Optimum Shot Peening Specification - II

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Summary: Following is the second part of an article begun in our last issue. The first part covered basic shot peening theory, shot peening controls, and considerations that should go into developing a shot peening specification. Part II covers optional peening methods and the relationship of shot peening specifications to the drawings.

Optional Peening Methods and Additional Considerations

Some additional peening methods and considerations which the reader may want to include as part of any general specification are shown below.

Strain Peening or Stress Peening - This technique is applied when parts are stressed in one direction only and longer fatigue life is desired than that obtained by conventional methods. The part is shot peened in a stressed or loaded condition, and compressive stresses produced by the peening can be as high as the compressive yield stress of the material itself. This technique has been used heavily in numerous industries.

Dual Intensity Peening - This technique also can be used when substantially longer fatigue life is required. Research done on carburized steel indicates that dual peening, which is high intensity shot peening, followed by lower intensity shot peening with smaller shot, increases the magnitude of surface compressive residual stress.[1] Additional testing on other materials have confirmed this data.[2, 3] (See Figs. 1 and 2.)

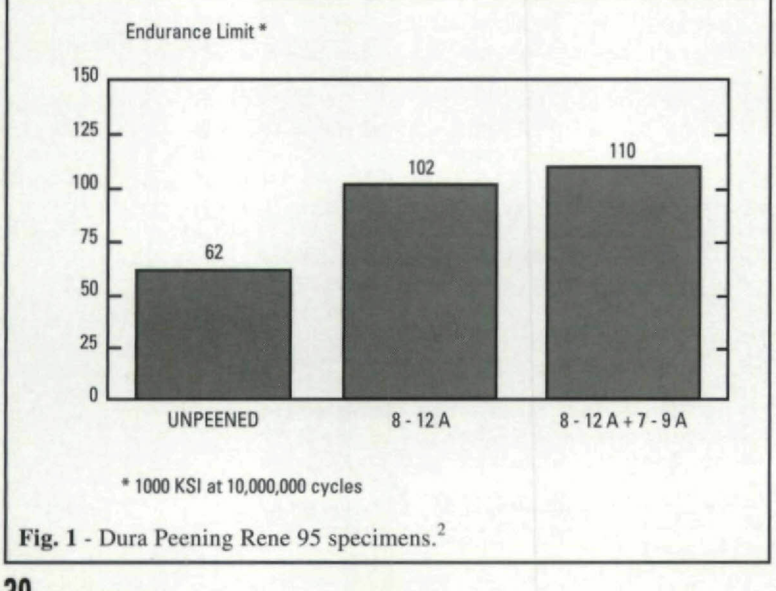

Fig. 1 - Dura Peening Rene 95 specimens.[2]

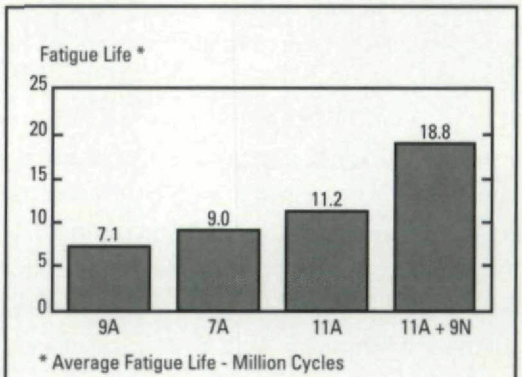

Fig. 2 - Dura Peening Titanium 6AI-4V Blades.[3]

Plating and Salvage Methods - If machining discrepancies in production are sometimes salvaged by building up an area for remachining by the use of chrome or other plating techniques, or if plating is used for a wear or protective surface, shot peening prior to plating can be used. The shot peening will prevent crack propagation from microcracks in the plating to the parent metal if the part is subjected to a cyclical

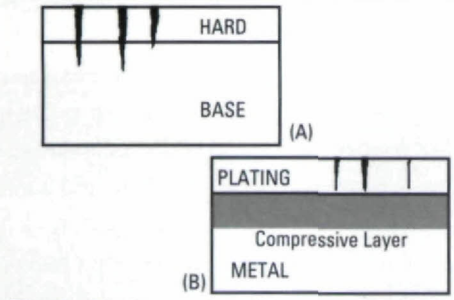

Fig. 3 - Plating cracks will not propagate into pre-stressed base.

load. Cracks will not propagate into layers of compressed stress. (See before and after shot peening illustrations in Fig. 3.) In addition, significant increases in fatigue strength closely approximating original unpeened surfaces are shown in Fig. 4. In some cases, shot peening prior to plating may be required by other contractual agreements. Specifications, such as Federal Specifications QQ-C-320 and MIL-C-26074A, require shot peening on steel parts that are chrome or electroless nickel plated.

