Practical and Technical Challenges of TWT Grid Spherical Radius Characterization

Timothy S. Dyer, President
Elcon Precision LLC
San Jose, California, 95133

Abstract:

This paper examines the capability and limitations of advanced optical CMMs to measure the spherical radius (SR) of titanium hemispheres with variable diameter and surface finish. Prior to optical CMMs, optical comparators were used to characterize TWT grid spherical radius. However, due to increasing quality data requirements, most of our customers now use optical CMMs to quantify TWT spherical radius. These devices measure spherical radius indirectly and there is no offical standard. Using precision manufactured hemispheres as a proxy for TWT control and focus grids, we simulated characterizing grids of variable Measurement Difficulty Factor (MDF). MDF is the ratio of the spherical radius of the TWT grid divided by the grid chord length. The Z-axis or height determination for grid dimensional characterization is primarily influenced by surface finish and by the measurements taken furthest out on the diameter from the apex of the part. The outside diameter of a TWT grid is challenging to characterize since the grid spherical radius changes from target value to infinity at the grid flange. Using a Mitutoyo QV404 Apex optical CMM, we investigated SR characterization using multiple measurement patterns, number of locations, the pattern type and MDF. The results from the pattern examination show that there is no significant relationship between pattern type and SR accuracy. The results also show that a dull surface gives a smaller deviation (difference between true value and measurement) on the height measurement compared to the shiny surface. The results also show a larger SR gives a smaller deviation for the Z-axis measurement. Measurements taken too far along the grid radius are less accurate since the optical CMM is not measuring height orthogonal to the grid surface. attendees with a good source of documentation.

Keywords: Spherical radius; Z-axis height measurement; TWT; Optical CMM; Hemisphere.

Introduction

Currently, Optical CMMs are used to characterize the extremely fragile TWT grids manufactured by Elcon Precision since they are non-contact devices. Elcon Precision uses a Mitutoyo Apex QV404 outfitted with 200X and 400X objective lenses for characterization of etched TWT grid spherical radius, diameter, and bar withs. Per the manufacturers specification, the QV404 Apex tool has an X, Y, and Z measurement resolution of 1.2 microns. TWT grids are challenging for spherical radius characterization, since they are mostly open meshes, with optical transparency ranging from 20% to 70%. To simplify interpretation of spherical radius data, we purchased certified half spheres made out of polished and anodized Titanium. Our spheres were measured using a calibration stylus profilometer to establish their true spherical radius. Measurement difficult factor, spherical radius divided by cord length, can be changed by intentionally by measuring grids of increasing diameter on our Titanium hemispheres of different spherical radius. For small diameter grids, measurement lighting is traditional since most of the data points used to quantify spherical radius are right below the CMM objective lens, nearly orthogonal to the optic axis of the CMM. For large diameter grids, lighting becomes difficult on the outside diameter of the as the arc angle of the grid light reflected back into the CMM exceeds 45 degrees. Outside 45 degrees, or 90 degrees absolute arc, reflected light off the sphere is reduced by approximately 50%, therefore complicating measurements. Our optical CMM is equipped with a parabolic mirror to help focus more light on OD features. For this study, we made adjustments to the parabolic lens to maximize light reflected back into the optical axis of our CMM. In addition, we attempted a variety of measurement point patterns on the sphere surface to determine if edge or center weighted measurements altered measured spherical radius values.

Experimental Results I: Polished Half-Spheres

We started our testing using polished Titanium hemispheres. First, comparing the results of the titanium half balls with SR 0.503” and 0.200” (both have a shiny surface finish), the results from the SR 0.503” in Figures 1 and 2, respectively, show that the deviation between the measurement and the hand calculation is less than 0.001” up to 55 degrees from the sphere apex. After about 60 degrees, the Z-axis tends to have a larger deviation (> 0.001”). The results from the SR 0.200” specimen shows that the deviation between the measurement and the hand calculation is random and may possibly be due to the small SR dimension. While more parts with different SRs would paint a clearer picture, these two titanium hemisphere parts show that the bigger SR gives a more accurate SR result.

Experimental Results II: Textured Half-Spheres

For the second part of the experiment, we decided to add the variable of surface finish to our measurement study. In practicality, we have found that Hafnium, Copper, and Molybdenum TWT grids all have very different surface reflectivity. When comparing the titanium half balls of SR

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0.503” (shiny surface) and 0.375” (anodized dull surface) shows that the dull surface yields more accurate results.

