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A MINI-COMPUTER CONTROLLED AMMUNITION
CASE SURFACE FLAW INSPECTION SYSTEM^(a)

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A MINI-COMPUTER CONTROLLED AMMUNITION
CASE SURFACE FLAW INSPECTION SYSTEM

ABSTRACT

A prototype case surface flaw inspection unit based on optical scattering instrumentation has been developed for the 5.56 mm cartridge case. This unit includes a system for feeding and handling cases at a rate up to 1200 cases per minute, a computer-based inventory and process control system, optical flaw instrumentation, and process control instrumentation. A dedicated computer is necessary to acquire data on-line in real time and provide rapid data output suitable for process operator decision making. Future use of this measurement system will include output of flaw data to a larger host computer for more sophisticated data analysis and integration with the total process data base.

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INTRODUCTION

The Small Caliber Arms Modernization Program (SCAMP) of the Frankford Arsenal is developing the capability for production of small caliber arms ammunition continuously at high rates. Previously, manufacture was done by batch processes with manual inspection using sample data techniques. It is the goal of the modernization program to inspect every case that is produced.

Battelle Northwest has developed a prototype case surface flaw inspection unit for the 5.56 mm cartridge case based on optical scattering instrumentation which is capable of a variable case throughput inspection rate up to 1200 cases per minute. Surface flaws include scratches, dents, scaling, folds and pits. The development effort included a system for feeding and handling cases at these case throughputs, a computer-based inventory and process control system, optical flaw instrumentation, and process control instrumentation.

SYSTEM DESCRIPTION

The case surface flaw inspection system consists of three major components; mechanical handling, electro-optic instrumentation, and on-line, real-time computer system. Fig. 1 shows the total system. The large mechanical assembly on the left is a case accumulator which is used to store 6000 incoming cases to be inspected. The accumulator assembly feeds a twin roller, translating fork assembly which moves and rotates the cases at 9000 RPM under the optical detection station. System specifications are listed below:

- . 1200 Cases/Minute Throughput Capability
- . Non-Contact Flaw Detection - Scattered Laser Light
- . Continuous 100% Inspection of Each Case
- . Case Flaws Identified by Zone
- . Video and Hardcopy Data Output

FIGURE 1
CASE SURFACE FLAW
DETECTION SYSTEM

- . Keyboard Control of System Operation
- . Computer Controlled Removal of Unacceptable Cases
- . Computer Monitoring of System Integrity
- . Computer Controlled Flaw Data Inventory

The cases to be inspected are stored in the accumulator unit shown in Fig. 2. The accumulator assembly rotates and drops cases into the transfer station which feeds the cases to the inspection unit where the electro-optic transducers are located. After the cases pass under the flaw monitor the unacceptable cases are removed from the line and the computer verifies that the case is no longer on the conveyor belt. Other necessary process signals required for system timing and status are located on the inspection unit.

FLAW DETECTION TECHNIQUE

An initial feasibility study indicated that cartridge case surface flaws could be monitored using surface scattered light and electro-optic instrumentation.

Referring to Fig. 3, a laser line source is focused on the case. Photomultiplier tubes are used to gather both reflected and scattered light. Three detectors are used to enable one (reflected) to function as a reference while the other two are used as flaw signal detectors. The reference signal is subtracted from the scattered light signals to obtain the flaw signal. Analog comparator circuits are used to compare the flaw signal with preset rejection levels to output a digital reject signal to the computer.

COMPUTER SYSTEM

The Data Acquisition and Control system is centered around a DEC PDP-8E mini-computer. The computer system which is shown in Fig. 4 is configured as follows:

CARTRIDGE CASE FLOW AND TRANSDUCER DIAGRAM

FIGURE 2
CASE FLOW AND
TRANSDUCER POSITION
DIAGRAM

- . DEC PDP-8E Having 8192 Word Memory (12 Bit Words)
- . Real Time Clock
- . Power Fail/Auto Restart
- . ASR-33 Teletypewriter
- . High Speed Paper Tape Reader/Punch
- . Datapoint 3300 Video Display Terminal and Keyboard

A block diagram of the case flaw detection system electronics is shown in

Fig. 5. The process input signals are:

- . Fork Synchronize
- . Fork Present
- . Zone 1, 2, 3
- . Case Present
- . Count of 24 Synchronize
- . Case Reject Reject Confirmation
- . Flaw
- . Status Signals (e.g., Laser Malfunction)

Interface logic was designed to condition and synchronize process signals into computer compatible inputs. The interrupt and skip facilities of the PDP-8E were used for control of all I/O operations.

All process events are synchronized relative to the FORK SYNCHRONIZE signal. This signal is obtained from an LED/Phototransistor pair mounted on the belt pulley shaft. FORK SYNCHRONIZE is input to the computer program interrupt and skip facility.