An added side effect is the prevention of hydrogen embrittlement by shot peening of this parent metal prior to the plating operation. Since atomic hydrogen is extremely mobile and able to penetrate and interact with metal easily, the metal's ductility and ability to withstand cyclic loads is reduced. Peening has been proven effective in retarding the migration of hydrogen through metal.[5] (See Fig. 5.)

Contour Correction - Just as it is possible to create a desired curvature and shape to components by shot peening, it is also possible to correct the shape and form of parts. The shot peening process avoids the unfavorable (tensile) residual stresses produced by other straightening methods and instead produces favorable (compressive) residual stress. (See Fig. 6.)

Increasing Wear Due to Work Hardening - In the discussion on material considerations, considerable space was given to whether a material

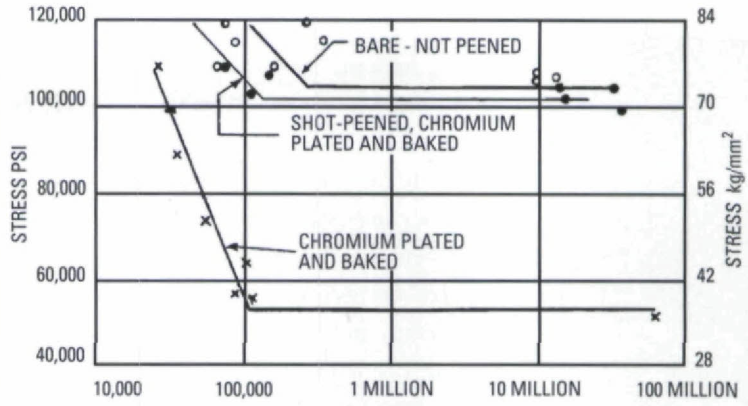

Fig. 4 - Cycles to failure 4340 steel, 52-53 Rc rotating beam fatigue.[4]

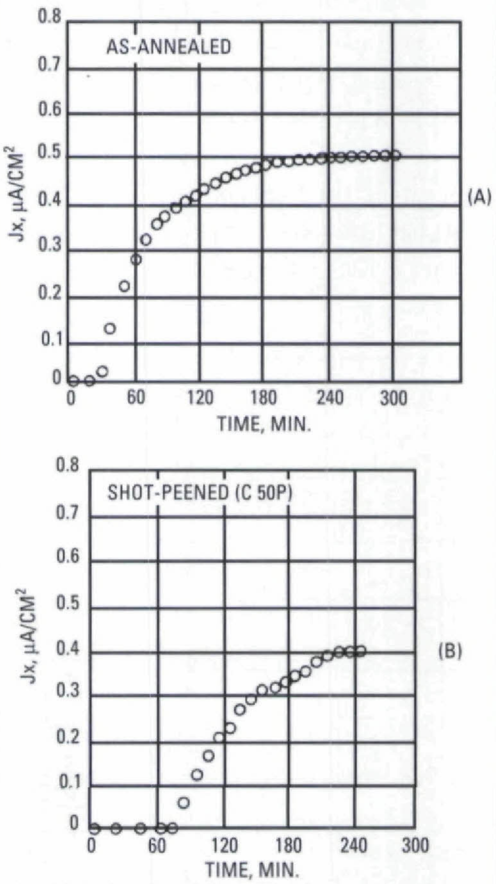

Fig. 5 - Effect of shot peening on hydrogen migration. J[8], A/CM² hydrogen permeation rate. A) Non-treated surface. B) Shot peened surface.[5]

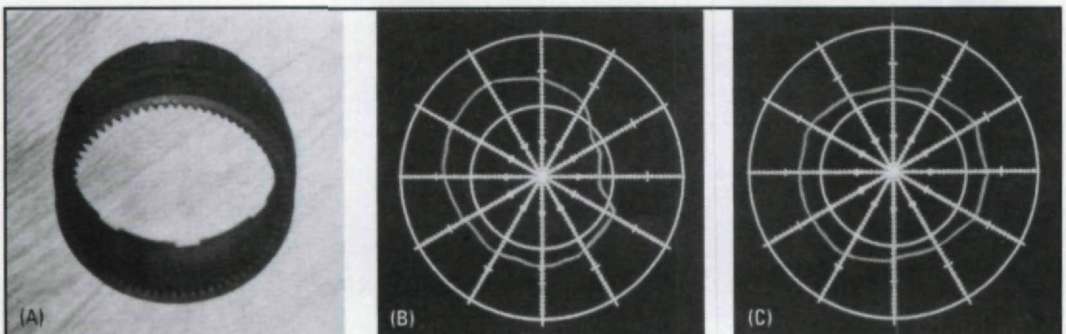

Fig. 6 - Contour correction. A) Ring gear. B) Before peenforming. C) After peenforming.

