Time Delay Element Consisting of Timer Relays (A Component of HMG Etrich Type Auto Chain Gill)

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Abstract

The HMG Etrich Type Auto Chain Gill developed by the Hansatische Motoren Gesellschaft, of West Germany, is primarily intended for processing card slivers and is equipped with an automatic sliver-evening device. The authors have investigated the characteristics of this automatic sliver-evening device both theoretically and experimentally with emphasis on its unique time delay element consisting of timer relays.

Results:

1. The sliver-evening device does not respond correctly to a sinusoidal input signal because it skips one signal every 2 or 3 cycles when the period of the sinusoid becomes less than twice the timer setting in the time delay element. It follows, then, that the evening device cannot be expected to attenuate sliver weight variations whose period is less than the value mentioned above.

2. A theoretical investigation has shown that the characteristics of the time delay element is approximately equal to that of a pure time delay within a certain frequency range when there is no hysteresis in its limit switches.

The hysteresis in the limit switches tends to increase the effective time delay at both ends of the frequency range concerned, although it does not prevent the sliver-evening device from effectively attenuating long-term weight variations.

1. Introduction

The automatic sliver-evening device contained in the HMG Etrich Type Auto Chain Gill is an open-loop control system like most other sliver evening devices now available commercially. The open-loop control system is inherently capable of attenuating weight variations in a wider frequency range than the closed-loop system if other conditions are made equal.⁽¹⁾

The open-loop control system generally needs a time delay element to compensate for the transportation time the sliver takes to move from the detecting element to the drafting zone. The most widely used time delay element consists of a wheel which has a number of slide pins located around its periphery with the information stored in it for a predetermined time as the position of slide pins. Unlike this usual practice, the time delay element of the HMG Gill uses two timer relays in its minor feedback loop, so that its overall characteristics become similar to a pure time delay.

2. Theoretical and Experimental Investigations of the Time Delay Element

Fig. 1 Automatic sliver weight-evening device used in the HMG gill

The general arrangement of the sliver-evening device containing two timer relays is shown diagrammatically in Fig. 1.(2,3) A frequency response test was made by giving a sinusoidal displacement to the measuring roll with the aid of an eccentric cam and by recording the resultant changes in the front roll speed (Fig. 2). Then the same frequency response was derived graphically, as shown in Fig. 3, on the assumption that the amplitude of the input sinusoid was 7.6%, its period 14.5 sec, timer setting 2.0 sec, the ascending speed of the AEG Hydromagnet reflected on the sliver weight 6.6%/sec and the descending speed 18.0%/sec.(4)

It is also assumed here that the limit switches have a hysteresis of $\Delta\%$, that is to say, the position of the switching lever which turns the switch off is $\Delta\%$ below the position which turns it on. The two solutions shown in Fig. 3 are for the conditions $\Delta=0\%$ and $\Delta=1\%$, respectively. These graphical solutions agree very well with the results of the afore-mentioned test shown in Fig. 2.

See Fig. 2 and note particularly that:

- i) The output of the time delay element is always stepwise;
- ii) When the period of the input sinusoid is less than 4 seconds, the output signal skips the input signal once every 2~3 cycles.

The output response shown in Fig. 2 was broken down into Fourier's series to obtain the amplitude and

Fig. 2 Measuring roll displacement and calculated and actual values of front roll speed

Timer setting 2 sec

Servo ascending speed 6.6%/sec

Servo descending speed 18%/sec

Hysteresis Δ in limit switches	Equivalent time delay L_e (sec)
1	1.16
0	1.02

Fig. 3 Graphical solution of the response of time delay

the phase angle of the first harmonic. Fig. 4 shows the effective gain α and the effective phase angle φ of the time delay element derived by relating the input sinusoid and the first harmonic of the output signal. Fig. 4 shows also the effective time delay L_e of the time delay element defined as $L_e = T\varphi/2$. Gain α maintains a constant value of 0 db within the frequency range $\omega < 0.9$, regardless of hysteresis up to $\Delta=1\%$. The effective time delay L_e also maintains a constant value equal to half the timer setting. However, a hysteresis of $\Delta=1\%$ makes L_e deviate at both ends of the frequency range now concerned.

