INTERACTIVE SHOT PEENING CONTROL

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ABSTRACT

The advantages and disadvantages of existing methods of shot peening control are considered leading to a proposal that interactive control should be used in certain circumstances. A method of interactive control is proposed based on the use of linear variable displacement transducers to monitor the development of curvature during the shot peening process. This method uses disc-shaped test pieces rather than the traditional rectangular Almen strips. The need for different thicknesses of Almen strip, to cater for a wide range of peening intensities, is eliminated by using different exposed areas of a given disc. The correlation between Almen intensity and disc curvature is considered in detail.

KEYWORDS

Shot peening control. Almen gauge. Curvature. Interactive control.

INTRODUCTION

Shot peening control aims to either reproduce a previously-established intensity of peening or to induce a specified level of peening intensity. The "Almen Gauge" introduced by J O Almen in 1943 has served the shot peening industry very well. Rectangular steel strips of controlled chemical composition and thermal history are shot peened whilst being held flat and the deflection of the strip on release is measured. The deviation from flatness is the "Almen Arc Height", H, being measured using an Almen gauge and is presented for strips of one or other of three thicknesses. These three thicknesses accommodate the wide range of peening intensities that need to be used for different applications.

The actual parameter that is involved in monitoring peening intensity needs to be considered. Essentially as the "intensity" of peening is increased the curvature of an Almen strip is increased. This curvature is due to two components. The first component is the non-uniform plastic deformation of the peened strip. This causes the peened surface to expand bending the strip into an arc. The second component is the development of a residual stress system which changes from when the peened strip is held flat to when it is released. A layer of compressively-stressed material is induced by shot peening with a corresponding bending moment which is resisted while the peened strip is held flat using four screwheads. On release of the strip this bending moment is no longer resisted and the strip bends to an arc to accommodate a balancing of the bending moments in the strip setting up a new residual stress pattern in the strip. Both of the components bend the strip in the same direction of curvature so that we have a total curvature made up of the two elements. The essential cause of the curvature is the work being done on the strip by the shot particles which have

had to be accelerated to a high enough velocity to cause plastic deformation of the workpiece surface.
The total work done on the strip, W, can be expressed by means of the following equation:

$$W = \sum_{0}^{t} p_j.½.m_j.v_j^2.n.dt \qquad (1)$$

where p_j = proportion of the kinetic energy, $½.m_j.v_j^2$, absorbed by the strip when it is struck by an individual shot particle, j, of the n particles that strike the strip in an interval of time , dt, within the total peening time, t, and m_j is the mass of the shot particle, j, travelling at velocity, v_j.

Equation (1) epitomises the problems that are associated with effective shot peening control. The proportion of energy absorbed from a particular particle will vary according to such factors as the angle of impact at the workpiece surface and the material characteristics of that surface. The mass of each particle will vary within the range of diameters allowed for a particular grade of shot. Velocity of shot particles will vary according the physical and mechanical characteristics of the peening equipment. Finally the rate of delivery of particles, n/dt, will not remain constant. The great advantage of the Almen gauge is that it integrates the relevant factors over the total peening time, t. Above all it is the only universally-accepted standard measure of shot peening intensity. Fuchs (1) has given an effective account of the several advantages and disadvantages of the Almen gauge. The major disadvantage of the Almen gauge is that it is retrospective, in the sense that it looks back at the total work that has been done, The gauge deflection gives no indication of variations during peening. The development of overall peening intensity can only be assessed by using a series of gauges exposed for different periods of time to nominally the same intensity rate. An interactive method would assess the work being done during the peening process. This would then allow available control procedures to be activated during the peening process to ensure that a desired peening intensity is effected. Some control procedures are well-established. These include those for monitoring and controlling the flow of the shot peening media (2), air pressure, nozzle distance and peening time.

The control of coverage is another important aspect of shot peening. This is progressive during peening of any particular component but is not normally monitored interactively. Techniques such as the "Peenscan™" procedure (3) enable the overall coverage of the component to be checked but again this is retrospective rather than interactive.

INTERACTIVE PEENING INTENSITY MEASUREMENT

An initial attempt to produce an interactive peening intensity measurement device involved the use of standard Almen strips but without the standard four-screwhead securing procedure. This is illustrated in Fig.1 where an Almen strip is held in spring-loaded jaws, A and B. Block B is fixed to the base block but block A can move in a groove in the base block. Block A is spring-loaded by the spring, S, which terminates groove in the base block. A compression spring is secured inside blocks A and C. The spring compression is adjusted by a bolt acting through the threaded fixed block D. A linear variable displacement transducer (LVDT) passes through the base block being secured in position by a 'grub screw'.

