"Tolerance Stack Up Analysis And Simulation Using Visualization VSA"

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the Degree of

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(CAD/CAM)

By

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CERTIFICATE

This is to certify that the major project report entitled **"Tolerance Stack up Analysis and Simulation Using Visualization VSA"** submitted by **Harshal Ashok Chavan** (Roll No.-05MME004) towards the partial fulfillment of the requirements for Master of Technology (Mechanical) in the field of CAD/CAM of Nirma University of Science and Technology is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work, to the best of our knowledge, have not been submitted to any other University or Institution for award of any degree or diploma.

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ABSTRACT

Tolerance analysis is used to predict the effects of manufacturing variation on finished products. Either design tolerances or manufacturing process data may be used to define the variation.

VIS-VSA is a powerful dimensional analysis tool used to simulate manufacturing and assembly processes and predict the amounts and causes of variation VIS-VSA can help reduce the negative impact of variation on product dimensional quality, cost and time to market.

Tolerance stackup in machining results from using operational datums that are different from design datums. It is inevitable due to economic considerations of the machining process. Conventional methods used for tolerance stackup analysis include worst-case and statistical analysis. These methods are based on strong assumptions and have certain drawbacks.

The Monte-Carlo simulation is the most popular statistical tolerance technique currently in use. Comparative studies show that this new method has better accuracy than existing moment based techniques and is faster.

Keywords: VIS-VSA, Monte-Carlo Simulation, Dimensioning and Tolerance, Stackup Analysis.

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GLOSSARY OF NOTATION

Cpk : A process capability index which accounts for mean shifts

Cp : Performance Index

K : Bias Factor

LSL : Lower Specific Limit

USL : Upper Specific Limit

CHAPTER 1

INTRODUCTION

1.1 PRELIMINARY REMARK

Tolerances are used to control the variation in size that exists on all manufactured parts. The amount that a size is allowed to vary depends on the function of the part & its assembly. The more accuracy required in a part (smaller tolerance) the greater the cost. Tolerances allow for interchangeable parts, which permits the replacement of individual parts in an assembly instead of replacing the whole system if a part goes bad or fails.

There are many benefits for implementing a 3D tolerance analysis tool like the UGS Teamcenter Visualization VSA product known as VisVSA. When used early on in the detailed design phase of new product development, it can help reduce the number of physical prototypes just as other CAE processes like FEA. Without valid tolerance analysis prototype parts are received and changes are physically made to features to get prototypes parts to assembly and/or function. Often, the dimensional issues result in prototype tool changes resulting in additional physical prototypes, time, and money just to get a design assembled and functioning for further verification and validation. With VisVSA 3D tolerance analysis, thousands of virtual engineering builds can be performed using Monte Carlo simulations and tolerance iterations can be performed quickly based on each set of results to optimize the design for function with optimal tolerances that allow for easier lower cost manufacturing with better capability to clear, concise, and valid requirements.

To estimate tolerance accumulation in an assembly requires the calculation of the tolerance sensitivity of critical assembly features to each source of dimensional variation in the assembly. A Root-Sum-Squares expression may then be formulated to predict the variance and percent rejects to expect in production. To analyze accumulation in a mechanism, rather than a static assembly, requires that this procedure be repeated in multiple positions, since the sensitivities change with the position geometry.

Tolerance analysis is a valuable tool which can aid in the reduction of manufacturing costs and improve quality. Computer-aided tolerance analysis, based on tolerance sensitivities, has made this tool available to designers. Many designers also use commercial kinematic packages based on kinematic sensitivities (ratios of the output to the input motion) to determine velocities and accelerations in mechanism. The objective of this is to determine the relationship between the tolerance sensitivities and the kinematic sensitivities, so that kinematic analysis software can be used to perform tolerance analysis of assemblies and mechanisms. Tolerance variation in mechanisms is dependent on the position of the mechanism. That is, the mechanism will have different tolerance sensitivities for each new position of the mechanism (Figure 1.1). This requires rebuilding and re-analyzing the mechanism for each new position of interest. This process is time-consuming and prone to error.

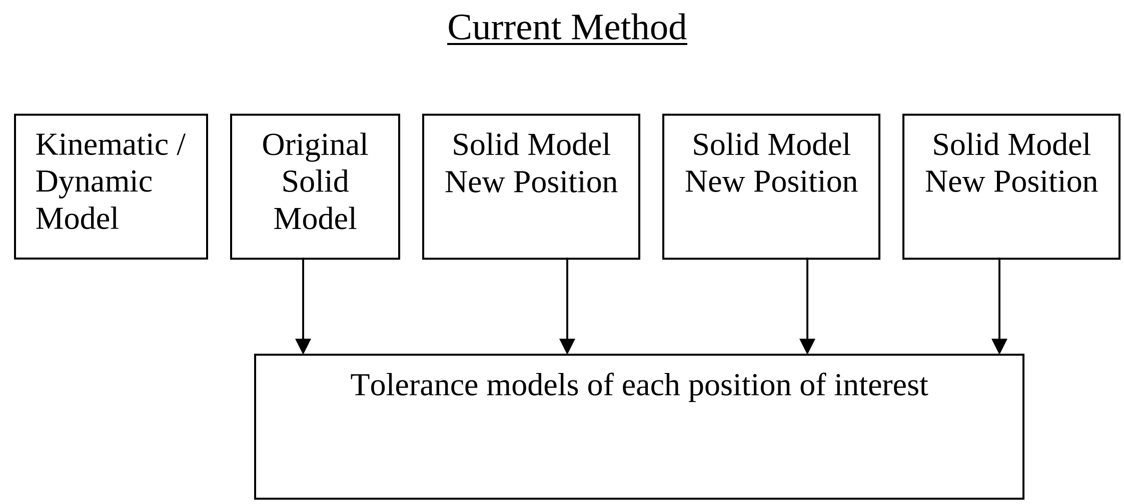


Figure 1.1 Current techniques used for modeling tolerance and kinematic / dynamic properties of mechanisms.

Ideally, the designer could use the kinematic sensitivities generated by commercial kinematics software for tolerance analysis (Figure 1.2). This would allow the tolerance analysis to be quickly performed for each position of the mechanism, leading to a dynamic tolerance analysis over a full range of motion of a mechanism.

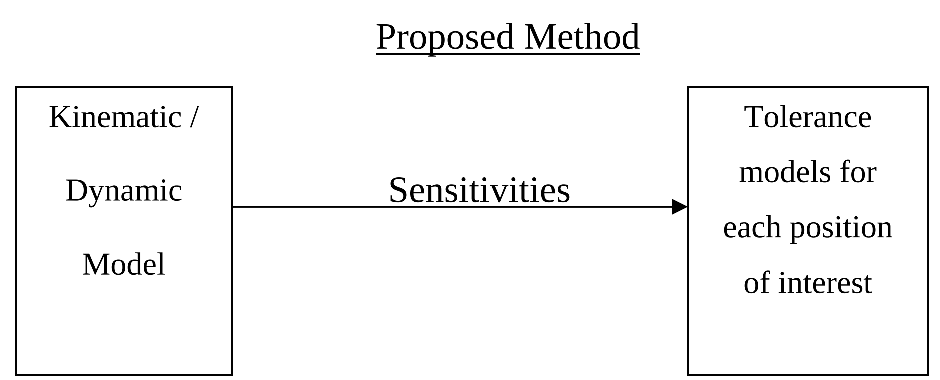


Figure 1.2 Proposed method for tolerance analysis for mechanism

This method would be equally applicable to static assemblies. Many static assemblies have mating conditions between the parts that require a kinematic model to describe the internal adjustments which occur due to dimensional variation. A kinematic modeler would seem ideally suited for this task, except that kinematic models do not account for varying dimensions. An alternative method of calculating tolerance sensitivities provides computer-aided tolerance analysis to designers who don't have access to commercially available tolerance analysis software.

1.2 TOLERANCE STACKUP ANALYSIS

Tolerance stackup can be defined as the accumulation of errors when machining a feature using different operational datums than the ones specified in the blueprints. Analysis of tolerance stackup is critical to ensure accuracy of the machined component. The two traditional methods used to analyze tolerance stackup in machining are worst-case analysis and statistical analysis. These methods are based on assumptions that are too restrictive and have several drawbacks:

(1) Worst-case analysis assumes that all tolerances simultaneously occur at their worst limit; and thus, is exaggeratedly pessimistic in calculating tolerance stackup.

(2) Statistical analysis assumes individual tolerances to be independent and have a normal distribution, which allows the use of root sum squares for stackup calculation. This will lead to conservative results since individual tolerances are more or less correlated in machining.

(3) The analysis is restricted to dimensional tolerances. In other words, tolerance stack between features is preformed in one dimension, which does not represent the actual three-dimensional features of interest.

(4) The root cause of tolerances, namely, manufacturing errors, are not taken into account.

The need to analyze geometric tolerance stack up became apparent in the mid 1990s when the new ANSI standard [ANSI (1995)] is published with emphasis on geometric tolerancing for improved quality control. According to the ANSI standard, there are two types of dimensional tolerances and fourteen types of geometric tolerances. Dimensional tolerances include "Limit-of-size" tolerances that are applied to only one surface (e.g., the diameter of a hole), and those that are related to two surfaces (e.g., the length of a shaft). Geometric tolerances can be divided into five subcategories: (1) form tolerances that include Straightness, Flatness, Roundness, and Cylindricity, (2) orientation tolerances that include Parallelism, Angularity, and Perpendicularity, (3) location tolerances that include Concentricity, Symmetry, and Position, (4) runout tolerances that include Circular Runout and Total Runout, and (5) profile tolerances that include Profile of a Line and Profile of a Surface. Form tolerances are not subject to stackup because there are not related to any datums. Some researchers have studied the stackup of position tolerance [Ngoi et al. (1999), Shan et al. (1999)]. A position tolerance is usually specified on a hole. The axis of the hole is projected to its primary datum and the problem is converted into a dimensional tolerance stackup problem. Unfortunately, this approach cannot be extended to deal with orientation tolerances since parallelism, angularity and perpendicularity are specified on a surface.

Although researchers have recognized the important role of manufacturing errors in machining tolerance stackup [Lin and Zhang (2001), Huang and Zhang (1996)], no systematic analysis method is available. A simulation-based method driven by feature discretization and manufacturing error analysis. The basic idea is to represent the surface of interest with a set of discrete points. The effect of various manufacturing errors on the spatial location of these points is then simulated. Finally, virtual inspection is performed to evaluate geometric accuracy of the surface. This method is generally applicable and is particularly useful for the analysis of tolerances specified on a surface. It is more accurate and less conservative compared to traditional analysis methods. In other words, using the proposed method for stackup evaluation will result in much less expected rejects per million parts when using the same manufacturing resources.

Clearly, a tool to evaluate tolerance requirements and effects would be most useful in the design stage of a product. To be useful in design, it should include the following characteristics:

1. Bring manufacturing considerations into the design stage by predicting the effects of manufacturing variations on engineering requirements.

2. Provide built-in statistical tools for predicting tolerance stack-up and percent rejects in assemblies.

3. Be capable of performing 2-D and 3-D tolerance stack-up analyses.

4. Be computationally efficient, to permit design iteration and design optimization.

5. Use a generalized and comprehensive approach, similar to finite element analysis, where a few basic elements are capable of describing a wide variety of assembly applications and engineering tolerance requirements.

6. Incorporate a systematic modeling procedure that is readily accepted by engineering designers.

7. Be easily integrated with commercial CAD systems, so geometric, dimensional and tolerance data may be extracted directly from the CAD database.

8. Use a graphical interface for assembly tolerance model creation and graphical presentation of results.

First, traditional tolerance analysis methods assume objects have rigid geometry. Variance is increasingly “stack-up” as components are assembled. Tolerance of assembly is always assumed to be larger than its subassembly. Rigid body tolerance analysis over-estimates variations of flexible materials, such as assemblies containing sheet metal, polymer, and plastic parts, which are common in aerospace, automobile, and electronics industry. For example, an airplane skin can be slightly warped, and yet it can be riveted.

