COMPARATIVE PERFORMANCE OF GLASS BEADS IN SUCTION AND DIRECT PRESSURE SHOT PEENING APPLICATIONS

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ABSTRACT

The total in-plant manufacturing cost of shot peening includes labor, energy and the loss of consumable media during processing. To this cost must now be added the cost of safe disposal of the spent media. It is essential, therefore, that media utilization be optimized to minimize total media usage. The purpose of this paper is to present data on the consumption of one type of media, glass beads, of varying size ranges in two modes, direct pressure and suction peening applications. The objective was to achieve "equivalent" treatment level as defined by the time to saturation or Almen arc height peening intensity. Processing variables, along with media size, included grit feed stem diameter and working pressure. These variables permitted adjustment of media flow rates to obtain the desired affect. A media consumption theory is presented based on velocity distribution in both direct and suction peening. Beads at velocities greater than that which is optimum for imparting compressive stresses to the part being peened, will fracture. Thus, adjustment in velocity distribution patterns at equivalent mass media flow rate could reduce both peening times and media consumption. Engineers may use the information presented to assess the relative value of each mode for any given application over a range of glass bead particle sizes from 70 to 1700 microns and Almen arc heights of 0.03 mmA to 0.69 mmA.

KEY WORDS

Suction peening, direct pressure peening, peening intensity, Almen arc height, media consumption, glass beads.

Introduction

Glass beads have been used in a variety of shot peening applications for an extended time period [1]. They successfully compete with and supplement other shot peening media [2-10]. Selection of the glass media most suitable for an application involves comparison of bead performance, e.g., consumption, at equivalent Almen intensity. In order to evaluate glass media performance, the process parameters which affect the outcome of the evaluation must be identified.

Glass bead peening is usually conducted in a direct pressure or a suction mode [11]. During our early laboratory work it was observed that the consumption of glass beads depended on the mode of blasting, particularly for larger bead sizes [12]. No conclusive findings on the cause of the differences between suction and direct pressure were made.

We have now conducted a comparative study of glass bead media performance with a broad range of bead sizes in both the suction and the direct pressure modes. The effect of the bead size, equipment setup, and blasting parameters on consumption was established.

No attempt has been made to assess the value of one process versus the other. Each may have unique benefits depending on local conditions. However, information presented on "equal treatment" level should assist in the evaluation.

Experimental

The glass beads of various sizes listed in Table 1 were used in our experiments. The larger A-series beads (725 microns to 1700 microns) were manufactured by one furnace process. Smaller size ranges were made by another process. Beads are produced by Potters Industries Inc. in North and South America, Europe and the Pacific Rim. In Japan, the beads are produced by Toshiba Ballotini Co., Ltd., a joint venture partner of Potters.

TABLE 1: GLASS BEAD SIZES

Potters Grade	U.S. Sieve	Mean Size Microns	Size Range (Microns)
A-170	10-14	1700	1410-2000
A-100	16-20	1015	840-1200
A-70	20-30	725	590-840
C	40-60	340	250-425
AC	60-100	200	150-250
AE	100-170	120	90-150
AH	170-325	70	44-90

A modified Mark II Dry Honer manufactured by Vacu-Blast Corporation was used in our experiments. The unit was operational in both the suction and the direct pressure modes with the same setup (9.5mm nozzle and grit feed stem of various diameters). A 4.76mm air jet was used in suction. We determined percent per cycle consumption by measuring the quantity of material which remained above the bottom screen of a series of screens before and after the experiments. The series of screens varied depending on the original bead size. Peening was done at an 80° angle and a distance of 15 cm against a flat mild carbon steel target with a hardness of 92 Rockwell B. Almen intensity measurements were conducted using N, A, and C test strips, according to the SAE J442 standard.

The actual arc height peening intensities were established in accordance with the United States Military Standard S-13165C, Section 4.2.3. This procedure defines the arc height as the value at which a doubling of time will not result in a 10% increase in arc height. Figure 1 shows an arc height of 0.29mm at 20 seconds. As the arc height at 40 seconds is greater than 10% over the value at 20 seconds, 0.29mm is the correct intensity.