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would readily work harden. If this factor is a major consideration, then it should be addressed in the specification. (See Fig. 7) For materials which cannot be heat treated, but require wear resistance, shot peening should be considered.

Porosity - When this is a concern, porosity should be reviewed as a specification option. Typically this is not utilized for the compressed stress benefits, but rather is used to compact the surface[7] or reveal some sub-surface porosity prior to machining. It can, therefore, be utilized as an inspection tool before machining of questionable castings.

Salvage; Grinding; Before and After Shot Peening - In cases where a severe grinding operation has developed resultant residual tensile stresses and surface brittleness, shot peening of the surface after grinding should be considered. Fig. 8 reveals S-N curves for a part originally designed for an endurance limit with a gentle grind, the resultant lowered endurance limit after grinding, and improved endurance limit of the severely ground surface followed by shot peening.

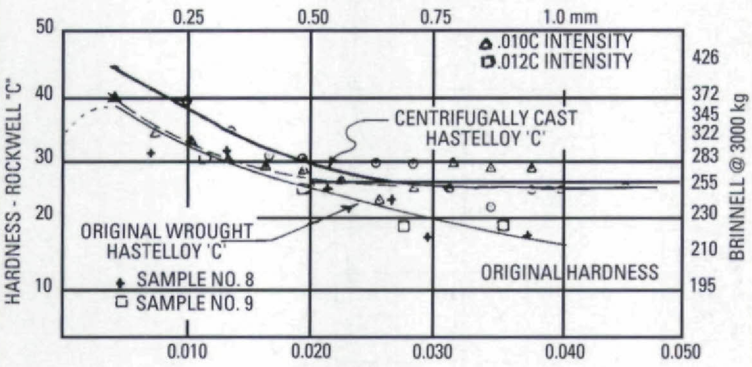

Fig. 7 - Hardness vs. distance from surface for shot peened hastelloy "C" samples.[6]

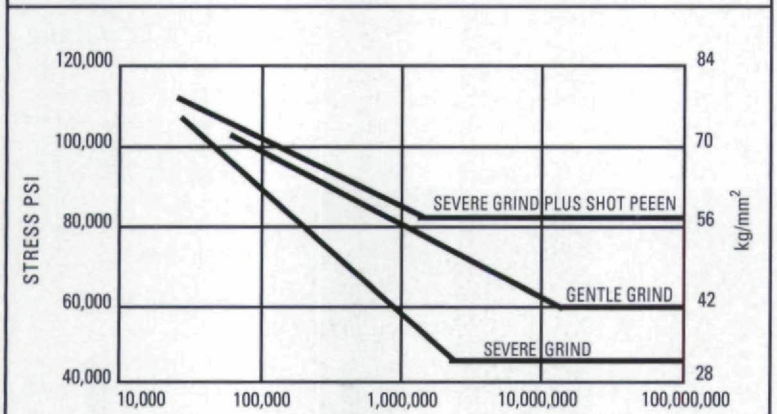

Fig. 8 - Shot peening improves endurance limits of ground parts. Reversed bending fatigue of flat bars of Rockwell hardness C45.[8]

Another technique that can be used, especially on particularly difficult grinding operations or materials, is to shot peen prior to grinding to prevent grinding cracks. Since grinding of carburized gears can produce high tensile stresses, these stresses can initiate cracks in the tooth surface. Shot peening prior to grinding will greatly reduce this tendency. Peening here is used to prevent crack propagation from the grinding and not to increase bending fatigue strength.

Stress Corrosion Cracking - In particularly hostile environments where a material being used may be affected adversely by general corrosion coupled with residual or applied tensile stresses, shot peening may be a consideration. The peening will change the surface residual tensile stresses to compressive stresses, which will eliminate the conditions needed to promote stress corrosion cracking.

The Part Drawing

Once a satisfactory in-house specification has been established which addresses the particular needs of a company, it is still necessary to translate this information to particular gears. The general specification should assist the design professional regarding the necessary steps to properly select an optimum drawing specification. The information must then be transferred to the manufacturing drawing.

In specifying shot peening requirements on part drawings, the following parameters should be identified:

1. Areas to be shot peened
2. Areas to be masked
3. Optional areas
4. Areas where shot peening fades out
5. Shot size, hardness, and material
6. Locations for intensity verification and intensity range at each location
7. Coverage requirements for all areas to be peened, including the method used for coverage determination
8. Applicable shot peening specification.