1.2.1 THE BASICS OF TOLERANCE STACK UP ANALYSIS

- Where to begin a stack?
- Designating positive and negative routes.
- Which geometric tolerances are factors?
- Finding the mean.
- Calculating boundaries for GD&T, MMC.
- LMC and RFS material condition modifiers.
- Mean boundaries with equal bilateral.

1.3 IMPORTANCE OF TOLERANCE STACKUP ANALYSIS

It is important for the designer to consider tolerance analysis thoroughly in the early stages of product development for optimal design of assembly. To illustrate the problems associated with 2-D tolerance analysis, consider the simple assembly shown in figure 1.3, as described by Fortini [1967]. It is a drawing of a one-way mechanical clutch. This is a common device used to transmit rotary motion in only one direction.

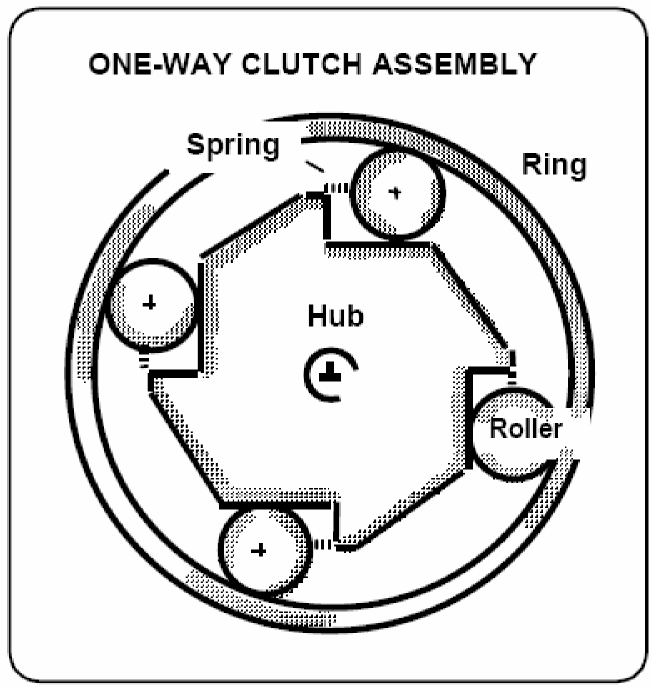


Figure 1.3 One-way clutch assembly.

When the outer ring of the clutch is rotated clockwise, the rollers wedge between the ring and hub, locking the two so they rotate together. In the reverse direction, the rollers just slip, so the hub does not turn. The pressure angle Φ**1** between the two contact points is critical to the proper operation of the clutch. If Φ**1** is too large, the clutch will not lock; if it is too small the clutch will not unlock.

The primary objective of performing a tolerance analysis on the clutch is to determine how much the angle Φ**1** is expected to vary due to manufacturing variations in the clutch component dimensions.

The independent manufacturing variables are the hub dimension **a**,

The cylinder radius **c**,

The ring radius **e**.

The distance **b** and angle Φ**1** are not dimensioned.

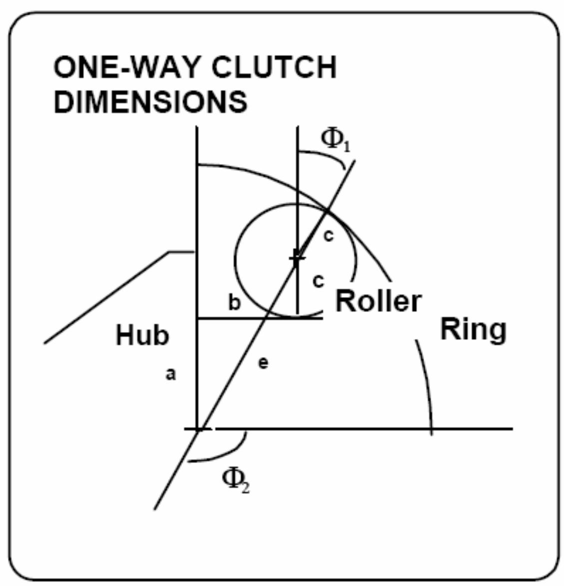


Figure 1.4 One way clutch dimensions

They are assembly resultants which are determined by the sizes of **a**, **c** and **e** when the parts are assembled. By trigonometry, the dependent assembly resultants, distance **b** and angle Φ**1**, can be expressed as explicit functions of **a**, **c** and **e**.

1.4 OBJECTIVE OF THE PROJECT

Increased global competition has forced manufacturing organizations to look for ways to improve the quality of their products without increasing production costs. As a consequence of this drive, quality standards such as parts per million, zero defects, etc., have emerged. These quality standards are the force behind the reduction of defects at every stage of manufacturing. However, this objective can only be achieved by systematically building quality into the product throughout its design and manufacturing cycle. Over the years, many methods have been proposed, such as experimental design, Taguchi techniques, SPC, etc., for this purpose. These techniques, though useful in enforcing the conformity to design specifications during manufacturing, provide little help in confronting the root cause of many quality problems. According to a recent study', improper tolerance allocation is identified as the major cause of quality problems in the factory. Improper tolerance allocation is mainly caused by traditional tolerance allocation techniques, which are mostly based on manual calculations with the aid of a handbook. These traditional techniques obviously have serious limitations and can no longer be safely used to meet today's exacting quality standards.

However, the current tools have several limitations as follows.

1) The inability to model non-normal process distributions accurately;

2) Inaccuracies in non-linear tolerance stack-up analysis; and

3) Lack of speed in performing statistical tolerance synthesis.

CHAPTER 2

LITERATURE REVIEW

2.1 NEED FOR TOLERANCE STACKUP ANALYSIS IN ASSEMBLIES

Tolerance analysis is used to predict the effects of manufacturing variation on finished products. Either design tolerances or manufacturing process data may be used to define the variation. Current efforts in tolerance analysis assume rigid body motions. This present a method of combining the flexibility of individual parts, derived from the finite element method, with a rigid body tolerance analysis of the assembly. These results can be used to predict statistical variation in residual stress and part displacement. This will show that manufacturing variation can produce significant residual stress in assemblies. It will demonstrate two different methods of combining tolerance analysis with the flexibility of the assembly.

Tolerance analysis is the process of determining the effect that the tolerances on individual manufactured parts will have on an assembly of these parts. Tolerance analysis is a subset of Design for Assembly (DFA) and Design for Manufacturability (DFM). As such, tolerance assignment forms an important link between the design and manufacturing processes. Tolerance variation in an assembly is derived from three major sources: size variation, geometric variation, and kinematic variation. Size variation occurs due to the variability of the dimensions. Geometric variation occurs due to variations in form, such as flatness or cylindricity. Kinematic variation occurs as small adjustments between mating parts in response to dimensional and geometric variations. As parts are assembled the tolerances in each part add together to form "tolerance stack-up". The result is that much small tolerance.

Variations can add together to form a large residual stack-up, which can affect product performance and cost. Unfortunately, designers often view tolerance assignment as either a “black art” that they don't understand or as a trivial part of the total design. With the increasing emphasis on DFA/DFM, these views become untenable. To overcome this kind of thinking, engineers must be provided with tools that will allow them to understand the consequences of tolerance assignment and their relationship to product performance. This will provide an overview of a tolerance analysis package that is integrated into the design process and show how the tolerance information for calculating assembly stresses due to tolerance stack-up. This methodology can provide engineers and designers with a useful measure of the effect of manufacturing tolerances early in the design process.

Tolerance stackup in machining results from using operational datum those are different from design datum. It is inevitable due to economic considerations of the machining process. Conventional methods used for tolerance stackup analysis include worst-case and statistical analysis. These methods are based on strong assumptions and have certain drawbacks, the most critical one being the inability to analyze geometric tolerances. This presents a novel method based on feature discretization, manufacturing error analysis, Monte Carlo simulation, and virtual inspection. It is generally applicable to stackup analysis of various types of tolerances and produces more accurate and less conservative results. The trade off is longer computational time.

2.2 THREE SOURCES OF VARIATION IN ASSEMBLIES

There are three main sources of variation which must be accounted for in mechanical assemblies:

1. Dimensional variations (lengths and angles).

2. Geometric form and feature variations (position, roundness, angularity, etc.).

3. Kinematic variations (small adjustments between mating parts).

Dimensional and form variations are the result of variations in the manufacturing processes or raw materials used in production. Kinematic variations occur at assembly time, whenever small adjustments between mating parts are required to accommodate dimensional or form variations.

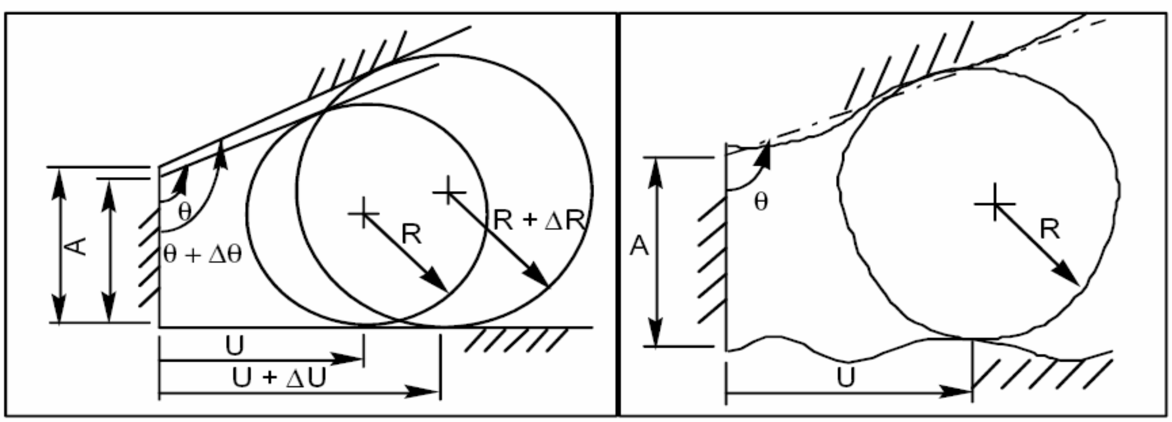


Figure 2.1 Kinematic adjustments due to component dimension variations

Figure 2.2 Adjustment due to geometric shape variations

2.3 METHODS AVAILABLE FOR TOLERANCE ANALYSIS

This will briefly review the methods available for nonlinear tolerance analysis when an explicit assembly function is provided which relates the resultant variables of interest to the contributing variables or dimensions in an assembly. The purpose of the review is to provide background for a discussion of a generalized method for treating implicit functions.

Traditionally there are six tolerancing approaches:

1) Consult standard tolerance analysis.
2) Worst –case tolerance analysis.
3) Statistical method.
4) Sensitivity analysis.
5) Computer-Aided tolerancing.
6) Cost-based optical tolerance analysis.

Chase K.W. says that when an explicit assembly function is available is relates the resultant variable of interest to the contributing variable or dimensions in an assembly. Several methods are available for the performing a statistical tolerance analysis.

This includes:

a) Linearization of the assembly function using Taylor series expansion.
b) Method of system moments.
c) Quadrature.
d) Monte Carlo simulation.
e) Reliability index.
f) Taguchi method.

