The Use of the Shot Peen Process as a Design Tool Through the Use of Microprocessors.

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An abundance of data has been presented and recorded over the last 40 years on the benefits of mechanically prestressing components which are subject to metal fatigue as well as stress corrosion cracking. The most flexible and inexpensive method has proven to be the shot peening process. However, prior to the advent of sophisticated sensors and computers, lack of precise control over the process has not allowed the design engineer to take credit for the use of the process in his original design calculations.

With the introduction of computer aided manufacturing (CAM), controlling, monitoring and recording of the variables within the shot peening cabinet became feasible. This coupled with the following innovations: 1) improved nozzle and workpiece fixturing devices, 2) robotic controls, 3) improved media specifications, 4) addition of in-line media size and shot shape control systems, 5) introduction of sophisticated fluorescent tracer systems for determining uniform shot peening coverage, and 6) development of software programs to give hard copy data on the control of the variables within the peening cabinet during processing have allowed the establishment of life enhancement programs which extend the useful life of components through the shot peen process.

To date, these life enhancement programs have been introduced in specifications for several turbine engine builders, rotary and fixed wing airframe manufacturers and industrial transmission manufacturers. There is substantial work being funded by government and private industry in the area of fatigue life optimization, and the use of the computers to control the critical variables in the shot peen process. These advantages in shot peening technology will allow shot peening to be used as a viable design tool in life enhancement programs. The optimization programs are designed to more accurately define optimum media, intensity and coverage specifications for shot peening. For instance, several airframe manufacturers who use high strength aluminum have proven that larger shot sizes give deeper depths of compression for a given intensity as compared to smaller shot sizes. This phenomenon is due to larger dimples which are created by the larger shot in this relatively soft material. There is also less risk in tearing of the surface and a better surface finish is realized through the use of the larger shot at proper angles of impingement (Fig. 1). Turbine engine manufacturers have determined that coverage in excess of 500% on strain hardenable alloys such as Inconel 718, can reduce the optimum benefits that can be realized through shot peening making uniform and close control of coverage of paramount importance.

Users of Beta solution treated titanium 6AL-4V have documented that intensities above 12N cause subsurface damage which overcomes the benefits of using shot peening on this alloy. The Alpha and Alpha-Beta phases of the alloy, however, have found that they can take advantage of higher intensities, i.e. up to 10A. Users of high strength steel heat treated above HRC50 find greater benefit from relatively high intensities (16-20A) using special hardness shot (HRC 55-62). The writer has observed many cases where finite element analysis of original component designs show a deficiency in predicted fatigue life and where introduction of life enhancement procedures, such as computer controlled shot peening, has allowed achievement of the specified fatigue life. Therefore, it is highly probable that serious users of the process will specify computer controlled shot peening within the next ten years as outlined further in this paper.

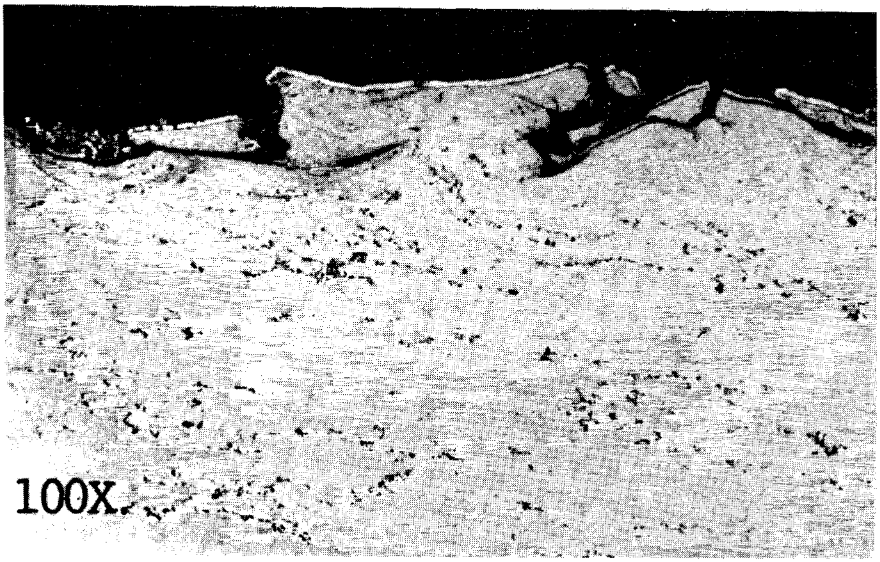

Fig. 1: 100X. Keller's Etch. This section was removed from a part that was peened using poor media and improper impingement angles on high strength aluminum. The operation has caused a tearing of the material surface resulting in numerous flaws.

The four most important variables in the shot peening process and the subjects of these improved controls in order of importance are as follows:

1 - Media.

Ideally, the media impinging on the surface of components should be at, or near, normal angles to the surface and be perfect spheres creating a minimum of surface damage. However, recognizing that perfect spheres are not always practicable, the following illustration (Fig. 2, Ref. 1) shows the type of shapes that are considered to be acceptable. Shot should be preconditioned prior to use so as to remove any undesirable shapes as well as scale or sharp edges. The shot peen machinery must be equipped with shot size and shape control systems that would remove undesirable particles during the operation, delivering only media of the quality shown in Figure 2 to the workpiece. Investigations are currently proceeding to develop new spherical media which does not readily break down and will yield minimum surface damage during the peening operation. The use of good media in the process is of paramount importance and without it precise control of the other three variables becomes superfluous.

Acceptable Shapes (Ref. 1)

Fig. 2: Approximate magnification 10X.

2 - Depth of Compressive Stress.