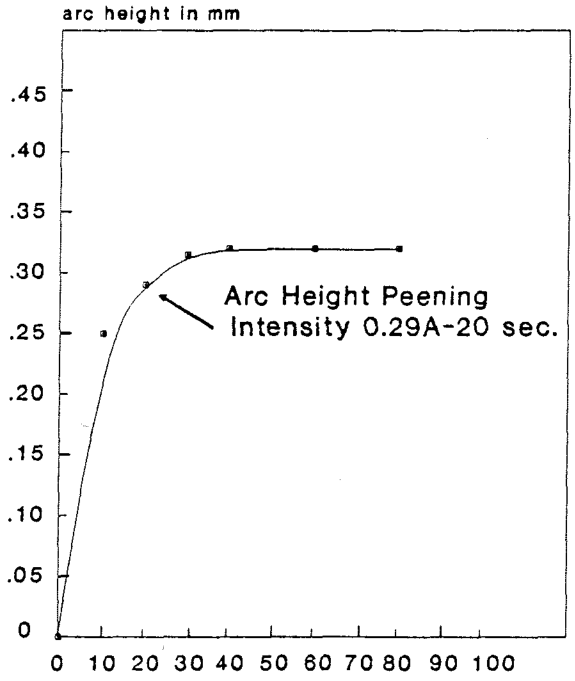

Figure 1
Typical Almen Arc Height Intensity Curve

Over 50 experiments were conducted to achieve equal Almen intensities by adjusting pressures in both suction and direct pressure blasting. For each bead size, data for at least 2 values of Almen intensity were developed (Table 2). Although not presented in the table, media flow rates varied from 50 to 200 kilograms per hour depending on bead size and mode of operation.

TABLE 2: BEAD BLASTING EXPERIMENTS

Grade	Grit Stem Diameter mm	Almen Intensity A, mm	Saturation Time/Seconds		Almen Intensity A, mm	Saturation Time/Seconds	
			Direct	Suction		Direct	Suction
A-170	6.35	0.53	80	80	0.69*	20	30
A-100	6.35	0.36	20	30	0.48	10	30
A-100	3.97	0.36	20	40	0.61	20	40
A-070	3.97	0.30	20	20	0.43	20	20
C	3.97	0.15	10	10	0.23	10	10
C	3.18	0.15	10	15	0.28	10	10
AC	3.97	0.10**	10	10	0.10	10	10
AC	3.18	0.10**	10	10	0.15**	10	20
AE	3.18	0.058**	10	15	0.08**	10	10
AH	3.97	0.028**	10	25	0.058**	10	20
AH	3.18	0.041**	10	10	0.046**	10	10

* - CONVERTED FROM C   ** - CONVERTED FROM N

Results and Discussion

Table 3 shows selected data from the study highlighting the general trends observed. Of particular interest is the use of large glass beads to achieve high Almen intensities at low consumption rates in both the direct pressure and the suction modes. In the two cases selected, consumption with suction blasting is lower than with direct pressure. Extensive treatment and discussion of the data follows in Figures 2 through 8.

TABLE 3: SELECTED DATA FROM STUDY

Bead Size	Arc Height Peening Intensity	Saturation Time Seconds	Flow Rate Kg/Hr	Consumption %/Cycle
A-170 Suction	0.69mmA	30	195	1.75
Direct	0.69mmA	20	155	3.53
A-070 Suction	0.30mmA	20	100	1.79
Direct	0.30mmA	20	100	2.24

Figure 2 shows that consumption of beads in suction shot peening at equal Almen intensities remains essentially constant over a range of bead sizes from 70 to 1700 microns. On the other hand, consumption increases with bead size in the direct pressure mode. The difference between direct and suction consumption increases with bead size. In Figure 2, high intensity is above approximately 0.3mmA and low intensity is below 0.3mmA.

