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MASTER

AUTOMATIC CARTRIDGE CASE INSPECTION AND PROCESS CONTROL MONITOR*

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Abstract

Battelle, Pacific Northwest Laboratories has developed an advanced cartridge case measurement/eject system (COMES) which automatically inspects and rejects cases at up to 1200 per minute. The system consists of a mechanical handler, measurement instruments, and a dedicated computer. System operation is monitored and controlled while the product is being measured. Five case dimensions are measured by an electro-optical system using diode arrays to measure a case image at unity magnification. By scan averaging, measurement standard deviations as small as 2.5 microns are obtained at a throughput of 1200 cases per minute. Measurements made with the system fall within the uncertainties of hand-gauged values for the same cases. Four zones on each case are examined for surface flaws, such as dents and scratches, by detecting light scattered from the surface. The system can detect these surface flaws at inspection rates of 1200 cases per minute. Using electro-optic methods, two additional measuring stations detect vent hole presence and gross size deviations to prevent mechanical jams. A third station employs an eddy current technique to detect splits and folds in critical regions of the cartridge. The overall system has passed quality assurance tests administered by the sponsor and will soon be installed at the Lake City Army Ammunition Plant.

Introduction

Battelle, Pacific Northwest Laboratories (BNW) has developed an advanced version of the small caliber automatic high-speed case quality assurance accept/reject monitor. The initial system described in earlier publications was installed at the Twin City Army Ammunition Plant located in the Minneapolis, Minnesota area.^(1,2,3) This paper describes the advanced system and provides information on the individual measurement techniques and unique quality assurance problems encountered in high speed automatic inspection.

The cartridge case measurement/eject system (COMES) is an automatic system for inspecting and rejecting cases produced by a cartridge case manufacturing line at rates up to 1200 per minute. The system consists of a mechanical handler and measurement instruments under the control of a dedicated computer. The mechanical system is designed to accept manufactured cases from the case line and orient and handle them in a manner acceptable to the measurement instruments located on the mechanical handling frame. The measurement instruments are located at inspection stations spread throughout the path of the cases as they travel through the mechanical handler. The measurement electronics are located at the measurement station, while most of the processing electronics are in an airconditioned rack positioned near the mechanical handler. The process data is sent from the instrument console to the control computer. The control computer takes the data from the measurement system, keeps a running tally, and sends reject signals back to the mechanical handling unit which rejects unacceptable cases. Jets of high pressure air are used to remove the rejects from the path of the acceptable cases. The computer allows quick access to the processing information, providing some 17 formats in which to report the data. In addition to monitoring the manufactured cartridge cases, the system has a number of transducers and control systems which monitor overall system operation while the system makes product measurements. The system-monitoring functions are communicated to the operator through indicator lights on a motor control panel or through messages displayed on the video terminal.

The system monitors for case dimensions, surface flaws, vent hole presence, and for the presence of splits in selected regions of the case. The system measures five dimensions with a standard deviation of 0.1 mil at the operating rate of 1200 cases per minute. The dimensions measured are head thickness, head diameter, extractor groove diameter, gas seal length and total length. Four zones on each case are examined for surface flaws, such as dents and scratches, and cases with fine scratches or small dents can be detected and eliminated by the system. Any case lacking a vent hole will be rejected. Splits in the case head region and splits or folds in the case mouth region are detected by an eddy current transducer. In addition to these four primary measurement functions, another station is provided at the first interface wheel. This station will detect gross size deviations and reject such cases to prevent mechanical jam.

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Materials Handling

The materials handling equipment provides 1) hardware to interface with the cartridge case production line, 2) means for holding and positioning cartridge cases for the various measurements, 3) rejection of unacceptable cartridge cases, 4) insertion and retrieval of calibrated samples, 5) retrieval of a selected sample of product, and 6) a drive system capable of synchronous operation with the production line.

The inspection system (1200 pieces/minute throughput) is shown in Figure 1. The mechanical system consists of inspection wheels interconnected by transfer/reject wheels. The first interface wheel (breakaway) removes cases from the production line carrier chain. The entry transfer wheel transfers them to the respacer, which respaces the cases for a larger center-to-center spacing and transfers them to the first inspection wheel. The entry transfer wheel carries cases past process control instrumentation consisting of a case presence detector, out-of-range monitor, reject station, and a device for automatically inserting QA standard cases (sample insert).

Fig. 1. CCMES inspection module.

