COMPUTER MONITORED CONTROLLED DEFLECTOR PEENING

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ABSTRACT

Equipment and process techniques are described for fully automated deflector peening of bolt holes in a turbine engine disk. Unique design features of the equipment are presented along with the software path used to monitor process variables. The use of statistical process control (SPC) to select abort limits for air pressure and shot flow rate is also discussed.

KEYWORDS

Shot Peening, Computer, Software, Statistical Process Control

INTRODUCTION

Aircraft gas turbine design engineers are continually upgrading their demand for greater and more consistent engine performance. One way of complying with these requirements is to reduce variability in individual engine part life expectancy by instituting rigid process control procedures throughout the manufacturing cycle from the melting and processing (e.g. forging) of raw material to metal removal (machining) techniques and finally to mechanical surface treatment (peening) of the final part. Effective process control is achieved by methods which guarantee that a particular operation is performed the same each and every time within predefined limits for every parameter that can influence the end result. A measurement system provides feedback if any of these limits are not met, shutting down the peening operation, which is a signal for corrective action. Each limit must be set outside the range of random variation, but within the window required to meet specified technical requirements for the part.

For parts like the powder metal superalloy turbine engine disk shown in Fig. 1, it is desirable to place those surfaces exposed to high service tensile stresses in high compression. This can be accomplished by shot peening which, in effect, causes any potential cracks originating from an inherent material defect to initiate subsurface, resulting in a longer predictable life than for an equivalent size defect on or in the immediate proximity of an untreated surface. Shot peening also compensates for any surface related manufacturing defects such as machining grooves or scratches which serve as (tensile) stress risers. In deep holes, where service operating stresses are especially high, it is important that the peening process be guaranteed by having a snapshot record available of each controlled parameter taken at intervals as the peening operation is performed. Continuous monitoring of key parameters which control the kinetic energy of the shot stream, such as shot flow and air pressure used in nozzle type equipment together with movement of the shot stream over the part, can provide that guarantee. Should approved process parameters not be met at any time during the peening cycle, a provision is made to abort the process and advise the operator of the actual cause for machine shutdown.

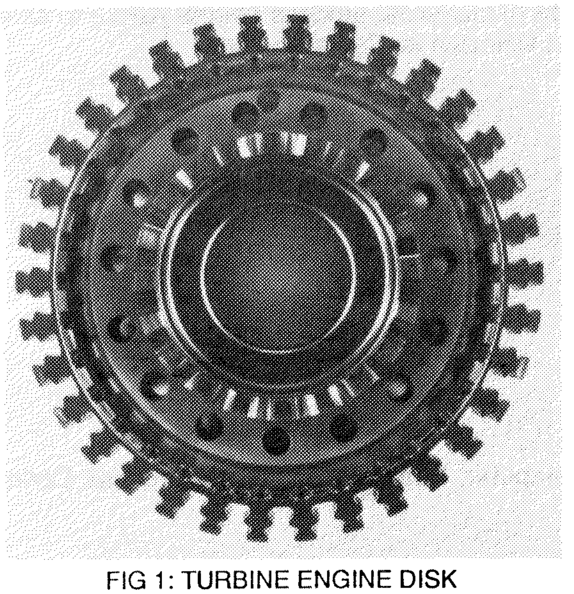

FIG 1: TURBINE ENGINE DISK

PROCESS OVERVIEW

Fig. 2 illustrates the deflector peening process used for holes. Shot exits the nozzle at high velocity and imparts a compressive stress in the hole by ricocheting off the tapered end of a reciprocating pin deflector. Selection of an optimum deflector diameter must be balanced between the time to achieve full coverage and intensity and the need to exit spent shot out the annular space around the deflector. Intensity calibration is achieved by a method described previously in the literature in which the center transverse portion of an Almen N strip, equal in width to the hole diameter, is peened under the same conditions as a fully exposed Almen A strip [1]. The resulting intensity is then matched in a fixture with a key hole where an N strip is positioned perpendicular and tangent to the hole diameter to receive shot redirected from the deflector. The parameters used to arrive at this intensity are then applied to peen holes in the actual part.

EQUIPMENT

Design Requirement

The objective was to design a fully automated system with continuous feedback for controlling air pressure, shot flow and deflector speed while peening each of the fifteen holes in the turbine engine disk shown in Fig. 1. The system would completely shut down (abort) if the pre-set minimum/maximum values for any of these parameters are exceeded. Actual readings would be recorded on a computer hard disk at regular intervals and could be made available on demand for subsequent review.

