BASIC CURVES OF SURFACE FINISH AFTER GLASS BEAD PEENING

G. P. Balcar and F. C. Maltby

Potters Industries Inc., 377 Route 17,
Hasbrouck Heights, New Jersey 07604, USA

ABSTRACT

Surface finish is of growing importance in shot peening operations. This paper presents data on the peening of metal surfaces of three hardnesses with different sizes of glass beads at three specific nozzle angles. The conclusions are that when arc height peening intensity is kept constant, (1) shallower nozzle angles produce a rougher surface texture (higher RMS value), and (2) in general, peening with smaller beads produces a smoother surface texture (lower RMS value). Also, when higher arc height peening intensities are used, rougher surface textures are produced at all nozzle angles. Data is presented for aluminum and stainless steel surfaces with Rockwell hardness values of $75R_B$, $80R_B$, and $89R_B$, showing the relationships between arc height peening intensities, surface texture and nozzle angle. Recommendations are made for proper use of Almen arc height to control parameters of cleaning, finishing and deburring applications, as well as shot peening.

KEYWORDS

Shot peening; surface finish (texture); arc height peening intensity; glass beads; depth of compression; Almen test strips; speed of cleaning; coverage; glass bead consumption.

INTRODUCTION

In 1967, Potters' Research and Engineering group was assigned a long-term program to develop the basic measurements of the behavior of glass beads in cleaning, finishing and shot peening applications. The motive was to provide the precise parameters needed for engineering major blasting applications and basic curves which could be used to estimate the results and costs. This program developed other basic research parameters of the usefulness of glass bead peening and other impact processes.

J.R. Ritter wrote on the subject of particle count and particle weight[1], thereby providing the basis for a new examination of the speed of cleaning and coverage in shot peening and developing new understandings of the process. W.E. Hanley then prepared the first study of glass bead consumption in blasting applications. This was summarized in an initial paper by Balcar and Hanley, which was given at the World Symposium on Aerospace Surface Treatment in Cannes in 1970[2]. Hanley continued his studies of glass bead consumption, of peening measurements, of depth of compression achieved in glass bead peening, and of the effectiveness of glass bead peening in the mitigation of stress corrosion. With F. C. Maltby he compared the fatigue results obtained on various metals before and after peening with glass beads and steel shot[3].

In their work, Ritter, Hanley and Maltby developed important basic concepts of the impact sciences and the impact processes. Difficulties in experimentation were encountered due to the number of variables involved for any set of peening conditions; specifically, the particle size being used, the blasting pressure, the nozzle distance, the nozzle angle, and the hardness of the surface. In a paper published internally in 1972[4], Hanley showed that it was necessary for the sieve analysis and roundness of particles to be precisely controlled to assure against variances of peening intensity, consumption and surface finish, which could affect experimental results.

In subsequent work, Hanley indicated that peening intensity should be the standard of measurement of impact force. The use of a specific air pressure, even with a specific air jet or nozzle diameter or, in the case of direct pressure equipment, a nozzle diameter and grit stem orifice diameter, would not necessarily standardize conditions adequately to provide reproducible results. Almen arc height peening intensity, however, is measurable for any given set of conditions and therefore could be transposed between different machines. Subsequently, it became the practice at Potters that arc height peening intensity was the standard measurement of force used to establish all cleaning and finishing applications.

OBJECTIVES AND EXPERIMENTAL DETAILS

The use of nozzle angles other than 90° in shot peening is normal as most items being peened are of varying geometry, making the 90° target angle only occasionally possible. A shallower angle avoids nozzle blinding and the resultant excessive particle consumption. Hanley measured blinding in a number of studies and found that in fixed conditions at the same peening intensity, consumption is lower at the 60° angle than at the 90° angle because of particles that were not reflected back into the blast stream. Where consumption of glass beads is a consideration in shot peening, the shallow angle is therefore helpful. Glass beads, normally used in peening to avoid surface contamination, are also used as a secondary peening media to clean surfaces and improve their texture (lower RMS value).

The study of surface finish was also associated with these efforts and serves to show process engineers the variances that occur when peening between 90° and 45° angles. Provided that arc height peening intensities are held constant, the metal surface texture (in terms of RMS values) increases as the nozzle angle is reduced.

