

Developing Parametric Models for the Assembly of Machine Fixtures for Virtual Multiaxial CNC Machining Centers

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Abstract. This paper dwells upon a variance parameterization method. Variance or dimensional parameterization is based on sketching, with various parametric links superimposed on the sketch objects and user-imposed constraints in the form of an equation system that determines the parametric dependencies. This method is fully integrated in a top-down design methodology to enable the creation of multi-variant and flexible fixture assembly models, as all the modeling operations are hierarchically linked in the built tree. In this research the authors consider a parameterization method of machine tooling used for manufacturing parts using multiaxial CNC machining centers in the real manufacturing process. The developed method allows to significantly reduce tooling design time when making changes of a part's geometric parameters. The method can also reduce time for designing and engineering preproduction, in particular, for development of control programs for CNC equipment and control and measuring machines, automate the release of design and engineering documentation. Variance parameterization helps to optimize construction of parts as well as machine tooling using integrated CAE systems. In the framework of this study, the authors demonstrate a comprehensive approach to parametric modeling of machine tooling in the CAD package used in the real manufacturing process of aircraft engines.

1. Introduction

Tooling is a part of technological complements to the machinery that is designed to perform specific tasks in the process. The main group of tooling consists of fixtures, i.e. machine accessories that help fix the workpiece in a specified position in accordance to operation specifications.

Use of fixtures helps:

- get rid of pre-machining workpiece sketching and make machining more accurate;
- improve the performance of operations;
- reduce the cost of production;
- make operations easier and safer;
- improve the technological capabilities of equipment;
- organize multi-machine servicing;
- use technologically plausible timings and reduce the number of workers involved.

To facilitate and speed up the design and production process in state-of-the-art systems, CAD/CAM systems are used. These systems enable one to create a parametric model, which is an applied program that controls the build of a new design object version upon any alteration or modification of its parameters. Fixtures as design objects have a number of features that make it feasible to develop their parametric models as user applications.



Siemens NX has a lot of parameterization tools, see Figure 1. The parameterization methods we propose have certain pros and cons; they are optimal for their specific modeling tasks. In its turn, each method provides for various parameterization techniques.

Our research was to integrate variance parameterization into a top-down design methodology to create a multi-variant and flexible fixture assembly model.