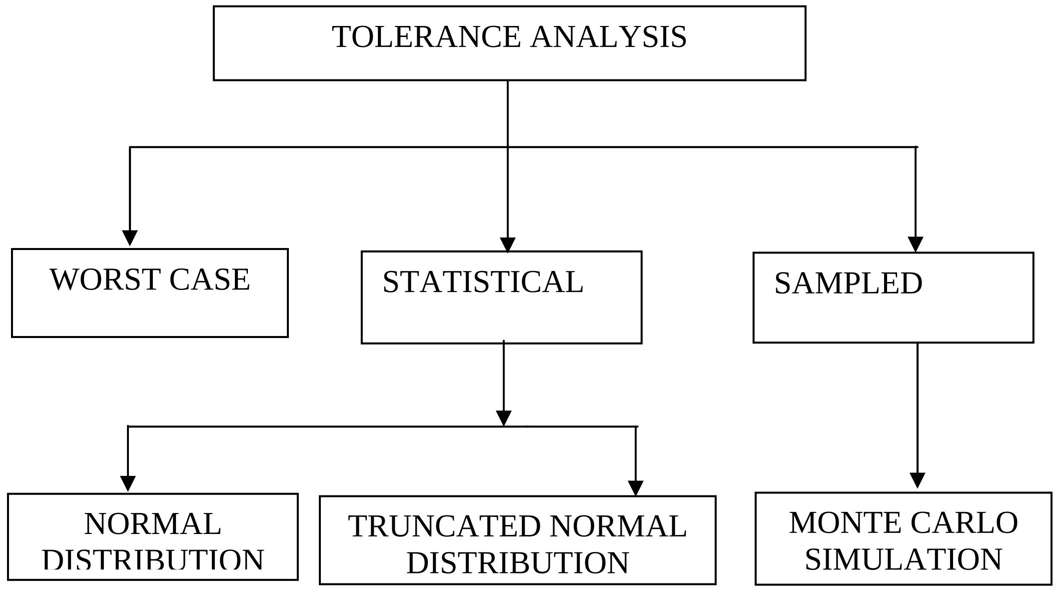


Figure 2.3 Models for tolerance stackup analysis

2.3.1 SIMULATION-BASED TOLERANCE STACKUP ANALYSIS

In order to overcome the limitations of the dimension chain model, we propose a simulation-based analysis method that utilizes the following strategies:

- A set of discrete points is used to represent the surface whose tolerances are involved in the analysis (Figure 2).
- Monte Carlo simulation is used to study the effect of various manufacturing errors on the spatial locations of these points.
- Virtual inspection can then conduct based on the coordinates of these points, which allows the analysis of any types of tolerances (geometric as well as dimensional).

2.4 VARIATION SOURCES IN ASSEMBLIES

In order to create a generalized approach for generating implicit assembly functions, the sources of variation in an assembly must be identified and categorized. With these categories in place, an engineer can use them to systematically create a model that can be used to derive the implicit functions. There are three main sources of variation in a mechanical assembly:

1) Dimensional variation.
2) Geometric feature variation.
3) Variation due to small kinematic.

Adjustments which occur at assembly time. The first two are the result of the natural variations in manufacturing processes and the third is from assembly processes and procedures.

Figure 2.3 shows sample dimensional variations on a component. Such variations are inevitable due to fluctuations of machining conditions, such as tool wear, fixture errors, set up errors, material property variations, temperature, worker skill, etc. The designer usually specifies limits for each dimension. If the manufactured dimension falls within the specified limits, it is considered acceptable. Since this variation will affect the performance of the assembled product, it must be carefully controlled.

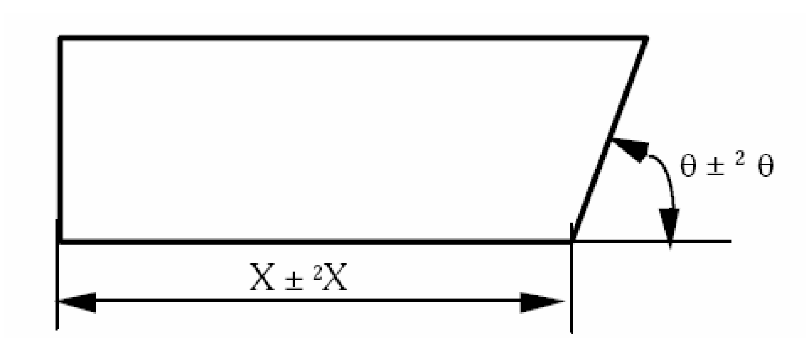


Figure 2.4. Example of dimensional variations

Geometric feature variations are defined by the ANSI Y14.5M-1982 standard [ASME 1982]. These definitions provide additional tolerance constraints on shape, orientation, and location of produced components. For example, a geometric feature tolerance may be used to limit the flatness of a surface, or the perpendicularity of one surface on a part relative to established datums, as shown in Figure 2.4.

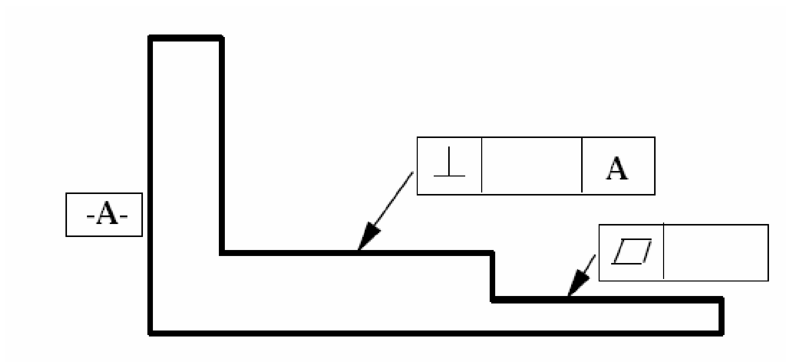


Figure 2.**5** Example of geometric feature variation limits.

In an assembly, geometric feature variations accumulate and propagate similar to dimensional variations. Although generally smaller than dimensional variations, they may be significant in some cases, resulting from rigid body effects [Ward 1992]. A complete tolerance model of mechanical assemblies should therefore include geometric feature tolerances. Kinematic variations are small adjustments between mating parts which occur at assembly time in response to the dimensional variations and geometric feature variations of the components in an assembly. For example, if the roller in the clutch assembly is produced undersized, as shown in figure 5, the points of contact with the hub and ring will change, causing kinematic variables **b** and Φ**1** to increase.

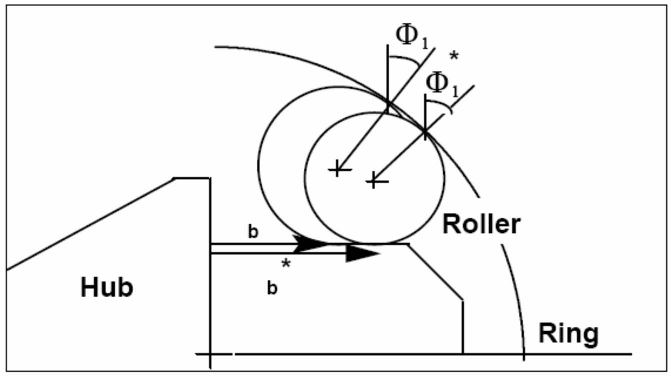


Figure 2.6 Example of kinematic or assembly variations due to a change in the roller size.

Usually, limiting values of kinematic variations are not marked on the mechanical drawing, but critical performance variables, such as a clearance or a location, may appear as assembly specifications. The task for the designer is to assign tolerances to each component in the assembly so that each assembly specification is met. It is the kinematic variations which result in implicit assembly functions. Current tolerance analysis practices fail to account for this significant variation source. In a comprehensive assembly tolerance analysis model, all three variations should be included. If any of the three is overlooked or ignored, it can result in significant error. Only when a complete model is constructed, can the designer accurately estimate the resultant assembly features or kinematic variations in an assembly.

2.5 NEED FOR COMPUTER AIDED TOLERANCE ANALYSIS

The tolerance design is an important step in product and process design of the precision assembly. The manual method of tolerance analysis for complex precision assemblies is tedious and sometime demands expertise on the part of designer .The automated tolerance analysis not only improves the performance of the precision assembly but also reduce there design lead time and cost of manufacturing.

First, traditional tolerance analysis methods assume objects have rigid geometry. Variance is increasingly "stack-up" as components are assembled. As shown in *Figure* tolerance of assembly is always assumed to be larger than its subassembly. Rigid body tolerance analysis over-estimates variations of flexible materials, such as assemblies containing sheet metal, polymer, and plastic parts, which are common in aerospace, automobile, and electronics industry. For example, an airplane skin can be slightly warped, and yet it can be riveted in place. Similarly, subassembly components of auto body with much larger variation than the specified can still achieve the final assembly specification. The conventional addition theorem of variance is no longer valid in these applications. Given the specification of an assembly, unreasonably tight tolerance requirements will be assigned to subassemblies and components during tolerance synthesis, as shown in Figure 2.6. The tolerance allocation based on the rigid body assumption increases manufacturing costs unnecessarily. These methods treat tolerances for rigid and compliant assemblies with the same scheme of +/- range. This does not capture the physical property difference between rigid and flexible materials and implied engineering meanings.

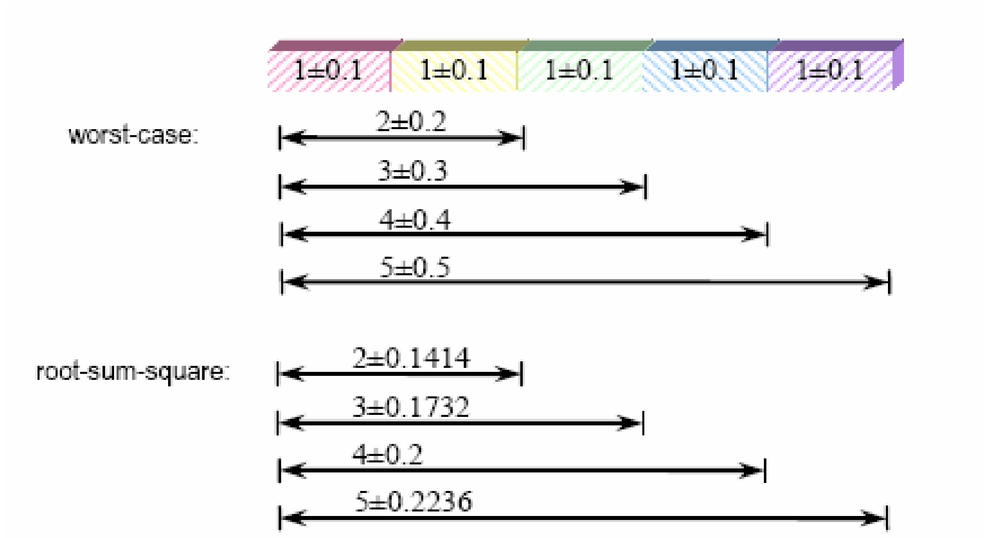


Figure 2.7 Tolerance ranges are monotonously increasing as assembly is built based on the rigid-body assumption

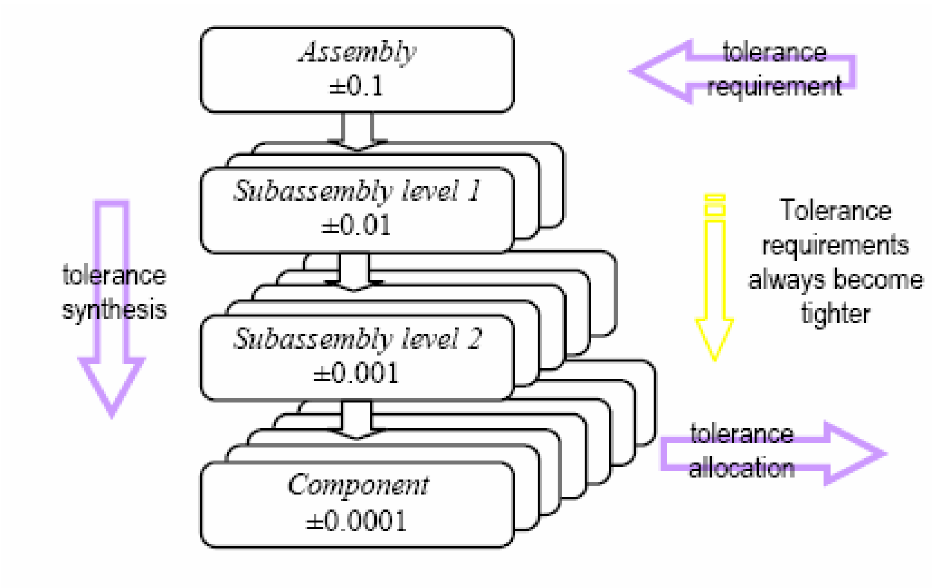


Figure 2.8 Tolerancing may become so tight that costs increase unnecessarily in flexible assembly based on current rigid-body tolerance synthesis schemes

An important consideration in product design is the assignment of tolerances to individual component dimensions so the product can be produced economically and function properly. The designer may assign relatively tight tolerances to each part to ensure that the product will perform correctly, but this will generally drive manufacturing cost higher. Relaxing tolerances on each component, on the other hand, reduces costs, but can result in unacceptable loss of quality and high scrap rate, leading to customer dissatisfaction. These conflicting goals point out the need in industry for methods to rationally assign tolerances to products so that customers can be provided with high quality products at competitive market prices.