Five metals of different hardness values were used in the program:

Metal	Rockwell Hardness
A.I.S.I. 1018 Steel	$44R_B$
AA 2024-T351 Aluminum Alloy	$75R_B$
AA 7075-T6 Aluminum Alloy	$89R_B$
A.I.S.I. 316 Stainless Steel	$80R_B$
C.D.A. 510 Phosphor Bronze	$93R_B$

The sizes of beads used were:

Potters Size	U.S. Sieve Size	Micron Diameter
B	30 - 40	600 - 425
D	50 - 70	300 - 212
H	100 - 140	150 - 106
AH	170 - 325	90 - 45

Three different nozzle angles were used: 90°, 60°, and 45°. In each case, a profilometer was used to measure surface texture and was frequently calibrated with a standard reference surface. The RMS values of the specimen surface textures were taken after hand-polishing them to an RMS of 4-7. The peening intensities were measured on Almen test strips before each individual experiment. The sieve analyses of the glass beads used were also measured by standard procedures. Peening was performed for each size of glass bead that was used. The test specimens were then peened according to the recommended procedure to obtain 100% coverage of the surface and were manually agitated under a fixed nozzle. Due to their larger areas, the time to reach saturation for the specimens was 2.55 times longer than on the test strips. The surface RMS results were recorded, and graphs were plotted of peening intensity versus RMS values. Due to space limitation, only the data for the stainless steel and two aluminum alloys are included in this paper (Tables 1-3).

DISCUSSION

At the time of the test program, a literature search did not reveal any specific findings on this subject. In other research, Hanley reported that the speed of cleaning was faster at shallow angles under standard conditions when removing heat scale. It was suggested that the mechanism of glass bead cleaning, particularly in heat scale removal, was by plastic deformation of the metal surface underneath the scale. This breaks the bond between the metal and the scale, with the scale coming off in the blast stream. Our test findings indicated, possibly because of higher RMS values at lower nozzle angles, that the speed of glass bead cleaning of tough scale could be improved. The results indicated that shot peeners should be aware of this phenomenon and should not necessarily rely on surface texture values obtained at 90° impingement angles to predict the surface finishes that would result on parts of varied geometry.

The graphs were drawn to the points observed. The curves suggest the tolerances or variations that might be expected. In ten of the twelve observations, the peak RMS value at 45° is located above the 60° lines. In all cases, the peak RMS value at 60° is above the 90° line. In one case, the 60° and 45° curves reverse (106 - 150 peened on 316 stainless). In four cases, the 45° and 60° curves cross at seemingly significant magnitudes. Eighteen of the thirty-six individual curves are "S" shaped. The points on the curves of the $80R_B$ hardness stainless steel appear much closer together than those relating to the aluminum surfaces.

Wider deviations between the individual curves relating to the aluminum surfaces occur with the smaller beads. An anomaly was observed in that shallow impacting angles, smaller bead sizes produced rougher surface textures than larger sizes of beads. Previous work indicated that smaller particles generally produce smoother surface textures with lower RMS values.

Microscopic examination of the surfaces impacted at shallow angles indicated that in addition to the (visual) overlapping craters of indentation, the surfaces were "wrinkled" and a lateral displacement of the metal was observed. This could produce a compound wave form which, in turn, would produce the higher than expected

RMS values.

Additional work has also indicated that primary peening intensities raise surface RMS values above desirable or acceptable levels, necessitating secondary peening operations at lower intensities and higher nozzle angles to achieve the desirable levels. This procedure also increases fatigue resistance, as shown by Snowman and Schmidt[5]. Previous references to this were made by Boch and Justisson[6].

As surface finish is of increasing concern, additional research of a greater variety of bead sizes, nozzle angles, peening intensities, and metal surfaces is in order. Study of the smoothening of peened surfaces is also desirable. The use of secondary peening is probably the simplest means of improving surface textures as it avoids any removal of metal. Normally it requires the addition of one supplementary peening system, incurring little or no additional labor and small capital investment.

CONCLUSIONS

With all conditions controlled, surfaces with the hardnesses of $75R_B$, $80R_B$ and $89R_B$ were peened with beads of different sizes at angles of 45^o, 60^o, and 90^o. Graphs drawn of surface texture versus Almen arc height intensities show increased surface RMS readings as the nozzle angle was decreased. The magnitudes of these differences are such that shot peening engineers should be aware of them when, in addition to the peening results, surface finish considerations are of importance. This also holds true for those primarily engaged in both cleaning and finishing operations. In the case of shot peening and understanding surface texture, further research into secondary peening with glass beads is in order to indicate what conditions and parameters might easily be met.

REFERENCES

[1]Ritter, J.R. (1970). Theoretical Size, Number, Weight, Volume and Area for Soda Lime Glass Beads. PII Report G-1.

[2]Balcar, G.P., and Hanley, W.E. (1970). Usefulness, Effectiveness, and Process Technology of Glass Bead Shot Peening. PII Internal Paper.