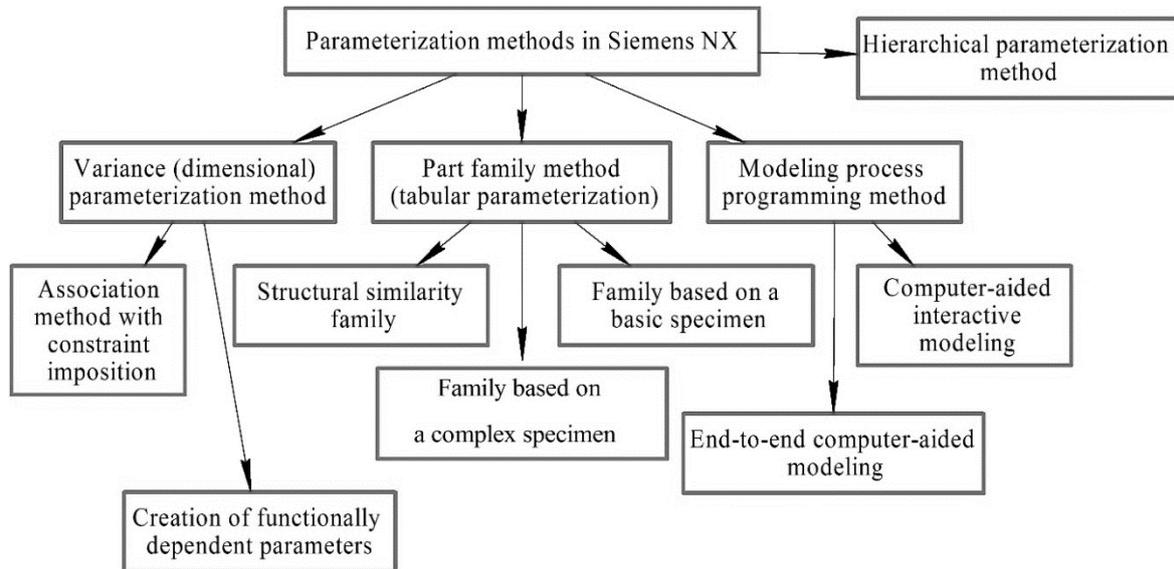


Figure 1. Siemens NX parameterization methods

Variance (dimensional) parameterization is the most common parameterization method implemented in Siemens NX. This method enables derivation of association models with geometric constraints and dimensions imposed during the building process. This method also helps specify the dependencies of different model parameters. Functional relations can be specified for the active sketch dimensions and parameters of 3D object operations.

Variance (dimensional) parameterization links the 3D model of a fixture to e-tables to contain geometric dimensions and calculation output.

2. Materials and methods

Variance or dimensional parameterization is based on sketching, with various parametric links superimposed on the sketch objects and user-imposed constraints in the form of an equation system that determines the parametric dependencies.

[1] summarizes the results obtained when solving the problems of CAD-enabled part and assembly modeling where possible 3D deviations were factored in. It therefore presents a new part and assembly modeling theory that factors in their spatial tolerances and enables one to analyze part assemblability at the stage of their geometric development in CAD systems.

[2] uses one of the CAD/CAE systems that helps quickly generate alternative designs at various levels of building modeling.

[3] dwells upon geometric modeling of spatial deviations in parts and assemblies. For each type of position and shape tolerances, it describes a method for building a configuration space, a point wherein helps obtain various positions of the marked frame and/or the modified coefficients of the quadratic forms of this surface within the tolerance; i.e. a full description of the 3D position of this surface.

[4] dwells upon a top-down 3D design and life-cycle management technology. This approach enables use of parallel business processes and organize efficient management of changes in a product. It works not only for 3D models at various stages of design, but also for requirement structures as well as functional and logical structures of the product. A 3D model developed by top-down design is an

integral part of the enterprise data and process model.

[5] dwells upon a 3D-based interface for modeling new and intuitive assemblies to support conceptual exploration works. In their modelign interfaces, unmarked segmented object components are assembled to create new 3D models.

In the future, 3D models will fully replace 2D drawings of parts and assemblies. 3D models built contain source data for CAE analysis based on the computational solution of differential equations [6,7].

For engineering and scientific computations, 3D models are divided into finite elements, whereupon boundary conditions are imposed. Computations helps refine the geometric parameters of part and make necessary adjustments. A modified 3D model of the part is then transferred to the CAM system to develop the manufacturing process [8-13].

Computing CAD models in CAE systems helps optimize the materials used in design [14,15].

To sum up, it is safe to conclude that in this focus area, researchers actively use various parameterization methods to link 3D models of fixtures to e-tables that will contain geometric dimensions and calculation output.

3. Developing top-down parametric models for the assembly of fixtures using virtual multiaxial CNC machining centers

In our research, variance parameterization is fully integrated in a top-down method. This method enables the creation of multi-variant and flexible fixture assembly models as all the modeling operations are hierarchically linked in the build tree.

The top-down method (see Figure 2) implies that all parts are created jointly using a combined build tree.

