (512x512 pixels).

3.3 Adjustment mechanism

The adjustment mechanism is composed of x ,y and θ tables with stepping motors and ball screws.

The parameters calculated by image processing are transferred to the adjustment mechanism through a feedback system.

The system configuration is shown in Fig. 3.

4. BASIC ADJUSTMENT CONCEPT

The basic concept for calculating head positioning errors for three adjustment items are:

1) The angle error between two symmetrically positioned heads is calculated, using the positions of the two head gap images, in regard to cursor positions on monitors, as shown in Fig. 4.

These cursor positions are calibrated as 180 degrees opposite each other, using a standard master cylinder unit.

2) Rotational angle error for the screw axis is calculated, according to the distance between the center of the interferometric fringes and the center of the gap, as shown in Fig. 5.

3) Distance Protruded from a cylinder edge is adjusted, where the fringe contrast is higher than a certain threshold level, using interferometric optics. Interferometric optics are also calibrated using the master unit.

Calculation accuracies for the gap position and the fringe center directly affect the adjustment accuracy. So, high speed , highly accurate and reliable algorithms are required, even though a noisy head image or dust particles on the gap were to appear.

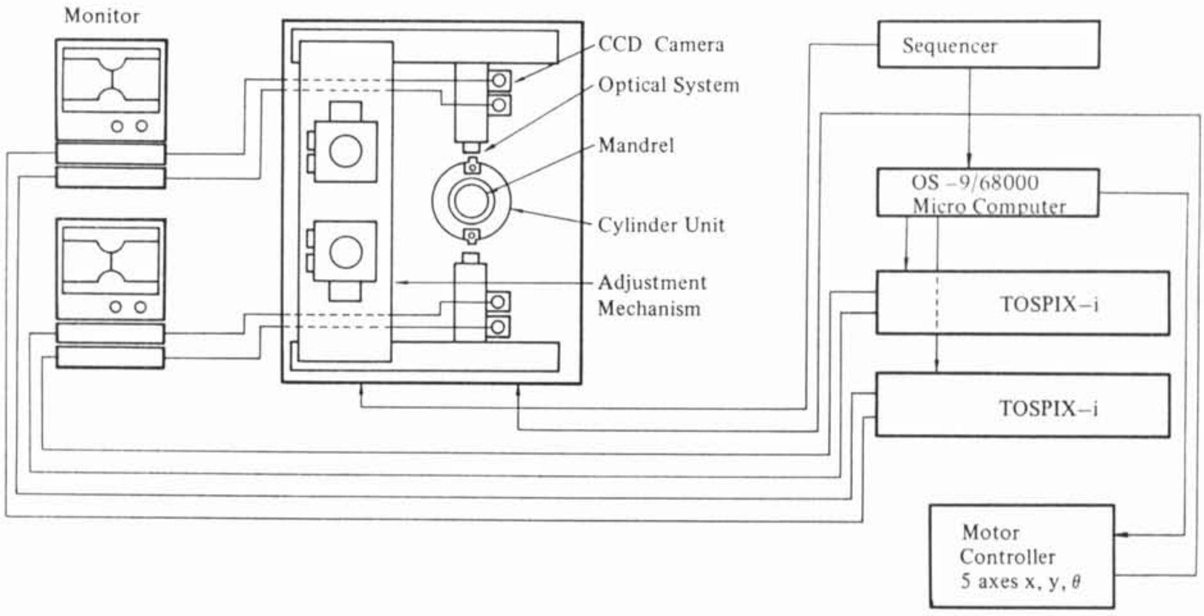

Fig.3 System Configuration

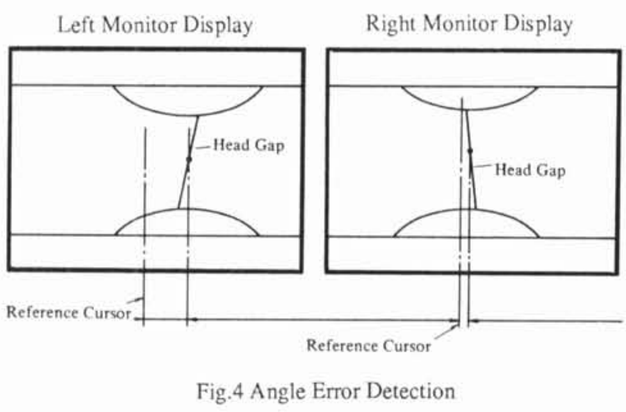

Fig.4 Angle Error Detection

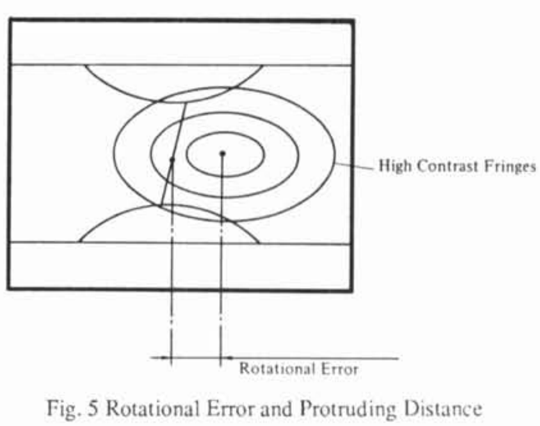

Fig. 5 Rotational Error and Protruding Distance

5. SOFTWARE CONFIGURATION