Even though holes in the turbine disk are located on the same 8.94 cm (3.52 in) diameter bolt circle, they are not all equidistant. This required a preprogrammed index for rotating the disk on a spindle from a reference or home position about the disk axis to bring the deflector and nozzle in alignment with the center of each 7.62 mm (.300 in) diameter hole. During rotation to each hole position, a location tolerance capable of guaranteeing process performance was required. Inability to achieve the proper position within a specified time would cause an abort.

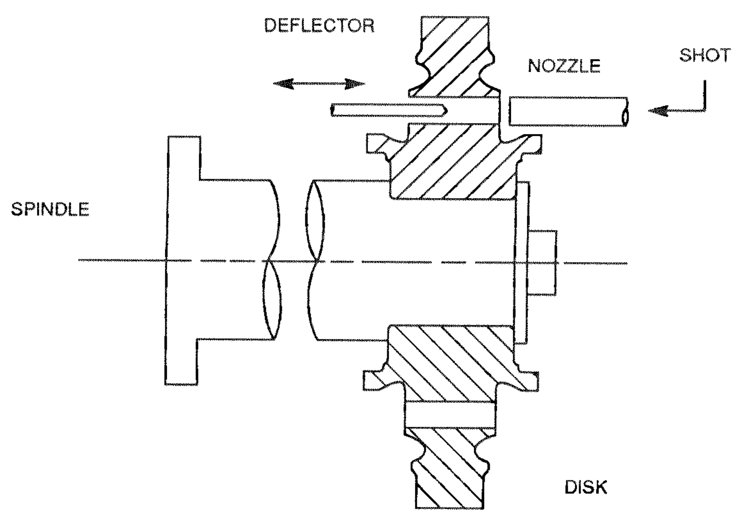

FIG 2: SPINDLE-DISK ASSEMBLY

Peening Machine and Software

The Peenamatic (R) machine developed for this task is integrated with a computer controlled shot peening system capable of processing the I.D. of small through-holes in workpieces up to 45.7 cm (18 in) diameter with hole depths up to 12.1 cm (4-3/4 in). The workpiece, in this case a turbine disk, is mounted to a spindle using an appropriate fixture, Fig. 2. The spindle provides angular positioning of the workpiece to present the desired hole to the nozzle and deflector. A carriage supports both the nozzle and deflector actuators and locates them radially with respect to the workpiece centerline. The carriage locates the nozzle and deflector opposite the hole to be peened within .51 mm (.020 in) to satisfy the design requirement. Both the deflector and nozzle share a common centerline which is parallel to that of the workpiece and holes to be peened. Their actuators locate them for the peening operation. The deflector actuator also serves as a reciprocator during the actual peening, and has a speed of up to 63.5 cm/min (25 in/min). This peening system uses one direct pressure nozzle, one deflector and a shot system which includes a pneumatic elevator and separator, continuous discharge screener, shot shape classifier, shot feeder and shot flow sensor.

The computer control is able to archive a large number of processing procedures, each of which establishes values, limits, cycle duration and other operating parameters for different parts. The following parameters are controlled and monitored by the computer:

Spindle location (during peening and hole to hole indexing)
Carriage location
Nozzle location (during peening and between holes)
Deflector location and speed
Shot flow
Air flow
Cycle duration

These items are monitored but not subject to computer control:

Air pressure
Shot system operation
Access door closure condition (safe or open)

The peening machine is able to accept up to ninety holes on any one part, each with its own radial and angular location. The production processing data is displayed on the machine operator's screen, and transferred to a hard disk for long term storage for the generation of a printout at a later date. Any deviation outside of the processing procedure parameters will cause an interruption of the process with the reason both displayed on the operator's screen and in the stored process data. The unit allows either resumption or a new cycle start when this occurs. The procedure for processing data consists of a number of features pertinent to each workpiece; including serial number, procedure number, work order number, date of processing, machine used for the process, operator identification and process values and tolerances (abort limits). A software path is shown in Fig. 3 which illustrates a typical system [2].