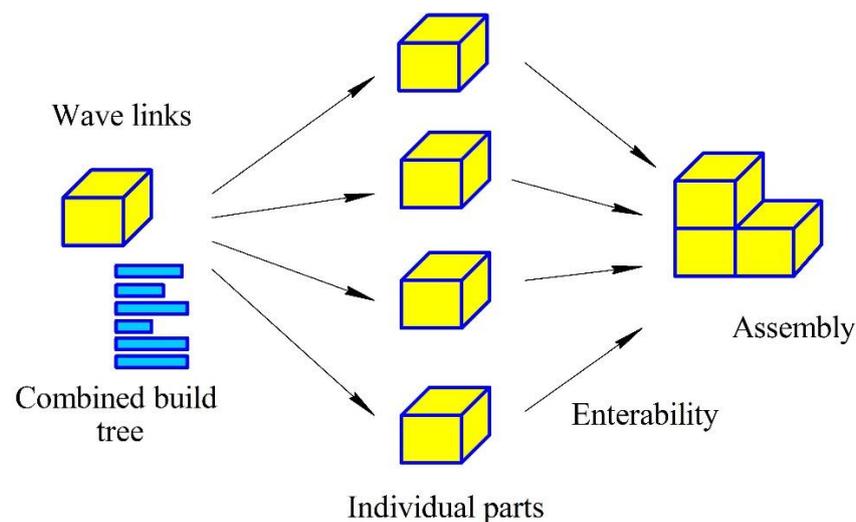


Figure 2. Top-down design

Thus, the resulting parts in the product layout only contain geometric copes derived from the service part that contains the combined build tree. This method has the following advantages:

- all parts are designed interrelatedly, no need to manually harmonize them;
- relations are physically included in the model, i.e. changes made to one of the parts will be reflected in all other parts it is connected to;
- the conceptual design is included in the model, i.e. top-level parameters and forms are connected to the parts and control them for consistency with the concept;
- the design process is easy to divide into the required number of interrelated stages (sketch project, work project, etc.);

- the process becomes considerably less prone to error when being based on the links relations between parts rather than engineers' imagination and memory.

Let's take a 3D machine fixture model as an example, see Figure 3. The parent of the product layout is an assembly model that combines the following components:

- source;
- work;
- result.

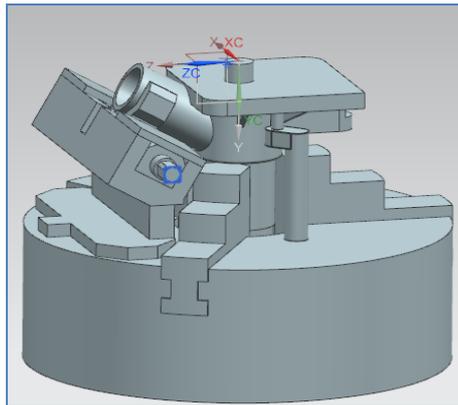


Figure 3. Fixture assembly model

For the source, we created a 3D Journal model, the sketches of which were controlled by a certain number of conceptual parameters, see Figure 4:

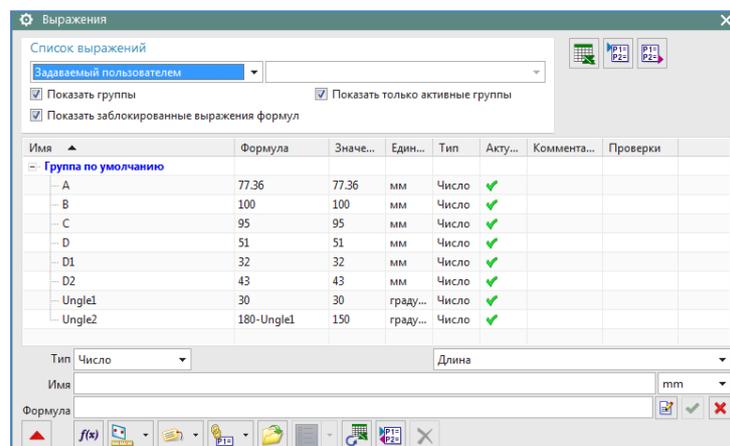


Figure 4: Conceptual Parameters Window

A is the length of the sponge-fixed nozzle;

B is the width of the platform (machined surface);

C is the length of the platform (machined surface);

D, D1, D2 are the diameters of the surfaces of the part;

Ungle1 is the inclination angle of the sponge-fixed nozzle;

Ungle2 is the angle at which the column is inclined relative to the chuck.

We further made the source sketches of the fixture (see Figure 5) that are associatively copied to the work by means of Wave. The work uses expression relations and Wave links to sketches to take data from the source; thus, all changes in the source will be automatically traced in the work.