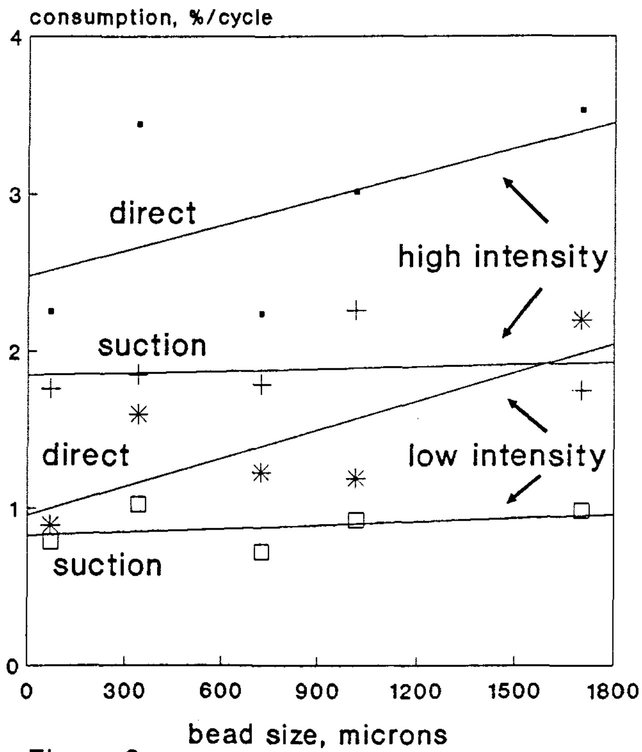

Figure 2
Media consumption versus bead size in direct and suction mode.

The number of beads consumed is a function of the force with which the beads are impacted against a target when other parameters (size distribution, target hardness and shape, equipment set up, bead quality) remain constant. The impact force is a function of the bead velocity. It was established [11] that when equal air pressure is applied to the media the velocity of media in the suction mode is only about 40% of that in the direct pressure equipment. The equal velocity in a suction setup can be achieved at about 2.5 times higher working air pressure. Therefore, it is postulated that at equal media velocity, similar bead consumption must be observed in both suction and direct pressure. The experiments conducted in this study appear to bear out this postulation. A theoretical explanation based on velocity distribution profiles is presented later in the paper.

Figure 3 shows the predicted effect, i.e., there would be equal consumption ($C_d/C_s = 1$) at a P_s/P_d of 2.5. At equal Almen intensity the lower the air pressure in the suction mode the greater the relative difference in consumption between the direct pressure and suction mode. There is also a strong effect of bead size, with the larger beads having the greater relative differences.

The study further suggests that the media flow itself may be an important parameter affecting the net bead consumption. As the concentration of beads in the media stream increases there is more opportunity for bead interaction with the hose and nozzle walls prior to hitting the target. Beads broken in this manner may affect the overall size distribution of the beads and their predicted effect on performance.

The number of beads allowed into the stream is controlled by the grit feed stem. The effect of the grit feed stem diameter on the media flow depends on the bead size. Figure 4 shows that an increase in grit feed stem diameter does not affect the consumption of small glass beads (70 micron) over the range studied. The geometry of the stem and true size of the passage way for bead flow did not affect consumption or Almen intensity. Of course higher consumption was observed with higher Almen intensities. With intermediate bead sizes, e.g., 340 microns, grit feed stem size significantly affects both the consumption rate and arc height attainability. With a smaller grit feed stem fewer beads flow through at a given pressure. The beads are accelerated to a higher velocity and achieve Almen intensities at a higher net consumption and possibly with less time. With the larger grit feed stem, beads flow with a lower velocity and achieve equivalent Almen intensity at a lower consumption but possibly increased time.

At higher pressures the effect of grit feed stem on consumption becomes more pronounced. We were unable to achieve an Almen value 0.61A with our equipment at 6.35mm grit stem and 1015 micron bead size. Therefore, an estimated consumption value is presented on Figure 4.

