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INVESTIGATION OF THE EFFECT OF SHOT PEENING PARAMETERS ON PEENING INTENSITY

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ABSTRACT:

In this paper, the shot peening process and the parameters affecting it are reviewed and discussed. The effect of the shot pressure, table rotational speed, exposure time and standoff distance on the shot peening intensity are investigated by conducting a 2^4 full factorial experiment. Sixteen runs with no replication were conducted randomly to neutralize the effect of any unknown factor. The data obtained from the runs are tabulated and visual display is presented graphically. Finally, the contribution of each of the parameter to peening intensity is determined.

INTRODUCTION:

Shot peening may be defined as multiple impact of metal or glass spherical particles on an elastic-plastic target in a defined and controlled manner [1]. This multiple impact of the shots produces a dynamic compressive stress at the surface of the target, thereby effectively improving the mechanical behavior and eliminates cracks and other imperfections [1,2].

Controlled shot peening is an operation which is largely used in the manufacturing of mechanical parts to increase their fatigue life [3,4]. So the goal of shot peening is to plastically deform the surface zone of a component using small steel balls which impact, with high kinetic energy, the component surface. The kinetic energy of the shot is transformed into plastic deformation of the work piece surface and the shot itself. The shot is reflected from the component surface with the remaining kinetic energy. The elastically deformed sub-surface layer tries to resist this surface expansion, inducing a compressive stress at the surface, balanced by a tensile stress of lower magnitude through the core of the material as shown in Fig. 1, however, the area affected by the compressive stress is equal to that affected by tensile stress [1,2].

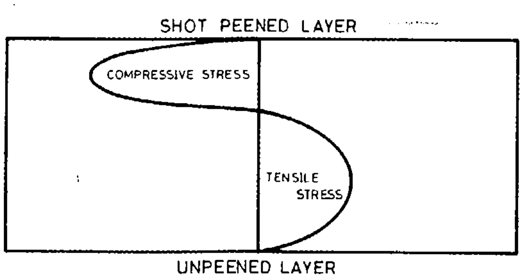

Figure 1: Stress distribution [2].

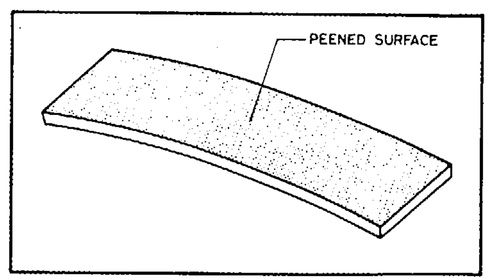

Figure 2: Curved shape developed after shot peening of upper side of the specimen.

If a thin material is peened on one side, a curve will develop in the part and the shot peened side will be convex [2] as shown in Fig. 2. To simplify this, Almen developed a method for the measurement of the resultant of all the process variables in the form of curvature of a strip, measured in thousands of an inch, referred to as shot peening intensity, provided saturation is achieved. Saturation refers to the condition that exists in the Almen test strip when doubling the exposure peening time does not cause more than 10% increase in arc height while the test strip has a uniform distribution and consistent magnitude of the compressive residual stress, and where coverage is close to 100% [2,5]. Almen provides three thicknesses of test strips suitable for different intensity ranges, details of the test strips are given in Ref. [2].

Shot peening, as a surface cold working process, is applied to a wide extent of materials such as steel, cast iron, (treated or untreated), copper alloys. aluminum alloys, and some other metals. It may also be suitable for some plastics [6]. At present the aircraft and automotive industries are increasing their use of shot peening. This is attributed to the assurance of satisfactory fatigue life and reliability of the shot peened components [7,8].

Peening intensity is the term commonly used to describe the overall effect of shot peening which is determined using the Almen test strip method. This method is used in the paper to determine the resultant effect of different parameters on the shot peening intensity.

SHOT PEENING PARAMETERS AND DESIGN OF EXPERIMENT:

From the available literature, the main shot peening parameters which have substantial effect on the shot peening intensity are: shot peening pressure, table rotational speed, stand off distance and shot peening time. The effect of these parameters are studied using the 2^4 full factorial experiment which was conducted within the parameters shown in Table I.

Each factor in the experiment has two levels: a low and high a level and the values of each level were decided upon from the experience gained in the aircraft industry as recommended by the staff of the Royal Jordanian Airlines Maintenance Department. The data obtained from the experiment are given in Table II. As it is seen in the last column of the Table II the 16 runs, with no replications, were conducted in a random order to neutralize the effect of any unknown factor.

