

# Excellence with No Exception

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*Forest City Gear operates a wide variety of state-of-the-art gearcutting equipment.*

From tainted food products to malfunctioning car parts, corporate reputations have been damaged and consumers have become more cautious due to a plethora of recalls. So, when I visited Forest City Gear (FCG) to report on the production behind their standard gears, it wasn't surprising when the story angle emphasized the importance of quality.

FCG's CEO Fred Young started the conversation with an explanation of how the silence of a gear is related to various characteristics, in particular:

- The number of teeth in contact between mating gears, which is known as the contact ratio of a gear set.
- Finished gear quality of individual gear elements.
- Material selection.
- Design of the gears and gearbox stability.

Young also emphasized the importance of understanding the four parameters of a gear tooth that contribute to gear noise; for example, affect the contact ratio and the resulting Transimission Error (TE). The lower the TE, the quieter the gear:

- Involute: The quality of the curved surface (involute) of teeth of mating gears is one of the controlling factors of TE. A high-quality part with low TE results in constant angular velocity during the rotation of mating gears.
- Lead quality or straightness of the tooth in the axial plane contributes to constant contact along the facewidth of the mating gears.
- Adjacent tooth index variation affects the uniformity of noise level along accumulated index variables.
- Pitch diameter run-out, or eccentricity from the centerline of the gear, creates its own noise signature.

"A lot of people don't understand the relationships of the individual parameters to gear noise," says Young. "If they don't understand them, they lack the understanding of the significance of each one to the noise signature, the vibration, and the longevity of the gear."

Noise reduction becomes more critical in certain applications, for example, an X-ray or MRI machine. Young explains, "It's already traumatic for the patient in those situations, and it's critical to do everything possible to reduce the noise signature."

## Room for Error

If there is a problem in the involute profile of the gear, a constant angular velocity/movement of the gear is not achieved, and the changes in speed of movement excite noise. "Being able to control errors very accurately and to minimum levels may remove the necessity of gear grinding afterwards," says Young. "Paying attention to the gear quality at the different manufacturing stages as it is produced, and monitoring the quality along each of these parameters allows, us to achieve a much quieter gear."

Lead error refers to the amount of area gears running against each other take up in space. It involves the shafts on which the gears are located not being perfectly parallel with each other, causing the face of the gears to contact on various points. The lack of load sharing across the facewidth of the mating gear results in increased noise and lower load carrying capability.



*At various stations around the shop, gear measuring is done in-process for quality validation.*

Transmission error is a noise exciter generator that is also affected by the index variation. "A gear with 360 teeth, for example, should have each tooth one degree apart from the adjacent tooth and, theoretically, a fixed duration in space into which each tooth should enter," explains Young. "When the teeth of gears are not at the appropriate location in space, there is nothing for the gear tooth to contact, or it contacts the mating tooth too soon, thus creating a high contact stress and considerable noise. This could also lead to pitting issues."

Young also explains if there is involute plus profile error at the tip, more noise is produced. Consequently, designers will incorporate an involute modification referred to as tip relief.

Each parameter, if not inspected adequately and correctly, can produce challenges in the quality of the gear.

"It's important to have the proper inspection equipment in order to know what is happening at each of the parameters," says Young. "By constantly monitoring these parameters, we can fine-tune the production of the gear to the point where we can reduce noise to a minimum."

## Quality Cutting Tools

A lot of gear manufacturers try to save money by buying cutting tools that are less expensive, but they are not accurate. Cheaper cutting tools run the risk of cutting fewer pieces and a better cutter also means a quieter gear with lower noise, because of improved involute quality.

"The involute error is largely a factor of the cutting tool. Finding a good cutting tool and correctly re-sharpening it is important. If the cutting tools are not sharpened correctly, an increase in errors can occur," Young points out.



*Diamond grinding wheels are used to keep the cutting tools and gear hobs in optimum condition.*

Taking a little extra time to make sure the machine is set up properly also helps reduce the noise. In the hobbing process, you shift the hob cutter to an unused part after each part is cut. Moving the cutter frequently during the run of a production lot minimizes the wear on the cutter, which in turn reduces the noise on the gear because a consistent involute is achieved.

"We are also doing something called diagonal hobbing, where we move across the cutting tool to get more cutting surfaces that are engaged," explains Young. "The finish and accuracy on the tooth becomes much better."

## The Importance of Quality Inspection & Education

Young points out that many gear manufacturers' inspection capabilities are highly inadequate, due to a lack of up-to-date and modern inspection equipment.

"The quiet gear is easy for us to achieve because we invest so much money into high-end, modern gear inspection equipment," says Young. "Another value of the inspection equipment is that we are able to monitor each one of those parameters and teach our people in the factory the importance of maintaining high levels of accuracy on each of those parameters."

He also stresses the importance of educating his employees on how these different errors influence noise, and what each employee can do to make corrections that will reduce those errors dramatically.

## Value Stream Mapping

FCG develops standard processes to look at the steps involved in producing, quoting, and finding gear materials in the most expeditious way. "Right from the start, with new jobs we ask 'How are we going to produce this? Where can it go wrong?' How are we going to make it better than the other guy?" explains Young.

FCG asks its customers for samples of what they have purchased in the past so the gearmaker can find visual clues on craftsmanship and workmanship. "In some instances it's strikingly obvious," says Young. "We can immediately see something that is really high quality versus something that is very low quality."



*While most gears produced at Forest City Gear are metal, the company also machines various thermoplastic and composite materials, such as this helical plastic gear.*

Inaccuracies occur because the previous supplier does not have the proper or high-quality inspection equipment needed to find certain flaws within the gears. Sometimes, after cutting the gear, some manufacturers will heat treat the gear and fail to look for any distortions or inaccuracies that may have occurred during the heat-treatment process.

"We are looking at quality continuously and making sure that every operation builds on the proceeding operations to end up with something that is extraordinary accurate, and hope, better than the quality that the customer specified on their print," states Young.

Young concludes that quality products result from manufacturers who have confidence in what they are producing. "The better the inspection equipment you have – and the more attention you pay to that on a continual basis across the board – the less susceptible you are to letting something that's defective get out your back door," says Young.

As quality seems to be a decaying issue for some manufacturers, FCG continues to prove their excellence with no exceptions.

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