Collaborative Development of High Precision Parts: from Design to Manufacturing

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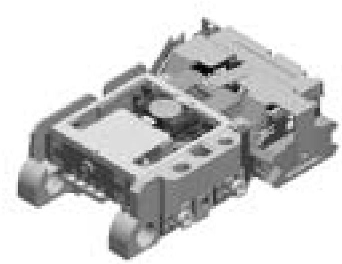
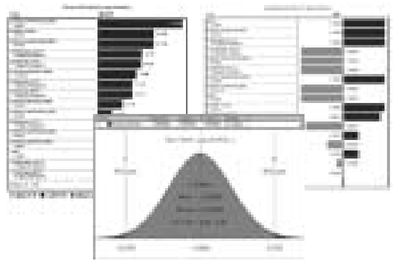


Digital Mockup

Collaborative Design



Tolerance Analysis

Abstract

The use of 3-D CAD(3-Dimensional-Computer Aided Design) has spread rapidly in recent years, in some cases allowing products to be developed without making a prototype. Survival in the manufacturing business depends on bringing a succession of attractive products to market quickly, something that can only be realized if products are developed in as short a period of time as possible. In order to achieve a shorter development cycle, design is performed in 3D, the resultant data is utilized until the actual production as much as possible, vertical hierarchical thinking is discarded, the idea that all personnel who have a hand in the product design are designers themselves is adopted, and development is expedited by simultaneously proceeding with product design, process design, and the development of manufacturing facilities and jigs which are derived from the aforementioned practices.

At FUJITSU TEN, collaborative design has been realized through the application of CA-DR (Computer Aided-Design Review) to the design of optical pick-ups, CD changer decks, etc. This report contains a detailed explanation of the practices described above.

1 Introduction

Recently, manufacturing industries have begun to recognize the increase in efficiency that three-dimensional CAD (3D-CAD) can bring to their operations, which has led to its prolific use. Although 3D-CAD was adopted at Fujitsu Ten Ltd. ten years ago, it was initially used for analysis and not design. Although design using 3-D CAD was attempted several years ago by a section of the Design Department, coordination throughout the design process from initial development to manufacturing was negligible. Unlike 2-D CAD, 3-D CAD cannot produce anything vague, which left designers with the impression that 3-D CAD was simply too time consuming. In order to gain a better understanding of the effects of 3D-CAD, CA-DR (Computer Assisted Design Review) as machinery design reform activities was begun by the Technical Information Systems Department pursuant to the objectives of reducing development periods, improving quality, etc.

In the strict sense of the word, "CA-DR" means "virtual design review". Applied more broadly, the term refers to the entirety of collaborative activities including Front Loading (quality assurance during the initial stages of development) and CAE.

These activities made a dramatic improvement in quality and a reduction in development time possible by using CAD data to coordinate the various phases of the design process and changing the way work is performed. This document contains examples of tolerance analyses that show the effects that CA-DR activities at Fujitsu Ten, Ltd., and the DMUs (Digital Mock-Ups) that support them have on precision components within CAE such as optical pick-ups and CD decks.

2 CADR Activities

2.1 Activity Objectives

During CA-DR activities, "Easy to Understand", the simplicity of 3-D-CAD is utilized to implement problem extraction and design integration at an early stage.

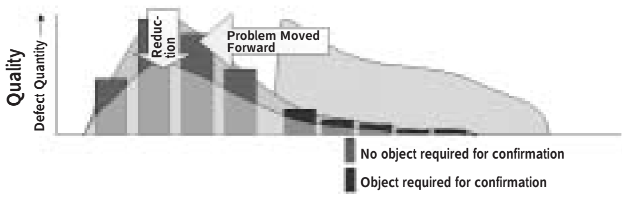


Fig.1 Front Loading

Prior to prototype creation, post-process departments such as Production/Manufacturing Engineering, Procurement, and Design share DMU models and incorporate the opinions of the Manufacturing Department and delivered <product> manufacturers regarding <production techniques> to finalize products on the spot.

