ON-LINE AUTOMATIC HIGH SPEED INSPECTION
OF CARTRIDGE CASES

by

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Battelle, Pacific Northwest Laboratory (BNW), has developed a small caliber cartridge case automatic inspection and reject system for Frankford Arsenal. It has undergone initial quality assurance testing and will soon be installed in their facilities. This system gauges case profile, surface flaw, wall thickness, and vent hole presence. A mechanical handling system coupled with computer control and data acquisition automatically inspects and rejects 5.56mm cases at the rate of 1200 per minute.

The present mechanical handling system uses two modules each running at 600 cases per minute. This rate corresponds to the manufacturing line which operates at 1200 cases per minute. These modules, interconnected by transfer/reject mechanisms, provide the hardware for imparting the proper orientation and rotary motion required for each of the several testing stages. Figure 1 is a schematic representation of this system and Figure 2 is a photograph taken during the development stage.

Electro-optical techniques are used to inspect case profile, surface flaws, and vent hole presence. Profile monitoring of individual cases at high production line speeds is accomplished with an optical diode array gauging technique. Optical scattering, using a line source and fiber optic receiver system, is used to monitor cartridge case surface flaws and two optical transducers perform quality assurance inspection of cartridge cases to verify the presence of the primer vent.

Eddy current techniques are used to determine wall thickness. Cases are rotated past four elongated eddy current coils to produce a circumferential thickness profile.

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Figure 1. Schematic View of Cartridge Case
Measurement Eject System

Figure 2. Cartridge Case Measurement Eject System

Information from the multiple inspection units is fed into the data acquisition and control computer. Operator communication with the quality assurance system is via video display, printer output and a computer function keyboard input. Outputs include hourly trend data and throughput alarm conditions to alert the operator when the number of rejected cases exceeds a preset threshold.

Figure 3 summarizes the measurements and corresponding measurement techniques used to inspect cartridge cases.

The mechanical handling system, the specially developed electro-optical and eddy current techniques, and the data acquisition and control system will be considered in more detail in the following pages.

Figure 3. Cartridge Case Measurement Summary

MECHANICAL HANDLING SYSTEM

The mechanical module consists of two inspection modules interconnected by transfer/reject mechanisms. The first interface unit removes cases from the production line chain and transfers them to the first inspection unit. The first interface unit is also used to verify the presence of a vent hole in each case and reject those cases failing this initial inspection. This unit may also be used to insert calibration standards into the inspection module to verify its operation.

The first inspection unit is used to examine the case profile. The second inspection unit measures case wall thickness and surface flaws. It then transfers the cases back to the production line chain. Reject of unacceptable cases occurs at the transfer points between inspection units and at the interface units.

ELECTRO-OPTICAL TECHNIQUES

Special electro-optical techniques were developed and used to inspect case profile, surface flaws, and vent hole presence.

CASE PROFILE

The case profile measurement for the small caliber automatic test system uses linear diode arrays and takes discrete diameter measurements at prescribed points on the case to characterize the profile. This instrument, seen in Figure 4, samples the diameter at 14 positions with one device and measures two lengths with a separate device. The computer compiles and outputs the diameter information of six diameters and three length measurements: total length, head thickness, and the gas seal length. The design goal was to measure each position to ± 0.001 inch.

Profile is measured by imaging the case onto the linear diode array. The mirror tracker simply tracks the case such that it appears to be stationary in the diode array plane as the case location moves on the perimeter of the rotary mechanical handler. The scanning mirror scans the case past the diode array allowing diameter sampling at the prescribed positions. A sink disc, which is located on the spindle tip, is also imaged onto the fiber optics positioning plane. As the sink disc passes the various fiber optics apertures the

Figure 4. Conceptual Design of Case Profile Monitor

detectors behind these apertures signal the diode array electronics to take a diameter measurement.

For length readout, two diode arrays are used, one for the cartridge head zone and one for the mouth. The head zone array also indicates head thickness. Combining this array with the mouth zone array provides a total case length.

The case profile is scanned over the diode array plane with the scanning mirror and optics assembly. An electro-optic encoder senses a case approaching the gauging station and initiates the profile readout sequence. As the case profile is scanned over the arrays, the diameter encoders sense the position of the profile on the array and generate a diameter sample signal. This provides a diameter readout at each of 14 points. Multiple array scans at each diameter position are made to improve the statistical measurement accuracy.