The first inspection wheel carries cases past the profile monitor which makes length and diameter measurements. The inspection wheel has 24 spindles to hold the cartridge cases during inspection. Each spindle corresponds to one of 24 manufacturing tool positions on the case line and permits correlation of inspected pieces with manufacturing station. Next in sequence is the transfer wheel carrying cases past a vent hole presence monitor, a process control reject station, and finally a reject verification sensor.

The second inspection wheel follows, carrying the cases past the eddy current and surface flaw monitors. Unlike the first inspection wheel, the spindles on the second inspection wheel rotate at high speed to permit examination of the entire cartridge case surface for flaws. Attached to the second inspection wheel is an encoder which provides the timing signals for the monitors, and for reject implementation.

Following the second inspection wheel is the exit interface wheel. Located in the path of cases for this wheel are two process control reject stations, one for flawed cases and the other for special rejects controlled by the computer.

A special rejecter on the exit wheel will collect selected samples for analysis. Typically, samples can be cases from particular spindles, or cases exemplifying a specific reject type, such as profile, vent hole, etc. A sample insert device on the entry transfer wheel can be preloaded with standard cases or selected cases for system testing. Cases in the inserter are inserted into selected spaces in the path of cases under computer control and are collected at the special rejecter.

Data Acquisition and Control Module

The data acquisition module collects measurement data from the monitors in real time. The computer receives all data in digital form over a high-speed serial data link from the measurement/eject module. A fixed format data block is received during every case-to-case interval. The data block contains measured values, accept/reject signals, and status information. All measured values are compared logically with high/low accept-range limits for reject determination and are used for limited statistical analysis. For measurements resulting in accept/reject signals, cases within acceptable limits pass through the test module and appear in the overall status format as an output number.

The computer responds to each data block received by transmitting a control message back to the measurement/eject module. The control message contains one bit to control the state of each reject solenoid during the next case-to-case interval. The computer then checks a confirmation bit for each reject station in the data block to ascertain correct accept/reject operation and to verify the materials handling operation.

The principal operator communication device is a video terminal and its function keyboard. The operator is able to obtain data displays on video or hardcopy by depressing a single function key. The rapid writing rate of the video display provides near-instantaneous data presentation. The formats available to the operator are listed in Table 1. Each format can be printed or viewed by operator-initiated function keyboard commands. Figure 2 is one of the profile status formats. Figure 3 illustrates the overall status format which is the priority format.

Table 1. CCMES 5X Computer Formats

No.	Format	Frames	PROFILE STATUS							05/03/77 11:45 SEG 00-00:27	
			HEAD DIAMETER NOM = .374.5 TOL = .3.5								
			LINE	N	MEAN	MIN	MAX	STD	DEV		
1.	Overall Status	(1)	1	1524	-.5	-6.8	4.1	1.3			
2.	Total Reject	(1)	2	1523	-.8	-4.7	3.5	1.3			
3.	Segment Reject	(1)	3	1380	-.7	-4.1	3.1	1.4			
4.	Profile Defects	(1)	4	1510	-.6	-3.6	3.5	1.3			
			5	1419	-.6	-4.8	3.6	1.3			
5.	Eddy Current Defects	(1)	6	1295	-.7	-11.4	3.1	1.4			
			7	1436	-.8	-5.8	3.2	1.4			
6.	Flaw Defects	(1)	8	1292	-.6	-5.1	3.1	1.3			
			9	1378	-.6	-4.7	3.1	1.3			
7.	Profile Status	(5)	10	1494	-.7	-4.7	3.7	1.3			
	(5 Parameters)		11	1405	-.5	-5.4	3.3	1.3			
			12	1234	-.6	-4.5	3.8	1.3			
			13	1519	-.6	-5.1	3.6	1.2			
8.	Operating Parameters	(1)	14	1519	-.5	-6.2	3.7	1.3			
			15	1290	-.5	-4.4	2.8	1.1			
9.	Snapshot Profile	(1)	16	1514	-.5	-5.3	3.4	1.1			
	(Select 1 Parameter)		17	1423	-.7	-9.3	3.4	1.3			
			18	1309	-.7	-3.9	3.3	1.3			
10.	Sample Insert Data	(2)	19	1502	-.6	-4.1	3.6	1.3			
			20	1306	-.7	-8.4	3.1	1.4			
11.	QA Sample Data	(2)	21	1379	-.6	-4.4	3.3	1.3			
			22	1471	-.7	-3.9	3.2	1.2			
			23	1395	-.6	-4.6	3.7	1.3			
			24	1237	-.6	-4.4	3.7	1.3			
		17									

Fig. 2. Sample status format showing actual measurement on brass.