The ratio of direct pressure and suction consumption is also affected by the grit feed stem diameter. As Figure 5 shows, the effect peaks at approximately 200 microns. In all cases a larger grit stem increases the consumption in suction blasting as bead size increases. For smaller grit stems, a consumption ratio of 1:1 is approached with small beads (70 micron).

Figure 6 presents flow rates versus bead size using different grit stems and arc height intensities. For each stem size, high and low Almen intensities follow the same patterns. However, larger grit feed stems give greater processing flexibility i.e., ability to handle a number of bead size ranges by setting each grit stem at a maximum flow rate.

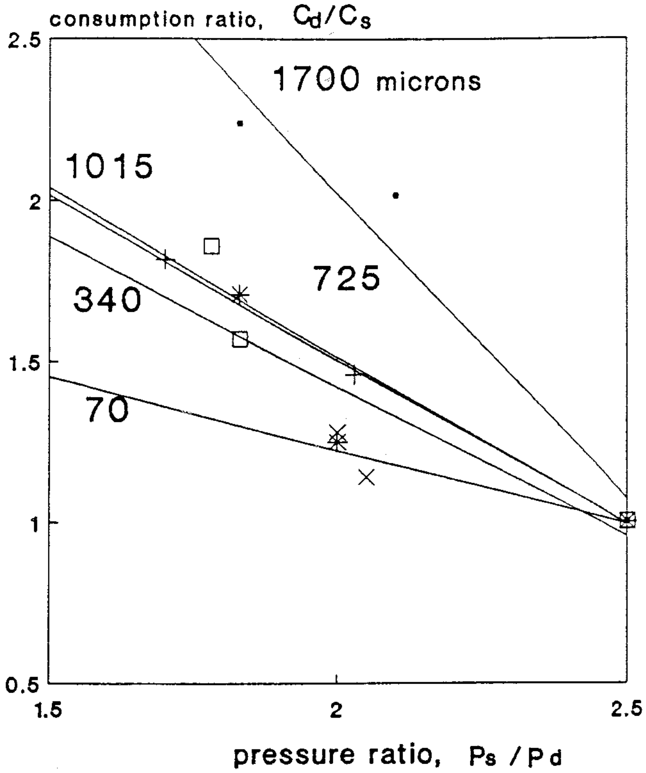

Figure 3
Direct/suction media consumption ratio versus suction/direct pressure ratio for various bead sizes (microns).

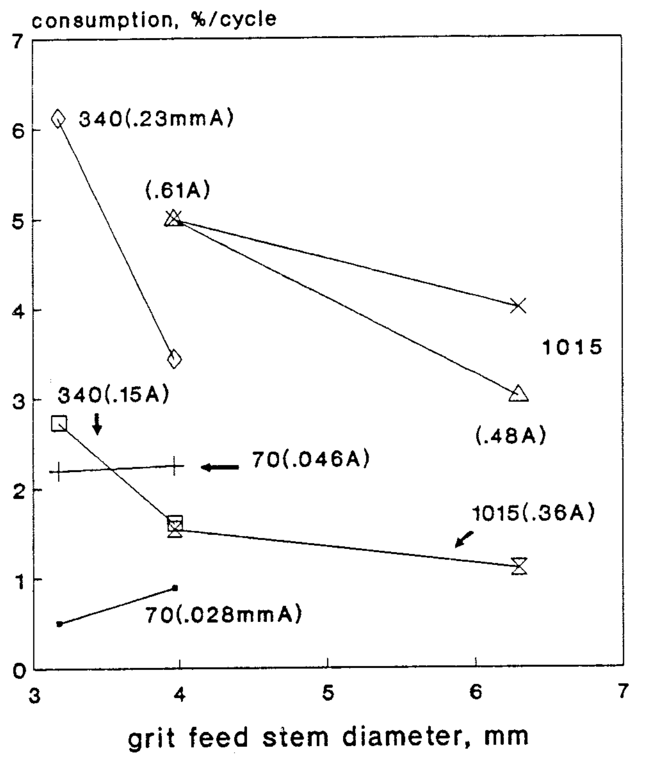

Figure 4
Effect of grit stem diameter on media consumption at various bead sizes (microns) and Almen intensities (mm).