CASE SURFACE FLAW MONITOR

The design goal of the flaw monitor is to simulate visual inspection. Each test position holds and rotates

a single case by means of tapered pins inserted into the case mouth and primer pocket. (See Figure 5.) Since the test position is moving along the perimeter of the wheel, wheel motion provides automatic position switching. A single laser source illuminates in sequence each test position on the wheel. Each test position has line-source production optics and fiber optics receivers. A case flaw scatters the light focused onto the case which is collected by the fiber optic aperture and directed to an optical detector. This scattered light is separated by bundling specific portions of the fiber optic elements. Each case zone will be directed to a specific detector by a separate electronic channel.

A wide range of flaw sensitivities is achieved with this multichannel comparator system. The case present signal is used by the computer for data logging and data handling. The comparator units provide an accept or reject signal to the computer to indicate the case quality status and start or inhibit the computer-controlled case reject cycle.

VENT HOLE MONITOR

Electro-optical techniques are also used to verify the presence of the case vent hole, which is one of the essential tasks of quality assurance monitoring. The vent hole system, shown in Figure 6, uses a stationary detection system, with case translation furnished by the material handling wheel motion. Three optical transducers verify the presence of a case, initiate the test of the vent hole, and verify the presence of a vent hole. Solid-state phototransistors are used in the electro-optical transducers. To verify the existence of a case vent hole, presence of a case must be simultaneously verified, since similar signals would be indicated by the vent hole with or without a case. The optical encoder provides station identification (if desired) as well as the gating signal for vent hole, or readout. The readout is an accept/reject signal compatible with the on-line computer. The simplicity of the vent hole monitor allows placement on one of the initial interface wheels.

EDDY CURRENT TECHNIQUES

Eddy current techniques were applied to the problem of wall thickness quality assurance with a design goal

Figure 5. Cartridge Case Surface Flaw
Detection System

Figure 6. Conceptual Design of Vent Hole Unit

of ± 0.005 inch resolution. The eddy current sensor system, illustrated in Figure 7, uses four eddy current test coils mounted in an aluminum shielding block. The aluminum block is machined to match the profile of a cartridge case allowing for a uniform cartridge-to-case spacing of the four test coils. The case rotates as it passes the inspection coil such that it essentially unwinds itself, allowing inspection of the thickness around the entire case diameter. Elongated inspection coils are thus used whose dimensions are dependent on the case throughput rate and the case rotational speed. The aluminum block is maintained at a temperature greater than its environmental surroundings. This elevated operating temperature minimizes inspection coil temperature fluctuations due to changes in room temperature. A temperature controller and heaters are indicated in Figure 7.

The test unit itself is mounted on an adjustable platform to allow proper orientation of the test coils with respect to an on-line cartridge case. Housed behind the inspection coils are preamps mounted on plug-in printed circuit (PC) board for easy replacement. Here the detected signal level is raised so that it can propagate triax cable to the main chassis of the processing electronics.

The processing electronics for each measured thickness zone is on a single PC board mounted in individually shielded modules which can be plugged into an instrument console chassis. This permits quick replacement in the event of any electronic component failure. To minimize the case-to-coil spacing, a precise linear balancing circuit is used at the input of the processing electronics. The degree of case-to-coil spacing, called lift-off, is determined primarily by case wobble. Commercial off-shelf electronic instrumentation sub-modules are used to fabricate the signal processing electronics package.

DATA ACQUISITION AND CONTROL MODULE

The data acquisition module acquires data from the measurement units in real-time. Electrical signals input to the computer are either digital accept/reject values, analog maximum/minimum values, absolute analog values, or binary data. For quality assurance tests which result in accept/reject signals, cases which are measured to be within acceptable limits pass through the test module

Figure 7. Conceptual Design of Thickness Monitor

Figure 8. Process Data Reporting System

without inputting data (other than throughput) to the computer. Analog signals are digitized and compared logically with high/low accept-range limits for reject determination. The digital values are also used for qualitative data logging and trend recording.

The computer controls the rejection of cases by solenoid-actuated mechanisms. A confirmation signal immediately following each reject station is read by the computer to ascertain correct system operation.

CONTROL FUNCTIONS

The control functions performed by the computer system include reject functions (performed at four locations), sample case insert, sample case reject, and watchdog timer. Program logic traces the sample case through each test unit and determines if and where it was rejected. System communication with the operator concerning the sample case is via the video terminal. (See Figure 8.) The sample tracing software functions are logically independent of normal case testing.