CHAPTER 3

DIMENSIONING AND TOLERANCING

3.1 WHY ARE DIMENTIONING AND TOLERANCE IMPORTANT?

Dimensioning allows a designed part to be manufactured and are always in real world units.

Tolerancing is important to the manufacturer because it determines the accuracy and cost of the final product. In general, tolerances should be as large as possible to balance expense with function.

Geometric Dimensioning and Tolerancing (GD&T) is a method for precisely defining the geometry of mechanical parts. It introduces tools which allow mechanical designers, fabricators, and inspectors to effectively communicate complex geometrical descriptions which are not otherwise able to be described in a defined language.

All manufacturing processes require a dimensional tolerance range within which the size can be guaranteed. The smaller the tolerance range required the more expensive the manufacturing process required is likely to be. Assigning very narrow tolerances to every dimension causes a component to be more expensive than is necessary to achieve the function intended. It is the designers' role to analyse the product and decide which dimensions are critical to achieving the product function.

Geometric Dimensioning and Tolerancing is a vast language of which there are many facets. However, what is commonly used is a small subset of the total. This subset is based on concepts which must be learned in order to progress further. Without a solid understanding of these fundamentals, one cannot gain a firm grasp of later topics. We will present the most essential (and often misinterpreted) topics in a step-by-step fashion, starting with a simple two-dimensional case. After the 2D case has been understood, the full three-dimensional geometry will be described. We also include common areas of confusion and a reference section, but at this point the primary objective is to explain the fundamentals. Please select "2D DATUMS" from the menu bar to the left to continue.

Geometric Dimensioning and Tolerancing symbols have been in use since at least the turn of the century. GD&T was especially important during the Second World War in relation to extremely high volume production of Liberty Ships, aircraft, and ground vehicles. The automotive industry, with its high volumes, has also benefited from GD&T. The computer industry, in particular mass storage manufacturers, have used GD&T extensively to increase their yields of high-volume and low-margin hard disk drives. However, as with most engineering and scientific methodologies, GD&T was not rigorously established and documented until later in the twentieth century. The American National Standards Institute publication in 1982 of ANSI Y14.5M-1982 was a turning point in the rigorous, unambiguous standardization of the methodology.

3.2 BASIC TOLERANCING PRINCIPLES Ref. ANSI Y14.5M

- Each dimension must have a tolerance
- Dimensions of size, form, and location must be complete
- No more dimensions than necessary shall be given
- Dimensions should not be subject to more than one interpretation
- Do not specify manufacturing method

3.3 GEOMETRICAL SYMBOL

Symbol	Description	Geometry
∠	ANGULARITY	ORIENTATION
◎	CONCENTRICITY	LOCATION
⌭	CYLINDRICITY	FORM
⏥	FLATNESS	FORM
//	PARALLELISM	ORIENTATION
⊥	PERPENDICULARITY	ORIENTATION
⌖	POSITION	LOCATION
⌓	PROFILE	PROFILE
⌒	PROFILE OF A LINE	PROFILE
○	ROUNDNESS	FORM
↗	RUNOUT	RUNOUT
—	STRAIGHTNESS	FORM
⌯	SYMMETRY	LOCATION
⌰	TOTAL RUNOUT	RUNOUT

Symbol	Modifier
Ⓕ	FREE STATE
Ⓛ	LEAST MATERIAL CONDITION
Ⓜ	MAXIMUM MATERIAL CONDITION
Ⓟ	PROJECTED TOLERANCE ZONE
Ⓢ	REGARDLESS OF FEATURE SIZE
Ⓣ	TANGENT PLANE
Ⓤ	UNILATERAL

Table 3.1

CHAPTER 4

SOFTWARE USED

4.1 TEAMCENTER

Teamcenter is a proven portfolio of configurable lifecycle domain and industry solutions, uniting product knowledge with process innovation to deliver business value throughout the product lifecycle. Teamcenter's PLM digital enterprise backbone brings together the collective information of the enterprise in an open, collaborative environment that extends the reach of product knowledge to every user's desktop, in every organization.

Teamcenter leads the industry with solutions for product and portfolio planning, digital product development, digital manufacturing and sales and support that deliver fast time-to-value. Teamcenter portfolio products include enterprise data management, engineering process management, lifecycle collaboration, project management, requirements management, enterprise integration and visualization.

Throughout the lifecycle.

Teamcenter enables you to manage and share all of the diverse intellectual assets created throughout your extended enterprise, as well as across the planning, development, manufacturing, and support phases of the product lifecycle.

Across industries.

Teamcenter offers industry solutions to address the key business challenges driving the industry, combining industry expertise and best practices for fast time-to-value.

4.2 Unigraphics NX3

The user interface of Unigraphics is made simple through the use of icons. Most of commands can be executed by navigating the mouse around the screen and clicking on the icons. The keyboard entries are mostly used for entering values and naming files

Unigraphics Gateway :

The following figure shows the typical layout of the Unigraphics window when a file is opened. This is the Gateway of Unigraphics from where you can select any module to work on such as modeling, manufacturing, etc. It has to be noted that these toolbars may not be exactly on the same position of the screen as shown below. They might be placed at some other place of the screen. Look out for the same set of icons.

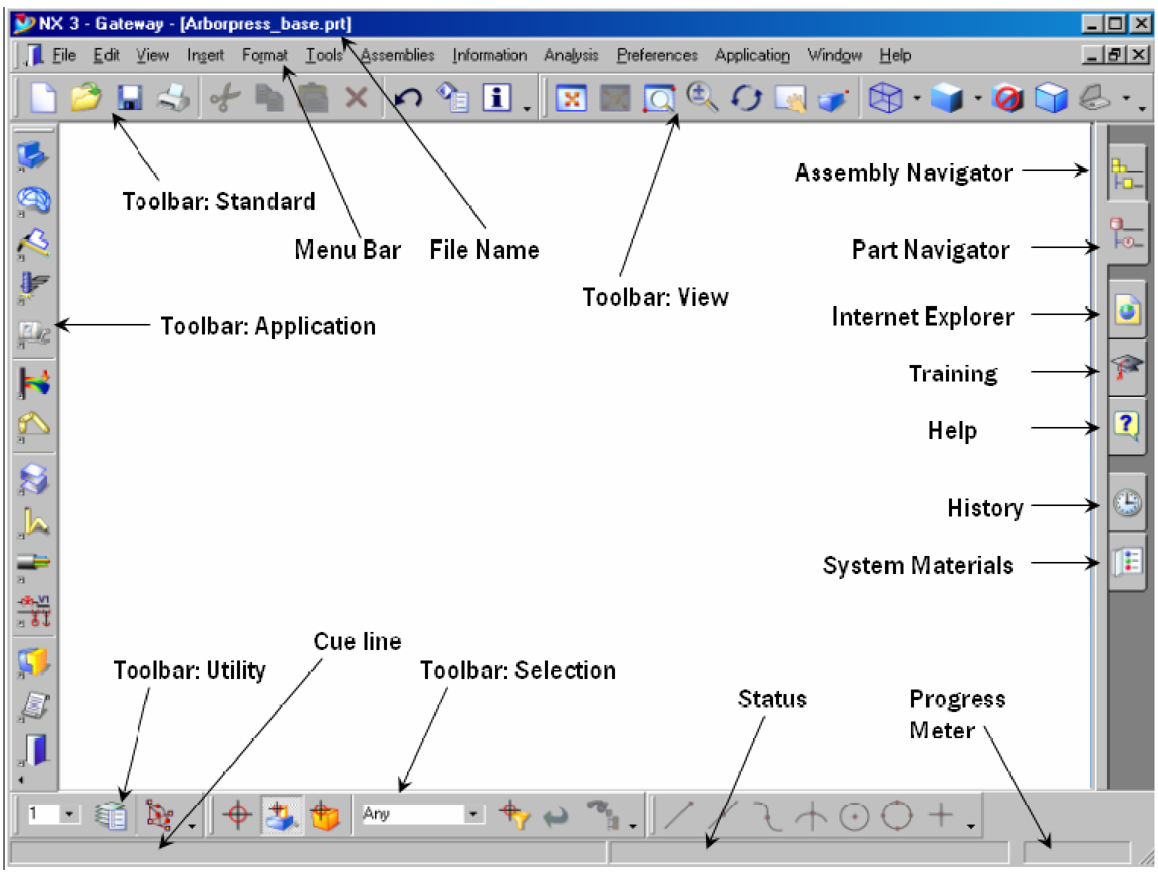


Figure 4.1

- **Geometry Selection**

Geometry Selection properties are very advanced in Unigraphics-NX3. You can filter the selection method, which facilitates easy selection of the geometry in a close cluster. In addition, you can perform any of the feature operation options that Unigraphics intelligently provides depending on the selected entity.

The Mouse cursor in the Graphics screen will normally be in the shape of a circle as shown in the figure. Selection of items can be based on the degree of the entity like, selection of Geometric entities, Features and Components. The selection method can be opted by choosing one of the icons in the Selection Toolbar.

Feature Selection:

Clicking on the icon as shown in the figure below will let you select the features in the part file. It will not select the basic entities like edges, faces etc.

Figure 4.2

General Object Selection:

Clicking on the icon as shown in the below figure will let you select the general object entities displayed in the screen.

Figure 4.3

User Preferences

Use Preferences are to define the display parameters of new objects, names, layouts, and views. You can set the layer, color, font, and width of created objects. You can also design layouts and views, control the display of object and view names and borders, change the size of the selection ball, specify the selection rectangle method, set chaining tolerance and method, and design and activate a grid. Changes that you make using the Preferences menu override any counterpart customer defaults for the same functions.

Choose **PREFERENCES** on the Menu bar to find the various options available

Figure 4.4

4.3 Vis VSA

- **Dimensional analysis to reduce variation and improve product quality**

Vis VSA is a powerful dimensional analysis tool used to simulate manufacturing and assembly processes and predict the amounts and causes of variation. Vis VSA can help reduce the negative impact of variation on product dimensional quality, cost and time to market. Since Vis VSA's foundation lies within Teamcenter. Visualization, it also extensively leverages the digital prototyping and visualization capabilities of Vis Mockup, UGS' powerful real-time visualization and digital prototyping solution.

- **Vis VSA's business value**

Optimize product and process: Vis VSA allows users to identify dimensional problems early in the design cycle, thereby avoiding assembly build and quality issues due to excessive variation. With this solution, design flaws can be caught before committing to tooling. Identify critical dimensions: Vis VSA identifies critical dimensional tolerances and assembly processes that are key contributors to variation. These areas have a significant impact on product quality and therefore warrant careful monitoring. Reduce costs: Vis VSA reduces cost by improving product quality and accelerating time-to-market. In addition, manufacturing costs can be reduced by maximizing allowable part tolerances, while still controlling critical assembly dimensional specifications. Controlling these dimensional characteristics helps minimize scrap, rework and warranty defects. With Vis VSA product quality is significantly improved by insuring that parts fit and work together properly – the first time.