This so-called "Collaborative Design," is done using 3D-CAD.

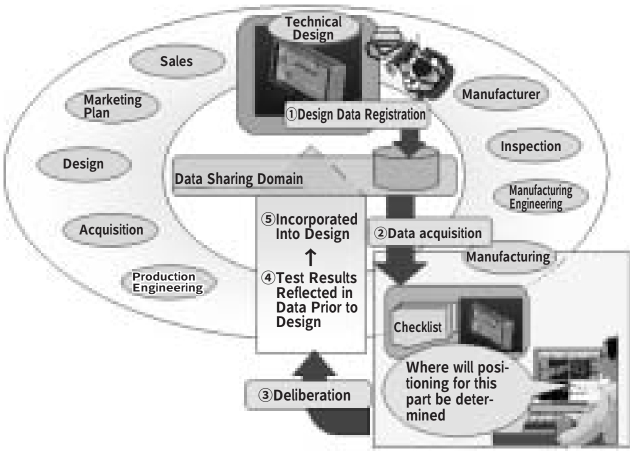


Fig.2 Collaborative Design

In order for this to be realized, it is necessary to implement DR (Design Review) and PR (Product Review) using DMUｓ as much as possible and to eliminate extracted problems with CAE.

However, sufficient verification time could not be secured with a serial work flow that utilized conventional 2D-CAD drawings because DMU model sharing was slow and required a significant amount of re-design time . Because of this, it became necessary to take advantage of DMUs, design using which is highly rated in many different ways, to facilitate changes that would enable "collaborative design".

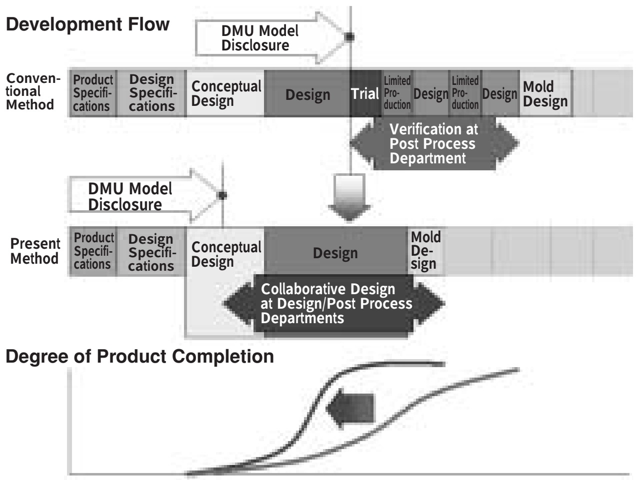


Fig.3 Business Operation Flow

2.2 Specific Implementation Examples

The conversion to operations that made use of 3D-CAD data necessitated a change in the attitudes of Design and related departments.

Specifically, an investigation of past product design defect factors proved that the use of CA-DR would secure early fault detection.

It became apparent that 63% of the defects in the model investigated in this trial could have been extracted in advance. (Refer to Figure 4 in following paragraph.)

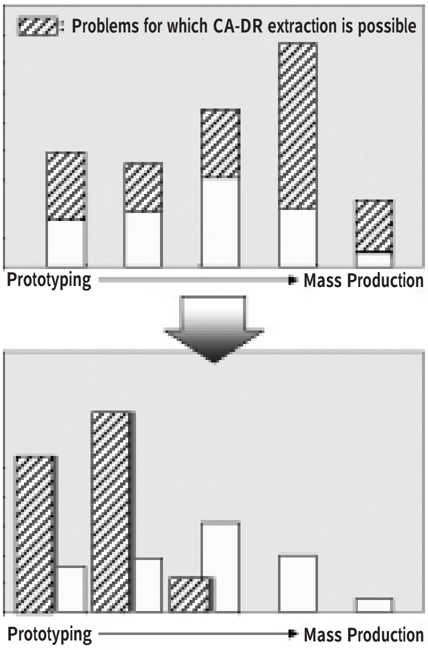


Fig.4 Defect Cause Investigation Results

The following environmental maintenance was performed in order to secure efficient CA-DR activity implementation:

- Maintenance of DMU 3D projector, personal computer-equipped DR room
- Development of a framework for sharing 3D data of designs in process over the intranet
- Development of a system for sharing images and attached comments created in DR using DMUs over the intranet

Fig.5 DR Result Sharing System

After the aforementioned preparations were completed, DMU models were used to implement DR/PR from the design concept stage, enabling the shift from conventional DR/PR, in which many design mistakes and defects were indicated, to "collaborative design", which seeks to produce better products through the use of design proposals.

Fig.6 DR Scenery (Photograph) Taken using DMU

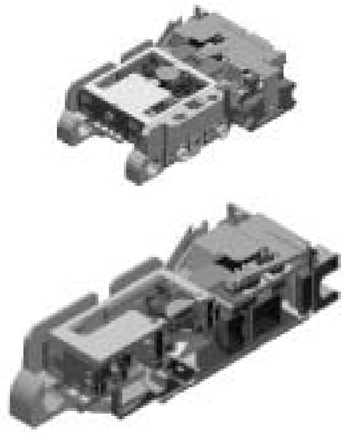
The following chapter contains detailed examples of CA-DR activities.

3 DMU Use

The previous chapter described the use of effective tools to increase design efficiency and the establishment of CA-DR design activities pursuant to short-term development. The example in this chapter describes development activities for "optical pickup", one of the most important audio product parts.

3.1 Collaborative Design Using DMU

In the past, paper drawings were heavily used during DR at the design concept stage. Understanding product structure from drawings requires skill. Once products such as optical pickups that are composed of minute/detailed parts were disassembled, too much time was spent trying to understand their structure, which reduced planned topics for discussion and detailed pro-



DMU Tool: VPS (Virtual Product Simulator), a FUJITSU product

Fig.7 Optical Pickup DMU

posals involving other departments.

This led to incomplete prototypes and, ultimately, to a situation in which prototypes had to be produced multiple times.

In these activities, the entirety of 3D design as well as DMU creation based on 3D-CAD data was performed during product development. As shown in Fig. 7, product structure can be understood at a glance, from part form and build status down to the finest details. DMU utilization allowed personnel in departments ranging from Design and Manufacturing Engineering to express their abundant technical viewpoints in DRs used to make a multitude of improvements to products early in the design phase before the construction of prototypes. DMU sharing over the intranet enables related departments to confirm the latest DMUs from the designer at any time. Simultaneously, each section can directly write comments and proposals to DMUs, which has had a considerable effect on early problem extraction. (tense?) Collaborative Design is used as described here to drastically reduce faults and increase product quality from the prototype stage.

3.2 Product/Jig Simultaneous Design

In the past, assembly jig design was begun after the completion of product mechanism design.

For this reason, it was difficult to secure a reference side and a positioning point, which resulted in a complex jig structure. The design period, including the period of time until completion, will be lengthened. Product development will also be affected. (ick!) Since product specifications and quality of optical pickup assembly are heavily influenced on detailed part assembly jigs, examination of reference side and positioning point is critical. An example of linked product/jig 3D-CAD design implemented at Fujitsu Ten, Ltd. to greatly reduce development time is shown here. (Refer to Fig. 8.)

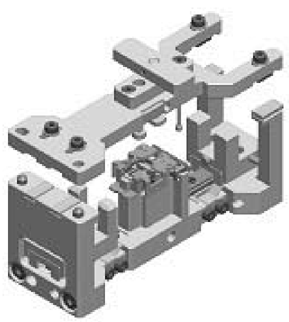


Fig.8 Assembling JIG

When a model is created, specifications such as reference side are determined and jig design is simultaneously carried out based on Production Engineering Department design data.

DMU is also used to assess workability. DMU (of workers' hands and tools) are created; jig verification is implemented simulating actual work. (Refer to Fig. 9.)

