AUTOMATED SHOT PEEN QUALITY CONTROL THROUGH THE USE OF PARAMETRIC SENSORS

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Introduction

This paper describes a microprocessor controlled multi-nozzle peening system designed to achieve the desired intensity and coverage called out on the engineering drawing. The development of this type of automated, parametrically controlled shot peen system by the Metal Improvement Company was necessitated by the ever increasing complexity of aircraft hardware manufactured by the General Electric Company.

The required parameters for intensity, shot mass flow, air pressure, oscillation, turntable rotation and cycle time are entered into the computer by means of a micro cassette. Each of the preceding parameters is individually controlled through minimum and maximum limits, which shut down the equipment when exceeded.

A comprehensive data record is produced during the peening cycle as is illustrated in Table I. The record consists of recorded parameters for shot flow, air pressure, oscillation rate and position, turntable rotation and time measurement increment. At the completion of all cycles a permanent record has been produced which can be used as a Certificate of Conformance. Prior to the development of parametric sensors the operator had very little knowledge of the behavior of any parameters other than air pressure and perhaps oscillation during the peening cycle.

System Description

The microprocessor controlled computer has been developed for a Peenamatic 2343 shot peen system. The measurement section consists of sensors which are located in the air pressure manifold, the shot flow line, table notation system and the oscillation system. The shot flow system has since been modified from the time of this data and no longer requires a shot flow sensor. In our case the output signal used conjunction with the calibration factor for each nozzle, yields the information required for shot flow which is interfaced with the microprocessor together with the signals from the remaining parametric sensors.

Parameters for a proposed peening cycle are introduced manually into a peening machine computer (microprocessor) specifically designed for the peening industry. The parameters are optimized in the Set-Up Mode until they are ready for transfer from the computer screen to tape in the Computer Mode (Master Computer). The Computer Mode monitors the peening cycle going through a menu sequence until the peening cycle is completed. After transfer to tape the optimized cycle becomes Production Data and is contained in Production Data Storage. Production Data from the optimized peening cylce can now be printed out upon a Texas Instrument Keyboard/Printer. Manual Input can be accomplished also from a Master Terminal into the Master Computer for processing procedures from storage. The Computer Software Path may be seen in Figure 1.

CUSTOMER :							AIR PRESS TMR = 2 SEC					
PART NUMBER :							SHOT FLOW TMR = 2 SEC					
SERIAL NUMBER :N/A							TURNTABLE TMR = 2 SEC					
SPECIFICATION :							SPEED CHANGE = 2 SEC					
OPERATION :NOZZLE TEST PROGRAM							MAX SHOT FLOW = 25 LBS					
							TURNTABLE RPM = 16.0 RPM					
MIC PROCEDURE :MIC-V2												
SHOT SIZE :							MODE = HORZ					
INTENSITY :100%							CYCLE COUNT = 0002					
COVERAGE :100%							CYCLE TIME = 0:00:00					
SATURATION TIME:1:55:30												
100% COVER TIME:10 MIN												

	NOZZ. 01		NOZZ. 02		NOZZ. 03		NOZZ. 04		NOZZ. 05		NOZZ. 06	
	AIR PSI	SHOT LB/M	AIR PSI	SHOT LB/M	AIR PSI	SHOT LB/M	AIR PSI	SHOT LB/M	AIR PSI	SHOT LB/M	AIR PSI	SHOT LB/M
HI LIMIT	10	15.0	10	15.0	10	15.0	10	15.0	10	15.0	10	15.0
DATA												
LO LIMIT	2	10.0	2	10.0	2	10.0	2	10.0	2	10.0	2	10.0

OSCILLATION PROGRAM POS.	IN/MIN	POS.	IN/MIN	NOZZLE PROGRAM NOZZ.	ACTIVE	FRI 4:16:20 PM AUG 17, 1983
HOME 1=35.0	32.0	11= 9.0	15.0	1= 0:00:00	A	
START2=25.0	5.0	12= 7.0	18.0	2= 0:00:00	A	
3=24.0	6.0	13= 6.0	20.0	3= 0:00:00	A	
4=23.0	7.0	14= 6.0	20.0	4= 0:00:00	A	
5=22.0	8.0	15= 6.0	20.0	5= 0:00:00	A	
6=21.0	9.0	16= 5.0	22.0	6= 0:00:00	A	
7=20.0	20.0	17= 4.0	24.0	7= 0:00:00	A	
8=15.0	1.0	18= 3.0	26.0	8= 0:00:00	A	REMAINING CYCLES
9=14.0	10.0	19= 2.0	28.0	9= 0:00:00	A	
10=10.0	12.0	TA= 1.0		10= 0:00:00	A	0

NOZZ. 07		NOZZ. 08		NOZZ. 09		NOZZ. 10		TURNTABLE SPEED	OSCILL. SPEED	OSCILL. POSITION
AIR PSI	SHOT LB/M	AIR PSI	SHOT LB/M	AIR PSI	SHOT LB/M	AIR PSI	SHOT LB/M	RPM	IN/MIN	INCHES
10	15.0	10	15.0	10	15.0	10	15.0	20.0	+ 1.0	
2	10.0	1	10.0	2	10.0	2	10.0	10.0	- 1.0	