4.3.1 FEATURE AND BENEFITS:

Vis VSA is one of several interoperable tools in the Teamcenter Quality solution. With Vis VSA, manufacturers can:

- Identify tolerances and assembly processes that contribute to variation and perform quick “what-if” analyses to optimize tolerances, design and the assembly process.
- Create feature-based models before or after geometry is available. Creating models prior to geometry helps drive the design before parts are made or tooling is cut.
- Leverage the most powerful variation assembly constraint engine in the world.
- Perform comprehensive statistical or simulated worst-case analyses
- Incorporate component flexibility through linking with finite element analysis results.
- Display a variety of graphical reports tied to 3D geometry
- Represent tolerances with different types of distributions.
- Extend the analysis to support user-defined equations such as gear backlash, pressure, imbalance, etc.
- Capture knowledge and reuse models; morph features to new geometry

4.3.2 USING TEAMCENTER VISUALIZATION VSA

With Teamcenter Visualization VSA, a 3D digital prototype iscreated to simulate the production build process. The digital prototype includes a comprehensive representation of geometry, product variation (tolerances), assembly process variation (sequence, assembly attachment definition, tooling) and measurements. The model is used to predict if there will be any assembly builds problems – before any physical parts are made or tooling is cut.Teamcenter Visualization VSA also identifies the root causes of the build problems and enables the design, tolerances and assembly process to be optimized very early in the product development process. Teamcenter Visualization VSA features several major capabilities including:

Teamcenter Visualization foundation:

The CAD neutral, lightweight Teamcenter Visualization environment allows the geometry from dissimilar CAD systems to be combined and included in the analysis. In addition, this enables the analysis of large assemblies and leverages many of the digital mockup capabilities such as cross section, 3D clearance/markup/measure and more.

Geometric tolerancing capability:

Teamcenter Visualization VSA supports feature-based modeling with the features varied based on the ASME Y14.5M tolerancing standard. Key tolerancing aspects supported include maximum material condition, composite position and profile, multiple datum reference frames and unilateral/unequal bilateral surface profile.

The Teamcenter Visualization VSA advantage:

No other dimensional analysis solution on the market:

- Works in a CAD-neutral, graphically rich digital prototyping environment.
- Is feature-based using tolerances based on GD&T.
- Supports over- and under-constrained static and kinematic assembly operations.
- Links to FEA solvers for comprehension and analysis of component flexibility.

4.4 SIMULATION

It is evident that there are many problems of real life , which can not be represented mathematically due to complexity in problem formulation or conflicting ideas needed to properly describe the problem under study . Under such circumstances simulation is often used when all else fails. This method is always used as “Method of last Resorts “

Simulation analysis is a natural and logical extension to analytical technique used for solving the problem in quality engineering .Simulation, which can appropriately be known as management laboratory; determine the effect of alternate policy without distributing the real system.

Resent advances in simulation methodologies, software availability, and technical development had made simulation one of the most widely used and popularly accepted tool in quality / reliability engineering and operations research. It helps us in deciding best polices with the prior assurances that is implementation will certainly prove to be beneficial to be organisation.

The analysts and designers in physical sciences have long applied the simulation technique and it has now become an important tool for dealing with the complicated problem of managerial decision making.

4.4.1 MONTE CARLO SIMULATION

Any method which solve the problem by much suitable numbers and observing that fraction of numbers obeying some property or properties. This guideline written and designed with the intention of assisting practicing engineers to deploy the monte carlo simulation while driving out common fear of statistics among them the emphases that have been on providing a step by step explanation to model the product or process and facilitate decision making process using the result of simulation exercise.

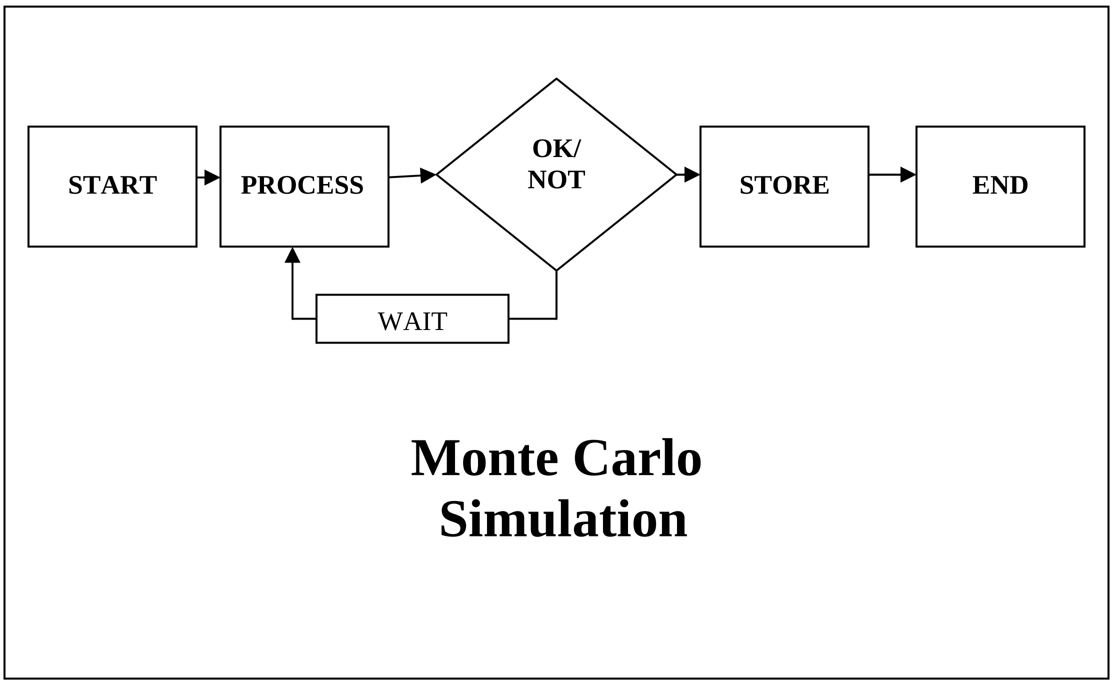


Figure 4.5

Two things, which are always scarce in the product development stages are,

1. Time
2. Money.

Yet, Engineers are expected to take decisions with minimum risk.

This calls for adequate data about the product process behavior. Such data may be available if the product/process being developed is an improvement over the existing product/process.

But,

“What product / process being developed is totally new?”

“What if the available data does not fit any distribution to enable statistical inferences?”

“What if the cost implications of physical verification about the effectiveness of decision taken, are very high?”

Simulation can to a large extent address the above apprehension.

The rule of thumb for the decision making process, is:

“When every thing else fails, simulate!”

4.4.2 WHY MONTE_CARLO?

Monte_carlo simulation can be used to study a verity of fields, practices and discipline. It can simulate many different entities; product; processes; facilities and environments depending upon the sphere of influence of the decision .The primary advantage is that it is extremely versatile and easy to deploy .

CHAPTER 5

WORKING WITH VIS VSA

The Vis VSA is broken up into four sections,

- Getting Results in Vis VSA.
- Documenting and Analysing an Assembly Process.
- Displaying Simulation Results on the Web.
- Using Common Process Documents.

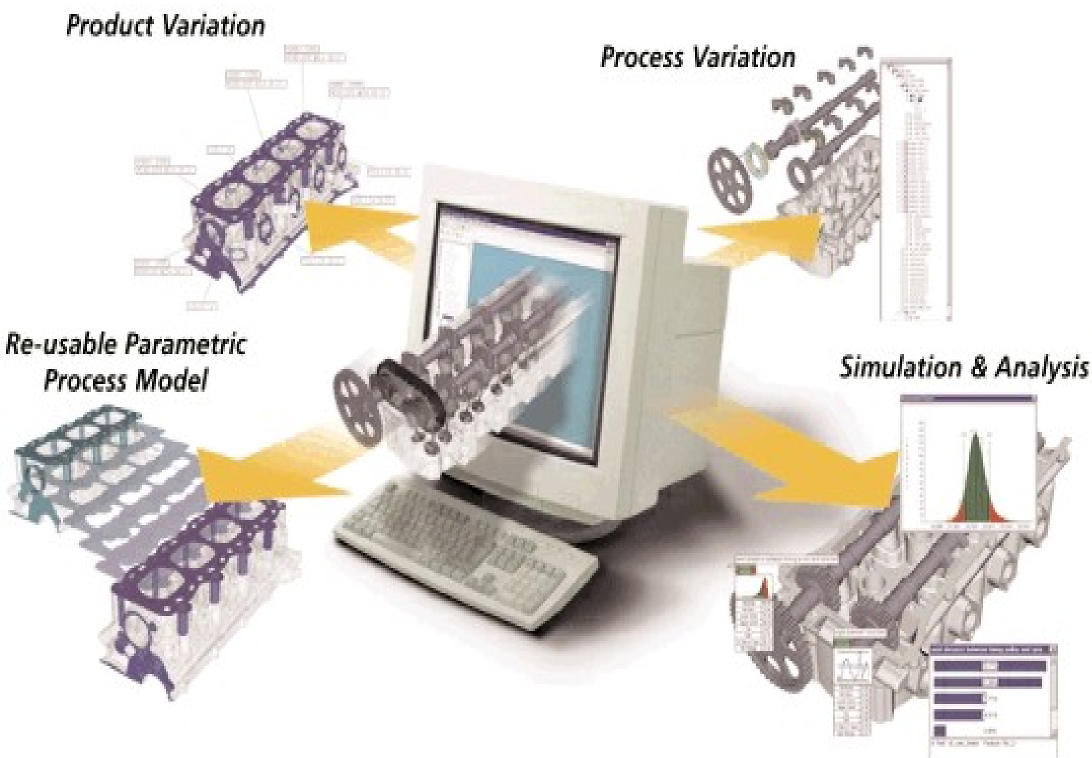


Figure 5.1 Teamcenter Vis Vsa Process

5.1 ASSEMBLING THE FRONT END ACCESSORY DRIVE OF AN ENGINE

Following is the process document that defines the process for assembling the front end accessory drive of an engine.

Process features are surfaces (pins, holes, planes, tabs, and slots) to which tolerances are applied and which impact or are affected by variation in the assembly process. Points are also included as process features. They can be used in Teamcenter Visualization VSA for simulating variation in irregularly shaped surfaces (general surfaces) and for defining assembly and measurement operations.

5.1.1 ANIMATING A NOMINAL ASSEMBLY BUILD

The process document for the engine assembly includes operations that define how various components of the engine's front end accessory drive are to be assembled. These assembly operations can be used in Teamcenter® Visualization VSA to simulate the assembly process.

5.1.2 CREATING PROCESS FEATURES

In this part we will define process features to represent the surfaces used in two assembly operations one for attaching the pulley to the water pump (which creates the water pump assembly) and one for attaching the water pump assembly to the engine block. We’ll also create process features to be used in a measurement operation a measurement of the distance between the pulley and the engine block.