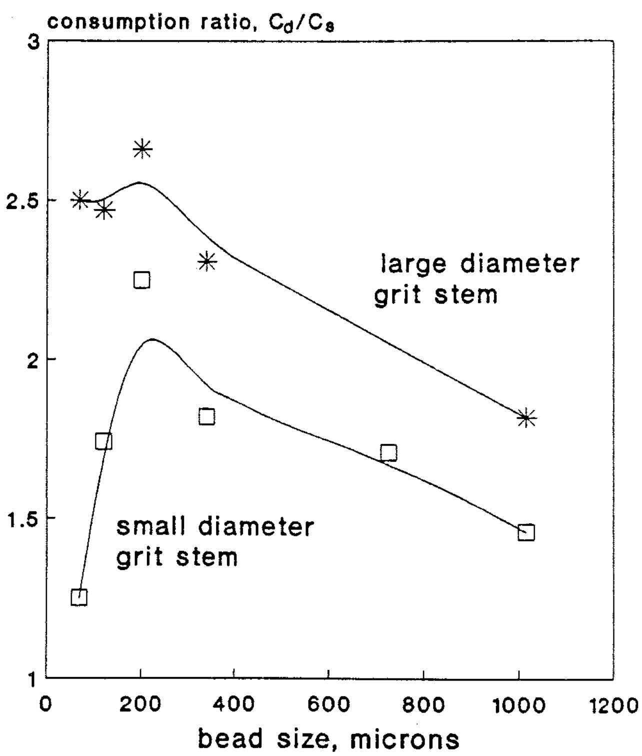

Figure 5
Effect of bead size and relative grit feed stem diameter on media consumption.

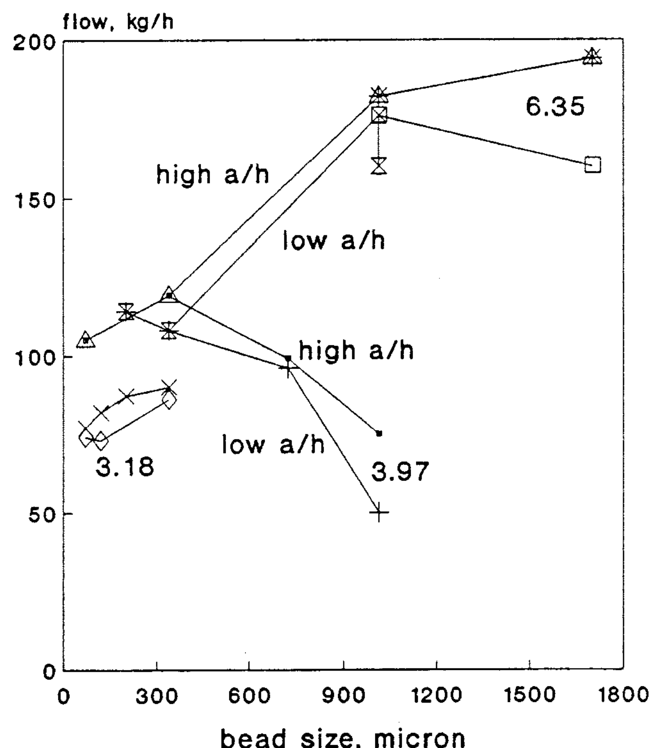

Figure 6
Effect of bead size and relative Almen intensity on media flow rate at grit feed stem diameters of 3.18, 3.97 and 6.35 mm in suction mode.

In direct pressure blasting, bead flow rate is affected by the pressure used, as shown in Figure 7. In general, as the pressure increases, the bead flows increase. There also appears to be an inflection point in the curves around a bead size of 150 to 200 microns.