Using these methods, assembly jigs were verified without prototypes, jig design was started earlier, and product design period reduction was secured.

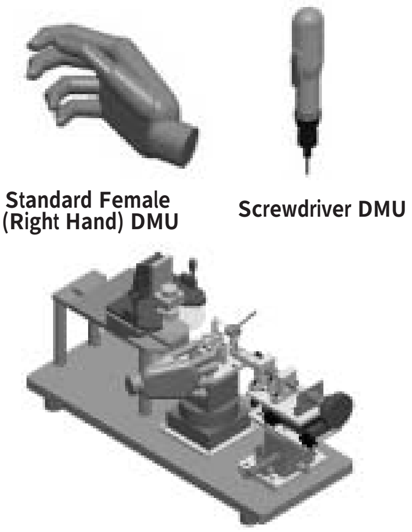


Fig.9 Task Model DMU

3.3 Simultaneous Product/Process Design

DMUs are configured per part.

Since all parts are designed using 3D-CAD, ease of assembly can be verified with DMU tools on a part-by-part level.

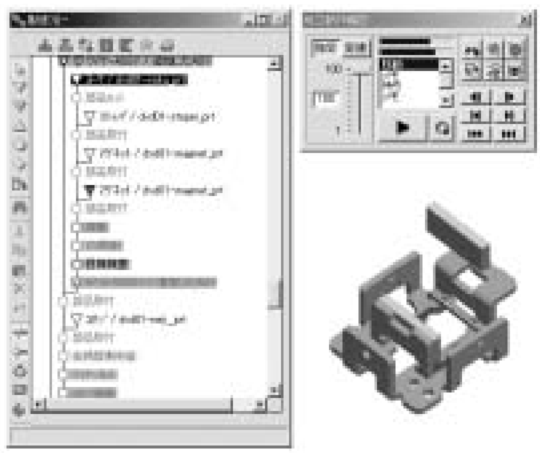


Fig.10 Optical Pick Up Process Flow

At Fujitsu Ten Ltd., 3D-CAD design was used to perform part assembly verification and process design in order to maximize its effectiveness. Products are disassembled per unit and the order in which the components of the unit are assembled is examined. Next, the dimension and form of parts, assembly operations/directions, and conclusion methods are defined, enabling comprehensive evaluation of man-hours and ease of assembly for each part. Since assembly order can be modified freely, it can be continuously reevaluated on the model, which enables simultaneous design of products and processes.

In addition, the jigs and equipment necessary for each process as well as inspection contents are defined, and product function errors were omitted.

4 Tolerance Analysis Use

Since verification using DMUs, described in the preceding chapter, is the central value used during design, it includes no allowances for part/assembly dispersion. However, dispersion is responsible for 30% of faults in precision parts like optical pick-ups and CD decks that are demand an exceedingly high degree of processing. Although designers could verify data through simple calculations using the conventional method, considerations for part processing and ease of assembly were inadequate. This chapter gives examples of tolerance analysis implemented in the Design and Production Engineering Departments in order to realize design that takes processing and assembly into account.

4.1 Simultaneous Product/Jig Analysis

This time, tolerance analysis was carried out on the actuator unit. Wire insertion hole position slip (X, Y directions) was measured at the lens holder and damper holder.

Tolerance analysis was carried out on the actuator unit. Wire insertion hole position slip (X, Y directions) was measured at the lens holder and damper holder. An outside view of the actuator unit is shown in Fig. 11.

The function of this area is not closely related only to part dispersion, but also to jig dispersion and assembly dispersion.

For this reason, jigs and products were simultaneously analyzed, and the adequacy of tolerance settings on both sides as well as crucial dimensions were extracted.

