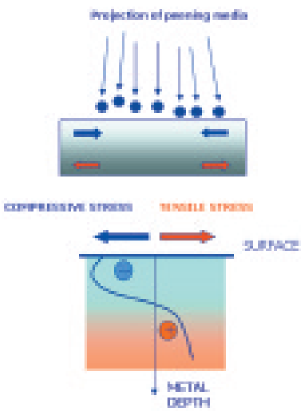
Gear Peening: The Intense Story

by Kumar Balan

Automotive designers have traditionally relied on the advantages of shot peening of transmission parts to enhance their useful life. Commonly, shot peening machines are found post-heat treat and at the end of a production process for critical parts such as ring and pinion gear sets.

In peening circles, it is common knowledge that indentation of a metal surface by bombarding it with metal projectiles at high speed induces compressive stresses in the layer. With this as the basis of any shot peening application, it is not unusual to find any 'available' shot peening machine being put to active use to peen critical components. However, premature transmission failures and recalls are now prompting gear manufacturers to re-evaluate this seemingly simple process and develop it along the lines of an 'application based' approach for their peening needs.

Mechanism and Effects of Shot Peening



Impingement of metallic media (shot or cut wire) causes plastic deformation on the part surface. This extends the superficial layer creating compressive stresses underneath and providing a balance to the tensile stresses. This residual compressive stress delays the formation of fatigue cracks thereby increasing the useful life of a component.

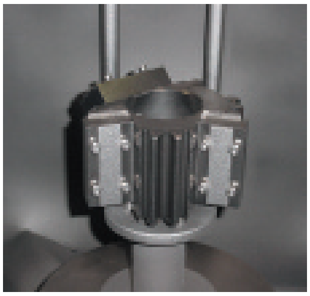
Continuous impact of peening media on gear surfaces (after heat treatment) also transforms the residual austenite to martensite. This increases the hardness of the base material and induces compressive stresses.

With specific reference to gears, maximum shear stress appears at the root areas and in the transition radius. Increasing loads are experienced in the drive and coast faces. Therefore the focus of peening gears is on:

- Drive face
- Coast face
- Root areas

Finish requirements, namely intensity and coverage vary from one gear set to the other and are dependent on the final application. Whereas coverage is purely a visual check, intensity is a measure of deflection of a representative strip of spring steel (commonly called the Almen Strip).

Intensity Measurements



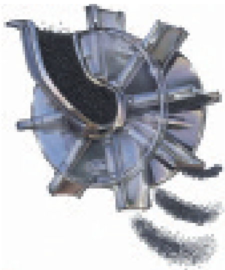
Part Verification Tools (PVT), such as the one shown here are designed to hold test strips in strategic locations. Test strips in these locations simulate areas of the part where intensity requirements and therefore measurements are critical.

Intensity ranges could be anywhere from 0.015 to 0.030 on the 'A' scale, depending on the application. Coverage requirements could range from 100% to 200%.

The above results can be achieved through a limited choice of peening techniques, each with its own distinct advantages over the other. These are:

- Using centrifugal blast wheels
- Using pressure blast nozzles
- Using hybrid machines (combinations of wheels and nozzles)

Media Propulsion Types



Centrifugal blast wheels certainly offer no comparison to any other media propulsion technique when productivity is in consideration. The media flow generated by a blast wheel covers a larger surface area than a blast nozzle. However, the limitation is usually set by the size of the gears being peened. In cases of smaller gears with narrow root areas, it may be required to employ multiple blast wheels positioned in strategic angles to achieve adequate coverage.

Alternatively, multiple direct pressure blast nozzles, each focusing on specific tooth areas, provide targeted blast coverage.

Both types of media propulsion systems are widely in use, though airblast peening systems are gaining popularity in relatively newer peening systems.

Process Variables

Though not very common, hybrid systems (combination of wheelblast and airblast propulsion systems) offer the benefits of higher productivity

Continued on page 20

GEAR PEENING
Continued from page 18

with the wheel and 'touch-up' peening in required areas within the same machine using a pressure blast nozzle.