An LED/Phototransistor pair detect a FORK PRESENT when belt forks pass a fixed reference point. A missing fork detector circuit "ands" FORK SYNCHRONIZE and FORK PRESENT to derive a MISSING FORK signal that is input to the computer interrupt and skip facility.

Two LED/Phototransistor pairs are mounted on the belt pulley shaft to indicate CASE ZONE position presently being scanned by the laser. Process ZONE signals are input to the binary status register. Fig. 6 shows case zone areas. ZONE information is polled by computer inspection of the status register whenever a flaw occurs.

The CASE PRESENT signal is derived from the reference photomultiplier tube output. This signal is used by program logic to determine flaw validity. CASE PRESENT is input to the interrupt and skip inputs of the computer.

The COUNT OF 24 SYNCHRONIZE signal is derived from a manufacturing line *identification* magnet/reed relay transducer(s) mounted on the accumulator. This signal synchronizes the case sequence with up-process presses. The COUNT OF 24 SYNCHRONIZE signal is input to the status register which, when asserted, causes an interrupt.

The CASE REJECT CONFIRMATION signal is derived from an LED/Phototransistor pair. Whenever a case passes the light path, the interruption causes a status bit to be set. The contents of the status register are loaded into the accumulator and a *software* subroutine ~~making operation determines that a case is one-forth position past the reject station~~ *was* ~~confirm~~ *confirm* *(1) a good case was present, or (2) a flawed case was rejected* ~~software begins to determine~~ *software begins to determine* that either: *(1) a good case was rejected, or (2)* *3* *4* a flawed case was not rejected.

The FLAW signal is obtained from a comparison of reflected (reference) laser light and scattered laser light detected by photomultiplier tubes. Whenever preset HI/LO thresholds are exceeded, a binary FLAW signal is sent to the computer interrupt and skip facilities. Normally when a flaw exists, two FLAW signals will be input to the computer since the laser beam line length enables double inspection at the case translation/rotation ratio used.

The STATUS register facility of the process interface provides the capability for the computer system to monitor process integrity, e.g., laser power, mechanical

failures. These signals cause an interrupt and are input via the status register load instruction.

Computer output signals include the following:

- . Flawed Case Reject
- . Case Inhibit Reject
- . Watch Dog Timer

The FLAWED CASE REJECT signal is based upon computer logic which has detected and processed a flaw signal six fork positions prior to the reject station. The flaw reject input/output transfer (IOT) instruction generates a pulse which is stretched to 37 msec using a one-shot. This pulse controls a solid-state relay which gates off the 115 VAC power to an air valve solenoid. This air valve is fail-safe, i.e., if power is lost, the solenoid is de-energized opening the valve which causes air to reject all cases.

The computer controls the removal of a case from the transfer star wheel prior to its movement onto the conveyor where a fork is missing due to mechanical malfunction. If the case were dropped, it would result in having two cases pushed by one fork which would result in erroneous flaw detection and case rejection due to incorrect case position on the conveyor. The CASE INHIBIT signal is based upon MISSING FORK computer logic. It is output two fork positions prior to the position where the fork would normally push the case down the conveyor. The CASE INHIBIT instruction generates a pulse which is stretched to drive a solid-state relay which gates off the 115 VAC air valve solenoid. This valve is also fail-safe.

The WATCH DOG TIMER is a computer controlled circuit which enables the operator to know if the central processing unit has inadvertently "hung up." This could be the result of hardware malfunction, modified software; e.g., jump self, or an externally caused halt. Because the system is to operate in a noisy

environment, a light was chosen as the enunciator. When the light comes ON, the operator knows that the computer is no longer accepting data or controlling the process.

The timer works by the computer issuing an IOT instruction each clock interrupt (20 msec) which pulses an integrating one-shot that has timing components which alarm if not pulsed within 100 msec. Thus, in normal operation, the one-shot will never reset.

SOFTWARE

The software for the case surface flaw inspection unit is a real time data acquisition and control system. The data are acquired as process events occur, and the rejection of the flawed cases is done as the result of decisions made from the analysis of the acquired data from the cases being tested.

The start-up execution of the program begins with extensive initialization that sets pointers, flags, and data files to their respective initial values. When the initialization is completed, the interrupts are enabled and activated and program control passes to the executive monitor of the flaw system. Fig. 7 shows a graphical representation of program control and data transfer. The entire control program occupies 4096 words of core memory.

The executive monitor operates by examining software flags to determine if:

- . there are any flaw data sets to process,
- . there is a request to initiate a display on the CRT or TTY,
- . there is a display in progress that needs the next line of data formatted and the printing reinitiated,
- . the flaw count data files have been requested to be initialized to zero.

The monitor continually examines these flags in a sequential manner; and if a flag is found to be set, the monitor passes program control to the subroutine which services that flag request.