OVERALL STATUS

05/03/77 15:02 SEG 03-14:26

PARTS COUNT	INPUT	RJ-ABLE	REJECTED	OUTPUT	RATE
DAILY TOTAL	110297	7993	7926	102281	
THIS SEGMENT	37773	2672	2672	35003	1169 AVERAGE
SHORT TERM	536	44	44	489	1228 CURRENT

Fig. 3. Overall status format.

Figure 4 shows the video console as well as the operating parameter entry thumbwheels. The operating parameter entry allows one to change the date, control sample insert and/or sample selection, and change system reject limits.

The computer also controls all rejects, sample inserts, sample rejects and all special rejects. The computer monitors all cases as they progress through the system and will repeatedly attempt to reject unacceptable cases if the first reject fails for some reason.

The data acquisition system provides the capability to take a QA sample. The QA sample can consist of a case from a specific spindle or a case from each of the 24 spindles. The profile data from the QA sample for cases from each of the 24 spindles is shown in Figure 5. This provides a real time check on the profile monitor of the inspection system. In addition, the capability to insert QA standards can be initiated through the data acquisition parameter entry device. The operator can choose the parameter entry device and the spindle location for the inserted case. This provides a quick check of the system. The data from the inserted case is available for hard copy output or video evaluation.

Fig. 4. Video console with data entry thumbwheels.

Measurement Monitors

The case measurements to be made are rough dimensions (out-of-range cases), case profile, vent hole presence, surface flaws, and splits/folds in the case head and mouth area. The CCMES includes a specialized device to monitor each measurement.

Out-of-Range Monitor

Grossly defective cases must be prevented from entering the system, because they can become jammed in the mechanical hardware and cause serious damage. Improperly trimmed cases may be too long; those with damaged mouths may be too short or have an unacceptable mouth diameter. The out-of-range monitor shown in Figure 6 will optically detect these conditions and reject the affected cases before they enter the respacer. Dimensions outside a ± 30 mil window will be rejected.

SAMPLE PROFILE					
85/03/77 15:00 SEG 03-14:26					
	NOM = 374.5	329.0	1497.0	41.5	1755.0
LINE	HEAD D	EX GR	GAS	HEAD T	LENGTH
1	= 1.0/	= 1.3/	= 2.0/	= 2.7/	= 2.3/
2	= 1.7/	= 2.2/	= 1.3/	= 3.7/	= .4/
3	= 1.3/	= 1.8/	= 1.4/	= .7/	= 2.5/
4	= 2.2/	= 1.9/	= 2.5/	= 1.2/	= 2.6/
5	= 2.4/	= 2.6/	= 1.8/	= 1.8/	= .9/
6	= 3.2/	= 2.0/	= 2.0/	= 3.3/	= .2/
7	= .1/	= .0/	= 1.4/	= 2.6/	= .5/
8	= .3/	= .3/	= 1.9/	= 3.9/	= 1.9/
9	= .9/	= 1.8/	= .6/	= .1/	= 1.3/
10	= 2.5/	= 2.9/	= 1.1/	= 5.8/	= .8/
11	= .8/	= 1.3/	= 2.6/	= 4.5/	= 2.9/
12	= 1.8/	= 2.1/	= .5/	= .9/	= 1.1/
13	= .8/	= 1.1/	= 2.6/	= 3.4/	= 1.9/
14	= 1.7/	= 1.7/	= 2.9/	= .2/	= 3.2/
15	= .8/	= 1.6/	= .6/	= 1.8/	= 1.7/
16	= .3/	= .2/	= .4/	= 3.4/	= 3.2/
17	= 1.0/	= .8/	= 2.9/	= 2.4/	= 1.9/
18	= 2.4/	= 2.8/	= 2.2/	= 1.6/	= .5/
19	= .8/	= .3/	= 1.6/	= 1.6/	= .3/
20	= 1.3/	= 1.6/	= 2.3/	= 2.5/	= 1.6/
21	= .9/	= .4/	= 3.2/	= 3.5/	= .9/
22	= .2/	= .3/	= .5/	= .2/	= 4.4/
23	= .7/	= 1.0/	= 2.5/	= .9/	= 1.5/
24	= .3/	= .5/	= 2.3/	= .4/	= 1.7/

Fig. 5. Quality assurance sample profile data.