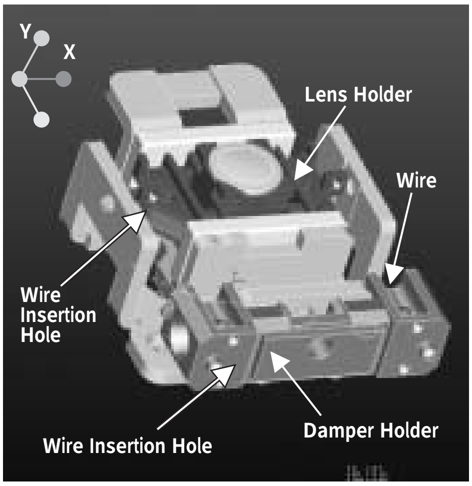


Fig.11 Actuator Unit

4.2 Analysis Results

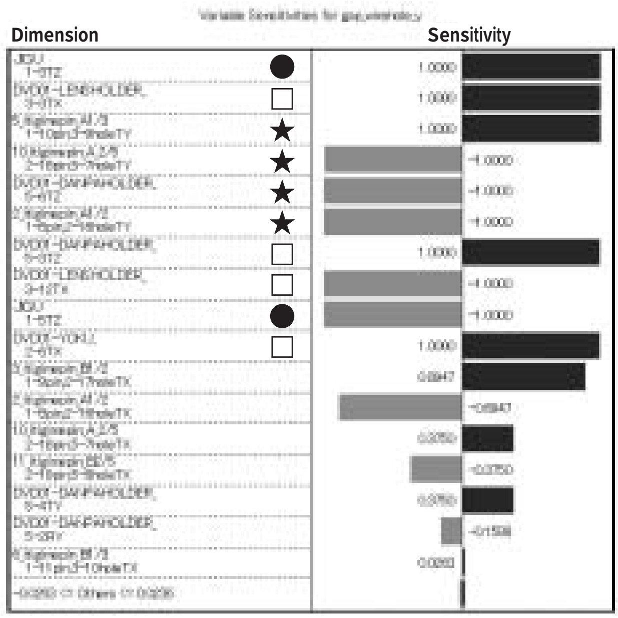
Tolerance analysis, which is performed using CE/TOL6σ (made by Sigmetrix, LLC of the United States), provides the following 3 results:

a. Sensitivity b. Contribution Rate c. Process Capability

Details of each are given below:

a. Sensitivity (Degree of Effect due to Dimension)

Rate of change of measured locations when the unit length (angle) of each dimension is changed is called sensitivity. One or more are considered important dimensions (high sensitivity). Results are shown in Fig. 12. As these results show, the gap between parts and the jig rather than the dimensions of the parts and jig themselves are the important dimensions for calculating the wire insertion hole position slip.



□ : Part Dimensions ● : Jig Dimensions ★ : Gap Between Part and Jig

Fig.12 Sensitivity

b. Contributing Rate (Tolerance Effect Ratio)

For each dimension tolerance, the ratio of the effect distortion has on each measured area is called the "Contribution Rate". This is the result of multiplying the aforementioned sensitivity by tolerance. The higher the sensitivity and the larger the tolerance area (maximum distortion), the higher this value will be. This is shown in Fig. 13.

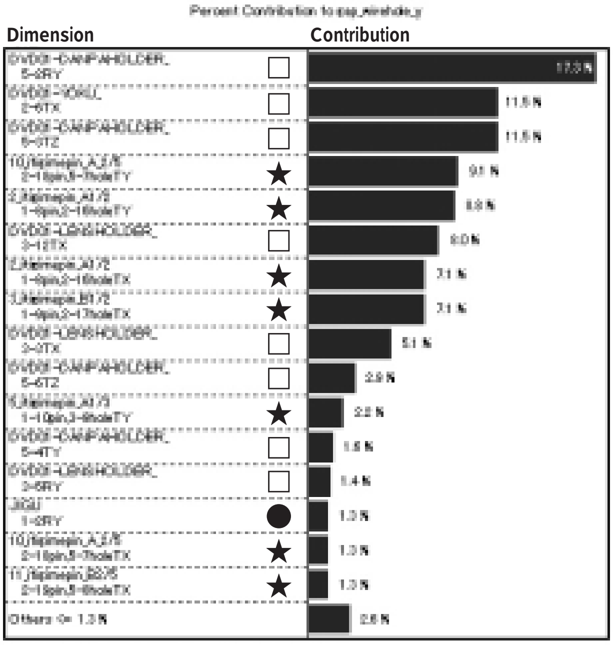


Fig.13 Contributing Ratio

As it can be seen, tolerance adquately manages jig dimension, which is the previous high sensitivity.

c. Process Capabilities

Process capabilities show wire insertion hole slippage distribution enabling prediction of defect rate and the amount of part interference.