The data are acquired by responding to interrupt signals from the flaw test station. The FLAW signal indicates that a flaw has been detected by the test station. The CASE PRESENT signal indicates that a case is passing through the flaw test station. The CASE ZONE identification signal provides the computer with the identification of the case zone in which the flaw was detected.

The acquisition of the data is interdependent, i.e., each test parameter is dependent upon other system conditions being met. Thus, abnormal test conditions are detected and decisions are made as to the disposition of the test data, and whether or not to reject the case in the test station. For example, if a flaw signal is received in a position where a fork is missing, the data are ignored.

The fork synchronization signal occurs during the time between optical examination of cases. When this signal occurs, the servicing subroutine checks the software flag status of the flaw test station for the time that the preceding case slot was being examined and determines if a case was present and if a flaw was detected in the case. If an acceptable (nonflawed) case was present, a flag is set to indicate an acceptable case is to be in this slot on the belt when it reaches the quality control confirmation detector. If a flawed case was present, a flag is set to indicate that this case is to be rejected when it reaches the reject station and that this belt slot is to be empty when it reaches the quality control confirmation detector. The program next examines the status of the case slot at the reject station; and, if a flawed case is there, a command is issued to reject the case. The program also examines the status of the case position on the belt that will receive the case which is at the inhibit station; and, if the belt position does not have a pusher fork, a command is issued to the inhibit air valve to reject the case. The status of the confirmation detector is read and compared with what the status should be. If the compared statuses are

different, then either the "flawed case not rejected" counter or the "good case rejected" counter is incremented according to which condition exists.

The fork synchronization program then sets the software process status flags to their respective initial values in order to read the next case position. A counter is incremented from which the clock service routine determines the belt speed. Belt speed is computed over a period of 60 seconds. Another counter is incremented and checked to see if the belt has completed a revolution. When a revolution has been completed, the number of missing pusher forks detected during the revolution is stored in the data files.

A flaw data set is saved for flaw data processing when a flaw is recognized in a zone of a case. A flaw data set contains the case zone in which the flaw was detected and the manufacturing line number (one of 24) of the case in which the flaw was detected. There will be only one flaw recognized per zone of each inspected case. The flaw counter is incremented for the flaw zone and manufacturing line designated by the flaw data set. Also, the "total flaws" counter is incremented for the designated manufacturing line.

The "total system reject" counter and the respective "manufacturing line reject" counter are incremented when the fork synchronize interrupt service routine recognizes that the case just inspected does contain flaws and is to be rejected.

The counter for the "cases rejected due to missing forks" is incremented when the belt position with the missing fork passes through the flaw detection station.

The display of the contents of the flaw count data files on the video display is initiated automatically every 30 seconds by request from the real time clock. The other displays are initiated by operator request through the teletype

keyboard. One of the three video formats available is shown in Fig. 8. Regular operator requests are inhibited during teletype printout. However, in urgent conditions, the teletype printout can be aborted after which operator requests can be made. This method insures that a hard copy of the operator-to-system communication is maintained. A typical hardcopy output is shown in Fig. 9.

CONCLUSIONS

This development program has demonstrated that a mini-computer can perform data acquisition and control of "in process" quality control measurements at high speeds. A dedicated computer is required to acquire data on-line in real time and provide rapid data output in a form suitable for process operator decision making. Future use of this measurement system will include output of flaw data to a larger host computer for more sophisticated data analysis and integration with the total process data base.

FLAW MONITOR STATION OPTICS

FIGURE 3
FLAW MONITOR STATION
OPTICS

FIGURE 4 The Computer System

PNL-56000-44 (45)

FIGURE 5 Block Diagram
Case Flaw Detection System Electronics

TYPICAL CARTRIDGE CASE SURFACE FLAWS

FIGURE 6

FIGURE 7 Program Control and Data Transfer Map

TIME	265	14	36			
1		4		2	4	10
2				1		1
3		1			3	4
4		1		6	2	9
5				1		1
6				3	2	5
7				1	1	2
8		1		3	1	5
9		1				1
10				1	1	2
11				1		1
12					1	1
13		1		2	1	4
14		3		1		4
15						
16						
17						
18						
19		1		3		4
20		1				1
21		1		1	1	3
22				1		2
23		1				1
24		1		2	2	5

FIGURE 8 Video Display Frame #1

FORMAT F2T SAMPLE PRINTOUT

Day of Year, Hour, Minute

TIME 265, 16, 16

TOTAL THROUGHPUT: 1671

TOTAL REJECT: 49

BELT SPEED: 622 *Cases/Minute*

MISSING PINS ON BELT: 1

CASES EJECTED DUE TO MISSING PINS: 9

FLAWED CASES NOT REJECTED: 1

ACCEPTABLE CASES REJECTED: 1

NOTE: *Italicized Items Are Not Printed in Teletype or
Video Display Outputs*

FIGURE 9

SAMPLE HARDCOPY OUTPUT