Table I: Experimental factors and their values

Factor	Label	Low	High
Pressure (Psi)	A	70 (0.48 MPa)	90 (0.62 MPa)
Raotational speed (rpm)	B	5	12.4
Stand off distance (cm)	C	15	20
Peening time (min)	D	2	4

RESULTS AND DISCUSSION:

The results of the factorial experiment whic was designed and implemented to study the effect of shot peening parameters on intensity is shown Table II. Sixteen runs were found enough to give an indication of the weight of each factor on the shot peening intensity, indicated by the arc height. As mentioned earlier randomization was taken into account to neutralize the effect of any unknown factor. It can be seen from this data that pressure called factor "A" has the greatest effect on the response of this experiment, e.g., if it is increased from a lower to a higher level, the intensity of the shot peening as measured by the height of the curved Al strip is increased by 2.475 thou. From physical point of view, as pressure increases the shot velocity; the latter's kinetic energy will also increase resulting in higher deflection, whereas table speed called factor "B" has a smaller effect. Stand off distance and exposure peening time called factors "C" and "D" respectively have approximately an equal same effect; which is higher than table speed and lower than pressure.

Table II: Experimental data of factorial experiment

Observation Number	Factors A	B	C	D	Arc Height (thou) [1 thou=0.4 micro-meter]	Order of Runs
1	-	-	-	-	10.4	(3)
2.	+	-	-	-	12.5	(11)
3	-	+	-	-	9.3	(7)
4	+	+	-	-	12.3	(15)
5	-	-	+	-	8.0	(1)
6	+	-	+	-	11.5	(9)
7	-	+	+	-	9.8	(5)
8	+	+	+	-	12.1	(13)
9	-	-	-	+	11.0	(4)
10.	+	-	-	+	13	(12)
11.	-	+	-	+	10.2	(8)
12.	+	+	-	+	13.1	(16)
13.	-	-	+	+	10	(2)
14.	+	-	+	+	12	(10)
15.	-	+	+	+	10.3	(6)
16.	+	+	+	+	12.3	(14)

Pareto-chart gives an indication of the effect of interaction among the different variable, e.g. varying factors B and C at the same time while fixing the other two factors, will cause an increase in the arc height by 0.575 thou. Negative value on this figure means the opposite effect, i.e increasing S from lower level to higher level will reduced arc height by 0.725 thou. These facts could be emphasized by the estimated reponse funcgtion shown in Figs. 3 to 8 inclusive.

The interaction of the table rotational speed with peening time, Fig. 3, with stand off distance, Fig. 4, and with pressure, Fig. 5, on intensity indicate that the table rotational speed has practically little or no effect on the shot peening intensity, at both low and high levels. This agrees with the findings of other researchers [2].

The interaction of the shot peening pressure with shot peening time, Fig. 6, indicates that increasing the pressure from low to a high level for a short peening time has more effect on peening intensity than for a longer time. Furthermore, increasing peening time at low levels of pressure has more effect on intensity than increasing time at higher levels of pressure.

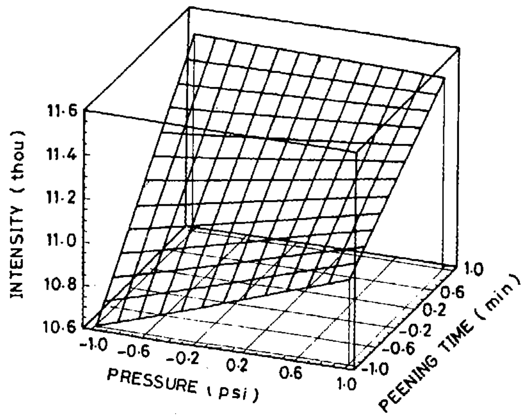

Figure 3: Estimated response surface.

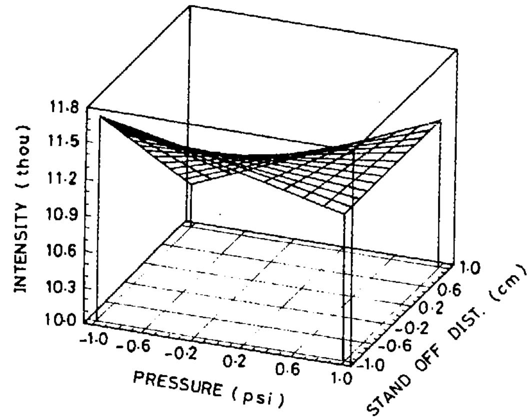

Figure 4: Estimated response surface.

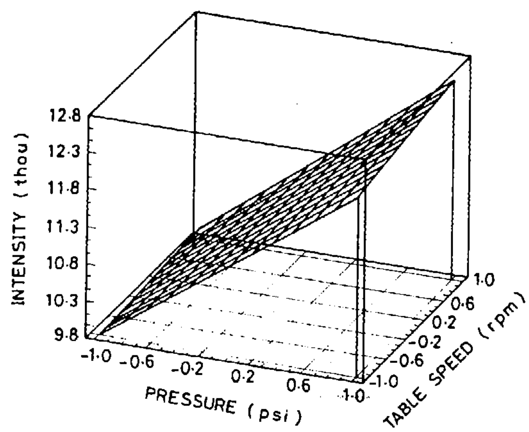

Figure 5: Estimated response surface.