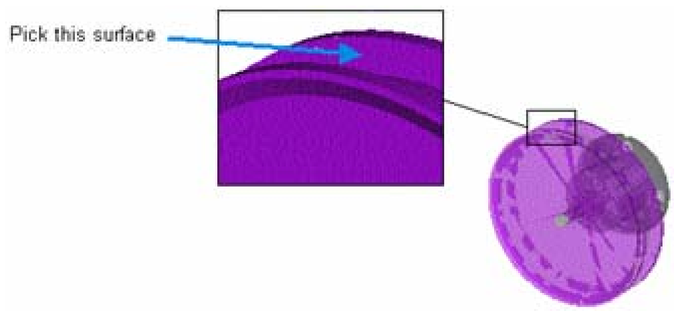


Figure 5.2 Back Inside Surface Of The Pulley

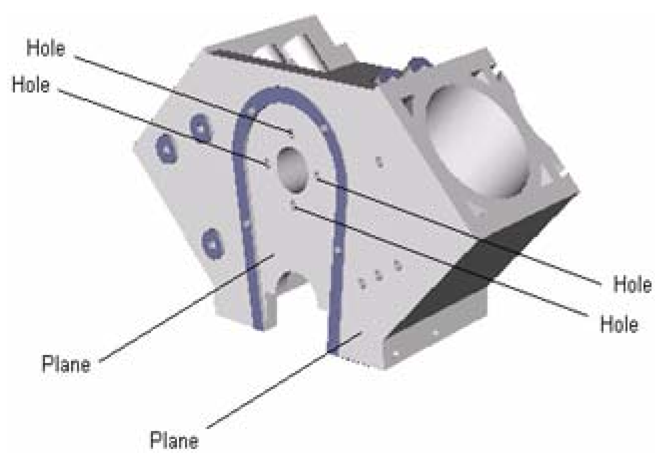


Figure 5.3 The Surface Of The Outer Face Of The Engine Block

5.1.3 DEFINING MEASUREMENT OPERATIONS

Measurement operations provide the basis for analyzing the effects of variation on an assembly process. We define measurement operations in Teamcenter Visualization VSA by identifying the process features from and to which measurements are to be made. For the engine assembly process, we'll be defining a measurement from a point on the pulley to the front face of the engine block.

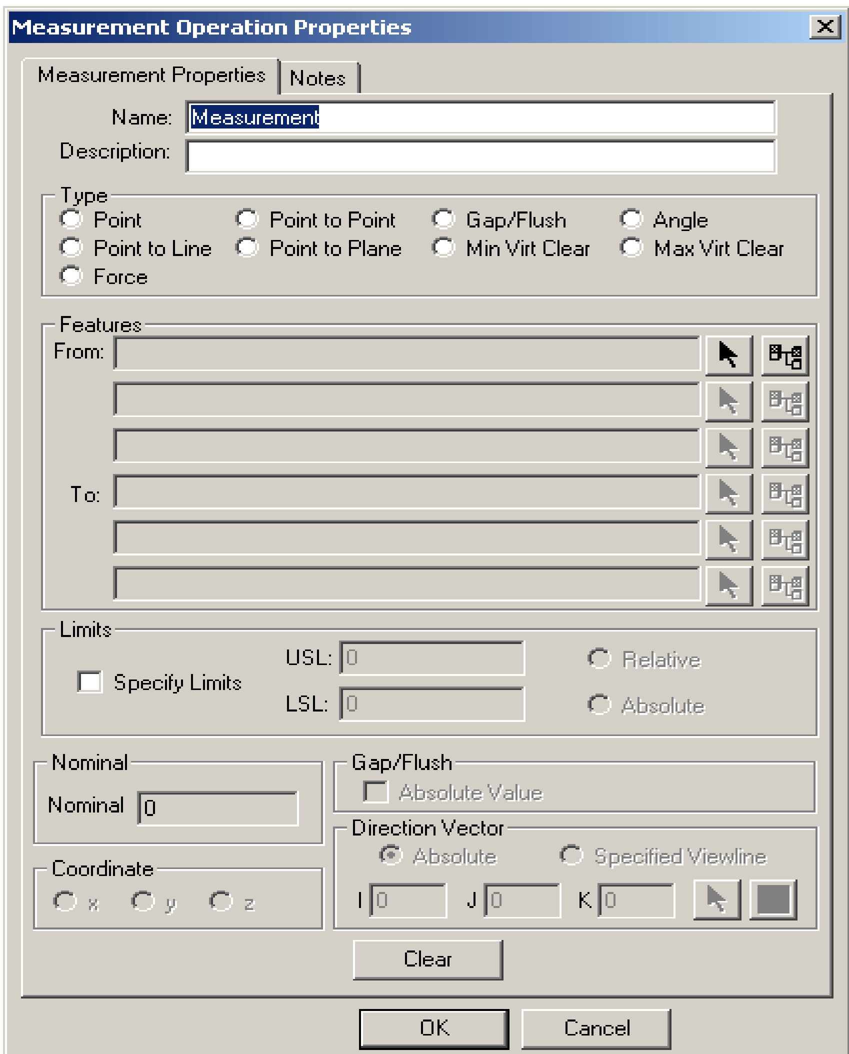


Figure 5.4 Defining Measurement Operations

5.1.4 RUNNING MONTE CARLO SIMULATIONS

Teamcenter Visualization VSA allows us to run several types of assembly process simulations, including Monte Carlo simulations that replicate the random nature of manufacturing processes. Monte Carlo simulations account for both component and process variation, and thus provide a good overall indication of the impact that variation is likely to have on an assembly process.

The process document for the engine assembly contains all information we need to run Monte Carlo simulations. In addition to the defined assembly operations that we saw executed in the nominal build animation, the process document contains defined measurement operations, which provide a basis for analyzing the simulations. The measurement operations get executed during each simulation, and the results are made available, in a variety of formats, upon completion of the simulations.

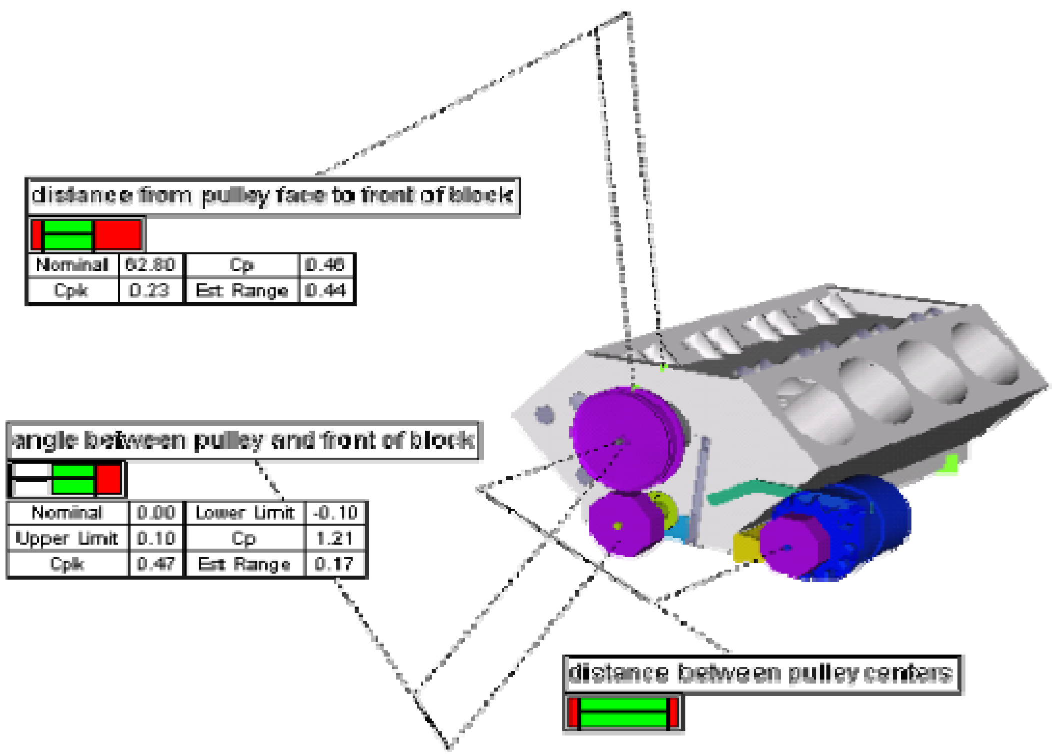


Figure 5.5 Simulation result of front end accessory drive

5.1.5 VIEWING SIMULATION REPORTS

In addition to results annotation, Teamcenter Visualization VSA provides several standard reports that you can use to review simulation results.

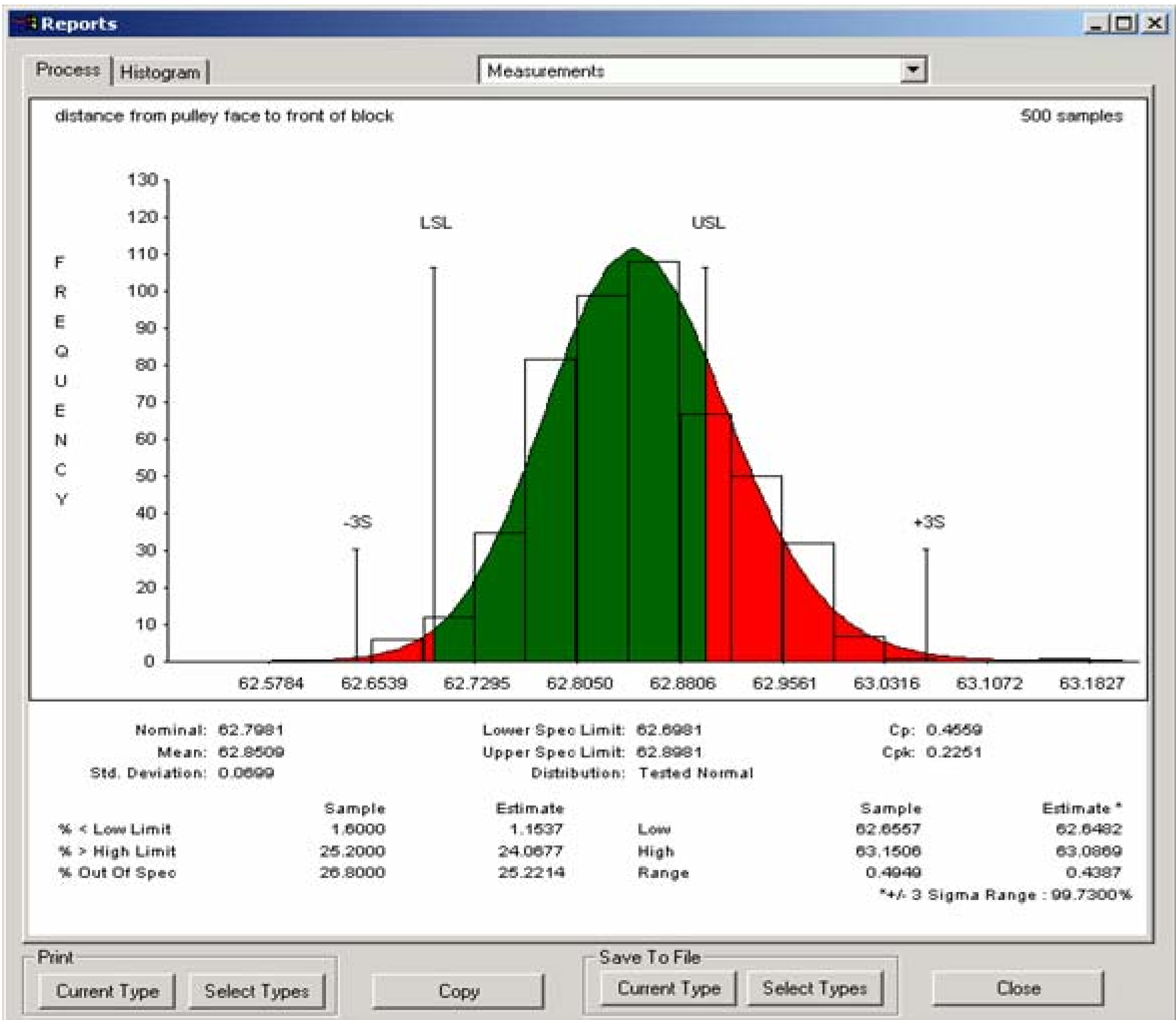
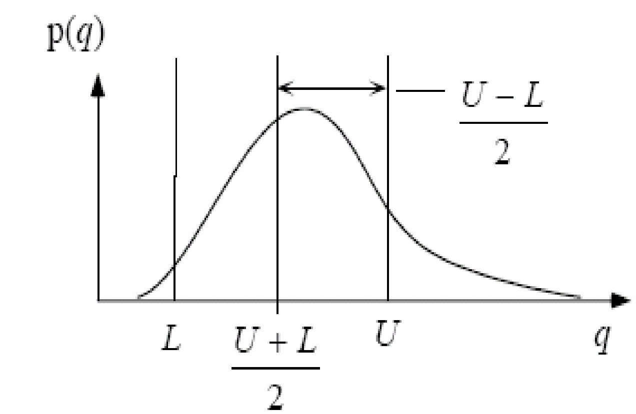


Figure 5.6 Viewing Result On Process Chart

5.1.6 PROCESS CAPABILITY INDICES AS SHOWN IN FIGURE



Process Capability Index:

$$C_p \equiv \frac{(U-L)/2}{3\sigma}$$

Bias Factor:

$$k \equiv \frac{\left|\mu - \frac{U+L}{2}\right|}{(U-L)/2}$$

Performance Index:

$$C_{pk} \equiv C_p(1-k)$$

5.1.7 RUNNING HLM (HIGH-LOW-MEDIAN) SIMULATIONS

In HLM simulations, individual process features are isolated and controlled variation is applied. Results from these simulations provide an indication of the extent to which the variance in a specific process feature affects a specific measurement operation.

