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BDX-613-1180

WIRE WOVEN TAPE MEASUREMENTS

Technological Spinoff Report

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December 1974

Prepared for the
United States Atomic Energy Commission
Under Contract Number AT(29-1)-613 USAEC

**Kansas City
Division**

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Printed in the United States of America

Available From the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

Price: Microfiche \$2.25
Paper Copy \$4.00

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WOVEN WIRE TAPE MEASUREMENTS

BDX-613-1180
December 1974

Prepared by C. W. Berry, Jr., D/142, under PDO 6989180

A method for measuring the length, width, and thickness of nylon/copper-wire woven tapes has been developed. Tapes are mounted on a constant tension and velocity reel system which allows continuous measurement of tapes. Length is measured with a rotary encoder and width and thickness are measured with flex-pivot strain gage devices.

THE BENDIX CORPORATION

KANSAS CITY DIVISION

KANSAS CITY, MISSOURI

A prime contractor for the
Atomic Energy Commission
Contract Number AT(29-1)-613 USAEC

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SUMMARY

Bendix Kansas City Division has future requirements for nylon/copper-wire woven tapes. To function properly the length, width, and thickness of these tapes must be controlled. One present tape, typical of a family of tapes that will be used on future systems, has the following requirements.

- Length is 200 +3, -0 feet (60.96 +0.091; -0 m).
- Width is 0.865 +0.040, -0.000 inch (22.0 +1.0, -0 mm).
- Thickness is 0.016 inch (0.406 mm) maximum.

Since Bendix had no previous experience in measuring similar tapes, development of methods for measuring large quantities of wire woven tapes was required. The objective of this project was to develop a rapid means for measuring the length, width, and thickness of wire woven tapes.

After several methods of making the required measurements were investigated, a rotary encoder driven through a gear train for length measurements and flex pivot strain gages for width and thickness were chosen for the measuring system. The length measuring system developed was tested by comparing steel tape measurements to those of the rotary encoder. This test showed that the length could be measured with an accuracy of better than 0.4 foot (0.12 m) for a 200-foot (61 m) length. The width and thickness measuring devices were checked with metallic masters of known sizes. The width measuring system had a repeatability of ± 0.0010 inch (0.025 mm) at two standard deviations and the thickness measuring system had a repeatability of ± 0.00024 inch (0.0061 mm) at two standard deviations. In addition to the above test of width and thickness, two wire woven tapes were measured with a microscope (width) and micrometer (thickness) and results were compared to the measuring system. This test showed that the measuring system will pick up waves in tapes caused by different tensions across the tape during weaving.

This report describes the tape drive system which was purchased with tooling funds, the measuring systems, tests and results, and recommendations for improving the accuracy of the measuring system.

DISCUSSION

SCOPE AND PURPOSE

A system for measuring the length, width, and thickness of nylon/copper-wire woven tape has been developed. This system was designed to measure 100 to 500-foot (30.5 to 152 m) woven tapes which have a nominal width of 0.885 inch (22 mm) and a thickness less than 0.020 inch (0.50 mm). The major components of the system are the Drive and Protection System shown in Figures 1 and 2, the Control Panel and Readout shown in Figure 3, the Length Measuring System shown in Figure 4, and the Thickness Measuring System shown in Figure 5.

ACTIVITY

Drive and Protection System

The tape drive assembly was designed by Floyd Drives and the tape protection system was designed at Bendix. The key features of this system are as follows.

- The feed reel is designed to give a constant tension which may be set at any value between one and five pounds. Control of the wire woven tape's tension is maintained by balancing the torque that results from the tape tension acting through a moment arm with a preset torque in the Floyd Drives controller. If the tension becomes too high the drive speeds up and if the tension becomes too low the drive slows down.
- A pair of protective switches which cut off the drive and take-up reels are located on the rear of the assembly to prohibit the system from feeding excessive tape and to prohibit excessive tension should the tape bind.
- A jog switch which overrides the protective switches is located on front of assembly so that the tape may be loaded. The jog cannot be operated without closing a switch on the control panel (Figure 3).
- The Mylar protective tape is fed through a secondary spool system to allow measurement of the wire woven tape. Limit switches are provided which shut off the drive and take-up reels should the Mylar tape become too loose or tight.
- The take-up reel was designed to provide a constant velocity which is selectable between 0.75 to 4.0 inches/second (19 to

Figure 1. Length, Width and Thickness Gage, Front View

Figure 2. Length, Width and Thickness Gage, Rear View

Figure 3. Control and Readout Console

Figure 4. Length Measuring Encoder and Gear Reduction System

Figure 5. Width-Measuring Strain Gages

102 mm/s). Control of the velocity is maintained by letting a small roller ride on the Mylar tape as the reel revolves. As the diameter of the Mylar and wire woven tapes increase, a lever is pushed down which reduces the rpm of the take-up reel.

- Power supplies and amplifiers for the width and thickness measuring devices are mounted to the rear of the assembly.