Using the 3 aforementioned tolerance analyses, appropriateness of present tolerance settings, effective locations for improving process capabilities, and overly accurate locations can be predicted without an actual object. In addition, these tolerance analyses also enable product and jig key points to be used in product and jig design.

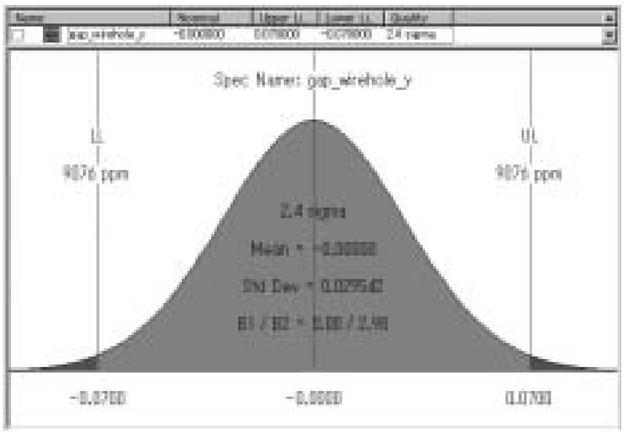


Fig.14 Process Capability

4.3 Joint Settings That Affect Analysis Results

Like other analyses, tolerance analysis requires that settings (contact definitions) be performed on the joints between parts. Actuator unit joint settings are shown in Fig. 15.

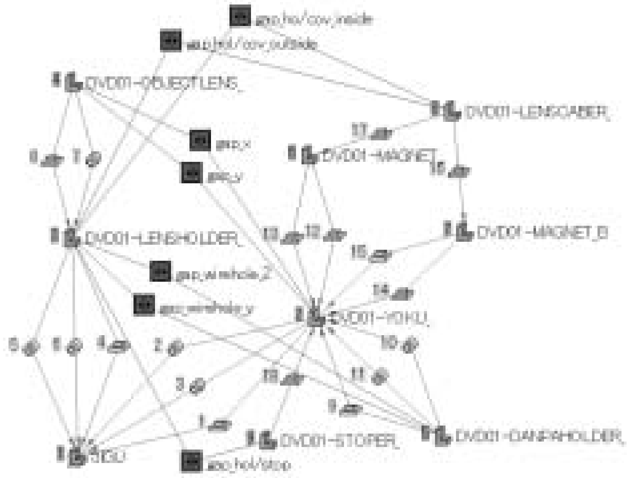


Fig.15 Joint Settings

Joint settings are restricted to 6 degrees of freedom (XYZ translation and rotation). However, transmission of distortion between parts varies completely depending on these settings, which results in the derivation of incorrect answers. For example, the position and attitude of the lens holder shown in Fig. 16 is determined by the jig support surface (planar surface:①) and pin (cylindrical surface:②).

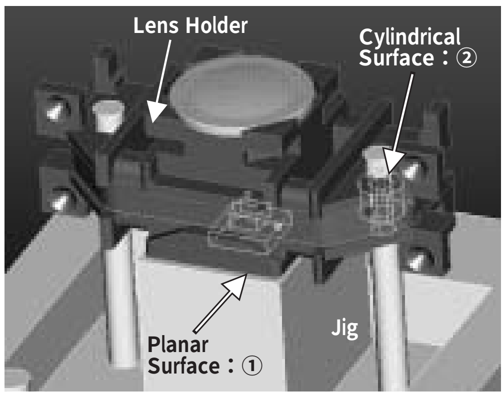


Fig.16 Jig-mounted Lens Holders

As shown in Figs. 17 and 18, rotation degrees of freedom may be restricted at either the planar surface or the cylindrical surface. Either setting can be calculated on the tolerance analysis system.