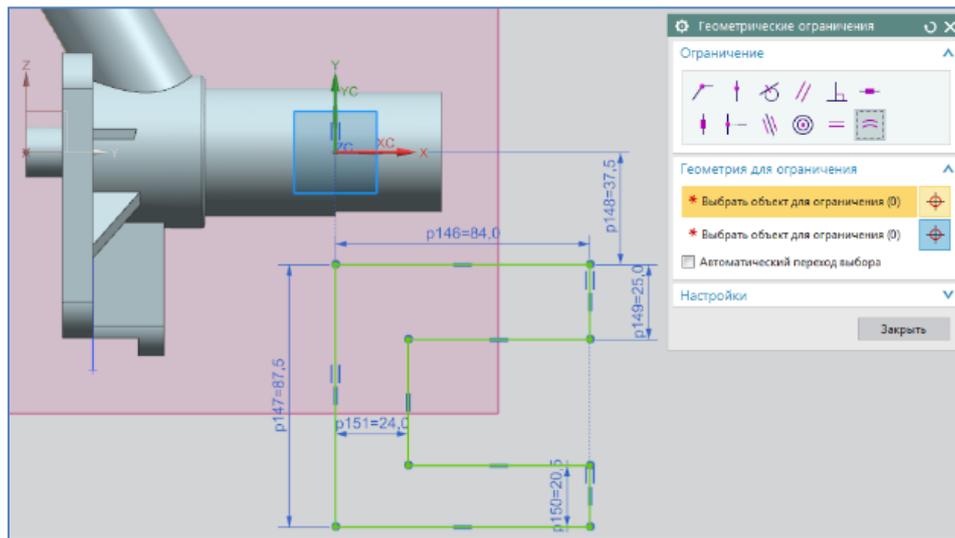


Figure 5. Source chuck sketch

Source sketches are the basis for all subsequently made sketches, which in their turn are the basis for building the solids representing the geometry of components.

This method can be seen in action when altering a conceptual parameter in the source. Let's change Unгле1 from 30 degrees to 45 degrees. Changing these parameters alters the inclination angle of the sponge-fixed nozzle as well as the inclination angle of the column. The initial form of the fixtures and the result of its parametric change are shown in figures 6 and 7.

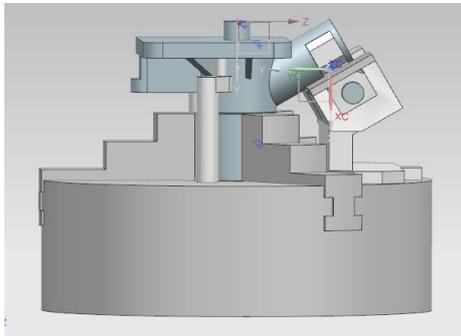


Figure 6. Unaltered column

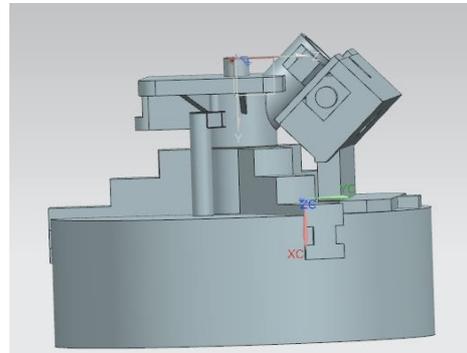


Figure 7. Altered column

Comparing the results obtained, we conclude that appropriate sketching and rigid fixation of fixture sketches and components relative to the part will cause geometric changes in the part to alter the geometry of such components.

The top-down method has an undeniable advantage which is that all the geometric properties of a product are harmonized, and the entire modeling process is fully contextual.

