

Sigmetrix: Providing Variation Management within the Digital Thread

Key Takeaways

Managing variation in parts and assemblies that make up products is a valuable competency that bridges product development and manufacturing processes.

Model-based definition (MBD) and model-based enterprise require the application of dimensioning and tolerancing specifications to shift left, earlier in the lifecycle, the resulting benefits to an organization can be dramatic, lowering cost, improving quality and shortening time to market.

Companies continue to struggle to achieve success in their digital transformation programs even as they adopt new agile-based deployment methodologies because they don't understand the impact of variation. Incorporating variation management into the digital thread helps close the loop putting digital transformation programs on track.

Successful variation management is a journey, and Sigmetrix has tools, platforms, and knowledge to guide their customers to success.

Introduction

Delivering manufactured products to market, especially in high volume or those with a high cost of failure (such as aerospace parts), is a complex process that drives companies to manage variation better. The product lifecycle from idea to concept definition, to design, to realization, to in-service operation, and end of life, is simple at a high level, but enormously complex in detail.¹ A critical transition where detail really matters is when the product moves from being a virtual design to being physically instantiated. At this point variation becomes real. Variation resulting from manufacturing and assembly processes requires engineers to specify acceptable tolerance limits, optimal dimensioning schemes, and robust designs to ensure manufacturing effectiveness and product performance. Holding tolerances tighter can reduce the variation but often at high cost. Optimizing performance while minimizing cost can be achieved by maintaining tight tolerances only for critical-to-function features and allowing more variation where the end product is not compromised.

¹ Research for this commentary was partially supported by Sigmetrix

Specifying and Managing Variation

Manufactured parts, assemblies, modules, and products all have physical variation. During the design phase, CAD models are developed with nominal dimensions and idealized assembly conditions. Tolerances are applied to geometric features, numerically on the dimensions, geometrically using GD&T or ISO/GPS symbols, and with notes specifying the required precision. Historically tolerances were determined offline with hand calculation and spreadsheets, then applied to drawings during the drafting stage of the design process. More recently 3D CAD software has added a capability known as product manufacturing information (PMI) that enables the creation of dimensions, GD&T, notes, and other related information directly on solid models. PMI data associated to the solid model provides several benefits.

- Design engineers apply PMI while they are focused on the design rather than later in the process. This way tolerances and dimensions are aligned with product functional requirements reducing the need for design changes and adding robustness to the design.
- PMI is readable by software applications. Automated 2D drawing creation, product simulation, tolerance stack-up analysis, manufacturing process selection and production planning, CNC and CMM programming, and automated process planning can all leverage PMI enabling parallelization of work, shortening product development timelines, and reducing manual data transcription errors.
- Releasing models with PMI shortens the design release timeline when compared to creating 3D models and 2D drawings in a serial process.
- Knowledge captured within PMI is accessible as part of a digital thread and easily reused.

In many organizations Design for Variation is learned on the job. Application of GD&T principles is complex and manufacturing planning is often company specific which means only the most experienced design engineers can develop a robust part and product variation management strategy. As PMI capabilities have been adopted, knowledge-based tools have been added to guide design engineers in the application of GD&T and the most sophisticated tools operate in real-time and are extensible enabling the addition of custom PMI validation rules. This advisor approach to software helps less experienced design engineers develop and execute a reasonable variation strategy.

As GD&T (including ISO GPS) is applied, tolerance stack-up analyses can be executed showing how variation affects assemblies and products. For example, when a series of parts form a complex connection linkage, bolt hole alignment and linkage sizes can become problematic making assembly difficult and impact the product's performance. Some assemblies may appear to be comprised of a simple linear stack of prismatic parts but could contain unexpected sources of rotational variation that result in critical product failure. Advanced stack-up analysis will identify the contributors and sensitivity to the variation of each dimension and enable tolerances to be adjusted increasing the probability that the holes line up and the linkage works. Furthermore, non-critical tolerances can be relaxed making parts easier to manufacture, lowering costs. Manufacturing planning can then easily estimate the part cost to determine product profitability and make adjustments before expensive sample parts or tooling are ordered. Furthermore, due to manufacturing processes, part dimensions are never perfect. Process simulations can generate statistical models of part variation and calculate the impact on assembly processes. As parts vary within their ranges, what happens when parts at their minimum tolerance are combined with parts at their maximum tolerance? Statistically this will happen, and it must be analyzed and accounted for. Again, tolerance analysis software will find parts and features that contribute to the variation enabling design improvements, better decisions, and more efficient production.

Why it Matters

Predicting variation using PMI shortens timelines for prototype and production design and reduces expensive production surprises reducing time to market. Minimizing cost while meeting product performance and quality requirements are core metrics that companies must manage to be successful. Variation affects cost and performance so it must be managed. By actively managing variation as part of a digital thread, controlling it where necessary, and relaxing tolerances where possible is the best way to ensure a balanced approach to the quality versus cost equation.

Historically tolerance stack-up analysis was a manual process done by the most experienced engineers. Unfortunately, this manual process often leads to discrepancies due to the bias and understanding of different engineers, leading to additional rework. Furthermore, as experienced staff retire and cost and time pressures increase, resources to support checking become scarce so checking and validation processes suffer. By using a software program to check PMI, the process becomes automated and repeatable reducing the need for specialized skills. Encoding the expert knowledge as custom rules in the software captures institutional knowledge and enables experts to develop further knowledge or address other vexing problems.