Regardless of the peening technique used, achieving the intensity targets in a repeatable and consistent fashion is the primary goal of any operation. It is therefore important to understand the critical variables that alter the final results in a peening process. They are:

Centrifugal Blast Wheel	**Direct Pressure Nozzle**
Blast Wheel	Blast Nozzle
Wheel HP	Nozzle Size
Wheel Speed	Blast Pressure
Blast Angle	Blast Angle
▪ Wheel positioning	▪ Nozzle Movement
▪ Control Cage Movement	▪ Multiple Nozzles

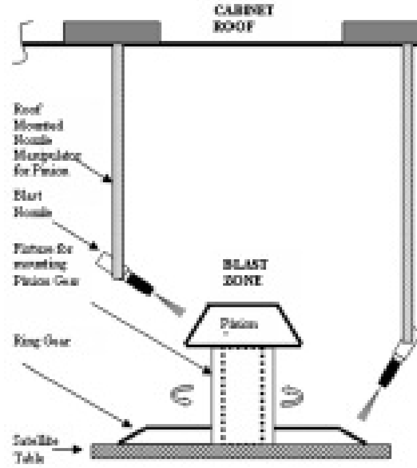
Each of the above process variables impacts the final result as follows:

- The diameter of the blast wheel determines the tangential velocity of the projectile (blast media). Being in direct proportion, a 17.5" diameter wheel generates a greater velocity and therefore higher peening intensity than a 14" diameter wheel at the same speed.
- Horsepower of the wheel simply determines the amount of media propelled by the wheel.
- Wheel size works in conjunction with the wheel speed (π x D x N) to achieve the desired velocity and thereby the intensity. Wheelblast peening machines can be equipped with variable frequency drives to vary the wheel speed and therefore the velocity.
- Blast wheels are always mounted in a permanent and rigid location in the blast cabinet. However, blast pattern alterations, if required, are achievable by altering the control cage settings. The control cage location determines the exact point of blast media discharge from the blast wheel.

In a direct pressure nozzle system,

- The blast pressure is analogous to the wheel speed in a wheel type system. Higher blast pressures help achieve higher intensities. Blast pressure in a sophisticated gear peening system is usually monitored in a closed-loop feedback loop arrangement using a proportional regulator. Any deviation from the pre-set pressure value triggers an alarm to shut the machine down.
- The nozzle sizes determines the amount of media propelled on to the part. The target factor being relatively higher in a nozzle type system, all the energy dispensed through the blast media is directly applied towards achieving the required intensity.
- Blast nozzle movements are possible by mounting the nozzle(s) on multi-axes nozzle manipulators. These manipulators, with the assistance of servo drives and motion controllers, are capable of providing interpolated motion to the blast nozzle(s), which results in the blast nozzle following the part contour. Following the profile of a pinion or ring gear results in a consistent stand-off distance and thereby more repeatable results.

Note:
When peening a set of pinion and ring gears simultaneously, it is important that attention be given to the fact that tooth angles vary significantly within the set. Therefore, in a nozzle style system, it becomes important to rely on independent nozzle settings in order to achieve desired results on the pinion and ring gears.



This is achieved using a dedicated nozzle carriage for the ring and pinion gears respectively. Other process variables affecting peening results include:

- Media Flow Rate
- Size of media
- Consistency of size
- Media flow rate is controlled using a commercially available flow control valve (MagnaValve – manufactured by Electronics Inc.). MagnaValves are provided at the feed side of the blast wheel or at the pressure vessel outlet in case of an airblast machine.
- Vibratory Classifier classifies the peening media into oversize, right and undersize/fines. A combination of two sieves ensures that a consistent size of peening media is available for every cycle.
- Size of steel shot (or cut wire) plays an important role in determining coverage and peening cycle time. As a rule, (a) smaller size of shot allows higher stress on immediate surfaces, (b) larger sized shot provides stress in material depths and (c) diameter of shot should be less than half the smallest radius in the part.

In summary
Gear peening systems have evolved over the past years. It is now possible to accord the same sophistication to peen gears in high volumes as is available to peen an aircraft landing gear. In both cases, the thrust is on repeatability and consistency of results.

Mechanical process variables in conjunction with sophisticated yet simple controls provide great flexibility in setting the process to achieve the desired peening effect on the part.

Contemporary automotive engineers are no longer restricted to using a traditional wheelblast machine or even just an airblast machine for their peening needs. Hybrid systems offer the benefits of both systems in an integrated platform designed to cater to specific needs.

Acknowledgement: Some data and illustrations in this article have been collected and assimilated due to the joint efforts of the several Wheelabrator group companies in Europe and North America.

Kumar Balan is a Product Engineer with Wheelabrator Group Equipment/Process Design & Specification Conformance. This article was originally published in *Gear Product News* and is reprinted with permission of the author. We commend Mr. Balan for advancing proper shot peening practices to the gear industry.