[3]Hanley, W.E., and Maltby, F.C. (1973). Fatigue Characteristics of 7075-T6 Aluminum Alloy When Peened with Steel Shot or Glass Beads. PII Report I-14.

[4]Hanley, W.E. (1972). Arc Height Peening Intensities for Ballotini Glass Spheres. PII Report I-8.

[5]Snowman, A., and Schmidt, R.G. (1981). The Improvement of Fatigue and Surface Characteristics of Aluminum Alloy 7075-T6 by Secondary Peening with Glass Beads. Proceedings of First World Symposium on Shot Peening, Paris.

[6]Bock, R.A., and Justusson, W.M. (1968). Lightweight Leaf Springs. SAE Meeting; Detroit, Michigan.

TABLE 1 - PROFILOMETER MEASUREMENT OF SURFACE TEXTURE
RMS MICROINCHES VS. PEENING INTENSITY

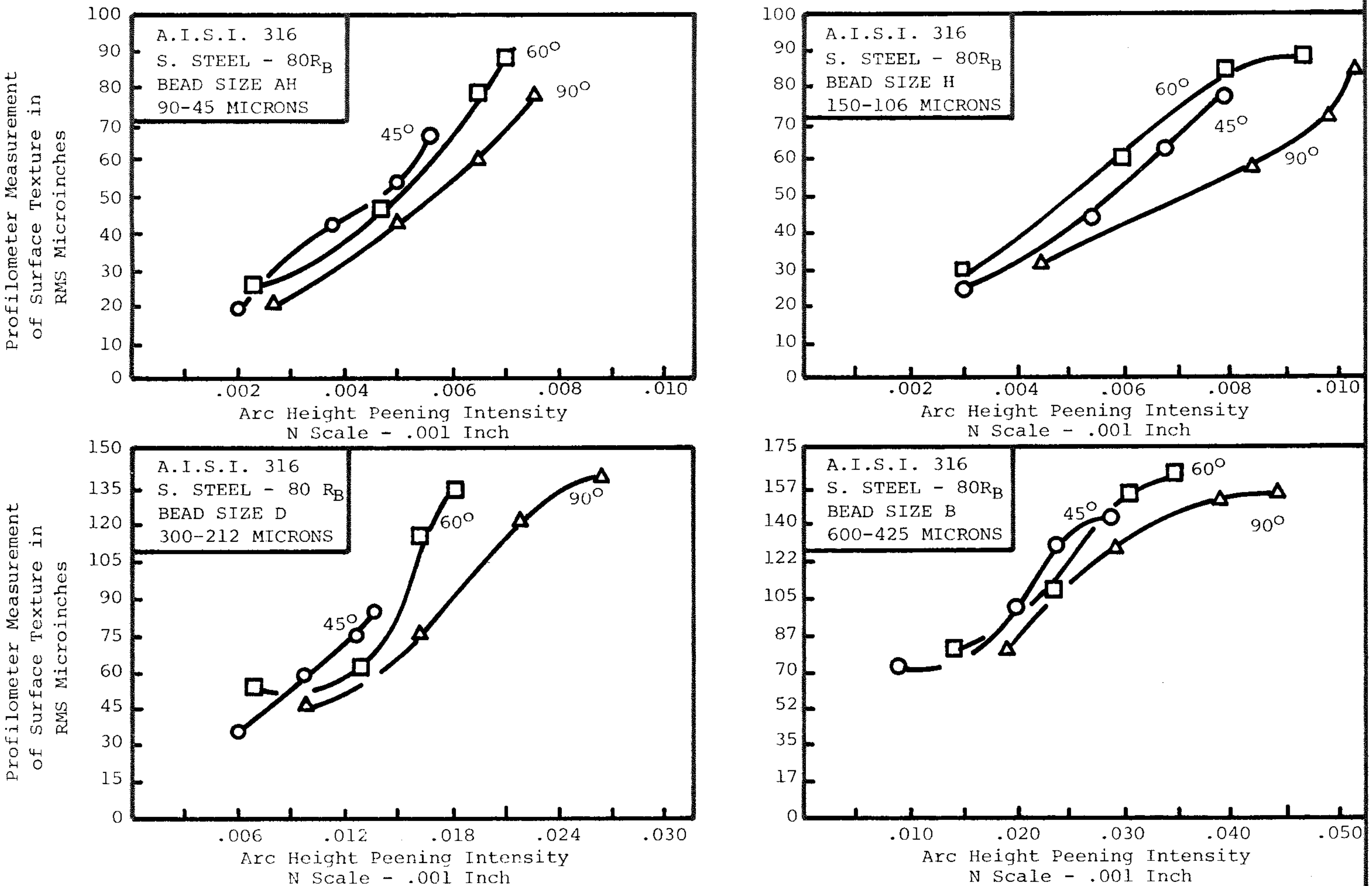

TABLE 2 - PROFILOMETER MEASUREMENT OF SURFACE TEXTURE
RMS MICROINCHES VS. PEENING INTENSITY

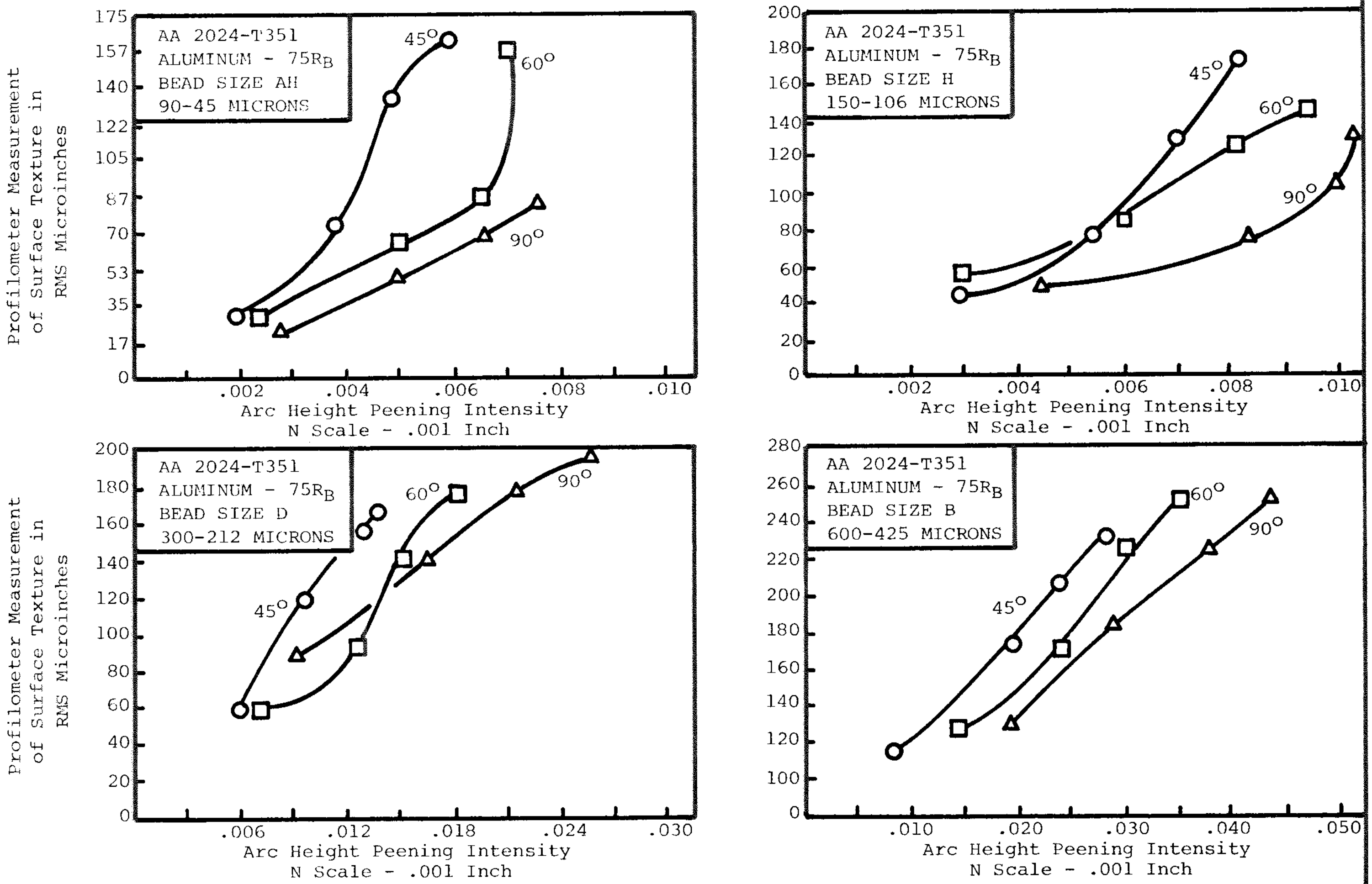

TABLE 3 - PROFILOMETER MEASUREMENT OF SURFACE TEXTURE
RMS MICROINCHES VS. PEENING INTENSITY