Sigmatrrix

Sigmatrrix is a global leader in dimensioning and tolerancing solutions, specializing in mechanical variation management. For over 30 years, they have provided comprehensive software solutions for tolerance analysis, geometric dimensioning and tolerancing (GD&T), and geometric product specification (GPS). Their tools integrate seamlessly with major CAD systems, enabling efficient product design, manufacturing, inspection, and assembly processes. Sigmatrrix's expertise helps companies across various industries, including aerospace, automotive, electronics, and medical devices, to create innovative, high-quality products while reducing costs, time to market, and ensuring robustness of designs.

Sigmatrrix has, in many ways, been waiting for the world to catch up with them. GD&T Advisor, CETOL 6 σ , and EZTOL work with the PMI capabilities within the leading CAD applications including Creo, CATIA, NX, and SOLIDWORKS. GD&T Advisor helps CAD users get GD&T callouts correct, and CETOL & EZTOL leverage PMI data to perform sophisticated tolerance analyses that improve design and manufacturing planning decisions.

Their newest solution, VariSight, with an expected release in the fourth quarter of 2024, will enable companies to expand their usage in multiple dimensions. Data from their applications will be captured in a database enabling sophisticated reporting and analysis. Integrations and Microservices will enable connectivity to enterprise and shopfloor systems and tools extending enterprise digital threads.

While PMI capabilities have been around for a long time, few companies have institutionalized their use even as they have made great use of CETOL and EZTOL within their digital threads. This is starting to change and as more PMI data is created the opportunity to do existing manual analyses faster is realized, and new analyses already encoded in CETOL and EZTOL become possible. This extension to the digital thread is critical to achieving digital transformation goals.

A unique element of Sigmatrrix's product line is their training and education program. While technology is critical to improving variation management, a deeper understanding is needed to effectively incorporate it into an organization or digital thread. To ensure customers have access to this knowledge Sigmatrrix has a series of online courses to educate people, and expert consultants that help companies address variation issues and define and implement a variation management strategy. These services

provide Sigmetrix with additional value and help customers become more efficient and effective as they grow in maturity.

Digital Transformation Enabled by Variation Management

A critical element missing from many digital transformation programs is addressing variation during design processes. Many believe that simply creating a 3D model is sufficient to support the model-based enterprise, especially when PMI is added. Companies are finding that applying PMI that is properly associated to maximize reusability in the digital thread is not easy. One aspect of variation management is helping with that process, but it goes far beyond. Understanding how variation is introduced and controlled allows engineers to better understand what PMI should be added and what tolerances should be applied to meet product requirements by balancing performance and cost.

At CIMdata we see proper variation management as a core technical enabler of digital transformation to a model-based enterprise strategy. Sigmetrix's GD&T Advisor improves the quality of variation specifications, and CETOL and EZTOL analyze the specifications to predict variational results. These two applications improve the quality of data within a digital thread while capturing why variation-related decisions were made. When it is available, VariSight will ensure that data is properly managed and leveraged to improve traceability across the digital thread. The Sigmetrix training and education program is critical as it helps organizations understand variation and how to manage it. The combination of tools, training, and consulting enable companies to transform their product lifecycle process to be more agile and effective improving product cost, quality, and time to market.

Customer Success

STIHL, a leading global manufacturer of chainsaws and power tools, used CETOL to analyze the potentiometer (actuated by the throttle trigger) for a hedge trimmer product. The function is critical for performance and safety. CETOL verified the design concept and helped identify critical dimensions and adjust tolerance ranges to meet requirements while considering manufacturing aspects. More detail can be found on the Sigmetrix website.² Using simulation Stihl was able to validate the product tolerance strategy before making the product, reducing risk and shortening time to market.

Conclusion

Once product designs become instantiated as physical parts and assemblies, variation becomes an issue. Variation is a result of manufacturing processes. Generally, processes that produce less variation are more expensive to execute. A hole made in a single operation with a drill will be faster and cheaper than one made with drill, bore, and ream operations, but it will be nowhere near as precise. The correct question is what is needed to meet cost, quality, and time-to-market requirements, not which is better. Modern tools such as those supplied by Sigmetrix are helping companies quantify and manage variation to improve business performance.

The Sigmetrix solution suite enables companies to create accurate variation specifications and analyze the impact of that variation. The upcoming VariSight solution will improve digital thread connectivity to variation data, leading to better product and manufacturing decisions. Companies looking to improve their variation management or improve the ROI of their digital transformation program should contact Sigmetrix to learn how better variation management can improve their business performance.

² <https://www.sigmetrix.com/case-study/stihl>

About CIMdata

CIMdata, a global strategic management consulting firm, provides services designed to maximize an enterprise's ability to design, deliver, and support innovative products and services. For more than forty years, CIMdata has provided industrial organizations, providers of digital technologies and services, and investment firms with world-class insight, expertise, and best-practice methods on a broad set of product lifecycle management (PLM) topics and the digital transformation they enable. CIMdata also offers research, subscription services, publications, and education through certificate programs and international conferences. To learn more, visit www.CIMdata.com or email info@CIMdata.com.