Gear Noise As a Result of Nicks, Burrs and Scale—What Can Be Done

DuWayne Paul

There are many different causes of gear noise, all of them theoretically preventable. Unfortunately, the prevention methods can be costly, both in equipment and manpower. If the design of the gear and its application are appropriate, in theory all that is necessary is to have a tight control on the process of producing the finished gear. In reality, there are many variables that can cause a process, no matter how well-controlled, to deteriorate, and thus cause errors, some of which will cause a gear to produce unwanted noise when put to use.

One of the main causes of gear noise can be plus material on the active profile of one or more teeth. When a gear tooth has plus material on its active profile, it can cause gear noise, which gives the impression of a poor quality product. There are three main causes of plus material on gear teeth: nicks, burrs and heat treat scale.

Nicks

Controlling the manufacturing process to avoid nicks on gear teeth is always a hotly debated issue. By their nature, nicks are caused by part handling, usually in the green, and not by gear processing machines. Part handling is the part of the gear production process probably the most susceptible to variables and process deviation.

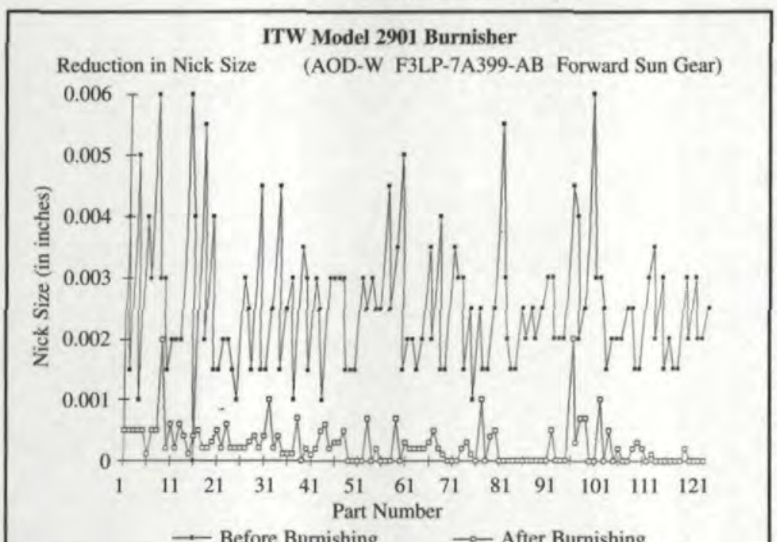

Fig. 1 — Reduction in nick size before and after burnishing.

Obviously, if the parts are subject to a great deal of manual handling, they will be vulnerable to nick creation. Most handling processes call for delicacy and attention to quality, but also fall prey to the process falling apart when production schedules are tight or the end of the shift is getting close. Any time a part in the green state is handled or moved, it is subject to nicking. This is why an automated part handling system can also create nicks.

A nick is plus material anywhere on the part. It is usually caused by gouging, which creates plus material that remains on the surface to be hardened into the part. Because of their action with other teeth, gear teeth with nicks on their active profiles cause noise. On the other hand, while a minus material gouge in the active profile is certainly not desirable, it will not create noise in most instances.

Noise from gear tooth nicks can give the impression of a poorly produced product, thus sending the wrong message to valued customers. Through experience, transmission manufacturers have found that nicks greater than .002" can cause transmission noise. If the gearbox or transmission is part of another device, such as an automobile or electric motor, it can give the customer the impression that the entire product is poorly produced.

Burrs

Burrs are raised material normally found where the involute profile meets the face. After hobbing or shaping, there are very large burrs left on the face of the gear, and the next operation is typically a face deburring and chamfering. Since this face deburring works the face of the gear, there is a natural tendency to roll a very small burr back onto the involute profile. This burr will become hardened after heat treatment, thus causing the potential for gear noise when put into use.

Heat Treat Scale

Heat treat scale is oxidized material left after the heat treating process. Left on the gear, this scale can cause noise, or if it comes loose, it can *put contamination into the transmission.*

Such small defects can cause large problems. Some nicks, burrs and heat treat scale will burnish themselves away when put into use. But the question still remains, "What happens to the debris from this natural burnishing effect, and will it cause other problems?" What most likely will happen is contamination of the transmission, causing future problems.

Solutions for Nicks

So what can be done? First of all, a tolerance for nicks has to be developed. Determine what level of nick causes a problem. If the product is such that gear noise is not an issue, then nothing needs to be done. On the other hand, if a .002" nick on the active profile causes noise problems, then something below that number should be the tolerance, and procedures should be implemented to reduce the occurrence of larger ones. The methods of reducing nicks can take many shapes and forms and can cost varying amounts.