The operator-selectable output formats are listed in Table 1. Each of these formats is output on either the printer or video terminal by operator-initiated keyboard commands. The data module is also programmed to output the "Overall Status" format.

Table 1. Operator Selectable Output Formats

1. Overall Status
2. Process Reject Status
3. Profile Reject by Zone (6 Zones)
4. Flaw Reject by Zone (13 Zones)
5. Thickness Reject by Zone (4 Zones)
6. Sample Case Measurement
7. Profile Trend Data (6 Total Frames)
8. Thickness Trend Data (4 Total Frames)
9. Process Control Quality Status
10. Transient Data Status

In addition to the outputs available on the teletypewriter and video terminal, a process monitor alarm

enunciates whenever the number of rejects per given throughput exceeds a preset threshold. This alarm rapidly alerts the operator to an otherwise unnoticeable condition since normal data display formats (even trends) integrate the data in such a way as to mask a rapid rate of change.

TREND DATA ANALYSIS

Data are acquired through an accumulator transfer, under control of the program interrupt facility. The acquired data values are used by a monitor task to compute an average for a period of one minute. Another monitor task in turn computes an average for a period of one hour. The hourly average is placed in the trend output data file which is available for output on command. Output trend data are then meaningful to operational personnel in relationship to changes such as tool wear, materials, and other manufacturing parameters.

SOFTWARE DESIGN CONSIDERATIONS

The conceptual data acquisition and control module requires that the central processing unit simultaneously and asynchronously perform unrelated tasks for the various test units in real-time. This is accomplished by having each individual module function written as a small, special-purpose program, with each of these small programs operating under the control of a supervisory program called a "real-time executive." The executive is configured to supervise all input/output operations for the data modules.

SUMMARY

This cartridge case measurement eject system has undergone initial quality assurance testing. The data are being analyzed but initial evaluations indicate that the basic goals have been achieved; i.e., profile gauging to ± 0.001 inch, vent hole verification, thickness to ± 0.005 inch, and surface flaw detection equivalent to human inspection.

This system, when installed on the manufacturing line, will replace traditional random sampling methods which involve visual inspection and hand gauging tools for dimensional measurements and flaw determination. It is also anticipated that these special high speed

inspection techniques and associated instrumentation can be applied to quality assurance and inventory control for other continuous manufacturing lines.

**FLAW AND THICKNESS
INSPECTION WHEEL**

**PROFILE
INSPECTION
WHEEL**

A MODULE

B MODULE

**ENTRANCE INTER FACE,
SAMPLE INJECTION,
VENT HOLE INSPECTION,
REJECT AND RESPACER WHEEL**

**TRANSFER AND
REJECT WHEEL**

**EXIT INTERFACE REJECT ,
AND RESPACER WHEEL**

TEST	TECHNIQUE
• VENT HOLE PRESENCE	OPTICAL
• PROFILE	OPTICAL
TOTAL LENGTH	
HEAD THICKNESS	
18 DIAMETERS	
• SURFACE FLAW	OPTICAL
3 ZONES	
• THICKNESS	EDDY CURRENT
4 ZONES MAXIMUM/MINIMUM

PROCESS DATA REPORTING

INSPECTION UNIT

VIDEO DISPLAY WITH
FUNCTION KEYBOARD

MEASUREMENT ELECTRONICS
AND COMPUTER SYSTEM

HARDCOPY
PRINTER

TYPICAL HARDCOPY
AND VIDEO OUTPUTS

OVERALL STATUS

14:1336

	INPUT	REJECT	OUTPUT	RATE
CUMULATIVE	938402	19125	917282	
THIS PERIOD	3450	96	3356	1598
ALARM STATUS				
DATA OUT-OF-LIMIT TRANSIENTS				
PROFILE				

PROCESS REJECT 14:0946

INPUT: 549450 REJECT: 2593 OUTPUT: 546782 RATE: 1598

LINE	VENT	PROFILE	FLAW	THICK	TOTAL
1	145	265	126	158	847
2		12	23		24
3	3	7	8	1	21
4	13	6	49	51	76
5	3		6		
6	275	153	47	38	749
7		10	7		15
8				25	35
9	23	57	95	37	127
10	157	25	16	49	263
11			36		41
12	115	382	193	9	386
TOTAL	734	917	806	368	

OUT-OF-RANGE: PROFILE 10 THICK 13

DATA ARE CORRELATED TO PRESS
IDENTIFICATION AND TIME

DATA ARE AVERAGED FOR
HOURLY TREND REPORTS