Fig. 4 Equivalent frequency response of the time delay element

Fig. 5 Magnitude of higher harmonics produced by the time delay element compared with the first harmonic

It can be safely said, therefore, that the time delay element is equivalent in its characteristics to a pure time delay within the frequency range $\omega < 0.9$ when the hysteresis is sufficiently small.

The output of the time delay element, being stepwise in shape, inevitably produces higher harmonics. The magnitude of the higher harmonics is readily derivable from the Fourier analysis mentioned. The largest amplitude of higher harmonics, amounting to about 2% weight change, occurs when its period is 4~5 seconds, which is approximately twice the timer setting (Fig. 5).

The characteristics of the time delay element having been approximated by a pure time delay L_e , the sliver-evening device as a whole can be described by a block diagram as shown in Fig. 6. The variables and system parameters included in the block diagram are percentage input sliver weight variation z/z_0 , output sliver weight variation x_1/x_0 , proportional gain α , equivalent time delay L_e and transportation time L_f . L_f is the time needed for

Fig. 6 Block diagram of the sliver evening device

the sliver to move from the measuring roll to the drafting zone.

From the block diagram a number of relations shown below are immediately available, assuming the input signal z/z_0 to be sinusoidal:

$$z/z_0 = a \sin \omega t \quad \dots\dots(1)$$

$$x_1/x_0 = y_1/y_0 - v_1/v_0 \quad \dots\dots(2)$$

$$y_1/y_0 = a \sin \omega(t - L_f) \quad \dots\dots(3)$$

$$v_1/v_0 = a \alpha \sin \omega(t - L_e) \quad \dots\dots(4)$$

$$x_1/x_0 = a \sqrt{1 + \alpha^2 - 2\alpha \cos \omega(L_f - L_e)} \times \sin(\omega t - \theta) \quad \dots\dots(5)$$

The second factor on the right-hand side of equation (5) braced by the square root sign is nothing but the amplitude ratio of the output signal over the input signal. In other words, it is the ratio by which a sinusoidal weight variations in the input sliver are attenuated by the sliver-evening device when weight variations are expressed in percentages. It is also a function of frequency ω and is called here the reducing ratio $A(\omega)$. Because of the non-linearity due to the fixed ascending and descending speeds of the AEG Hydromagnet, $A(\omega)$ depends also on the amplitude of the input sinusoidal.

The reducing ratio $A(\omega)$ for a 7.6% input amplitude is derived from the data in Fig. 4 and is plotted against frequency ω , as shown in Fig. 7. Regardless of the hysteresis Δ , the reducing ratio $A(\omega)$ is small in lower frequencies, indicating that the sliver-evening device is useful for attenuating long-term weight variations.

Fig. 7 Reducing ratio

3. Performance of the Sliver-evening Device in Actual Mill Run

Test 1.

Worsted card slivers contain a clearly periodical weight variation with a period equal to the operating interval of the automatic weigh feeder which is about 30 meters in terms of sliver length.⁽⁵⁾ These slivers were fed to the HMG Gill to see the extent to which the periodical weight variation was attenuated by the automatic sliver evening device.

Conditions of test:

Wool slivers from a worsted card was fed to the HMG Gill

Weight of slivers fed ... 14.4~15.6 grams/meter

Method of weighing output sliver

.....240 consecutively cut 5-meter samples

Sliver-feeding rate..... $v_f=20$ meter/min

Average draft ratio ... $d_0=5.0$

Timer setting $T_r=2.4$ seconds

Average thickness of input sliver at the measuring roll..... $h=4.0$ mm

The output sliver was cut into consecutive 5-meter samples to express their weights in a number series from which to derive the autocorrelation functions shown in Fig. 8.