Part Handling. Obviously, the first way to reduce nicks is to instill careful and delicate part handling on the green side of gear production. Use every method of employee training possible and study equipment variables to eliminate unnecessary moving of parts. This method takes constant micromanagement and intense attention to detail.

Form Finish Grinding. Beyond this, there are in-line equipment options that can be utilized. One is using a form finish grinding process that will touch all of the active profiles of the tooth and deburr the tooth ends. This can give the part an excellent finish and assure a closely toleranced gear. The downside is that it takes a highly accurate (and expensive) grinder and is too slow when doing gears in quantity, thus making it a very costly process as a final operation before inspection.

Hard Honing. Yet another method is to use hard honing to remove nicks and burrs and give the gear a much improved tooth finish. An advantage of honing is the potential ability to correct errors in the gear tooth profile, lead, spacing, etc. On the other hand, this approach again takes a fairly expensive piece of equipment and a considerable amount of tooling. As with grinding, wheel dressing is required and can sometimes add considerably to the costs. Honing will essentially produce a good gear with no nicks or burrs and a very good tooth surface, but it can be slow and very costly as a method of removing plus material before final inspection.

Shaving. Shaving is a third choice as a finishing operation in the hard condition. As with honing and grinding, an expensive piece of equipment is required, and the tooling cost can be significant. The advantages are that it can correct errors in tooth profile, lead and spacing, impart a crowned tooth form and remove very large nicks.

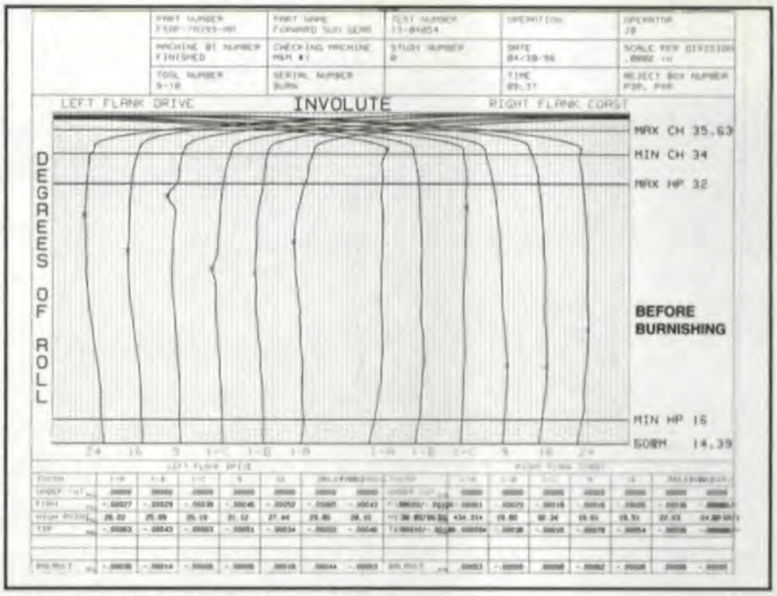

Fig. 2 — Tooth profile before burnishing.

Burnishing. A fourth method is to burnish the gears. It is very effective in dealing with all three types of plus material at a cost-efficient rate. Burnishing is typically done by capturing the gear between burnishing dies and rolling it in tight mesh with them. Most of the time this action is accompanied by oscillation of the gear in a parallel plane with the bore of the burnishing dies and flooding the work area with coolant. The oscillation allows for maximum burnishing effect, and the coolant prolongs tool life. Burnishing equipment usually costs half as much as a finish grinder or honing machine. The initial cost of burnishing dies may be higher than the tooling cost for grinding, honing or shaving. However, the life of burnishing dies is significantly longer (typically 500,000–750,000 cycles), and there is no ongoing maintenance, such as wheel dressing, making the total tooling cost significantly less.

The Gerac Burnishing System (patented by ITW) incorporates the use of three separate dies acting on the piece part, each of which works a different part of the gear tooth. Each of the three different profile dies operates on its own heavy duty spindle in a triangular configuration. The three dies have the following functions:

Burnishing Die A operates at a lower pressure angle than the operating pressure angle of the piece part.

Burnishing Die B has a shortened base pitch. This causes the burnishing die to come in contact with the tips of the gear teeth, jarring loose particles off the tip and flattening surface imperfections.

Burnishing Die C operates at a higher pressure angle than the operating pressure angle range of the piece part.