5.2 TOLERANCE ANALYSIS FOR THE INJECTOR CLAMP

The injector clamp is used to hold the injector in the injector bore. The injector rotation and vertical moment is arrested by inserting the injector clamp on the flats .

In some engines after tightening the injector clamp a gap was observed between the injector and the clamp. This gap has to be avoided to prevent the injector from coming out. To analyse the cause of the above phenomena some analytical calculations were done to check the gap between injector and clamp.

In Vis Vsa we can do the stack up analysis just by considering the planes at the specific dimensions.

The calculations are performed from the cylinder head block joint face

The dimensions are as follows:

- Cylinder head height
- Injector clamp spacer resting face on cam cover
- Injector clamp spacer thickness
- Injector washer thickness
- Injector slot height
- Injector resting face height

By calculation we get the result as the gap of **0.95** mm between the heights.

.

By going through the result which obtained by Vis VSA are as follows:

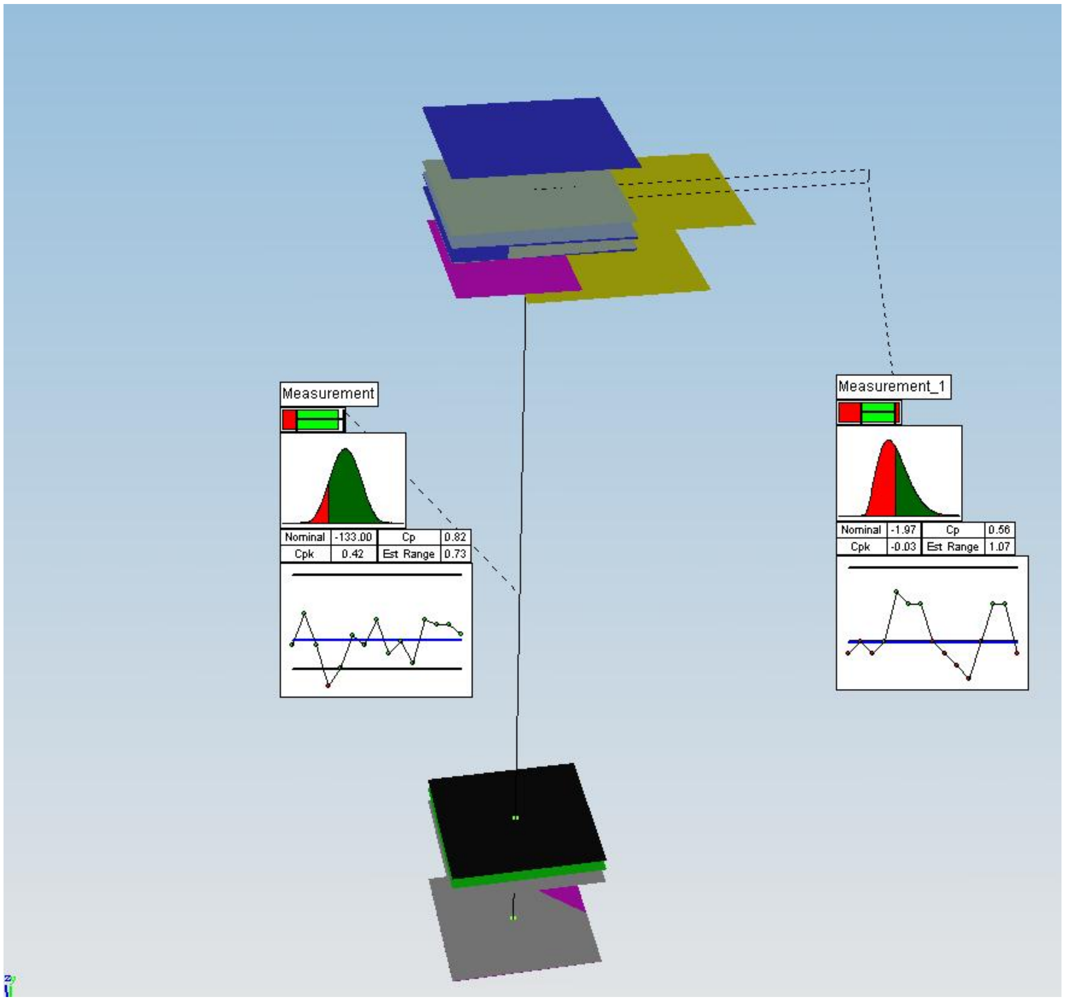


Figure 5.7 Planes for injector clamp

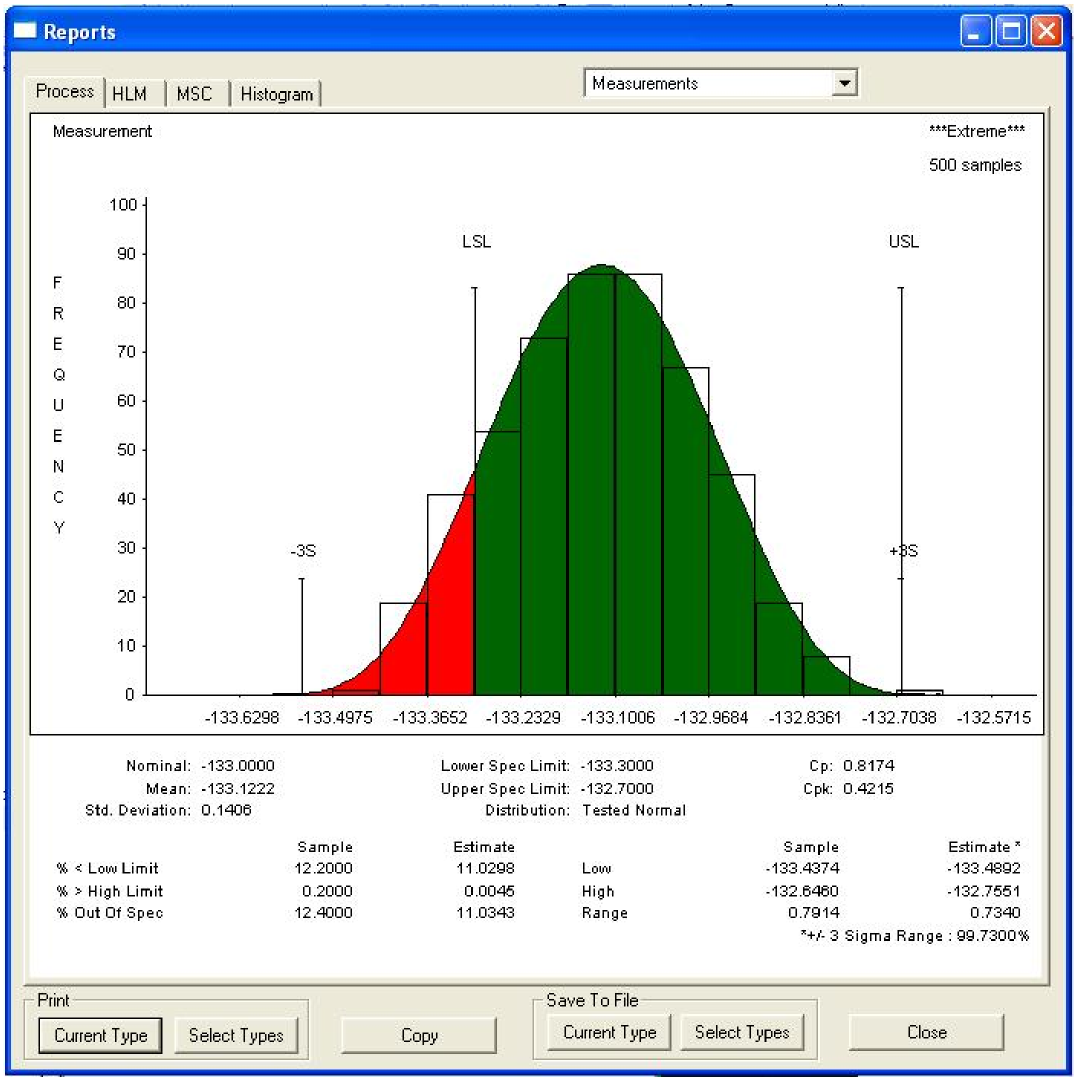


Figure 5.8 Process chart result for injector clamp

5.3 TOLERANCE ANALYSIS FOR THE TIMING CHAIN SYSTEM:

In your motor, timing is everything. That's why your timing chain and/or timing belt are so vital to the operation of your entire vehicle. You see, without a properly installed and adjusted timing chain or timing belt, the valves on your engine don't open and close at the appropriate times. A sloppy timing chain can result in poor running, valve clatter, and loss of power, while a broken timing belt can cause your engine to stop running or, on an interference application, cause your valves to crash into your pistons.

Therefore, Timing Chain System plays an important roll in every automobile and non-automobile engine. The tolerance stack up analysis of timing chain is carried out in three parts.

- Crankshaft Sprocket
- Camshaft Sprocket
- FIP Sprocket

From the software application we have to add only planes for the datum from which calculation for the tolerance stack up analysis in VIS VSA are carried out. So, this is not require to create the model of the system we can carry out the tolerance stack up by only creating planes at the appropriate dimensions.