Table I -- Recorded Data/Certificate of Test

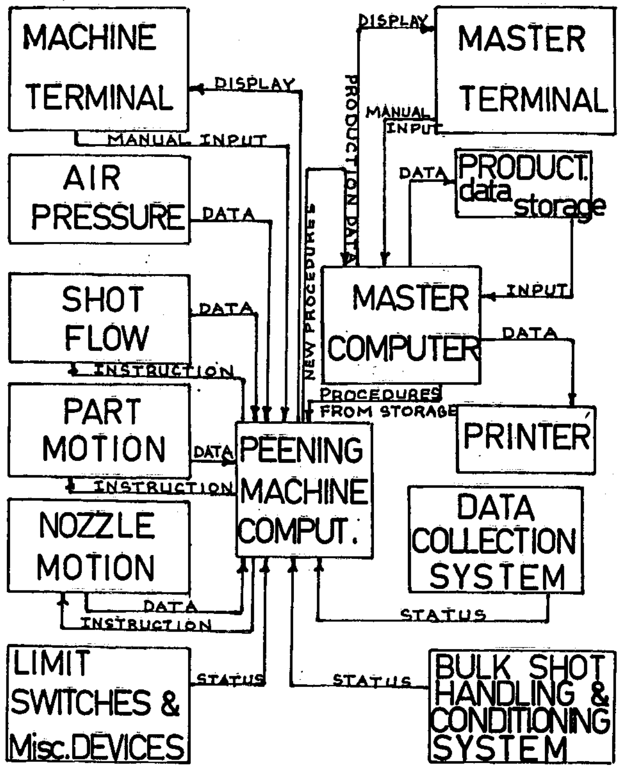


Fig.1: Software Path

There are three (3) primary control systems associated with this equipment, namely, shot velocity, shot feed rate and coverage. Shot velocity is controlled primarily by air pressure setting and shot feed rate to each calibrated nozzle. Coverage is controlled through the use of programmed oscillation.

The shot peen system was designed to utilize the most advanced components available in today's technology in order to reduce the unacceptable tolerances present with many manufactured components. The system offers continuous shot control through the use of dual screens and an air wash system which uses a spiral to eliminate fractured shot and unacceptable shapes. Limits of control are for better than those required by Mil-S-13165B or AMS2430. A ten (10) nozzle, fixed position nozzle fixture offers excellent coverage and better arc height control then previously attained. The use of a part holding fixture, a fixed nozzle fixture and the control offered by the microprocessor, results in data generated which is equivalent or superior than any dedicated system. The control limits may be seen in Table II.

PARAMETER CONTROLLED	CONTROL LIMITS
Shot Delivery	--Control shot to each nozzle ±0.2 PPM (0.09 KPM) --Monitors shot feeders of each nozzle to verify operation ±0.1 PPM (0.045 KPM) --Record shot flow of each nozzle in 0.1 PPM (0.045 KPM)
Air Pressure	--Monitors air pressure to each nozzle to 1 PSIG (0.07 KSCG) --Records air pressure to each nozzle in 1 PSIG (0.7 KSCG) increments
Turntable Rotation	--Controls turntable RPM to ±0.1 RPM --Monitors turntable RPM to ±0.1 RPM --Records turntable RPM to ±0.1 RPM increments
Oscillation Rate	--Controls oscillation rate to ±0.1 IPM (0.254 CPM) --Monitors oscillation rate to ±0.1 IPM (0.254 CPM) --Records oscillation rate to ±0.1 IPM (0.254 CPM) increments
Programmable Oscillation	--Can change oscillation rate during peening cycle in 0.1 IPM (0.254 CPM) increments
Programmable Nozzle Shut-Down	--Can shut down any or all nozzles at any time during the peening cycle in 1 second increments
Process Interrupt Parameters	--Process parameters (shot flow, air pressure, table rotation, oscillation) scanned and stored every second and printed out every 60 seconds on the average. --Machine status (doors, crash limits, air supply, shot level, shot system, etc.) scanned every 0.1 second with no print out. --When process interrupts occurs, the machine shuts down and prints time of occurrence, the last seconds' process parameters, status and cause of interrupt. When restarted will restart from exact point of interrupt and continue peening process to completion.