Stated above the top-down design methodology enables to create multi-variant and flexible model of fixture assembly models in which all operations of the modeling are connected among themselves hierarchically. This parametrization technique is proposed for use in a real production process in the manufacture of parts on multi-axis machining centers with CNC, which will significantly shorten the time for designing the tooling, as changing the geometry of the models will occur automatically and interrelated with the original part. In the Siemens NX CAD system, machine tooling files contain associative 2D documentation and processing strategies on CNC equipment, and when the 3D model is rebuilt, this data is automatically changed. In the future it is planned to integrate engineering calculations into the model of adaptation which helps to optimize the design of both parts and all equipment.

4. Conclusion

This paper gives an analytical review of papers on parametric modeling to prove the relevance of this focus area. Progressive top-down design technology is presented herein. The paper describes the advantages of this method as well as how it can be used when designing a machine fixture assembly model.

Top-down methodology combined with NX CAE and NX CAM can considerably reduce product design time and make the design and production stages less prone to error.

References

- [1] Gaer M A, Zhuravlev D A 2011 Bulletin of the Irkutsk state technical university vol 4(51) pp 24-26
- [2] Sacks R , Eastman C, Lee G 2004 Automation in Construction vol 13 pp 291-312
- [3] Gaer M A, Zhuravlev D A, Yatsenko O V 2011 Bulletin of the Irkutsk state technical university vol 10(57) pp 32-36
- [4] Lihachev M V 2015 Vestnik SibGAU vol 16 pp 423–429
- [5] Jaiswal P, Huang J, Rai R 2016 Computer-Aided Design vol 74 pp 45–54
- [6] Ermakov, A.I. and Uralapkin, A.V., The influence of a blade Vibrations connectivity on a degree of disturbance of turbine wheels rotation symmetry, Res. J. Appl. Sci, 2014, vol. 9, no. 11, pp. 800–805.
- [7] Ryazanov A.I. Mathematical model and numerical solution of the process of heating and melting of a traveling cylinder fed into a rocket chamber, ARPN J. Eng. Appl. Sci., 2014, vol. 9, no. 10, pp. 1859–1865.
- [8] Popov, G.M., Baturin, O.V., Kolmakova, D.A., and Krivtsov, A.V., Improvement results of TK-32 turbocompressor turbine with gas-dynamics and strength CAE-systems, Int. J. Eng. Technol., 2014, vol. 6, no. 5, pp. 2297-2303.
- [9] Ermakov A.I., Shklovets A.O., Popov G.M., and Kolmakova D.A. Investigation of the effect of the gas turbine compressor supports on gas flow circumferential nonuniformity, Res. J. Appl. Sci., 2014, vol. 9, no. 10, pp. 684-690.
- [10] Khaimovich, I.N. and Khaimovich, A.I., Analytical modeling of the microstructure evolution of titanium alloys during high-speed stamping of the blades of gasturbine engines, Russ. J. Non-Ferrous Met., 2015, vol. 56, no. 2, pp. 181-189.
- [11] Nekhoroshev, M.V., Pronichev, N.D., Smirnov, G.V. Computer simulation of high-speed anodic dissolution processes of geometrically-complex surfaces of GTE details Open Mechanical Engineering Journal, 8, pp. 436-440.
- [12] Melentev, V.S. and Gvozdev, A.S., Methods of building a parametric CAD-model of a piston micromotor with the systems, Int. J. Eng. Technol., 2014, vol. 6, no. 5, pp. 2331–2338.
- [13] Pechenin, V.A., Bolotov, M.A., and Ruzanov, N.V., Development of a method of ICP algorithm accuracy improvement during shaped profiles and surfaces control, Int. J. Eng. Technol., 2014, vol. 6, no. 5, pp. 2229-2235.
- [14] Balaykin, A.V., Nosova, E.A., Galkina, N.V Study of the Ti-5Al-5Mo-5V-1Cr-1Fe titanium alloy grain structure uniformity after bending and annealing. IOP Conference Series: Materials Science and Engineering, Vol. 177, I. 1. 2017.
- [15] Alexeev, V.P., Balyakin, A.V., Khaimovich, A.I. Influence of the direction of selective laser sintering on machinability of parts from 316L steel. IOP Conference Series: Materials Science and Engineering, Vol. 177, I.1. 2017.