# Understanding Shot Peening: A Case History

*A new technology it isn't, but when required, shot peening has proved its capability for improving casting cycle life by more than 700%.*

*Gregory A. Fett*
*Spicer Axle Div/Dana Corp*
*Ft. Wayne, IN*

Shot peening by some is often thought to be expensive, difficult to control, unsuitable for high volume work and used only on sophisticated aircraft components. While it may be true that shot peening has been used for years to increase the fatigue life of certain aircraft components, the other conceptions are certainly not very accurate. For example, did you know that every time castings are cleaned in a foundry shotblast machine they are also being shot peened to some extent?

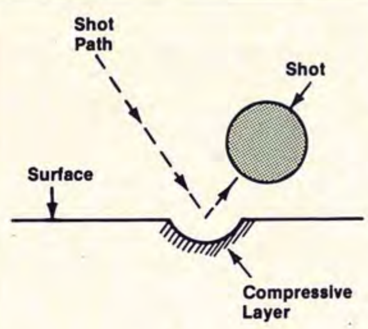


Fig. 1A

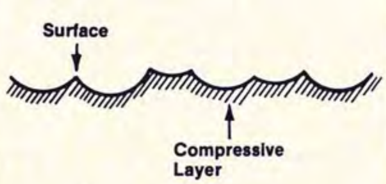


Fig. 1B

### What is Shot Peening?

Simply stated, shot peening consists of bombarding the surface of a part with small particles hurled at a high velocity. Each time one of these particles impacts the surface, it puts a small dent in the part. These particles must be at least as hard as or harder than the part or the part will dent the particle. The area beneath the surface of the dent is placed in compression (Fig. 1A). Eventually, when enough particles have bombarded the part and the entire surface is covered with dents, all of the area beneath the surface is in compression (Fig. 1B).

When a part is used in service, normally it is placed in tension, with forces trying to pull it apart. However, with a shot peened part, the surface and area directly beneath are in compression, which, in effect, pushes the part together. Therefore, when a load is placed on a shot peened part, it first has to overcome the compressive stress before it can register any tensile stress at the surface. Since most fractures originate at the surface, this can be very important. The effects are most dramatic in fatigue type applications where a part is repeatedly stressed at or below its yield point. Because the compressive layer is so thin, generally less than 0.030 in., the effect is usually not noticeable when checking the ultimate strength of a part.

### Shot Peening Equipment

As was pointed out above, castings cleaned in a shotblast machine were also being shot peened. The only real differences between shot cleaning and shot peening are the purpose and the controls. With shot cleaning, removal of molding sand and improving appearance are the objectives. With shot peening, the same objectives are accomplished but in addition, an attempt is made to control the layer of compressive