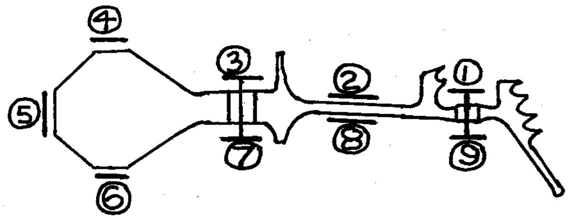
PPM -- Pounds per minute
KPM -- Kilograms per minute
PSIG -- Pounds per square inch gauge
CPM -- Centimeters per minute
KSCG -- Kilograms per square centimeter gauge
RPM -- Revolutions per minute
IPM -- Inches per minute

Table II -- Microprocessor Controlled Equipment

PARAMETER	TYPICAL SETTING	PREVIOUS TOLERANCE, PERCENT	MICROPROCESSOR CONTROLLED TOLERANCE, PERCENT
Shot Flow	10 RPM	±5 ±50%	±0.2 ±2%
Air Pressure	80 PSIG (5.6 kg/cm^2)	±5 ±6%	±1 ±1%
Oscillation Rate	10 IPM (25.4 cm/min)	±2 ±20%	±0.2 ±2%
Rotation Rate	15 RPM	±2 ±15%	±0.5 ±3%
Continuous Shot Classification	40 PER ¼ inch sq. (0.635 cm sq.)	N + 15%	8 + 3%
Almen Intensity (6-10A)	8A	±2A ±25%	
Preselected Almen Intensity *(±0.0005 flat)	7A	36 = ±2A ±29%	
Nozzle Angle Nozzle Distance Nozzle Target Area		±5° ±0.25 inch (0.635 cm) ±1.0 inch (2.54 cm) dia	±0.5° ±0.03125 inch (0.0794 cm) ±0.0625 inch (0.1588 cm) dia

*Accuracy of Almen Strip

Table IV -- Improvements in Control Using Microprocessor Controlled Parametric Sensors

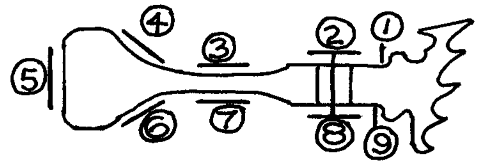


M62 ALMEN FIXTURE

*SATURATION POINT

AVERAGE INTENSITY READING

ALMEN STRIP LOCATION	Outer Holes 1/9	Web 2/8	Inner Holes 3/7	Rim 4/6	Bore 5
1 Cycle (70 Readings)	5.7	5.6	5.7	6.0	6.0
2 Cycles (10 Readings)	5.6	4.9	6.0	5.8	6.3
*3 Cycles (206 Readings)	6.7	6.9	6.8	7.0	7.0
4 Cycles (85 Readings)	7.5	7.8	8.0	7.9	7.6
6 Cycles (81 Readings)	7.2	7.0	6.9	7.2	7.3
8 Cycles (11 Readings)	6.8	6.4	6.8	7.0	7.4



M68 ALMEN FIXTURE

*SATURATION POINT

AVERAGE INTENSITY READING

ALMEN STRIP LOCATION	Outer Flange 1/9	Holes 2/8	Web 3/7	Rim 4/6	Bore 5
1 Cycle (45 Readings)	5.9	5.8	6.0	6.5	6.5
*2 Cycles (168 Readings)	6.7	7.1	6.9	7.1	6.8
3 Cycles (35 Readings)	6.8	7.0	6.6	7.2	6.9
4 Cycles (89 Readings)	6.6	7.2	7.1	7.1	7.1
6 Cycles (10 Readings)	7.4	6.9	6.7	8.0	7.5
8 Cycles (10 Readings)	7.2	7.8	6.8	8.1	8.2

Table III -- Microprocessor Controlled Shot Peen Data

Test Procedure

In order to certify the new 2343 machine for General Electric, saturation curves were run by Metal Improvement using an M62 and an M68 scrap part Almen strip fixture which depicted a piece of aerospace hardware. The M62 Almen fixture had five (5) Almen strip locations per side depicting locations at the outer bolt holes, web, inner bolt holes, rim and bore. The M68 Almen fixture had five (5) Almen strip locations per side depicting locations at the outer flange, bolt holes, web, rim and bore. Both fixtures were shot peened on each side to an intensity requirement of .006 to .010A and a minimum coverage of 125 percent. Data collected over a one year period can be seen in Table III. Although this population of data represents parts which were not shot peened using programmable oscillation, the system has since been adapted for programmable oscillation.

Discussion of Results

An analysis of saturation curves plotted for the M62 and M68 Almen fixtures indicated that saturation occurred in three (3) cycles and two (2) cycles respectively at all Almen strip locations. It is evident that the average readings and ranges for both the three cycle and the two cycle saturation points were well within the required .006 to .010A intensity range. In reality, the average readings and ranges could be considered acceptable for the narrower .006 to .008A intensity range. The improvement in control limits and process tolerance for this microprocessor controlled system versus a manually controlled system may be seen in Table IV.

Conclusion

A computer controlled system has been developed to control shot flow, air pressure, oscillation rate and position, turntable rotation and time measurement. The system has proved invaluable in shot peening aerospace hardware and supplying recorded data which was not here to fore possible. Evidence of savings as much as fifty percent has been demonstrated in some cases. The results summarized in this paper show that this system significantly improves the control limits of the shot peen process.