"Profile Tolerancing: Proof of Compliance -vs- Process Feedback"

Dr. Greg Hetland, International Institute of GD&T, USA

Abstract: Profile tolerancing is used more aggressively today throughout all discrete part manufacturing companies than ever before as it more precisely represents the mechanical designer's true functional intent for surface geometries. The perceived challenges seem to be in providing value-add measurement within the metrology / inspection group for "proof of compliance" as well as to the manufacturing group for "process feedback." In addition, providing low uncertainty measurement data back to the original designers for optimization of respective tolerances in their design through tolerancing optimization and stack up analysis. In most cases the analysis (analytical algorithms used) and the graphical representation provided would be completely different as the users are looking for different things. This presentation will make visible the different methods of analysis and provide insights as to why they would be different and how to utilize the tools to help manufacturing optimize their processes quicker to improve lead times and reduce costs and also increase confidence within the design and measurement environments at significantly reduced cost.

Implications to Technical & Business Disciplines:

- **Designers:** The desigers are more agressively using profile tolerancing today than ever as it better represents the surface geometries they are actually trying to control. Fundamentally what the designers are looking for is all of the features on the part to simultaneously lie within their respective tolerance zones. The tolerances can be larger in some areas and smaller in others but they all must simultaneously lie within their respective tolerance zones. If this is true then the only way to accomplish this, for surface geometries, would be to utilize profile tolerancing. It is essential that designers clearly define their explicite design intent through geometric callouts that can be defended mathematically. This presentation will make visible shortcoming of linear tolerancing and the robust and defendable strength of profile tolerancing.

- **Manufacturing:** Historically manufacturing has not trusted measurement results coming from the metrology group as it has not matched what they speculated it should look like. In addition the measurement data provided to manufacturing has been difficult to interpret and of limited benefit to manufacturing to know how to correct for the problem they are trying to fix. In fact we make many attempts to fix what we believe is the problem only to then be told there are other implications that were not made visible in the previous analysis. This presenation will make visible how measurement data can be analyzed to more efffectively prove the product being produced better conforms to the product specification then the metrologists believe. In addition this presentation will show how to more optimally analyze profile results so the information is of more value to manufacturing to expedite optimizing their manufacturing processes.

- **Metrology:** Historically analytical softwares provided with CMM's (contact & non-contact) have utilized algorithms most commonly referred to as "Best Fit," however the best fit algorithms were for the most part based on least-squares fitting which fundamentally averaged all the results. This means that if the metrologists only objective was to figure out a way for their results to be more repeatable and reproducible (GR&R) then what better way to accomplish this then to average all the results. Least-Squares fitting also does not take into consideration the tolerance which means by itself would not have the ability to optimzie the fit(s). For profile tolerancing the optimal algorithm to use would be a fitting algorithm which would optimze the fit within the respective tolerance zone(s) and proportionately optimize all related profile tolerance results simultaneously as a ratio of their respective tolerances. This presentation will make visible the shortcomings of least-squares / best fit algorihims and will also make visible the strength of proportionatly optimizing algorithms for proof of compliance.

- **Business:** To optimize our return on investment is essentail that we ensure all our technical disciplies have the critical skill-sets to preform their jobs at an optimal level. In addition is the critical we provide the necessary tools and equipment essential for all employees to achieve the goals and challenges we put in front of them. As we look ahead at some of the technology constrants in manufacturing enterprises the one common thing easy to agree on is that tolerances on critical features will continue to get tighter and in may cases the compontents and features within these components will get smaller. This brings natural challenges to the business model. This presentation will make visible some of the historical technical challenges that have resulted in negatively impacting timelines and budgets and will highlight key areas of opportunity for future cost and timeline reductions that have a positive impact on the business model.