5.1 Image processing software

The image processing program for calculating the head positions has two main parts. One is the program for calibration and autofocusing. The other is the program for calculating the head gap position and fringe pattern analysis, as follows ;

1) Calibration : Calibrate optical system magnifying force and set up reference cursor positions, using the master unit for 180 degree adjustment.
2) Autofocus : Software for autofocusing with 1 μm order resolution.
3) Rough position detection : Calculating rough head gap position.
4) Precise position detection : Calculating precise head gap position for 180 degree opposite distance.
5) Fringe contrast calculation : Calculate fringe contrast for adjusting the head protruding distance.
6) Fringe pattern analysis : Calculate the center position and fringe pattern size for adjusting the protruding distance and rotational angle error.

5.2 Control software

Offset monitoring and offset adjustment algorithms are installed in the software to compensate for head movement, appearing as slipping and deformation.

There are some statistical tendencies for head movement, such as moving directions and distances, depending on differences in head lots and head makers.

So, these parameters are set into the feedback software for the adjustment mechanism.

For unusual head movement, offset parameters in retrying sequence are decided by memorizing the head movements in the first adjustment sequence.

6. IMAGE PROCESSING ALGORITHMS

The main algorithms for automatic adjustment are used in calculating the gap position and for fringe pattern analysis, as follows ;