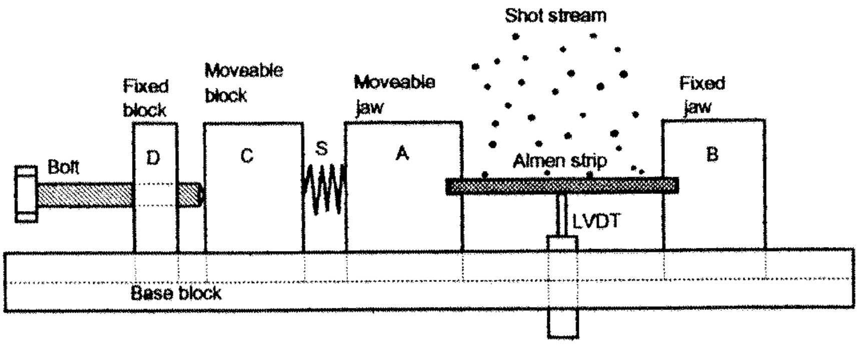

Fig.1 Initial interactive peening intensity measurement device.

The operation of the device shown above involves fitting an appropriate thickness Almen strip between the jaws with the spring pressure adjusted to maintain the strip securely but without bending. The LVDT position is adjusted so that its 'pointer' is depressed well within its 10 mm range. As the upper surface is exposed to the shot stream the strip curves upwards but the strip itself remains secure due to the spring force. The displacement of the strip from its original flat shape is monitored by linking the output from the LVDT to a displacement/time recorder. This arrangement allows a continuous record to be maintained of the change of displacement (analogous to Almen Arc Height).

Tests using the device shown in Fig.1 were carried out to study the relationship between the displacement monitored continuously and the Almen Arc Heights registered using a series of Almen strips peened for different times. Constant peening conditions were maintained as closely as possible throughout the series of tests and involved a nozzle air pressure of 34 psi, S330P steel shot, a stand-off distance of 195 mm and Almen "A" strips. The results of these tests are shown in Fig.2. For both techniques the strip displacement increases with peening time but at a decreasing rate. The most obvious difference is that the LVDT displacement is some fives times greater for each peening intensity stage. This would be particularly useful when saturation is being approached since the standard Almen gauge is then relatively insensitive. LVDT gauges themselves are extremely reliable and sensitive and the procedure lends itself very well to continuous monitoring and to closed-loop connection with control devices. The only problem experienced with the LVDT-based device was that it was sensitive to long-term damage. Further development of the LVDT-based device was considered to be appropriate given the encouraging results that had been obtained.

One feature of shot peened Almen strips is that they adopt two different curvature corresponding to the major and minor axes of the original rectangle. In developing th device circular test strips have been used which are held in position as shown in Fig.3.

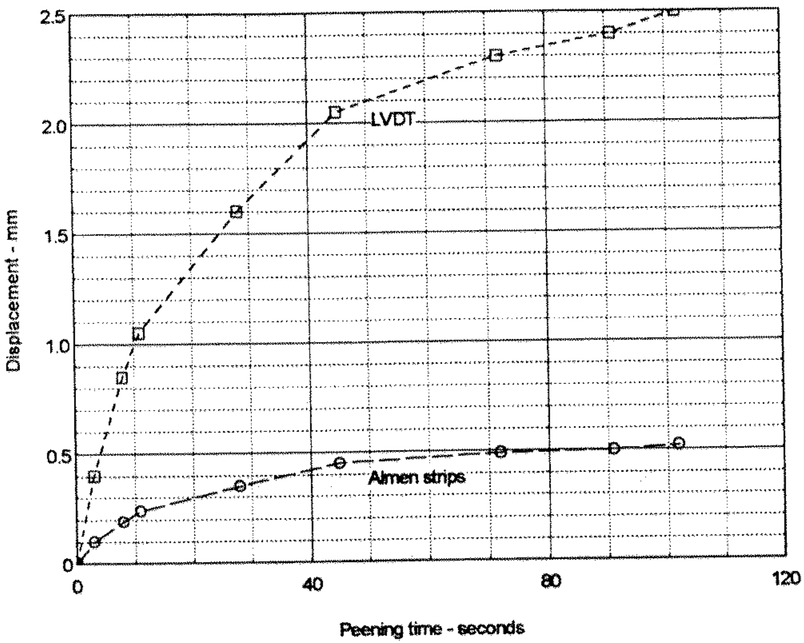

Fig.2 Comparison of displacements recorded using Almen strips and LVDT strip

A screwdown ring presses the circular test disc against a recess in the disc holder. An LVDT is secured in the disc holder by means of a grub screw and the output fed to a displacement/time recorder. The screwdown ring and disc holder afford excellent protection for the LVDT.