5.3.1 CAMSHAFT SPORCKET ANALYSIS

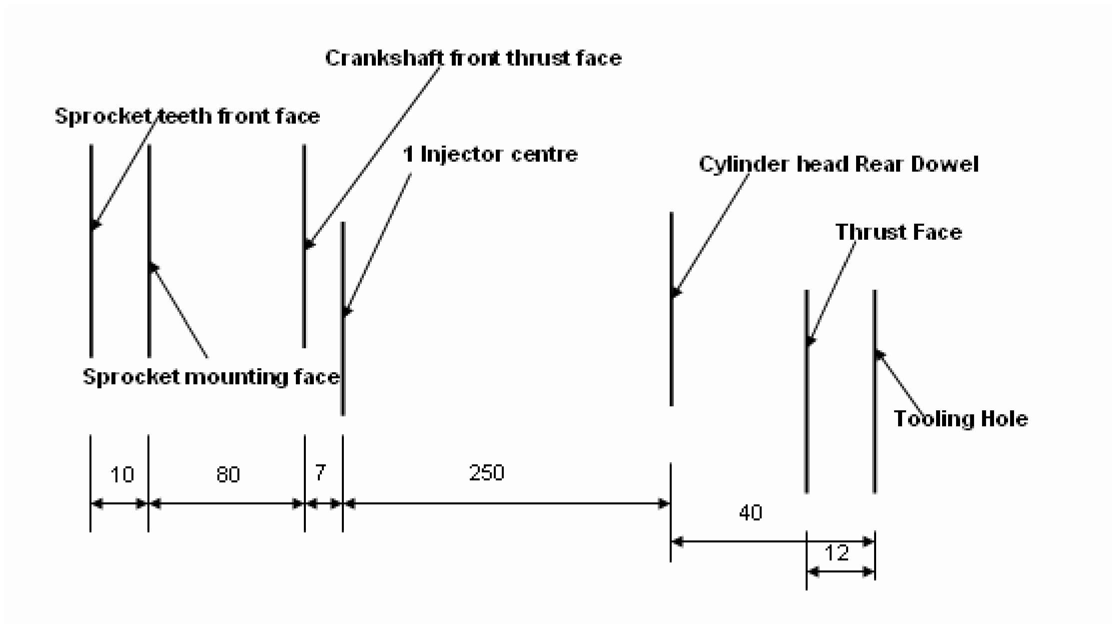


Fig 5.9 Planes For Camshaft Sprocket Stack up Analysis

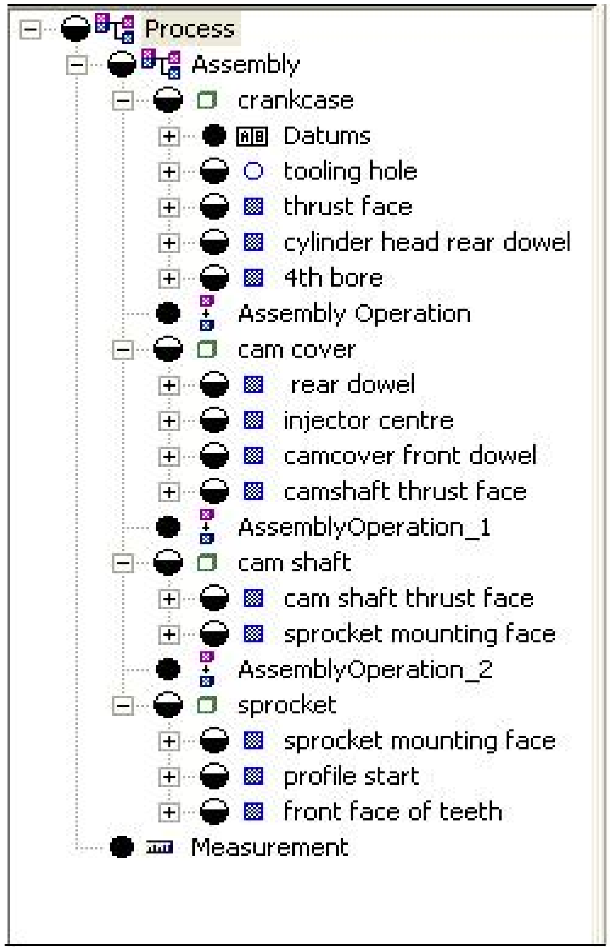


Fig 5.10 Process sheet For Camshaft Sprocket Stack up Analysis

5.3.2 CRANKSHAFT SPORCKET ANALYSIS

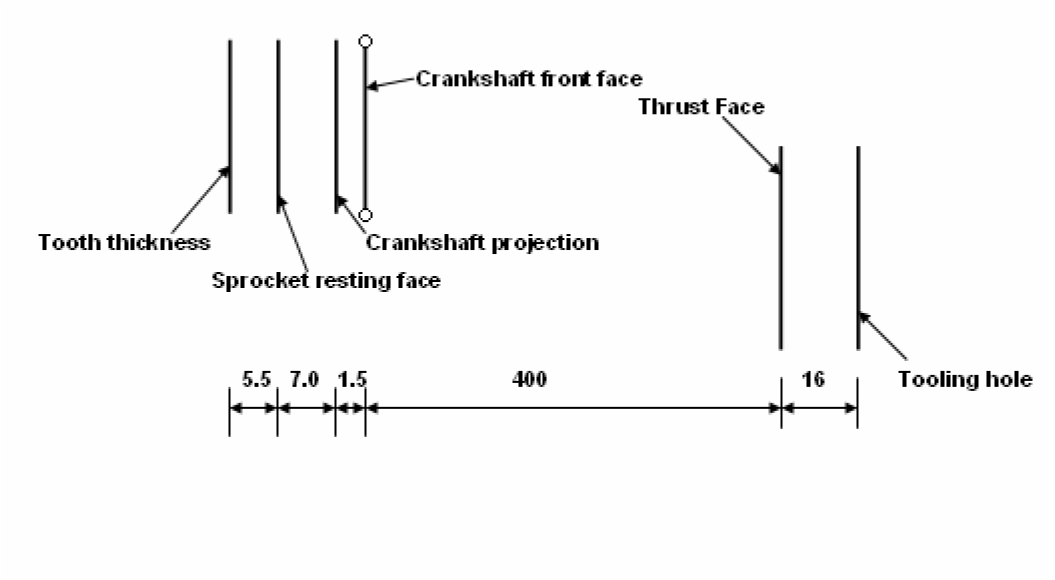


Fig 5.11 Planes For Crankshaft Sprocket Stack up Analysis

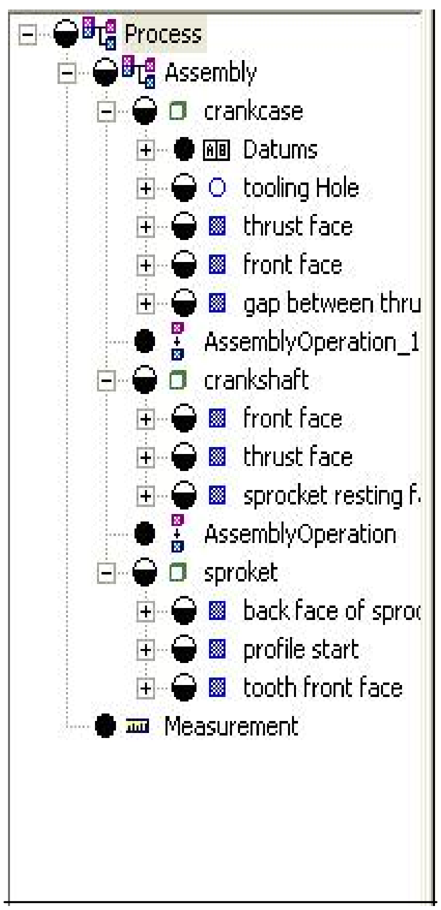


Fig 5.12 Process Sheet For Crankshaft Sprocket Stack up Analysis

5.3.3 FIP SPORCKET ANALYSIS

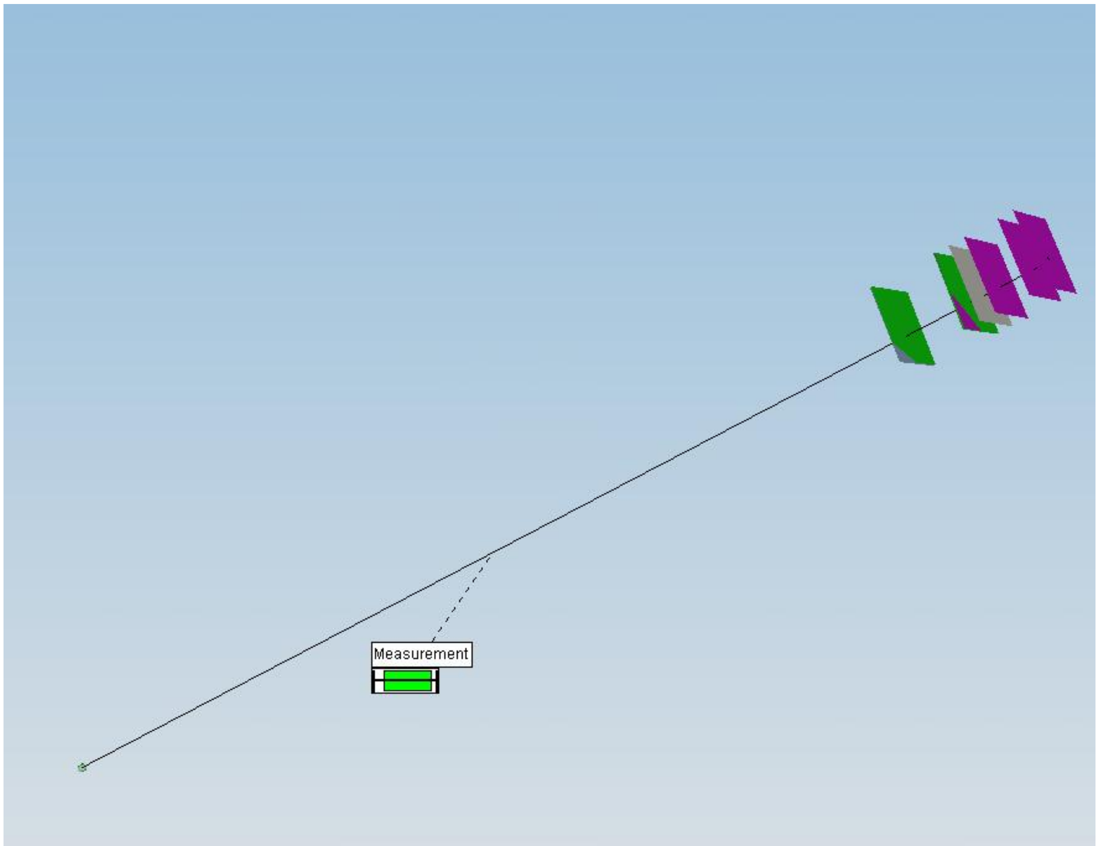


Fig 5.13 Planes For Fip Sprocket Stack up Analysis in VisVSA

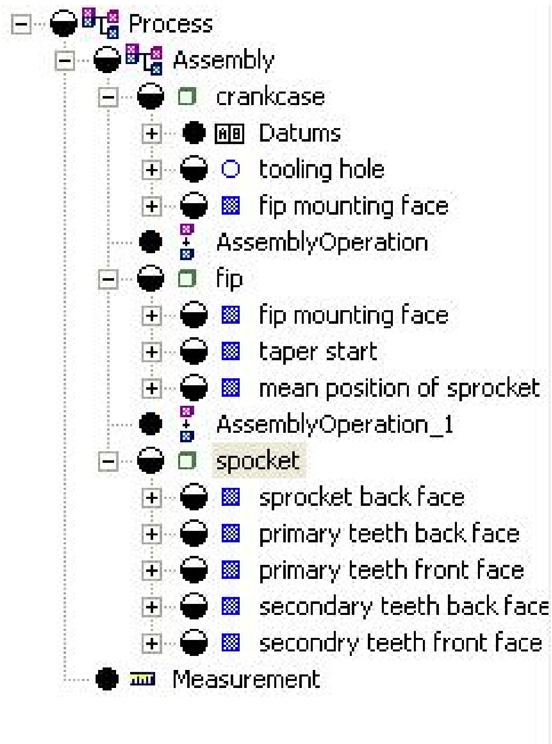


Fig 5.14 Process Sheet For Fip Sprocket Stack up Analysis

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

The new semantic tolerancing method captures engineering and logic relation between specifications and prevents the degeneracy of engineering semantics during mathematic calculation.

This tool is useful for a wide variety of design and manufacturing tasks: Predicting the final location of mating surfaces. Predicting distortion due to internal assembly stresses. Predicting internal stress and force due to assembly of geometry parts. Predicting percent of assemblies which will not meet design limits. Performing "what-if" studies and assigning tolerances throughout an assembly to minimize production/maintenance problems. Performing sensitivity studies to identify the critical sources of variation.

A method for evaluating tolerance stack up using Monte Carlo simulation driven by feature discrimination, manufacturing error analysis, and virtual inspection is proposed. This method is generally applicable to geometric as well as dimensional tolerances. It also gives less conservative results compared to the traditional ones (worst case and statistical methods). Overestimating tolerance stack up could result in precluding good process plans that should be accepted. Therefore, accurate evaluation of tolerance stack up can lead to cost-effective process plans.

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