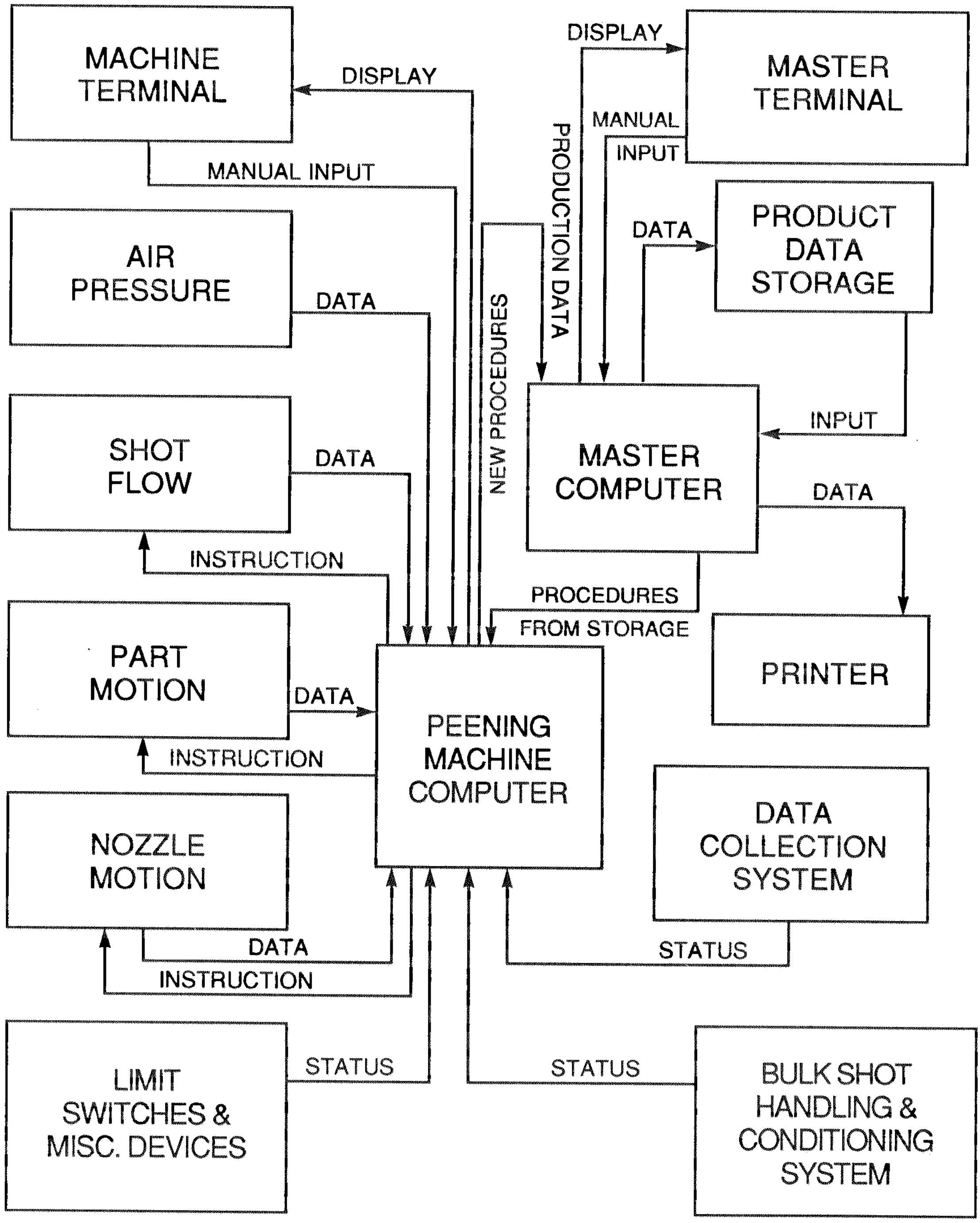

FIG 3: TYPICAL SOFTWARE PATH FOR COMPUTER-MONITORED EQUIPMENT

SELECTION OF PARAMETRIC VALUES

Parameter allowances for processing the disk were established within those limits for minimum intensity beyond which the intensity would fail to meet the drawing requirement which in this instance was 6-8A Almen intensity for a 7.62 mm (.300 in) diameter, 27.7 mm (1.09 in) deep hole using cast steel S70 shot. Equivalent values for conventional external peening of a 7.62 mm (.300 in) wide stripe across the center of an Almen N strip, Fig. 4, are listed below.