However, since flatness is specified at the jig support surface as shown in Fig. 19, it can be perceived that the jig designer intended to determine attitude (rotation of x and z axes) in a form that closely follows the planar surface of the support side. Provided that this is so, it is evident that the settings set in Fig. 17 are correct. However, if this is accidentally implemented as shown in Fig. 18, attitude will be determined by the lens holder holes and pin cylindrical surface, which will result in the

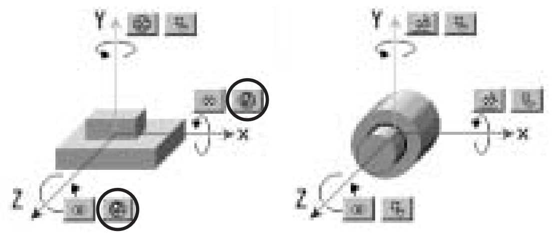


Fig.17 Constrained on Horizontal Surface（Correct Settings）

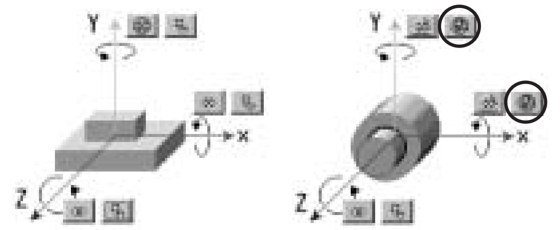


Fig.18 Constrained on Cylindrical Surface（Incorrect Settings）

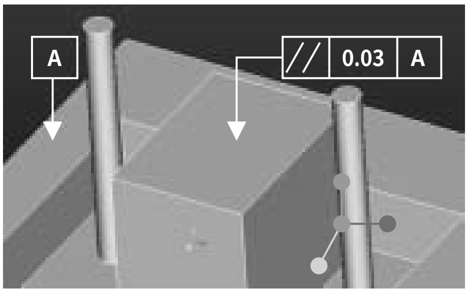


Fig.19 Jig Retained Surface Drawing Standards

pin angular distortion influence ratio being calculated instead of the influence ratio of the angular distortion at the planar surface.

CAE cannot judge whether or not settings are correct. This decision must be made by a person. At Fujitsu Ten Ltd., correct judgment is made because a group made up of one person from each of the following 3 departments--Design, Production Engineering, and Information Systems deliberates to make the decision as per "Collaborative Design", the concept behind CA-DR activities.

5 Results

Through the utilization of DMU and CAE in the new operating methods, effects were obtained on Q, C, and D as shown below. The following effects were obtained for "optical pickup" development.

a. Effects in the Design Department

Q: Part Manufacturing Problem Extraction Omission Reduction and Manufacturing Error Reduction

C: Effects as a Result of Error Reduction: Correction Cost Reduction (3 prototype units' worth)

D: 1.5 Month Reduction in Part Improvement Man-Hours Through Tolerance Analysis and Early Verification

b. Effects on Jig Design

Q: No Careless Mistakes (Part Interference) in Check Accuracy Improvement

C: 53% Jig Cost Reduction (at the Prototype Stage) due to Design Modification Compatible Reduction

D: Jig Design: Design Start Period Moved Up by Approximately 6 Months

6 In Closing

Details of how different tools were utilized during CA-DR activities through Collaborative Design in order to improve design quality and shorten the product development cycle are described above. Through these activities, design expands beyond the Design Department, making everyone who participated in the project a designer.

Implementation of these techniques taught us that it takes more than tools to change design methods. Changes in attitude and work procedure are what will actually lead to improved design quality and shorter development cycles. At present, CA-DR design is being applied to CD changers in addition to optical pickups. We intend to horizontally develop CA-DR, applying it to all mechanical products in 2004.

Reference Document
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