Journal of Materials Processing Technology 235 (2016) 143–148

Contents lists available at ScienceDirect

Journal of Materials Processing Technology

journal homepage: www.elsevier.com/locate/jmatprotec

Measuring shot peening media velocity by indent size comparison

E. Nordin[a,b,*], B. Alfredsson[b]

[a] Scania CV AB, Sweden
[b] Royal Institute of Technology, KTH, Department of Solid Mechanics, 100 44 Stockholm, Sweden

ARTICLE INFO

Article history:
Received 9 December 2014
Received in revised form 20 February 2016
Accepted 9 April 2016
Available online 16 April 2016

Keywords:
Shot peening
Media velocity
Almen intensity
Impact
Indentation

ABSTRACT

Shot peening is a manufacturing method that makes indentations on a components surface by impacting it with small steel balls (media). In a production environment the shot peening process is usually controlled by defining media size, coverage and Almen intensity. For simulating shot peening, the media velocity is needed and therefore it must be measured or correlated to the Almen intensity. This paper details a method to record indentations on a test plate and then compare them to single shot indentations with measured velocities. For small media sizes the results are in reasonable agreement with other published results but at larger sizes there is a larger spread in published results. It is therefore recommended that the media velocity is either measured directly or that the indents are analysed as presented in this paper.

1. Introduction

Shot peening is a manufacturing method that in the automotive industry mostly is used to increase bending fatigue strength. The process involves covering relevant surfaces with small indents. The plastic deformation causing these indents will try to stretch the near surface material but the material deeper into the part will resist the expansion. Equilibrium gives that the surface layer will have residual compressive stresses while the deeper material will have tensile stresses. Because the near surface layer induced by shot peening is relatively thin compared to the size of most components, e.g. gears or springs, the internal tensile stresses will be small in magnitude and thus not cause any major adverse effects for fatigue (Menig et al., 2001). The indents are usually created by having small hard metallic balls, called media, impact the surface at velocities that will create the intended effects. In a production environment the shot peening process is usually controlled by defining media size, coverage and Almen intensity. Coverage is the percent of the surface area that has been hit by an indent and is usually estimated visually through a loupe or by removal of fluorescent paint. Almen intensity is measured by exposing standardized Almen strips to the shot stream for different amounts of time. The strips will bend due to compressive stresses being generated at the shot peened surface and the arc height of the Almen strip is a measure of the indentation ability of the shot stream (Kirk, 2007). For a given media the Almen intensity is mostly dependent on the media velocity but also on impact angle, media hardness or the Almen strips properties. Although the Almen strips are standardized there is a tolerance on its parameters. The Almen strip hardness and thickness variations are reported to give measureable deviations according to (Bailey and Champaigne, 2005). The hardness is allowed to vary between HRC 44–50 according to (SAE Standard J442, 2008). Kirk (2009) also discusses the influence of variations in elastic modulus and measures values from 195 GPa to 205 GPa.

Industrial shot peening is done with two different type of machines; centrifugal wheel machines or compressed air machines. In the first type the media is accelerated by a centrifugal wheel and the velocity of the particles can be controlled by the rotational speed, RPM, of the wheel. In the compressed air type machines the media is accelerated by an air stream. With a given machine configuration the media velocity is then mainly controlled by changing the air pressure (although the amount of media fed into the air stream will also influence the final velocity). Therefore, the actual velocity of the media is seldom reported or even known for a shot peening process. This is not a problem for practical evaluation of shot peening but for shot peening simulations knowledge of the velocity is necessary.

There exist some experimental correlations between Almen intensity and media velocity in the literature. The different results are compiled into Fig. 1. The dashed results denominated “Empirical” are from (Shotpeener, 2014a). The results are probably from centrifugal wheel machine shot peening but unfortunately there is no source of origin or test set-up associated with the results.

* Corresponding author at: Royal Institute of Technology, KTH, Department of Solid Mechanics, 100 44 Stockholm, Sweden.
E-mail address: erlandn@kth.se (E. Nordin).

http://dx.doi.org/10.1016/j.jmatprotec.2016.04.012
0924-0136/

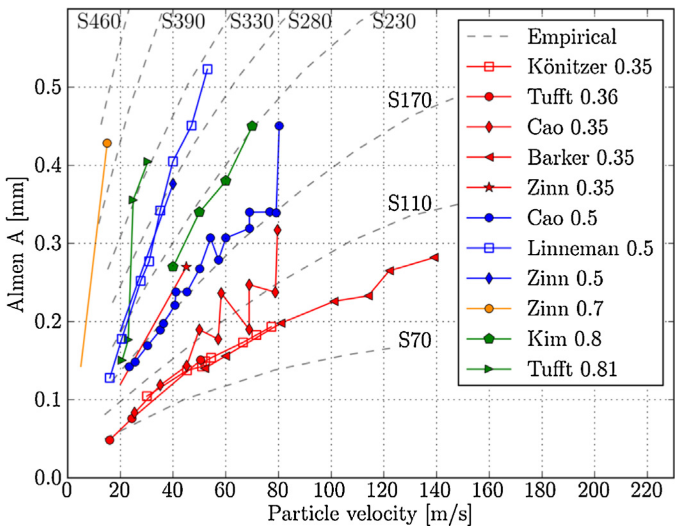

Fig. 1. Comparison of relations between Almen intensity and shot velocity from different sources. Numbers in the legend refer to average media diameter.