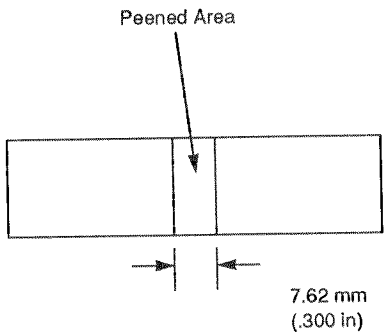

FIG 4: N TEST STRIP

A Intensity	N Intensity
6A	7N
7A	9N
8A	10N

A parametric study of N values was performed in the intensity calibration hole test fixture over a range of air pressure and shot flow rates for a constant deflector speed. Combinations were selected where air pressure varied from 4.92 to 5.98 kgm/cm^2 (70 to 85 psig) and shot flow rate from .11 to .34 kgm/cm^2 (.25 to .75 lb)/min. A few combinations (e.g. low air pressure and low shot flow) just achieved but did not violate the minimum 7 N intensity. On the other hand, no combination of settings produced an intensity above 8N for the 7.62 mm (.300 in) wide peened area.

The above study led to the determination of parameter limits which would cause the system to shutdown if they were exceeded. Nominal air pressure was set at 5.62 kgm/cm^2 (80 psig) with an allowable range of 5.27 - 5.98 kgm/cm^2 (75-85 psig). Shot flow rate was set at 227 gm (.50 lb)/min. with an allowed variation of + - 45 gm (.10 lb)/min. Computer settings for air pressure were calibrated against a master air gauge, and the shot flow rate was calibrated using measured catch weight. Statistical process control methods were applied to establish reproducibility for both air pressure and shot flow. Normal or random (3 sigma) variation was found to be within + - 1.4 kgm/cm^2 (2 psig) and + - 14 gm (.03 lb)/min. for all nominal settings. The abort limits that were selected, + - 3.5 kgm/cm^2 (5 psig) and + - 45 gm (.10 lb)/min, fall well outside the window of expected variability, but within the maximum tolerances required to meet 6-8A equivalent intensity.

Fig. 5 is a typical peening record for two holes in a disk. Thirteen readings for each hole were taken over a period of about 3 minutes total peening time. Note the uniformity of air pressure and rate of shot flow, which is the result of extensive technical effort devoted to perfecting the system controls and instrumentation. Air pressure and shot flow calibration is performed frequently to ensure that the control settings continually reflect actual values.

Hole Position	Deflector Speed		Shot Flow		Air Pressure	
	(cm/min)	(in/min)	(gm/min)	(lb/min)	(kgm/cm)	(psig)
1	12.7	5.0	222	.49	5.62	80
1	12.7	5.0	222	.49	5.62	80
1	12.7	5.0	227	.50	5.62	80
1	12.7	5.0	227	.50	5.62	80
1	12.7	5.0	231	.51	5.62	80
1	12.7	5.0	231	.51	5.62	80
1	12.7	5.0	227	.50	5.55	79
1	12.7	5.0	227	.50	5.62	80
1	12.7	5.0	231	.51	5.62	80
1	12.7	5.0	231	.51	5.55	79
1	13.0	5.1	227	.50	5.62	80
1	12.7	5.0	227	.50	5.62	80
1	12.7	5.0	231	.51	5.62	80
2	12.7	5.0	218	.48	5.70	81
2	12.7	5.0	222	.49	5.70	81
2	12.7	5.0	227	.50	5.70	81
2	12.7	5.0	227	.50	5.62	80
2	12.7	5.0	227	.50	5.70	81
2	12.7	5.0	227	.50	5.70	81
2	12.7	5.0	227	.50	5.62	80
2	12.7	5.0	227	.50	5.62	80
2	13.0	5.1	231	.51	5.70	81
2	12.7	5.0	231	.51	5.70	81
2	12.7	5.0	227	.50	5.62	80
2	12.7	5.0	227	.50	5.70	81
2	13.0	5.1	236	.52	5.62	80

FIG 5: RECORDED DATA

COMMENTS

High technology has been recently introduced in shot peening through computer monitoring which greatly enhances the reliability of the process. Hard copy data available for key process variables makes the process suitable for consideration in part life management by design engineers. This paper has described one application for computer monitored shot peening whereby process performance is guaranteed for deflector peening of deep holes, not by an operator, but by instrumented equipment designed for repeatability. Single nozzle robot and multi-nozzle machines have been similarly equipped to provide industry with the same level of process control for external peening of parts. The recent issued specification, AMS 2432, deals exclusively with computer monitored shot peening and the recently revised military specification, MIL-S-13165C, references its use as an alternative for critical fatigue applications.

REFERENCES

[1] Happ, M.B., "Shot Peening Bolt Holes in Aircraft Engine Hardware", Proceedings Second International Conference on Shot Peening (1984).

[2] Gillespie, R. & Hasty, W. Jr., "Automated Shot Peen Quality Control Through The Use Of Parametric Sensors". Proceedings Third International Conference on Shot Peening (1987).