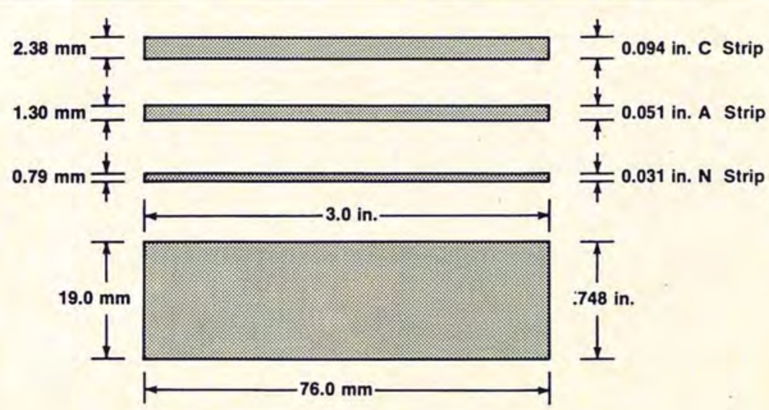


Fig. 2 Almen Strips

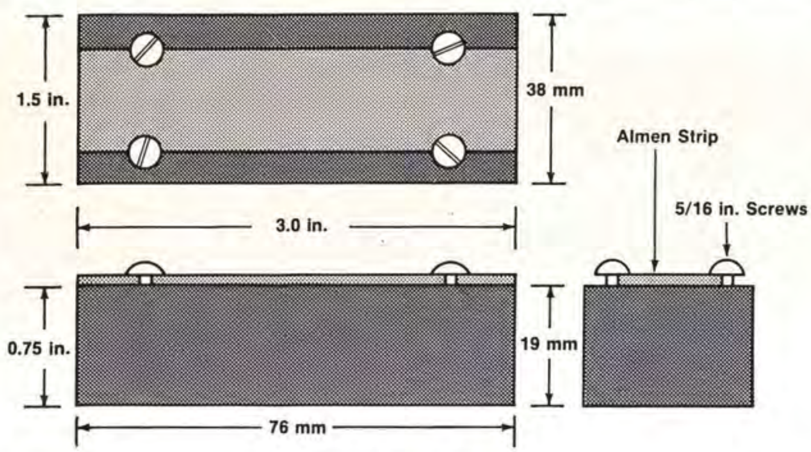

Fig. 3. Almen Block

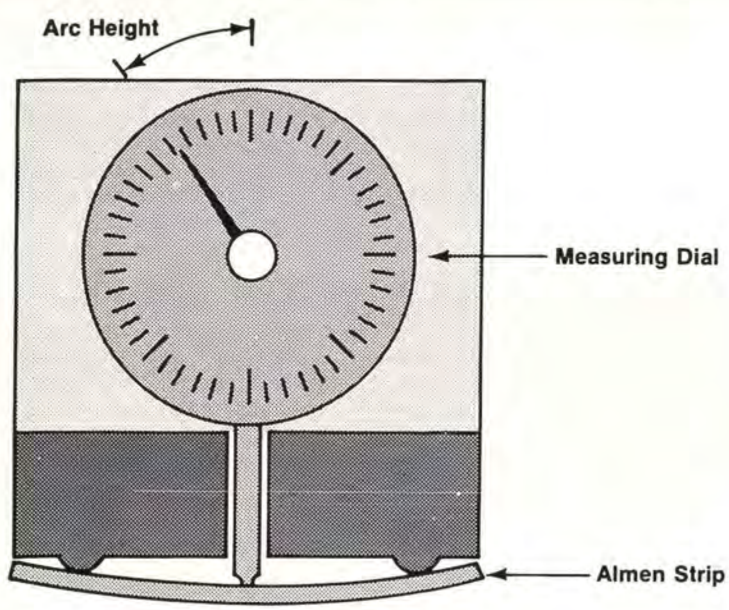

Fig. 4. Almen Gage

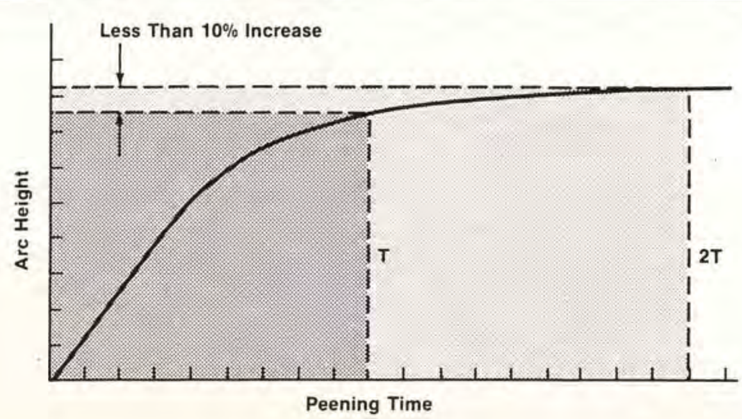

Fig. 5

stress at the surface. The same shotblast machines may be used for either.

The tools used for shot peening are quite simple. First, a shotblast machine is required. Again, it may be the same machine used to clean castings, whether it is a table-, tumble- or other type. The major difference is its capability to provide a reproducible means of blasting the part with a stream of shot. Tumble-type equipment blasts the entire surface of a casting with a random mixing type motion, while other equipment may concentrate the shot in a certain area of the part.

Secondly, Almen strips, blocks and gauges are used to measure the compressive stress. Almen strips are hardened strips of steel (Rc 44-50) which are mounted flat on a carburized rectangular Almen block with four screws (Fig. 2 and 3). One side of the strip is exposed to the shot just as the surface of the part would be. After peening, the strip is removed from the block. The compressive stress on the one side of the strip caused it to bow. The amount the strip bows is measured in thousandths of an inch with the Almen gauge and is called the arc height (Fig. 4).

Three classes of strips are available depending on the intensity of compressive stress to be measured. They are N, A and C, with C being the thickest and the one generally used for steels and irons. An intensity of 8C means a C strip bowed 0.008 in. after peening. For best results, the Almen blocks and strips are normally mounted directly on the part to be peened and in critical areas of the part.

Third, the shot used to peen the part must be as hard as or harder than the part. For most cast iron parts, standard steel shot (Rc 45-55) is sufficient. Shot also comes in different sizes, such as S330 or S390, with the number indicating the diameter of the shot (0.033 in. and 0.039 in., respectively). As in shot cleaning, the shot must be small enough to penetrate all of the radii of the part. The intensity obtainable is also proportional to the shot size. The larger the shot, the more momentum it has, hence, the higher the compressive stress. However, it also takes longer to completely peen the surface of a part with larger shot. For most foundry applications, sizes S330 and S390 are adequate.