The upper curve in Fig. 8 shows the autocorrelation function of the output sliver obtained with the sliver-evening device turned off so that the front roll was run at a constant speed. When the automatic sliver-evening device was turned on, the autocorrelation function of the output sliver decreased to the values shown by the lower curve in Fig. 8. The upper curve clearly shows the presence of a periodic weight variation in the output sliver 150 meters in wave length (or 90 sec in period and

0.07 rad/min in angular frequency) corresponding to the 30 m weight variation in the input sliver. No such weight variation is observed on the lower curve. The predominant sinusoidal weight variations are, therefore, practically eliminated by the sliver-evening device.

This result agrees with the theoretical results shown as in the reducing ratio $A(\omega)$ in Fig. 7, since the value of $A(\omega)$ in Fig. 7 at $\omega=0.07$ rad/min is close to zero, indicating that a periodical weight variation of this frequency should be almost totally eliminated by the automatic sliver-evening device.

The value of the autocorrelation function at $\tau=0$ is equal to the mean square value of the weight variation. It follows, then, that the two curves in Fig. 8 show that the mean square weight variation is reduced by a factor of

$$E^2 = \frac{R_w(0)}{R_r(0)} = \frac{2.1}{10.3} = 0.2$$

when the samples are 5 meters in length⁽⁶⁾.

Test 2.

The reducing ratio shown in Fig. 7 also predicts that the sliver-evening device cannot attenuate sliver weight variations of frequencies above 0.6 rad/sec.

To confirm the validity of this point experimentally, the delivery sliver was cut into shorter samples than before to see the effect of sliver-evening device on short-term weight variations.

Conditions of test:

Wool slivers from a worsted card were fed to the HMG Gill.

Weight of slivers fed.....15.2~15.4 grams/meter

Samples weighed240 consecutively cut 1-meter samples

Samples weighed: 240 consecutively cut 5 meter samples

Fig. 8 Effect of automatic sliver evening on autocorrelation function of output sliver weight

Samples weighed: 240 consecutively cut 1 meter sample

Fig. 9 Effect of automatic sliver evening on autocorrelation of the output sliver weight

Sliver-feeding rate $v_r=24$ meters/min

Average draft ratio..... $d_0=5.0$

Timer setting $T_r=2.0$ sec

Average thickness of input sliver at the
measuring roll $h=4$ mm

Slivers were passed through the HMG Gill with and without the automatic sliver-evening action with the autocorrelation functions for the two cases obtained as shown in Fig. 9.

The two curves in Fig. 9 are quite similar with respect to short-term weight variations 3~5 meters in wave length. This indicates that such short-term variations are not appreciably affected by the sliver-evening device and verifies the point stated before.

The decrease in mean square error this time is

$$E^2 = \frac{R_w(0)}{R_r(0)} = \frac{3.4}{5.4} \doteq 0.6.$$

4. Conclusions

The authors have investigated, theoretically and experimentally, the dynamic characteristics of the sliver-evening device used in the HMG Etrich Type Auto Chain Gill with special attention directed to its unique time delay element consisting of a pair of limit switches and timer relays with a neutral zone (or hysteresis) to prevent oscillation.

When the hysteresis Δ is zero, the time delay element of the HMG Gill has characteristics ap-

proximately equivalent to a pure time delay equal to half the timer setting T_r . A positive Δ tends to increase the equivalent time delay L_e in both low and high frequencies, although it slightly affects the effectiveness of the sliver-evening device in lower frequencies.

A proper amount of hysteresis Δ , however, is necessary for satisfactory operation. Without it the limit switches make unnecessarily frequent on-offs.

It was also found that when the period of the input signal became less than twice the timer setting T_r , the time delay device skipped a signal every 2~3 cycles and thus failed to follow the input signal correctly. The sliver-evening device, therefore, cannot be expected to attenuate short-term weight variations of periods less than twice the timer setting.

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