Dependence of arc height intensity on pressure is a monotonic function for both the suction and the direct pressure modes for all bead sizes investigated (Figures 8 and 9). Figure 8 shows that the achievement of Almen intensities of 0.3A is unlikely with glass beads smaller than 340 microns in conventional direct pressure equipment or with small grit stems in suction equipment.

Arc height values versus pressure in suction and direct pressure are shown in Figures 10 and 11. Smaller grit feed stems give consistently higher Almens than larger grit stems.

As previously mentioned, a major factor affecting bead consumption is bead velocity [11]. Equal velocity in the suction mode and the direct pressure mode is achieved at suction pressure values about 2.5 times higher than in direct pressure. Therefore, under equivalent velocity conditions equal consumption rates should be observed.

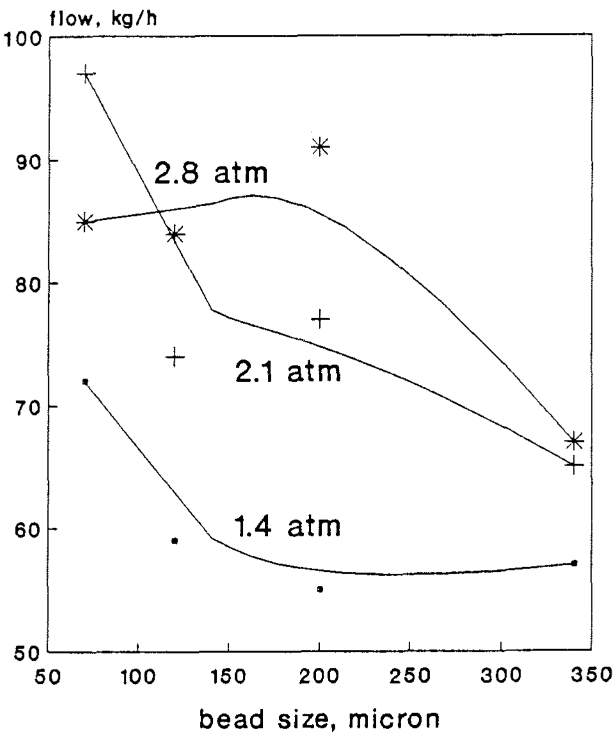

Figure 7
Effect of bead size and direct pressure (blasting intesity) on media flow rate at grit feed stem diameter of 3.18 mm.

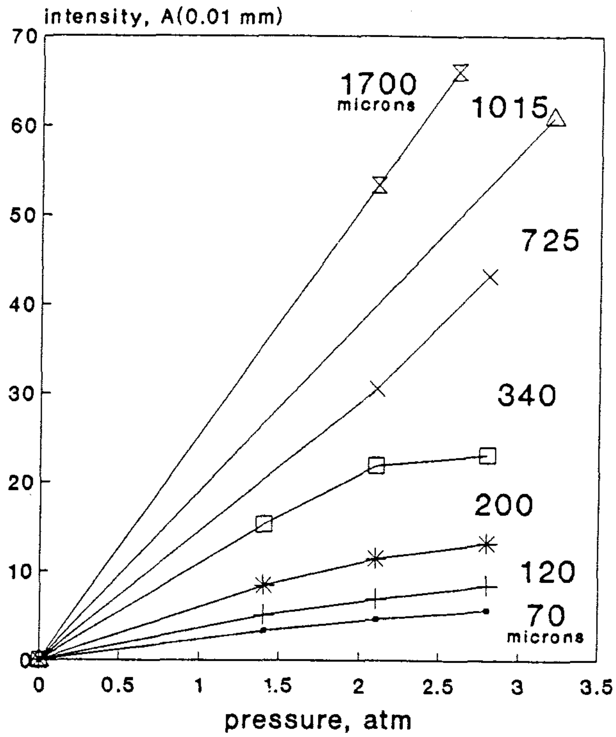

Figure 8
Achievable Almen intensities versus direct pressure blasting using various bead sizes microns) with small diameter grit feed stems.