6.1 Gap position calculation

1) Head image data is fed into an image memory through a

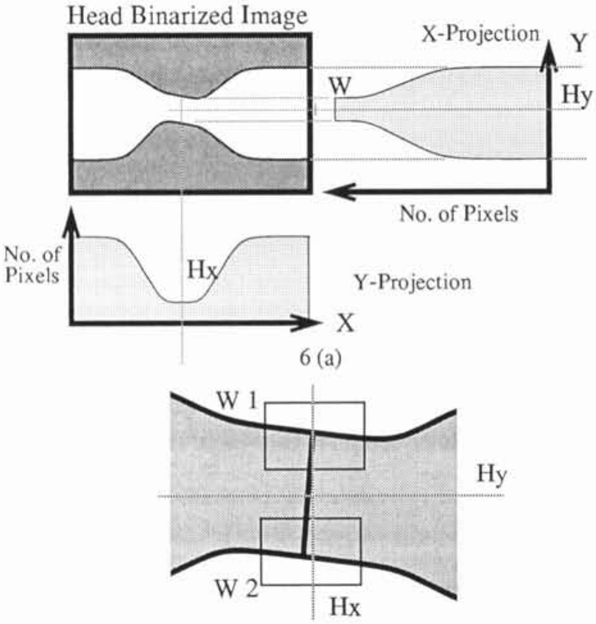

Fig. 6 Rough Position for Head and Windows

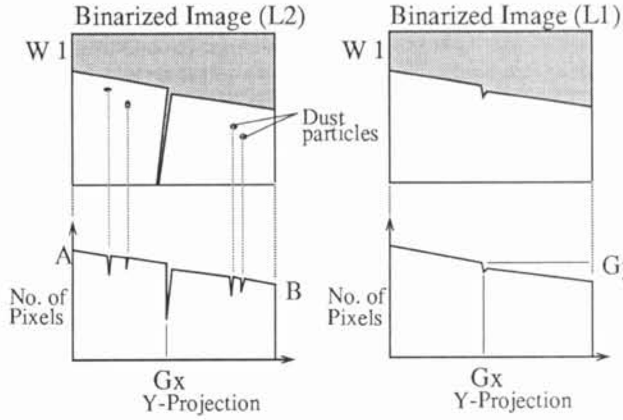

Fig. 7 Gap Position Detection

CCD camera. Then, the binarized level (L1) is determined, using a histogram of the head image. By this method, only the binarized head image is distinguished from the background. Rough positions for head (Hx, Hy) and track width (W) are calculated, by projection along the x, y direction, as shown in Fig. 6(a).

2) Two windows (W1, W2) are set on upper and lower positions on the head gap image, as shown in Fig. 6(b), considering the azimuthal angle for the head gap. Window sizes are variable, depending on the track width. Determine the binary level (L2) at which the binary gap image appears, by calculating the average intensity profile for one line along the x axis in the window.

L2 = (Average Intensity) - δ

Here, δ is decided by gap contrast.

By calculating the projection along the y axis in the window, the x position for the gap is detected at the deepest point in the projection, as shown in Fig. 7.

3) Again determining the binarized image by level L1, calculate the projection along the y axis in the window and find the precise position for the gap, within a few pixels. So, decide the y position for the gap (Gy), according to the x position for the gap.

4) Decide the lower x, y position for the head gap in similar manner.

The key of the basic algorithm depends on calculating the projection for two different binarized images by different threshold levels (L1, L2). This method is not affected by noisy head gap image and irregularities in head edge. So, the result is reliable, when the gap has low contrast.

6.2 Fringe pattern calculation

(A) Center position calculation

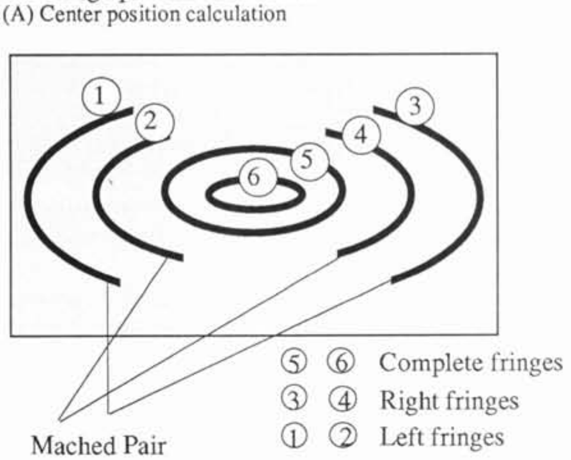

Fig. 8 Classify labeled fringes

1) Extract only the interferometric fringe pattern for the head, by pixelwise operation for two images, with and without fringe pattern, on the gap image.
2) After binarizing the fringe, remove noises and label each fringe region. Classify labeled fringes as complete fringes, right or left side fringes, as shown in Fig.8.
3) After matching right and left fringes, calculate the center position for each pair of fringes. Then, omitting irregular fringes, the fringe center Cf is decided upon, by averaging center positions for individual fringes.
(B) Fringe size calculation
Calculate the highest contrast fringe size as follows :
1) For an original image with fringe pattern, obtain the intensity profile for one horizontal line on the fringe center position Cf, as shown in Fig.9.
2) For on envelope of the intensity profile data, search the left side peak Pl and the right side peak Pr from the fringe center position Cf.
3) Calculate the highest contrast fringe size Sf as | Pr - Pl | .