Control Panel and Readout

The control panel and readout which are shown in Figure 3 are made from components obtained from available equipment or purchased with tooling funds. The control panel contains the switches necessary for operation of the gage and lights which indicate an out-of-tolerance condition; that the protective system is OFF; and conditions that cause the gage to stop during inspection.

Length Measuring System

The length measuring system shown in Figure 4 was designed to measure the tape length in 0.1 foot (0.03 m) increments and to drive the recorder which displays the width and thickness data. The key features of this system are as follows.

- The wheel which is driven by the wire woven tape is made of Teflon-coated bronze. Bronze was selected as the wheel material so that the error caused by change in temperature would be minimized. The Teflon coating helps prevent damage to the wire woven tape.
- The measuring wheel is spring-loaded against the wire woven tape so that thickness variation will not affect measurement.
- The pulley system is designed so that the encoder puts out a pulse every time the circumference of the measuring wheel moves 0.1 feet (0.03 m).
- In addition to measuring the length, the encoder drives the strip chart recorder used for display of width and thickness data. This allows location of out-of-tolerance areas on the tape should re-inspection be required.

Width Measuring Location

The width system incorporates two Bendix (Fluid Power Division) Free Flex Flexural Pivots (Figure 5). A Teflon-coated arm is attached to each flex pivot so that the flexure is converted to

a voltage. The two strain gages are wired so that the sum of their outputs does not change when they move in the same direction.

A guide for the wire woven tape is provided to prohibit excessive movement of either strain gage. All surfaces that the tape contacts are Teflon-coated.

Thickness Measuring System

The thickness measuring system shown in Figure 6 is mounted over the width measuring system shown in Figure 5. A strain gage is attached to a flex-pivot so that a movement of the pad attached to the flex-pivot through an arm causes a change in voltage.

There are three spring-loaded pads in the system which force the tape to ride against the Teflon-coated reference surface which is attached to the width measuring system.

Operating Procedure

The operation procedure for the gage is as follows.

- Check the length measuring system by setting the CMC counter to zero and rotating the Teflon-coated wheel 50 times. If the rotary encode is operating properly and the counter sensitivity setting is correct, the counter should read 60.0 $\pm$ 0.1 feet (18.3 $\pm$ 0.03 m).
- Calibrate the Width and Length Measuring Systems by inserting a master which is made to the limit of one tolerance and the nominal of the other tolerance (four required). The offset position and sensitivity of each channel of the strip chart recorder is set so that the desired range is obtained. The limits for width and thickness are set so that warning lights come on when the tape is out of tolerance. Figure 7 shows a typical master.
- Turn off the protective system to allow loading of the tape.
- Load the Mylar and wire woven tapes on the machine as shown in Figure 1. The wire woven tape is pulled through the width and thickness measuring system after attaching an 0.008 inch (0.2 mm) shim stock to the wire woven tape.
- Pull the tape through the system until the beginning of the woven section is directly over the measuring wheel.
- Raise up the measuring wheel until the spring has been fully compressed. Back the adjustment screw off a quarter of a turn and set counter to zero.

Figure 6. Thickness-Measuring Strain Gage

Figure 7. Tolerance Master

- Pull the tapes through the system so that attachment can be made to the take-up reel as shown in Figure 1.
- Take the slack out of tapes by jogging the two reels.
- Turn on the protective system.
- Turn on the feed reel.
- Turn on the take-up reel only after turning on the feed reel.
- Measure the tape; the gage will shut off when there is no more tape on the feed reel.
- Turn off the protective system. Check the remainder of the tape by using jog switch on the take-up reel. Make sure to stop wire woven tape when end of woven section is over measuring wheel and record length.
- Now remove remainder of tape and load next tape.

NOTE: The first two steps need be repeated only if more than 3 hours have elapsed since calibration. The system should be allowed 2 hours to warm up to obtain best results.

Tests and Results

The following are the tests that were made on the measuring system and their results.

- The length measuring system was tested before and after reducing the friction and inertia of the mechanism by measuring a 100-foot (30.5 m) length of wire woven tape.

(In some tests, the number of revolutions of the measuring wheel were counted in order to show that the wheel was slipping against wire woven tape. Recall that one revolution is equal to 2.1 feet or 0.37 m).