Fig. 6. Out-of-range monitor.

Vent Hole Monitor

The vent hole monitor verifies the presence of a vent hole in the case by passing light through the case as illustrated in Figure 7. A slightly converging source of light enters the case through the vent hole and exits at the mouth where it is detected. To prevent problems associated with light "leaking" past the side of the case, the electronics are designed to ensure that the light is present at the detector for a selected angular rotation of the transfer wheel. This is accomplished using an optical encoder. Because a vent hole signal can result from the unobstructed light when no case is present, a case present verification is done at the same time and is "anded" with the vent hole signal.

Case Profile Monitor

The profile monitor is designed to measure critical dimensions on the cartridge case with a standard deviation of less than 0.25 mil. A single diode array (CCD) is used for each of five measurements. Using a diode with 0.0005-inch center-to-center spacing and averaging 20 scans of the case image, measurements with a standard deviation of approximately 0.1 mil are achieved.

Fig. 7. Vent hole monitor.

Figure 8 schematically illustrates the operation of the cartridge profile monitor. The cases are back illuminated by parallel rays from a Xenon arc lamp as they pass through the profile measurement station. Cases are imaged onto a flat plate with cutouts located at points corresponding to desired measurement areas on the image. Fiber optic image guides fit into these cutouts and transfer the image of two edges corresponding to a single measurement onto a single diode array 125 mils in length. This "folding" of the image permits measurement of large objects with a small diode array. Fiber optic image rods with 5.5 micrometer fibers are used for the image folding.

Fig. 8. Fixed diode array profile monitor.

The diode arrays are clocked at 10 MHz and, for a diameter, the system simply counts the pulses falling in the dark region on 20 sequential scans. These raw counts are stored in buffers and transmitted to the computer for interpretation along with the data from the other measurements. Figure 9 shows the raw diode pulses and the clock pulses used in the measurement.

Fig. 9. Profile signal.

Figure 10 illustrates the five measurements made with the profile monitor. Only the two diameter measurements are made directly off the case. Length measurements are made on gauging surfaces on the spindle tips with the upper tip stationary and acting as a reference surface. Head thickness is measured from this upper gauge surface plus the underside of the head. Total length is measured from the upper surface to a tip which contacts the case mouth. The head-to-shoulder measurement uses a special fixture which simulates the portion of the gun chamber in the region of the gas seal area. This fixture exerts a light load during the measurement, simulating actual conditions. Figure 11 shows the hand gauges used to perform the same five measurements made by the present profile monitor. Figure 12 compares head diameter measurements made with hand gauges against measurements made by the profile monitor. Both measurement sets are based on randomly selected brass cases from a large series used in machine testing. The range on the hand-gauged measurements represents the ovalicity of the manufactured case. Profile monitor measurements can fall anywhere in this range because the orientation in the spindle is random. To make these measurements, the monitor was calibrated with precision-ground steel standards.

Fig. 10. Case profile measurements.

Fig. 11. Hand gauges.

Fig. 12. Comparison of hand-gauged and CCMES measurements on brass cases.

Table 2 shows a set of measurements made with the profile monitor on known steel standards. The system was operated in the closed loop configuration with the same standard measured on a given spindle 49 times. The overall average errors are shown at the bottom of the table. The standard deviations provide an estimate of the measurement precision while the means or RMSE (Root Mean Square Errors) provide an estimate of the measurement accuracy compared to a known standard. The diameter measurements (extractor groove, head diameter) are made directly on the cases and have average standard deviations of about 0.1 mil and a negatively biased mean of about 0.05 mil. The other measurements are made on gauging surfaces and include errors due to changes in the contact of the gauge with the cartridge case. The overall standard deviation for these measurements is on the order of 0.25 mil, while the average of the means varies from +0.18 to -0.25 mil. The overall average of all the standard deviations is 0.16 mil, while the overall average of all the means is -0.06 mil. Measurements are of very high precision and the overall accuracy is good considering the measurements on the standards are only accurate to ± 0.05 mil.