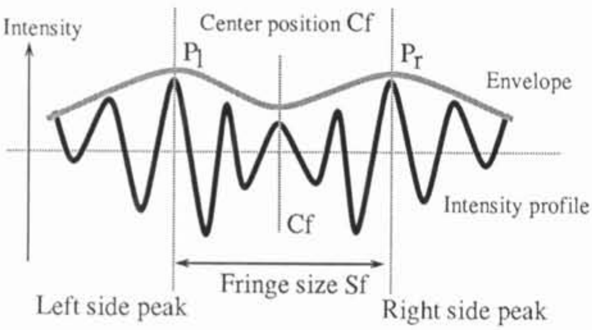

Fig. 9 Fringe intnsity profile

7. TOTAL SYSTEM AND ADJUSTMENT SEQUENCE

The adjustment sequence and an external view of the system are shown in Fig. 10 and Fig. 11, respectively.

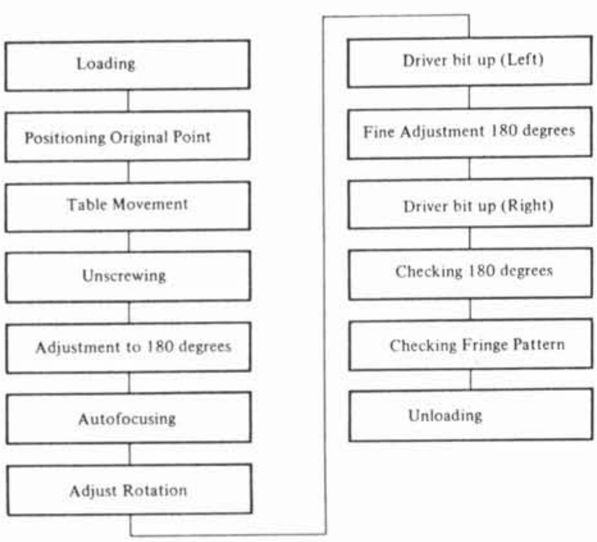

Fig. 10 Adjustment Sequence

An automatic screwing mechanism is one of key points in the system. The concepts is to develop mechanisms and software to reconstruct a skilled operator's work. The screwing mechanism uses pulse motors as actuators to control revolutional angle, speed and return angle of the screw accurately. To control the screw torque, a mechanical slip clutch and a remote center compliance mechanism is used in a screw driver mechanism to prevent head movement, due to unbalanced force applied by the driver bit.

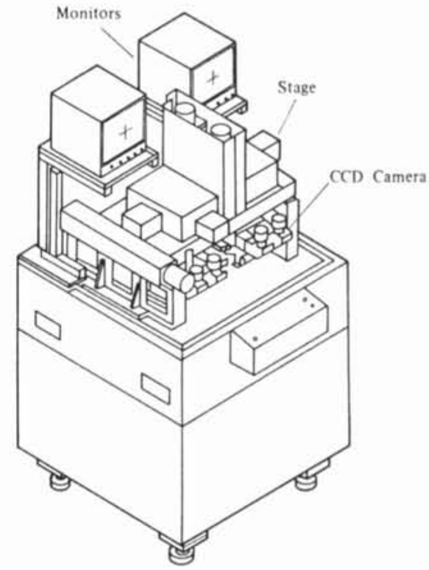

Fig. 11 External View of the System

8. CONCLUSION

The authors have developed an automatic adjustment system to eliminate the need for skilled workers in VCR cylinder lines.

Adjustment speeds are 29.9 sec/unit for single heads and 31.9 sec/unit for double heads. The adjustment accuracies and deviations for three items are listed in Table II.

Table II. Adjustment Results

	Protruded Distance (μm)	Rotational Error (minutes of arc)	Setting Angle Error (seconds of arc)
Specification	±3.0	±14.0	±25.0
Average	0.12	0.68	−0.87
σ	0.81	2.69	5.53

9. REFERENCE

1) T. Komatsu, A.Ono and N.Hoshina, Measuring Apparatus for Setting Errors of VTR Magnetic Heads, Annals of the CIRP vol.33/1/1984, pp.383-286
2) T.Komatsu, S.Nagashima and H.Tsukada, An Automatic Adjustment System for VCR Magnetic Heads on Cylinder Units, Annals of the CIRP vol.38/1/1989, pp.9-12