100-Foot (30.5 m) Length Measurement Before Modifications			100-Foot (30.5 m) Length Measurement After Modifications		
<u>Feet</u>	<u>Rev</u>	<u>Meters</u>	<u>Feet</u>	<u>Rev</u>	<u>Meters</u>
99.4		30.3	99.7	(83 2/12)	30.4
99.2		30.2	99.7	(83 1/12)	30.4
99.5		30.3	99.7	(83 1/12)	30.4
99.4		30.3	99.8	(83 2/12)	30.4
99.5		30.3	99.8	(83 2/12)	30.4
99.6	(83)	30.4	$\bar{X} = 99.74$		
99.6	(83)	30.4			
99.7	(83 1/12)	30.4			
$\bar{X} = 99.49$		30.32			30.4

Std Dev = 0.155' (47 mm)

Std Dev = 0.055' (17 mm)

An "F Test" of the variances shows that there was a significant improvement in the performance of the length measuring system at a 95 percent confidence level.

$$F_{05,8,5} = 4.82$$

$$F = \frac{\sigma_1^2}{\sigma_2^2} = \frac{(0.155)^2}{(0.055)^2} = 7.94$$

- A drift test was made on the width and thickness measuring system after allowing a half-hour warm up. The test was run for six hours. The test showed that the system's drift for a six-hour period was $\pm 1\frac{1}{4}$ divisions on the strip chart recorder [1 div = 0.0006 inch (0.015 mm) for width and 1 div = 0.00016 inch (0.004 mm) for thickness]. The drift during the last 5 hours of the test was $\pm 1/2$ divisions on the strip chart recorder.
- A test was run to determine the capability of the measuring system for width and thickness measurements with and without removal of the thickness measuring system to load the wire woven tape. The first test was run with 2 hours warm-up and lasted 1 hour. The second test was run after 5 hours warm-up and lasted 40 minutes. No adjustments in the systems

electronics were made between the two tests. Four metallic parts (Figure 7) of known sizes were used.

<u>Test</u>	<u>±2 Std Dev Width</u>	<u>±2 Std Dev Thickness</u>
Without Removal	±0.00104 inch (0.026 mm)	±0.00024 inch (0.0061 mm)
With Removal	±0.00062 inch (0.016 mm)	±0.00037 inch (0.0094 mm)

"F Tests" show that there was a significant improvement during second test for width (95 percent confidence) and a significant degradation by removal of thickness measuring system for loading wire woven tapes.

- A test was run to determine the repeatability of width measurements on a wire woven tape using a microscope and a micrometer. This measurement method was used as a reference in the last two tests. The repeatability was ±0.0019 inch (0.048 mm) at two standard deviations.
- A test was run to determine if a bias existed in measurement described in the above test, by measuring a gage block. The measuring microscope had a bias of -0.00055 inch (-0.014 mm) (measures smaller than actual).
- A test was run to determine the repeatability of a micrometer for measuring the thickness of a tape in a one-inch area along an edge. The repeatability was ±0.00054 inch (0.014 mm) at two standard deviations.
- A test was run on a 100-foot (30.5 m) length of wire woven tape for width, thickness, and length. Reference measurements described in the three tests above were used. Reference thickness measurements were taken by measuring the thickness of the tape at one point along the edge. The length measuring system had not been modified as described in the first test.

	Tape Gage		Reference	
	$\bar{X}$	Std Dev	$\bar{X}$	Std Dev
Length	99.6 feet (30.4 m)	- - -	100.0 feet (30.5 m)	- - -
Width	0.871 inch (22 mm)	0.004 inch (0.10 mm)	0.870 inch (22 mm)	0.016 inch (0.41 mm)
Thickness	0.016 inch (0.41 mm)	0.0006 inch (0.015 mm)	0.015 inch (0.38 mm)	0.0003 inch (0.0076 mm)

- A test was run on a 195.0-foot (59.4 m) length wire woven tape for length, width, and thickness. The reference measurements were made in the same manner as described in the test above and all modifications to length system had been completed. During this test, waviness of one edge of the tape was observed as the measurements were being made. This was probably due to unequal weaving tension during manufacturing.

	Tape Gage		Reference	
	$\bar{X}$	Std Dev	$\bar{X}$	Std Dev
Length	194.8 feet (59.4 m)	- - -	195.0 feet (59.4 m)	- - -
Width	0.886 inch (22.5 mm)	0.003 inch (0.076 mm)	0.984 inch (22.7 mm)	0.005 inch (0.12 mm)
Thickness	0.0165 inch (0.42 mm)	0.0007 inch (0.018 mm)	0.0148 inch (0.38 mm)	0.00033 inch (0.008 mm)

CONCLUSIONS AND RECOMMENDATIONS

- The width and thickness measuring system will measure waves caused by different weaving tensions across the tape and conventional measuring methods will not.
- If waves on the tape are not critical to function, the measuring system can be modified by reducing gaging contact area and increasing spring force used to hold tape against reference surface.

- Better measurements can be obtained by allowing long (4 hour) warm-up times and mastering gage before measuring each tape.
- Greater accuracy in thickness measurement can be obtained without removal of thickness measuring system for loading wire woven tape.
- If the CMC counter (obtained from pool) is ever replaced, a counter that will allow conversion to metric should be purchased.
- The length measuring system can measure a 200-foot (61.0 m) tape with an accuracy better than 0.4 foot. If desired, improvement in length measuring accuracy can be obtained by additional reduction of friction and inertia.
- The repeatability of the width measuring system is ± 0.0010 inch (0.025 mm) at two standard deviations.
- The repeatability of the thickness measuring system is ± 0.00024 inch (0.0061 mm) at two standard deviations.