Table 2. Profile Measurements Made on Precision Stainless Steel Standards of Known Dimensions

Spindle	N	Head Diameter			Extractor Groove			Gas Seal			Head Thickness			Total Length		
		Mean	Std.Dev.	RMSE	Mean	Std.Dev.	RMSE	Mean	Std.Dev.	RMSE	Mean	Std.Dev.	RMSE	Mean	Std.Dev.	RMSE
1	49	-0.08	0.06	0.08	0.02	0.14	0.03	0.11	0.04	0.11	-0.43	0.32	0.43	-0.57	0.16	0.57
2	49	-0.14	0.07	0.14	-0.03	0.14	0.04	0.32	0.17	0.38	-0.23	0.23	0.23	-0.13	0.14	0.13
3	49	-0.11	0.07	0.11	0.09	0.14	0.10	0.62	0.09	0.63	-0.58	0.40	0.58	-1.07	0.21	1.07
4	49	-0.05	0.07	0.05	0.03	0.12	0.03	0.30	0.11	0.30	-0.70	0.27	0.70	-0.65	0.08	0.65
5	49	-0.04	0.07	0.04	0.01	0.13	0.02	0.76	0.18	0.76	-0.45	0.21	0.45	-0.82	0.23	0.83
6	49	-0.13	0.07	0.14	-0.02	0.13	0.03	0.17	0.20	0.18	-0.42	0.19	0.42	0.74	0.08	0.74
7	49	-0.03	0.12	0.04	-0.04	0.34	0.06	-0.02	0.17	0.03	-0.61	0.24	0.61	0.76	0.06	0.76
8	49	-0.06	0.08	0.06	0.03	0.12	0.03	0.24	0.05	0.24	-0.06	0.16	0.06	-0.64	0.19	0.84
9	49	-0.17	0.07	0.17	-0.04	0.13	0.05	0.14	0.13	0.14	-0.18	0.14	0.18	-0.79	0.54	0.79
10	49	0.00	0.06	0.01	0.01	0.15	0.03	0.44	0.21	0.44	-0.05	0.22	0.06	0.46	0.14	0.46
11	49	-0.06	0.07	0.06	-0.09	0.12	0.09	-0.10	0.01	0.10	-0.14	0.35	0.15	-0.57	0.09	0.57
12	49	-0.05	0.07	0.05	-0.11	0.15	0.12	0.69	0.12	0.69	-0.09	0.15	0.10	-0.77	0.19	0.77
13	49	0.00	0.08	0.01	-0.03	0.16	0.04	0.27	0.15	0.27	0.19	0.67	0.21	0.11	0.08	0.11
14	49	-0.06	0.06	0.06	0.12	0.08	0.12	0.07	0.09	0.07	-0.27	0.14	0.27	-0.44	0.68	0.45
15	49	-0.06	0.07	0.08	-0.02	0.12	0.03	-0.02	0.05	0.03	0.56	0.10	0.56	-0.92	0.69	0.92
16	49	-0.06	0.07	0.06	0.12	0.12	0.13	0.14	0.25	0.14	-0.38	0.24	0.38	-0.62	0.66	0.63
17	49	-0.05	0.06	0.05	-0.09	0.12	0.09	0.14	0.14	0.14	-0.04	0.25	0.06	0.15	0.22	0.16
18	49	-0.06	0.08	0.06	-0.08	0.09	0.08	0.24	0.12	0.24	-0.41	0.29	0.41	0.33	0.10	0.38
19	49	-0.01	0.07	0.02	-0.01	0.11	0.02	0.14	0.07	0.14	-0.00	0.34	0.05	0.17	0.15	0.17
20	49	0.02	0.06	0.02	-0.14	0.09	0.14	-0.62	0.08	0.62	0.22	0.29	0.22	-0.01	0.14	0.02
21	49	0.03	0.06	0.03	-0.19	0.08	0.19	-0.06	0.07	0.06	-0.18	0.18	0.18	-0.00	0.24	0.03
22	49	-0.19	0.06	0.19	0.01	0.09	0.02	0.20	0.05	0.20	-0.26	0.22	0.26	-0.60	0.34	0.60
23	49	0.02	0.07	0.02	-0.14	0.12	0.14	-0.11	0.13	0.12	0.15	0.43	0.16	0.10	0.11	0.10
24	49	-0.00	0.07	0.01	-0.06	0.08	0.06	0.30	0.15	0.30	0.51	0.20	0.51	0.00	0.08	0.01
Avg: 1176		-0.06	0.07		-0.03	0.13		0.16	0.12		-0.16	0.26		-0.25	0.24	
Combined Avg:		-0.06	0.16													

Figure 2 showed a typical data format with head diameter measurements for a series of brass cases fed through the CCMES. The standard deviations are larger (~ 1.3 mil) as one would expect, because both measurement precision and the variation in the brass are being measured.