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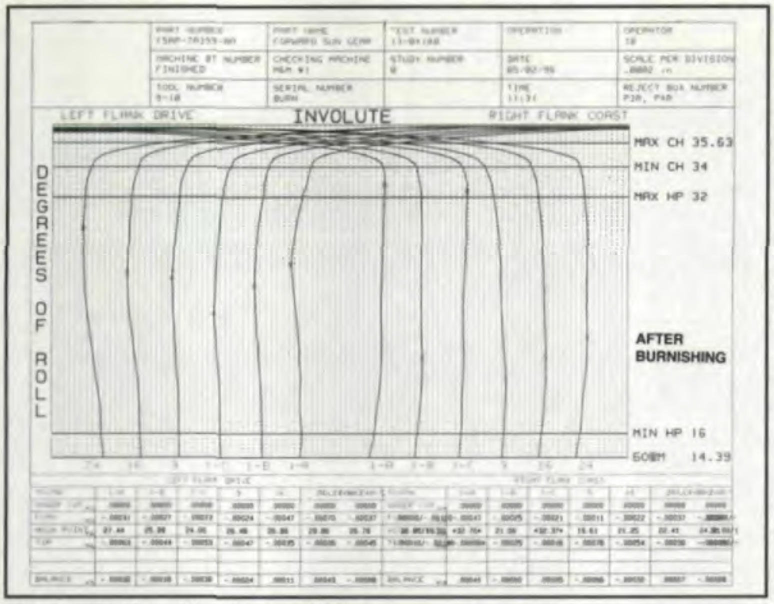

Fig. 3 — Tooth profile after burnishing.

The purpose of Dies A and C is to have a sliding action through the piece part's operating pressure angle range. The "rubbing" action wears the surface of the tooth to improve the finish and to remove nicks, burrs and scale.

The "arborless" system patented by ITW meshes the workpiece gear under pressure between the three burnishing dies, one of which is powered. In addition, a reciprocating oscillatory mechanism moves the workpiece in an oscillation movement parallel to its axis. Two of the burnishing die spindles have automatic spherical positioning to equally distribute the burnishing force across a straight, crowned or tapered tooth configuration.

Burnishing is not an abrasive method or metal removing process, and therefore does not change the tooth profile. It cannot correct errors in tooth profile, lead, spacing or damage where a large portion of the tooth has been rolled over. It is more of a "rubbing action," which takes the plus material and either knocks it off the tooth or smooths it back into the area from which it came. It is highly appropriate for high-production situations and can also be adapted to lower production runs by the use of tooling changeovers. It operates on very short cycle times (5–10 seconds) and can be very cost-efficient on a cost-per-piece basis.

Fig. 1 is a chart representing the results of a nick reduction study done with an ITW Heartland Model 2901 burnisher. In this study (done at a customer facility), 125 gears were inspected for nicks, burnished, and then inspected again to analyze the reduction in nick size.

Figs. 2 and 3 are the result of a study done to analyze the effects an ITW burnisher has on the tooth profile (involute).

Grinding, honing or burnishing all will remove plus material on gear teeth and improve the surface finish of the gear. Which of them would work best in a given situation should be determined by specifications, cycle times and budgets.

100% Inspection

In truth, the best method of absolutely ensuring that gear teeth are free of plus material is to inspect 100% of the gears produced. Many times this is not feasible or not considered necessary. On the other hand, the part of gear production that causes nicks is the hardest part of the process to control. If the lead is unwinding during heat treating, you can catch it by doing process inspection and making corrections. If the profile is not in specification, you can discover it by verifying setup and by process inspection, and then make your adjustments to the hob. But in the case of plus material induced either in the green or in heat treatment, there is no proven method of making sure every gear does not have plus material. Process inspection will not suffice because unless 100% inspection is utilized, some gears with potential nicks, burrs or scale will not be checked.

If 100% inspection is used, you do have options as to how to use equipment for nick reduction or nick elimination. One option is to put all gears through the equipment chosen before inspection. The other is to further process only those rejected for nicks, burrs or scale. Quite often, hand de-nicking and deburring with hand-held grinders is used to remove this material after inspection. This can work, but leaves much room for error. For instance, the hand de-nicking can cause other changes to the gear tooth profile or other gear geometry features. In either case, inspection is the only sure way to know that gears are going into assembly without plus material that is out of tolerance. Keep in mind that all gears which are inspected should be washed and dried before inspection.

The best quality possible is what we are all after in gear manufacturing processes and products. The most frustrating gear defects to control are nicks, burrs and scale. Your processes can produce a geometrically perfect gear, but if it has a nick or burr of .0015" which causes noise, the product quality has just been downgraded by the end user. If nicks, burrs and scale are not tolerable in the end product, methods such as those discussed in this article must be used to deal with them. ○

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