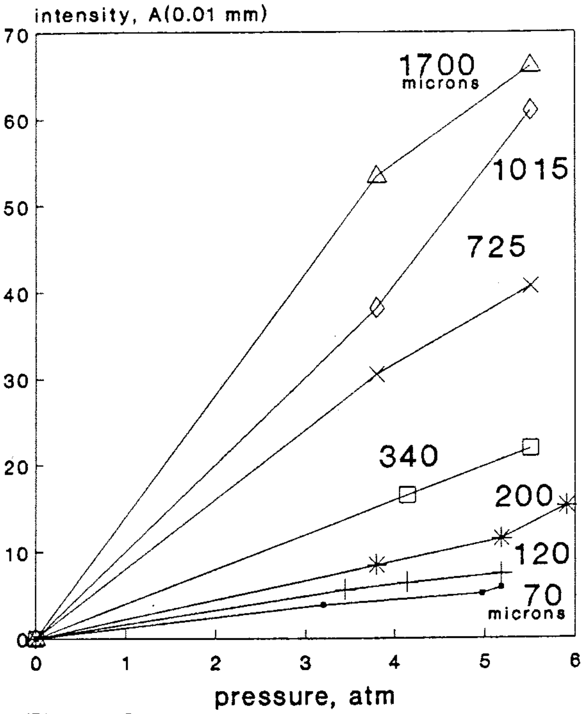

Figure 9
Achievable Almen intensities versus suction ressure blasting using various bead sizes (microns) with small diameters grit feed stems.

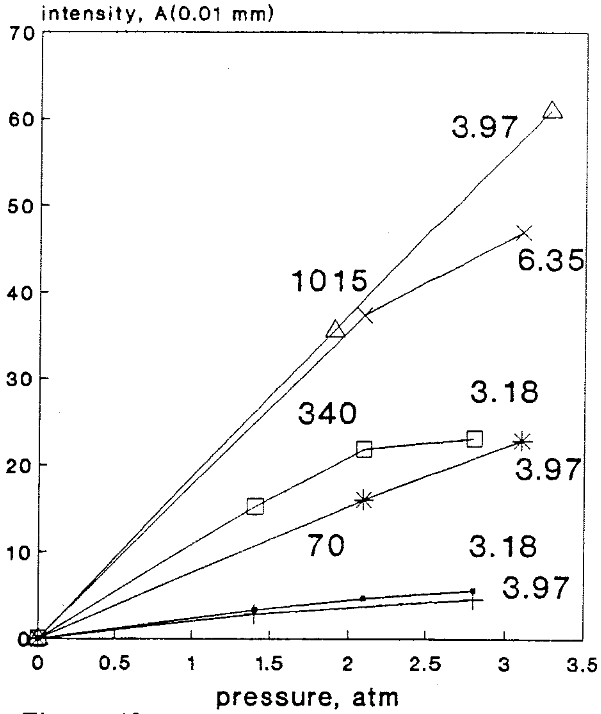

Figure 10
Effect of grit feed stem diameter (mm) on saturation Almen intensity for various bead sizes (microns) in direct pressure.