The CCMES operator can calibrate the system with precision steel standards. An off-line calibration in closed loop can accurately calibrate the monitor using various standards and fitting the measurements with a linear regression equation. The off-line calibration performs a complete diagnostic and statistical evaluation of all constants necessary to calibrate the profile monitor. Calibration also entails measurement of a correction factor for each spindle. Due to manufacturing tolerances, spindle-to-spindle variations exist in the measurement surfaces which must be compensated for to maintain the high precision desired.

During actual case manufacture, the CCMES operator can perform an on-line calibration by inserting standards through the case inserter. The on-line calibration changes only the offset constants while the off-line calibration changes the sensitivity factor of the system. The sensitivity factor relates back to the magnification of the optical system. Under normal operation the magnification remains constant and does not require change.

Fixed standards are located between two spindle positions which simulate case profile measurement surfaces. These standards are calibrated against the precision steel standards. The standards are measured on each rotation; resulting measurements are accumulated in a running average used to compensate for system drift. This guarantees high accuracy of the measurements over a long measurement period (several days).

Case Surface Flaw Monitor

The case surface flaw monitor utilizes optical scattering instrumentation to detect flaws. For simplicity, only one segment of the test wheel is graphically indicated in Figure 13. Each of the 24 test positions holds and rotates a single case by means of the spindle tips inserted into the case mouth and primer pocket. As the mechanical handling wheel rotates, a single laser source illuminates cases in sequence through lens/prism components. Each test position has line-source producing optics and a fiber optics receiver bundle. A flawed case scatters light into the receiver fiber optic aperture from the light focused onto the case. The wheel motion with respect to the collimated laser illumination and individual test position lens/prism assembly provides automatic spindle position switching. The receiver fiber optics are coupled to only one test station at a time. Scattered light from the case zones is separated by segregating specific portions of the receiver fiber optic aperture according to case zone. Each zone is directed to a separate detector and electronic signal processor channel. Figure 14 shows typical flaw signals from a dent and a scratch. The flaw signal is processed with band pass filtering; automatic gain control is used to compensate for variations in individual bundle transmission characteristics. Flaws are indicated and detected when the signal exceeds a prescribed threshold level for a preset time. Two amplitudes and one pulse width are used per zone for reject determination. Reject signals are fed to the computer to indicate case quality for data inventory and to start or inhibit the computer-controlled case reject cycle.

Fig. 13. Schematic layout of surface flaw monitor hardware.

Eddy Current Flaw Monitor

The original eddy current device on the first CCMES was a thickness monitor.⁽¹⁾ Operation of this system at the Twin City Army Ammunition Plant indicated that thickness is not a serious problem and did not warrant on-line measurement of this parameter. Evaluation of this system at the Twin City Army Ammunition Plant also revealed that the eddy currents were capable of detecting very tight folds and splits that were, at times, difficult to detect with the laser surface flaw monitor. In the new CCMES, the eddy current system is used solely as a flaw monitor. The monitor uses two eddy current coils, one located near the case head area where the body splits occur and one at the mouth area to assure reliable detection of tight folds. Figure 15 schematically illustrates the design of the eddy current flaw monitor.

Fig. 14. Typical surface flaws and flaw signals.

Fig. 15. Eddy current flaw monitor.

To assure reliable CCMES operation, several system monitors are incorporated into the overall unit.

Damage from mechanical jams is reduced or eliminated by three sets of sensors. Each of the guides at transfer points is spring-loaded and instrumented with a switch system designed to respond to movements of a few mils. Second, the drive system is instrumented to trip when over-current conditions are encountered. Finally, a shock and vibration detector on the system responds to unusual mechanical motions.

Temperature sensors and flow switches for cooling water assure that the monitors and associated circuitry remain within the designed operating ranges. Sensors monitor the rotation of the rotary spindles to warn of belt failure and an air pressure switch guarantees that adequate air pressure is available for reject operation. Operation of these

129-14

devices, which will shut the system down, is monitored by lamps on control panels in the control room and on the electronic rack.

Each measurement monitor is designed to send data indicating its failure to the computer. Error messages on the video tell the operator of monitor or reject failure. Improperly measured cartridge cases are tagged and rejected to prevent accumulation of unidentified cases in the final product bins.