Fig. 9 provides a theoretical example of a gear with a suggested specification. Utilizing the above points, the analysis of this specification is as follows:

1. Areas To Be Shot Peened - These are noted by DIM "A", and further critical areas are identified by "XXX." Five primary areas require the proper intensity. These are at the tooth root fillet, the gear pitch line, two shaft fillet transi-

tion areas, and the main shaft body. Since only one peening operation is to be performed, the shot selection would indicate that the apparent geometric limiting factor of the shot is the fillet radii of the gear teeth. Most likely the main shaft is being peened because the shaft may also experience problems with fatigue. It is possible that some machining may occur on the shaft body after shot peening, so rather than mask this area, peening is being allowed. The gear pitch line area is noted because pitting of the gear tooth may occur.

2. Areas To Be Masked - These are noted by DIM "B" and DIM "C". Most likely the O.D. of the gear has limitations on the potential of burring at the top land. This is costly and should be avoided unless alternate ways are not available. A potential alternative solution may be to break or radius all sharp edges in the areas prior to peening. This can minimize or eliminate the potential to burr. The threads at the shaft end do not require peening and must be masked as optional peening could damage these.

3. Optional Areas - Noted by DIM "D," these are the holes in the gear body.

4. Areas Where Shot Peening Fades Out - Not applicable to this example.

5. Shot size, Hardness, and Material - MI 110 shot, intensity 6-10A; the MI 110 designation defines a cast steel shot.

6. Location for Intensity Verification and Intensity Range at Each Location - Only one intensity is specified and is marked by "XXX." If other intensities or shot sizes are used, additional callouts and symbols are required.

7. Coverage Requirements For All Areas To Be Peened, Including the Method Used for Coverage Determination - 125% coverage verified by Peenscan.®

8. Applicable Shot Peening Specification - MIL-S-13165B.

This drawing specification clearly denotes a proper shot peening requirement and should easily be accomplished by the manufacturing group or vendor. This specification should readily coincide with the company in-house peening specification. Note, however, that this specification may not, and most likely will not, work on parts similar to this part. It is strongly encouraged that each gear requiring shot peening be first evaluated based on the general in-house specification prior to definite

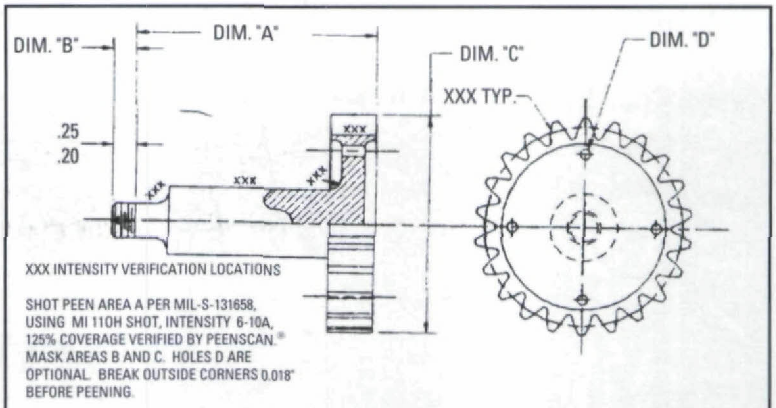

Fig. 9 - Theoretical example of a gear with a suggested specification.

shot peening callouts being made on a manufacturing drawing.

Summary

Confusion and some misunderstanding in properly specifying shot peening can cause difficulties in the manufacturing process. Concise in-house specifications covering considerations for shot peening, coupled with accurate manufacturing drawing callouts, can optimize the use of this effective tool. With the in-house specification addressing the particular needs of the manufacturing company's gearing requirements, and the correct specification on the manufacturing drawing conveying this to the vendor, shot peening can be utilized to its fullest advantage.■

References:

1. AHMED, A. and CROUCH, D. "Dual Shot Peening to Maximize Beneficial Residual Stresses in Carburized Steels." ASM International Conference on Carburizing, Processing and Performance. July, 1989.

2. "Determination of Mechanism by Which Surface Treatment Affects the Low Cycle Fatigue resistance of Advanced Disk Materials." October, 1986. General Electric Co.

3. CAREK, G.A. "Shot Peening Forti-6AL-4V Alloy Compressor Blades." NASA Technical Paper 2711. 1987.

4. COHEN, B. "Effects of Shot Peening Prior to Chromium Plating on the Fatigue Strength of High Strength Steel." Wright Air Development Center, Technical Note 57-176. June, 1957.

5. "Effect of Surface Modification on the Kinetics of Proton Discharge and Absorption into Steel." Thesis, 1966. Ohio State University, Columbus, Ohio.

6. HONNAKER, L.P. E.I. DuPont Co., Inc.

7. ANDERSON, E.F. "Shot Peening to Reduce Porosity in Die Casting." *Modern Metals,* 1957.

8. TARAZOV, L.P. and GROVER, H.J. "Effects of Grinding and Other Finishing Processes on the Fatigue Strength of Hardened Steel." *ASTM Proceedings.* Vol. 50, 1950.