The curves are shown for different media sizes according to SAE Standard J444 (2005). The average media size can be approximated by the indicated average diameter in (Shotpeener, 2014b) and are shown in Table 1. Roughly similar results can also be calculated by fitting a normal distribution to the sieve sizes defined in SAE Standard J444 (2005). Some researchers prefer to use the nominal shot diameter instead of the average. The nominal diameter corresponds to the nominal sieve opening where approximately 85% or more of the mass of shots will stay. The “S” in the SAE nr stands for “Shot” and the number is the nominal test sieve in ten thousandths of inches (SAE Standard J444, 2005).

Könitzer and Polanetzki (2011) use a compressed air machine fitted with an optical velocity measurement system. The peening media used was S110 and results for intensity versus velocity are presented for an impact angle of 70°. The relation is linear with an increase in intensity of 0.01 mm A for a 5 m/s increase in velocity. Könitzer and Polanetzki (2011) also draw the conclusion that the same intensity-velocity relationship is achieved irrespective of machine type, nozzle size or shot flow rate. Tufft (1999) uses an electro-magnetic velocity sensor to measure the media velocity. At an impact angle of 85° three results for a media with mean diameter 0.81 mm are reported and four results for 0.36 mm media. Both show an approximate linear relationship. Cao et al. (1995) used experimental data obtained with a commercial optical system called TRAVEL (Lecoffre et al., 1993). The data was obtained by personal communication and no further details are presented. Barker et al. (2005) uses another commercial system for media velocity measurements, ShotMeter from http://www.progressivesurface.com. Results are presented for S110 and S550. The S550, with a mean diameter of 1.68 mm, results are not included here however

Table 1
Common SAE media sizes.

SAE Nr	Average diameter [mm]	Nominal diameter [mm]
S70	0.297	0.178
S110	0.353	0.279
S130	0.419	0.330
S170	0.500	0.432
S190	0.594	0.483
S230	0.706	0.584
S280	0.841	0.711
S330	1.001	0.838
S390	1.191	0.991
S460	1.410	1.168

since it is so far from the other reported media sizes. Additionally these results were measured on Almen C strips and an approximate translation would have to be done to Almen A strips. The S110 results of Barker agree well with both Könitzer’s and Tufft’s results. The experimental results used by Cao for S110 agree at low velocities but show higher intensities with large scatter at velocities above 50 m/s. The 0.5 mm media presented by Cao agrees well with the empirical results for S170. Some sort of limit in velocity measurement seems to be reached at 80 m/s for both media types. Zinn and Scholtes (2005) measure the shot velocity with the system developed by Linnemann et al. (1996). Zinn and Scholtes (2005) present results for a large number of tests for S110, S170 and S230 media sizes. A fitted mean line is used here. The results for S110 deviate much from the other sources. Similar trends can be seen for the results for S170 and S230 also. A source of these discrepancies is attributed to the fact that there is a distribution of velocities coming from the nozzle of a compressed air machine. Differences in how a mean velocity should be calculated might give these deviations. The results from Linnemann et al. (1996) match Zinn and Scholtes (2005) results at the same media size. Kim et al. (2012) presents the times and arc heights from Almen saturation measurements at four velocities, 40, 50, 60 and 70 m/s. The Almen intensity is calculated by the program developed by Kirk (2005) and with the 2PF formula. The result shows a linear relation and fit quite well to the empirical S230 curve which however has a smaller average diameter of 0.7 mm. The inconsistent results at especially larger media sizes show that there is a need to measure the media velocity if the results should be used to compare with FEM-simulations.

This paper presents a method for comparing the indent size of a low coverage shot peening process to indent sizes of single shots with the purpose to determine the shot velocity at the peening process. Since the velocity distribution in the production shot stream vary the velocity determined here will be an equivalent velocity that creates on average the same indent size. The present results were compared to those of other researchers.

2. Experiment

Shot peening of square test plates, 30 × 30 mm and 10 mm thick, Fig. 2a, were performed in a compressed air machine. The plates were of case hardened SS (Swedish Standard) 92506 gear steel tempered to a surface hardness of 716HV1. The surfaces were ground before hardening (to avoid grinding burns after hardening) to a surface roughness comparable to that of gears, Ra 0.5 μm. In this case it gave an Rz value around 5 μm. Two media sizes were used which were both cut wire rounded to G3 grade and had a nominal diameter of 0.7 mm and 0.35 mm. The media had an average Vickers hardness of 742HV1. The 0.7 mm media is shown in Fig. 2b.

2.1. Low coverage shot peening

For the 0.7 mm media three different intensities were used; 0.22 mm A, 0.34 mm A and 0.49 mm A. For the 0.35 mm media the intensity 0.24 mm A was used. A test plate was shot peened with low coverage for each intensity. The 0.7 mm media used in the machine were sampled and the same shot media was used to make the single indents. The average diameter of the media was measured to 0.84 mm with a standard deviation of 0.1 mm.

2.2. Single indent shots

When making the single indents only larger balls were chosen to ease both the velocity and indent measurement. The average diameters of balls used for single impact were 0.92 mm. However, since the media is not completely round the indent crater will be influenced by which side of the ball that contacted the surface. Therefore