Our results demonstrate that the larger sized parts yield more accurate results. However, the SR 0.503” shiny surface part

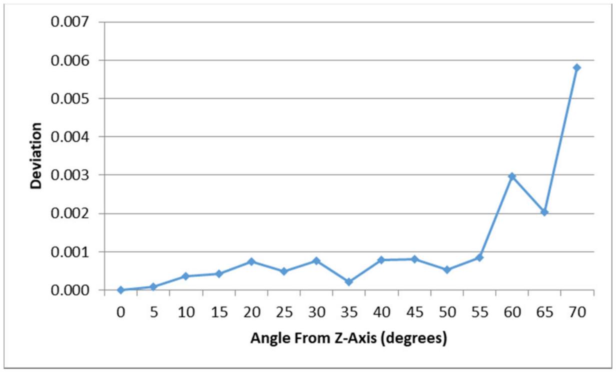

Figure 1. 0.503” Diameter polished Ti dome SR deviation from ideal versus inspection angle of incidence

and the smaller SR 0.375” dull surface part yield the same results. We can conclude that the dull surface gives a more accurate result than the shiny surface since we’d expect the smaller part to yield worse results if the surface finishes were the same.

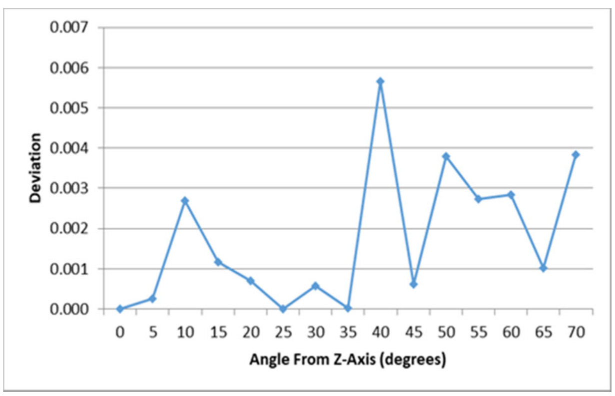

Figure 2. 0.200” Diameter polished Ti dome SR deviation from ideal versus inspection angle of incidence

Experimental Results III: Measurement Patterns

The results from the examination of the dull surface SR 0.375” specimen shows there is no significant relationship between pattern types and SR result. Examples of measurement patterns are presented in Figure 3, below.

However, the results show that the smaller MDF is more accurate (smaller difference between true value and measurement) than the larger MDF. On the other hand, the smaller MDF will be less precise (standard deviation) than the larger MDF. The results are summarized in the Table 1 below.

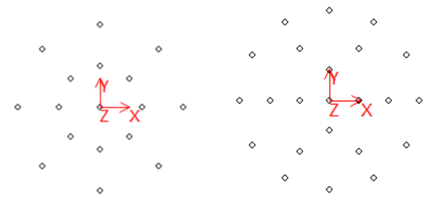

Figure 3. Examples of Spherical Radius Characterization Measurement Patterns

Table 1: MDF Impact for SR 0.375” titanium half ball.

MDF	Standard Deviation	Deviation From True
0.8	0.00046	0.00055
1.2	0.00025	0.00073
1.7	0.00024	0.00078

Discussion and Conclusions

For the shiny surface pattern examination, comparing how the method of measuring SR affects SR accuracy, it shows that there is no significant relationship between pattern type and SR accuracy. For this examination, the SR 0.503” part with a pattern of 4 rings/8 points each ring, gives an unexplainable result and is excluded from the results in this report. Now looking at the SR and MDF, the deviation of SR 0.503” at MDF 1.2 is 0.01331” and MDF 1.7 is 0.02097” and the deviation of SR 0.200” at MDF 1.2 is 0.00259” and MDF 1.7 is 0.02092”. This shows that the smaller MDF and the smaller SR yields better accuracy. On the other hand, the standard deviation of SR 0.503” at MDF 1.2 is 0.00466” and MDF 1.7 is 0.00110” while the standard deviation of SR 0.200” at MDF 1.2 is 0.00287” and MDF 1.7 is 0.00603”. For the SR 0.200”, it shows that the smaller MDF gives more precise measurements; however, the SR 0.503” shows that the larger MDF gives more precise measurements.

Overall, for the z-axis examination, SR 0.375” and SR 0.503” produce good results as long as the measurement point is not greater than 55 degrees from the sphere apex. However, SR 0.200” produces random results that can’t be explained from the current data set. It is recommended that all measurements be made such that the last measurement point is at 55 degrees. It is also recommended that the surface be made as dull as possible since dull surfaces yield better results.

For the spherical radius examination using optical CMMs, the measurement pattern does not have a significant impact on the machine’s capability. For the dull surface, the smaller MDF grid produces more accurate spherical radius results than a shiny surface. On the other hand, the larger MDF yields less precise measurements overall. When comparing the SR and the MDF for the shiny surfaces, the smaller MDF and SR produce more accurate results. Overall, optical comparators provide an easier method for spherical radius characterization than optical CMMs independent of surface finish and MDF.