The design engineer should refer to residual stress profiles that are documented and available today for various alloys. He should also review various shot peening callouts so as to assure himself that the desired residual stress profile is obtained with the shot size and intensity he intends to specify. (Ref. 2).

The intensity verification designations should be noted on the drawing at the points of the highest anticipated stress concentrations. This will ensure that Almen test strips are used to verify intensities in those areas of predicted high stress concentrations regardless of which peening source, be it the manufacturer or a contracted service, performs the shot peening.

Coverage requirements and the applicable shot peening specification should also be part of the shot peening callout on the drawing.

3 - Complete Coverage.

In most applications a minimum of 100% coverage is acceptable. However, exceptions would be where superficial work hardening of work hardenable alloys is desired through extended coverage (multiples of 100%) or where uniform coverage of strain hardenable alloys is required. The use of fluorescent tracers for determining uniform and/or complete coverage has gained wide acceptance in the last decade and is the preferred method for assuring shot peening coverage. A minimum of 100% coverage is of paramount importance to assure a uniform depth of compressive stress in extending fatigue life as well as retarding the phenomena of stress corrosion cracking. When fluorescent tracer systems are unavailable, the use of 10X magnification on the piece part is an acceptable alternate. However, it is less reliable and takes additional time of skilled quality assurance personnel.

4 - Computer Control.

When the user is assured of good quality shot media, intensity and coverage verification, he can then address the control of all critical variables within the peening cabinet to assure repeatability and reliability in using the process as a design tool. The computer controls and records the following data within the shot peen cabinet:

A - Shot flow
B - Air pressure
C - Air flow
D - Wheel speed
E - Amperage of wheel motor
F - Movement of wheels and/or nozzles
G - Angles of nozzles (when robotics are used)
H - Movement or rotation of the workpiece
I - The oscillation (of nozzles or wheels) including variable speed programs
J - Sequential shut down of nozzles or wheels (Fig. 3).
K - Peening time

CUSTOMER	:
PART NUMBER	:
SPECIFICATION	MIL-S-13165B AMMEND 2
OPERATION	:
MIC PROCEDURE	: 012
SHOT SIZE	: MI-170R
INTENSITY	: 6-10A
COVERAGE	: 100%
SATURATION TIME	: 6 MINUTES
100% COVER TIME	: 6 MINUTES

AIR PRESS TMR	5	SEC
SHOT FLOW TMR	15	SEC
TURNTABLE TMR	5	SEC
SPEED CHANGE	5	SEC
MAX SHOT FLOW	25	LBS
TURNTABLE RPM	16.0	RPM
MODE	HORZ	
CYCLE COUNT	NA	
CYCLE TIME	6 00 00	

OSCILLATION PROGRAM	POS		IN MIN	POS.		IN MIN
HOME	1	30.0	32.0	11	19.5	20.0
START	2	24.0	4.0	12	19.0	21.0
	3	23.5	8.0	13	18.5	22.0
	4	23.0	12.0	14	18.0	23.0
	5	22.5	14.0	15	17.5	24.0
	6	22.0	15.0	16	17.0	25.0
	7	21.5	16.0	17	12.0	25.0
	8	21.0	17.0	18	12.0	25.0
	9	20.5	18.0	19	12.0	25.0
	10	20.0	19.0	TA	12.0	

NOZZLE PROGRAM NOZZ.	ACTIVE	
1	2:00:00	A
2	2:00:00	A
3	2:00:00	A
4	2:00:00	A
5	4:00:00	A
6	4:00:00	A
7	4:00:00	A
8	6:00:00	A
9	6:00:00	A
10	6:00:00	A

TUE 5:19:47 PM
JUL 31, 1984

REMAINING CYCLES
0

	NOZZ. 01		NOZZ. 02		NOZZ. 03		NOZZ. 04		NOZZ. 05		NOZZ. 06		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	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	RPM	IN MIN	INCHES
HI LIMIT	60	18.0	60	18.0	60	18.0	60	18.0	60	18.0	60	18.0	60	18.0	40	16.0	40	16.0	40	16.0	11.0	+ 2.0	
DATA	55	16.0	55	16.0	55	16.0	55	16.0	55	16.0	55	16.0	55	16.0	35	14.0	35	14.0	35	14.0	10.0	6.0	
LO LIMIT	50	14.0	50	14.0	50	14.0	50	14.0	50	14.0	50	14.0	50	14.0	30	12.0	30	12.0	30	12.0	9.0	2.0	
SN0001	55	14.0	56	16.0	55	15.0	55	14.0	56	15.0	51	14.0	52	15.0	35	13.0	34	14.0	34	14.0	10.0	6.0	
SN002	ABORT 1:14:10 LOW SHOT FLOW NOZZ. 02 AT 12 LB MIN																						
SN002	56	16.0	56	15.0	57	17.0	56	15.0	57	16.0	55	16.0	54	15.0	36	14.0	34	13.0	34	14.0	9.5	5.0	

Fig. 3: Typical printout of one lot of components requiring shot peening.

Control of all of these variables assures the designer of desired process control and typically the following program is established: Prototype components, both peened and unpeened, are fatigue tested and a baseline for fatigue improvement is established on the shot peened component. The shot peening of the prototype component is closely controlled by computers so that the same program can be used on production machinery thereby assuring fatigue performance of production shot peened components as well. In the past this had never been possible. However with the aid of the computers, design engineering personnel can confirm to industry and their various inspection and government authorities that life enhancement through the use of controlled shot peening is a viable tool.

References

(1) U. S. Military Specification MIL-S-13165B, "Shot Peening of Metal Parts".

(2) "Shot Peening Stress Profiles", H. O. Fuchs 1986.