A critically important system monitor is a digital encoder which times the sequence of measurements, provides case identification for the computer and times the sequence of data transmission. The instrumentation console has a built-in scope and a signal switching system used to monitor the performance of the electronics. This allows rapid system troubleshooting in case of malfunctions and assists in setting up the system.

Quality Assurance Considerations for High Speed Inspection

Several items must be considered when automating at high speeds. The first and most important is to inspect only those items that are essential. When one initially automates, the tendency is to inspect for everything. However, if all parameters are to be inspected, all parameters could potentially be rejected. The noncritical parameters that are monitored increase the reject rates. Upon reinspection, using nonautomated methods, the rejected parts are quite often found acceptable. In the first system BNW built to automatically inspect cartridge cases, 18 profile data points on each case were monitored (Figure 16). It was later found that only seven of these were actually critical data points. The others only added to the number of rejects and were later dropped. Thus it is important in automating the QA process that only the essential parameters are selected and monitored to the required accuracies.

Fig. 16. Original case profile measurement positions.

A second problem often encountered in automatic high speed inspection is that QA people want to have all the data so they can carefully analyze it. The result is a volume of stored data so overwhelming that no one can really understand what is going on or what has happened. This problem can be reduced or eliminated by carefully selecting the data formats so the data can be quickly summarized and readily interpreted.

In today's computerized world, digital data is preferred. While computers can communicate with digital data very quickly, people communicate with the same data very slowly. However, when the data is in analog form, it can be comprehended much more rapidly. This is apparent from a comparison of Table 2 and Figure 17 which contain the same basic information. Thus, when designing formats, care should be taken to minimize the amount of digital data and to present the data in an easily understood manner.

Fig. 17. Profile measurements made on precision stainless steel standards of known dimensions.

With automatic inspection equipment, calibration and continuous monitoring of system performance is essential. Hand calibration is difficult and time-consuming. It is much more efficient and cost effective to program the computer system with the capability to calibrate the overall inspection system. In the first cartridge case inspection system fabricated and tested by BNW, calibration and performance analysis were done by off-line calculations. Calibration data generation required about 20 minutes; calibration calculations took another 2 days. To evaluate overall system performance, data generation took 4 to 8 hours; data analysis required another 2 months. In the advanced CCMES described here, all data collection and analyses were automated. As data was collected, it was stored on disc memory. At the end of the QA run, the data was retrieved from the disc, processed, and output. As shown in Table 2, total statistical data evaluation was available approximately 5 minutes after QA run completion.

In our opinion, it is important to assume that the automatic inspection equipment system is not trustworthy, and requires continuous verification of operation and proper decision-making. This capability is built into the CCMES design such that samples can be inserted to verify proper system operation. Special reject locations designed into the system permit sample retrieval with computer output of data generated by sample inspection. Figure 5 shows data from a QA sample taken during testing.

In high speed inspection systems, the data acquisition system is the only communication link to the inspection process. Any functions to be performed must have sensors to verify that they did, in fact, occur. It is essential that the equipment design provide adequate sensors and input to the data acquisition system to verify that the system is operating properly and to maintain control of the inspection process.

Conclusions

The CCMES is a complex measuring system capable of high speed precise measurement of dimensions, surface flaws, case folds and vent hole presence. Diameter measurements on standards were made with a standard deviation of approximately 0.1 mil which represents measurement precision. The mean for these measurements had an overall average error of 0.05 mil. When including all the measurements (two diameters, two lengths and head thickness), the overall average of all the standard deviations is 0.16 mil while the overall average of all the means is -0.06 mil. During preliminary quality assurance testing, the system reliably rejected faulty cases. The system is presently under installation at the Lake City Army Ammunition Plant and will undergo on-line acceptance testing at that location.

When operating with the manufacturing line, CCMES can replace the traditional sampling technique used for quality control. The sampling technique uses tedious visual inspection for flaws and vent hole presence and hand gauges (Figure 11) for dimensional measurements. CCMES can provide 100% inspection at manufacturing speed and real time quality control. Similar inspection techniques can be applied to other manufacturing processes involving precision parts which demand sophisticated quality control, parts sorting or adaptive control of the manufacturing process.

References

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DIGITIZED VIDEO
AFTER THRESHOLDING

RAW VIDEO

2.9
100%