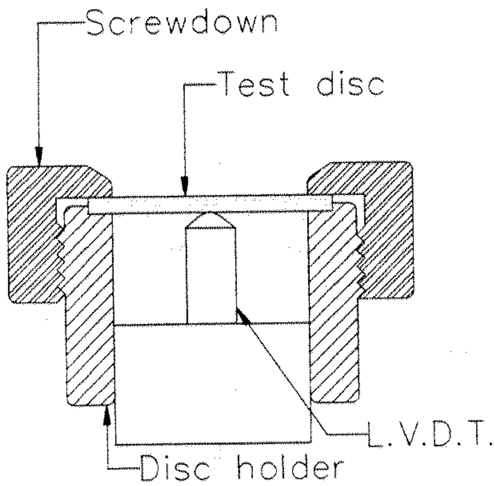

Fig.3 Clamping unit for interactive peening intensity measuring device

Initial tests with the device shown in Fig.3 involved 1 mm thick 40 mm diameter discs using steel of very similar composition and thermal history as that used for making Almen strips. These tests showed the same shape of displacement/peening time curve as that obtained with an Almen strip and the device illustrated in Fig.1. Again much larger displacements were recorded than those obtained using series of Almen strips and an Almen gauge.

The device shown in Fig.3 is capable of accommodating the same wide range of peening intensities as is achieved with the three different thicknesses of Almen strips. This can be effected either by using different disc thicknesses or by using different disc diameters. In order to simplify the situation a standard thickness and diameter of disc can be used but with masking washers to expose different areas to the incoming shot stream. These fit on top of the disc as shown in Fig.4.

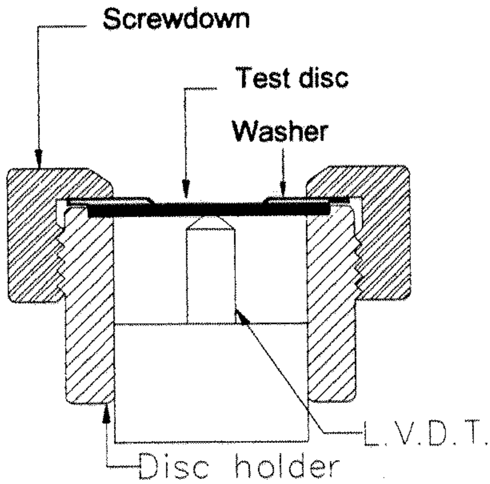

Fig.4 Interactive peening intensity measuring device incorporating masking washer

A range of masking washers have been used exposing 35 mm, 30 mm and 20 mm diameter areas respectively. This range has been found to accommodate the most severe range of peening intensities that we can induce. An alternative use for the masking washers is that one can obtain a one-to-one displacement relationship with Almen strips by choosing an appropriate exposed area.

The latest development of the interactive peening measuring device has been to connect the output from the LVDT to a "traffic light" display box. This is set up so that a green light is illuminated at the start of the peening operation. As peening progresses and the displacement increases the green light stays on until the required peening intensity is near. An amber light is then illuminated replacing the green light. When the required intensity has been achieved a red light is illuminated to warn that peening must stop. The display box has been miniaturised and duplicated for used both inside a peening cabinet as well as outside the cabinet. The object of this system was have equipment that was appropriate to industrial situations. Future developments will include the design and manufacture of miniature versions of the device involving test discs only a few millimetres in diameter. These would be particularly useful for monitoring peening intensity in very small areas that would be too large in any case for Almen strips.

DISCUSSION

The effective control of shot peening depends on the appropriate application of technological devices, theoretical understanding and experience. Future developments could include the use of closed-loop monitoring and control of peening intensity. It can be argued that too much reliance has been placed on traditional Almen strip tests which are essentially retrospective. The use of one standard test material may be considered necessary when the absolute peening intensity has to be measured. Rectangular strips are not, however, necessarily the best shape of test specimen. It has been found, for example, that discs offer the advantage of uniform curvature and are easy to miniaturise. Interactive techniques, such as the one presented here, can readily be used with either a standard test material or with material of the same composition and thermal history as that of the components to be shot peened. A considerable advantage of the technique is that a single test specimen gives a complete peening intensity/peening time curve rather than having to use a series of test specimens to produce a single curve. These factors allow for economic evaluation of different peening parameters applied to a range of component materials.

REFERENCES

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