### Shot Peening Controls

Two things are of prime importance in shot peening: intensity and coverage. Intensity was covered earlier to some extent. Basically it is a measure of the amount of compressive stress and is a function of the shot velocity, shot size and peening time. Intensity is measured in arc height with an Almen gauge. To control intensity, the shotblast machine needs to be maintained so it always hurls the shot at the same speed and in

**Fig. 6. Side-by-side photos show the front and back views of the steering knuckles used in the test at Wagner Castings. Front view shows the attachment of an Almen block.**

| Peening Time | 2 Min. | 4 Min. | 8 Min. | 16 Min. |
|---|---|---|---|---|
| Block 1 | 2 | 4 | 6 | 5.5 |
| Block 2 | 2 | 5 | 4 | 5.5 |
| Block 3 | 2 | 5.5 | 5 | 6 |
| Block 4 | 2.5 | 3 | 5 | 4 |
| Block 5 | 1.5 | 3 | 5 | 6 |
| Avg. | 2 | 4.1 | 5 | 5.4 |

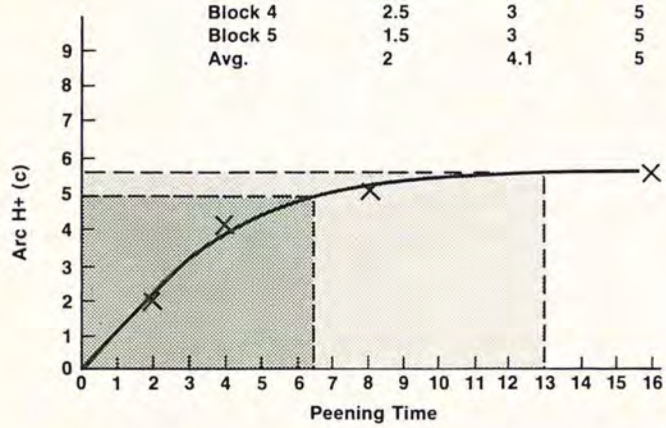


Fig. 7

| Sample # | Peening Time | Cycles | Average |
|---|---|---|---|
| 1 | 0 Min | 113,700 | |
| 2 | 0 Min | 110,940 | |
| 3 | 0 Min | VOID | 149,030 |
| 4 | 0 Min | 182,230 | |
| 5 | 0 Min | 189,250 | |
| 6 | 6 Min | 640,740 | |
| 7 | 6 Min | 968,890 | |
| 8 | 6 Min | 663,270 | 860,804 |
| 9 | 6 Min | 1,238,510 | |
| 10 | 6 Min | 792,610 | |
| 11 | 16 Min | 1,642,220 | |
| 12 | 16 Min | 269,570* | |
| 13 | 16 Min | 1,527,110 | 1,075,604 |
| 14 | 16 Min | 1,444,160 | |
| 15 | 16 Min | 491,960 | |

*NOTE: Defect in casting arm

Fig. 8

the same pattern. Also, the shot size needs to be kept reasonably constant. Shot wears and breaks down with use. A properly functioning separator will sort out undersized shot.

Coverage is a measure of the amount of surface area which has been peened. To be effective, the entire surface should be peened. Full coverage is also known as saturation and can be determined with Almen strips. When a part is peened for longer and longer times, the intensity or arc height will increase to a point, then level out. Peening beyond this point will do little or no good. Saturation or full coverage is defined as that point when doubling the peening time results in a 10% or less increase in arc height (Fig. 5). Saturation is maintained by controlling the peening time. In a tumble-type machine, it is also necessary to maintain the load size because a larger load will take longer to completely cover.

## Case History

SAE grade 4018 ductile iron steering knuckle castings were shot peened for varying lengths of time and fatigue tests were conducted. The castings were peened in a 14 ft$^3$ tumble-type machine at Wagner Castings, Decatur, IL. Size S330 shot was used and the load was kept constant.

To measure arc height, five Almen blocks were mounted on a knuckle casting which was included with each load (Fig. 6A and 6B). Saturation was determined by running loads at increasing cycle times. After each cycle, the Almen strips were removed and read. New strips were then placed on the casting for the next cycle.

Figure 7 shows the results. Saturation was approximately 6.5 minutes. Castings were then peened for 0, 6 and 16 minutes under the same conditions and returned for fatigue testing. These results are shown in Fig. 8. Peening to just under saturation gave a 581% increase in fatigue life. Peening well beyond saturation, to 16 minutes, increased the cycle life 721%. Even with a defect (sample 12), fatigue life increased 180%.

## Conclusions

Shot peening can be a valuable tool for increasing the fatigue life of castings. It is relatively simple to perform and requires only slightly more control than normal shot cleaning. For each part and blast machine, the following would be necessary to shot peen.

- Establish loading to be used (number of parts or containers, etc).
- Plot arc height vs. peening time to determine saturation.
- Establish cycle time or basis of saturation (100% of saturation time, 150%, 200%, etc; 150% will offer some degree of safety).
- Maintain blast equipment and shot size.
- Periodically check arc height of established cycle to maintain intensity.

Castings should be ground and heat treated prior to shot peening. If a part is ground after peening, the layer of compressive stress is removed. Likewise, peening is only effective on areas of the part which are not machined. Heat treating after shot peening will also destroy the compressive stresses.

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