Roughness measurement tips: 2- vs. 5-micron

Depending on operating conditions and the flank surface being measured, there are times a 2-micron tip can measure a significant difference compared to a 5-micron radius tip.

I’ve written three articles on gear flank roughness measurement for this magazine (Materials Matter; January 2016 and February 2016, and an issue-focus article in January 2019). Those articles gave guidance on the setup and measurement of the roughness parameters (Ra, Rz, Rmr, etc.), the complete roughness diagram needed to specify roughness on a gear drawing (the check mark), and the shop floor contact stylus profilometer. It was a goal of those articles to provide the reader with a basic understanding of roughness and its measurement such that robust and reproducible profilometry of gear flanks could be carried out on the shop floor.

So, how about a follow up article on roughness measurement tips? On the other hand, how about several articles on tips? Wait, you say! If I had done my job properly in my earlier columns, why would you need several articles on roughness tips?

Well, I am not talking about pragmatic shop floor wisdom on roughness or folksy stories on profilometry. I am talking about the contact stylus, specifically the diamond 2- or 5-micron tip stylus. By definition, a 2- or 5-micron tip means the radius of the cone shaped diamond mounted at 90 degrees to the plane of the stylus. See Figure 1 for an example of a 2-micron diamond tip.

This tip is what touches the flank surface being measured and is the most delicate component in what otherwise is a very rugged measurement system. Obviously, a 2-micron tip is much more delicate and costly compared to a 5-micron tip. So, it would be great if ground gear manufacturers could all use 5-micron tips. Fortunately, only for the measurement of surface waviness do you use a “skidless” probe. For the measurement of the R-parameters, you can use a skidded probe. Skidless probes are more fragile than skidded probes. In all examples discussed below, both sizes of styli used the more robust skidded probes. Nevertheless, the 2-micron skidded probe is still very delicate and expensive. It would be advisable to minimize its use on a shop floor.

The later articles in this series on “tips” will discuss the use of profilometer calibration pads and checking the condition of a diamond tip stylus.

2-MICRON VERSUS 5-MICRON TIPS

Today, precision ground gears typically have Ra’s between 0.2 µm to 0.8 µm. Superfinished gears will be even smoother. Therefore, by and large, precision gear flank roughness measurement should use the delicate 2-micron tip. However, there is a little wiggle room here. ISO-3274 notes that for surfaces of Ra > 0.5 µm and < 2 µm, a 5-micron tip can be used without significant differences in the measured results. Similarly, if all parties agree, and it is documented in the check mark diagram or on the gear drawing, the use of a 5-micron tip is acceptable on surfaces of Ra < 0.5 µm, within limits. See below.

Will a 5-micron tip used on a flank of Ra > 0.5 and < 2 µm result in significantly different roughness results compared to a 2-micron tip? In terms of gear performance, will the differences in the measured results equate to a gear performance difference related to, say, lubrication or surface distress? Let us look at the difference in roughness measurement results first and discuss the impact on gear performance second.

ROUGHNESS COMPARISON; Ra 0.3 – 0.4 µm

I was involved in a major study where hundreds of flank measurements were taken on similar precision ground gears using 2- and 5-micron tip styli. The finish specification on the tooth flanks was Ra < 0.5 µm.

All measurements were taken following ISO specifications. Measurements on the gears were taken on identified flanks and multiple roughness measurements per flank. The averaged roughness measurements are shown in Table 1.

Depending on the machining techniques used, I expect ground tooth flank surface roughness will vary 20 percent from one area to the next on a single tooth or from tooth to tooth on a gear, or from gear to gear in a series production run. The variation in the results of Table 1 are indicative of well ground gears with very consistent flank finishes. Regarding performance, these are industrial gears.
operating at steady state loads and speeds. I would predict equal performance in terms of lubrication or surface distress if presented with the roughness results in Table 1.

In this case, the flank roughness ranged for both styli from $Ra > 0.34 \text{ to } < 0.41 \mu m$ and was considered very consistent. There is little difference in the roughness measurement results when using a 5-micron tip versus a 2-micron tip. In addition, no difference in gear performance difference was predicted. Conclusion: Document the stylus type and use the 5-micron tip on these gears.

SMOOTHER FLANK FINISHES

What about finishes smoother than $Ra < 0.3 \mu m$? Remember, precision grinding now routinely achieves $Ra \approx 0.15 - 0.25 \mu m$. The temptation would be to push the use of a more durable 5-micron probe in these circumstances. Will there be a significant difference in roughness measurement when using a 2-micron versus a 5-micron tip on such a finely finished surface? How much of a difference will there be, and can it influence gear performance?

In one study of gears targeted for finishes of $Ra < 0.15 \mu m$, an issue arose regarding the measured roughness results of the flanks and the gear performance came into question. Initial testing of the finished gears showed occasional scuffing, which was not predicted, and was unacceptable. The operating conditions were considered high load and high speed.

Gear testing was stopped and the flank finishes were re-measured after it was discovered that some of the gears had been measured for roughness using a 5-micron tip stylus. The roughness results are averaged in Table 2. All measurements were taken following ISO specifications except one profilometer used a 2-micron tip and one used a 5-micron tip.

In the case above, the tip size shows a significant difference in the measured surface roughness. In addition, in testing, the gears were experiencing occasional scuffing. The solution was to remanufacture the gears to the specified $Ra < 0.15 \mu m$ flank finish, using the 2-micron tip to measure flank roughness. The resumption of testing produced acceptable results. In this case, the difference in tip radius was significant in being able to accurately measure the flank roughness and to be able to predict gear performance.

CONCLUSION

There is a point in the degree of smoothness where the use of a 2-micron tip can measure a significant difference compared to a 5-micron radius tip. Moreover, under operating conditions such as high speed and high load, this difference can be significant in predicting gear performance. Use of a 2-micron tip is recommended for flank finishes of $Ra < 0.3 \mu m$.

ABOUT THE AUTHOR

Mark Michaud, REM Technical Fellow of REM Surface Engineering, is the inventor and pioneer of REM Surface Engineering’s chemically accelerated finishing technology. He has authored numerous patents and technical papers and served a term on the AGMA Board of Directors. He continues to serve as vice chair of the AGMA Aerospace Committee, as a member of the AGMA Wind Turbine Committee and as a shadow delegate on the ISO 61400-4 Wind Turbine Committee. He can be reached at mmichaud@remchem.com.