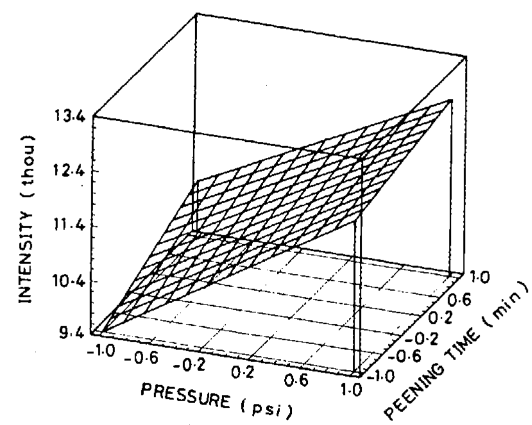

Figure 6: Estimated response surface.

Regarding the interaction of pressure with stand off distance, it can be seen from Fig. 7, that increasing pressure at low levels of stand off distance has more effect on intensity than at higher levels and that increasing stand off distance from its low level to high level resulted in reduction in shot peening intensity at both levels of pressure. This is attributed to the dispersion and scatter of the jet as stand off distance increases.

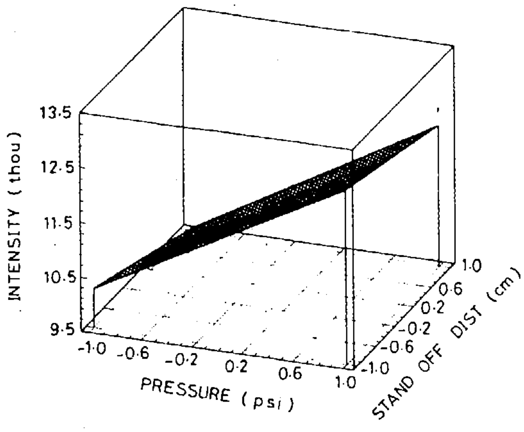

Figure 7: Estimated response surface.

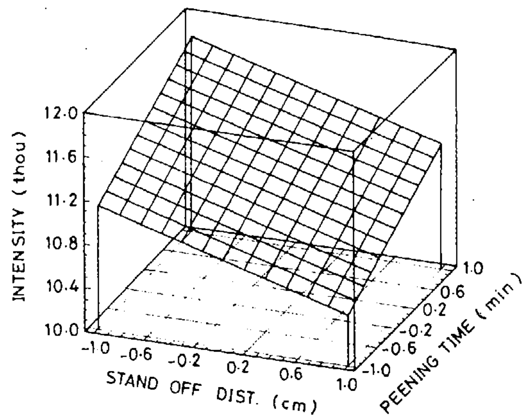

Figure 8: Estimated response surface.

The effect of exposure time on intensity at different pressures is shown in Fig. 10. from which it can be seen that intensity increases as exposure time increases up to a limit where saturation is achieved. Normally, to achieve a certain intensity the shot peening parameters are fi ~ ed and the pressure, main parameter, is varied until saturation and hence the intensity is determined.

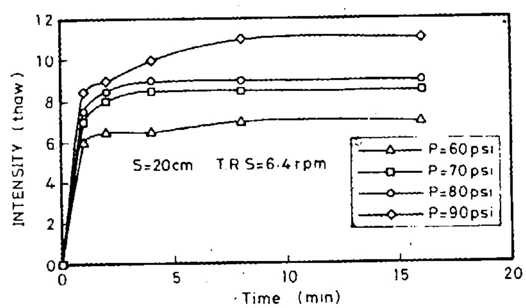

Figure 9: Intensity versus time at various pressures.

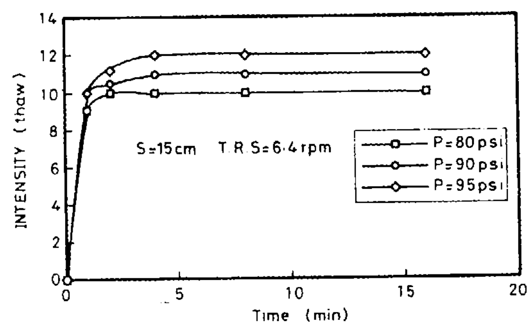

Figure 10: Intensity versus time at various pressures.

The present study revealed thah this is not always applicable and to achieve certain intensity particularly values higher than 11, variation of other parameters is a necessity. This is supported by the result of Fig. 10. A trial was made to achieved an intensity of 12 thou, at stand off distance of 20 cm and table rotational speed of 6.4 r.p.m., but was not possible, at any peening pressure and exposure time, Fig. 9. However when the stand off distance was reduced to 15 cm at the same table rotational speed, this intensity was achieved after 4 minutes, Fig. 10.

CONCLUSIONS:

From the results of this work the following points are concluded:

- The shot peening intensity is determine by shot peening pressure followed by exposure time and stand off distance. It increases with shot peening pressure and exposure time and decreases with an increase standoff distance, whereas the table rotational speed has very little or no effect on the former.
- Determination of the effective parameter is a prerequisite for achieving the required intensity, which emphasizes the importance of the factorial experiment for this purpose.

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