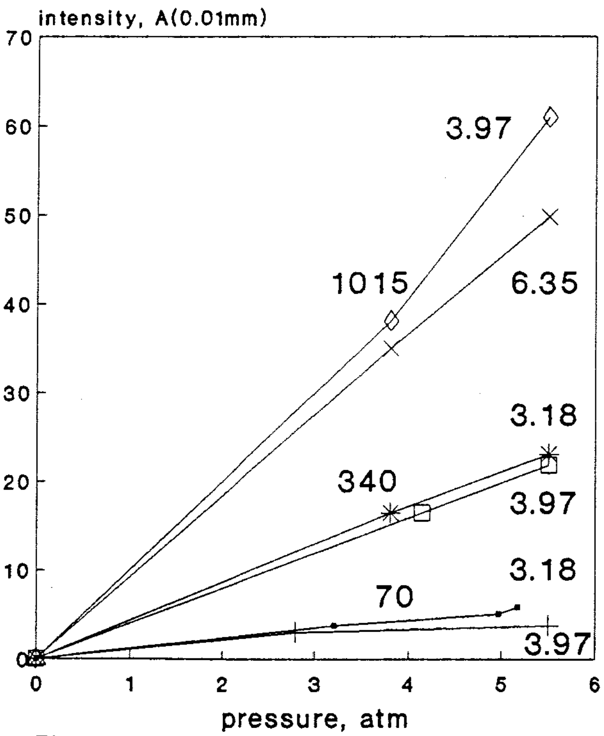

Figure 11
Effect of grit feed stem diameters (mm) on Saturation Almen intensity for various bead sizes (microns) in suction mode.

In some instances, we observed equal media flow rates, Almen intensities and time to saturation but lower consumptions in the suction mode than in the direct pressure mode. Figure 12 illustrates the hypothetical velocity distribution of beads in the direct pressure and the suction modes. The mean velocity of the beads (V_m) is typically lower for the "suction beads", unless $P_s/P_d = 2.5$. At the same time fewer beads reach the fracture velocity (Vk_r) and the velocity required to achieve a desired arc height (V_a). In order to achieve that desired saturation Almen intensity a certain number of the "V_a-beads" must impact the Almen test strip. If the suction media flow is great enough to compensate for the lower relative number of the "V_a-beads" the saturation time will be close in the direct pressure and suction mode. Otherwise, longer saturation times will be required in the suction mode. In our experiments the saturation time in the suction mode sometimes exceeded the time in direct pressure by a factor of 3 (Table 2).

Figure 12 assumes that the glass bead velocity distribution curves in suction and direct pressure are the same. If the distribution curves around equivalent mean velocities (V_m) are not the same, then it is possible to have more beads reaching fracture velocity Vk_r) in one mode than another. We therefore postulate, based on our experiments with large glass beads, that for some bead sizes, more beads reach fracture velocity in the direct pressure mode than in suction. More beads reaching fracture velocity would result in higher consumption.

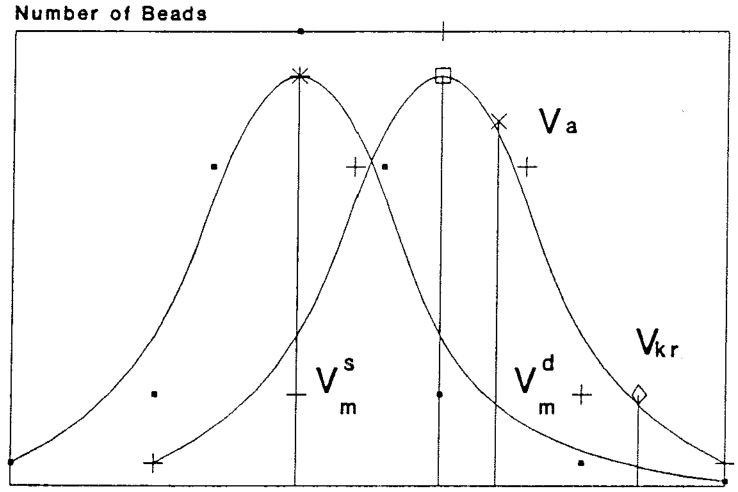

Figure 12
Hypothetical bead velocity distribution in suction and direct pressure mode.

Conclusions

The performance of glass bead peening media depends on the mode of peening (direct pressure or suction), the equipment setup and process parameters (pressure, flow rate), in addition to the strength characteristics intrinsic in glass.

Consumption rates in the direct pressure mode are generally higher at Almen intensities similar to those obtainable with suction mode peening. This means bead velocity is higher and a larger relative number of beads reaches the critical speed at which they fracture upon impact.

By monitoring flow and pressure in the suction mode, a consumption and saturation time which is close to that found in direct pressure may be achieved.

Acknowledgment

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