

# Modeling of Machine Design with Numerical Control in UG NX 7.5 System

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## -----ABSTRACT-----

*The paper considers the features of metalworking machines. The methodology for kinematic calculation of the main drive machine motion is considered. The modeling of the mounting tool holder detail is carried out. UNIGRAPHICS NX 7.5 creates a sketch and assembly of work piece parts. Modeling a detail in the UNIGRAPHICS NX with the specified properties will allow you to achieve maximum performance at all creating stages the design elements of the machine.*

**KEYWORDS** - Modeling, Construction, Assembly, Machine, UNIGRAPHICS NX

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## I. INTRODUCTION

Despite the progress in the chemical industry development and the development of state-of-the-art durable polymer materials, from which components for many devices are being created, the metal remains the most relevant raw material for the manufacture of component details of engines, devices, fastenings, structures and many other objects without which the comfortable existence of civilization is impossible [1].

Modern industry cannot be imagined without equipment such as a metalworking machine, because metal is one of the most promising materials [2]. Automatic tools, manipulation and world-class metalworking equipment are always required. In many respects this was because of its extensive function [3].

Metalworking machine – a machine designed for dimensional machining of metal blanks in accordance with the drawing (sketch) by removing the material mechanically using a cutting tool. Mechanical instrument design (nodes and elements) must remove connectivity and connection errors in the installation of nodes and elements that could be a source of danger [4, 5].

Large modern metal manufacturers are seeking to expand their reach to the global consumer market. For this purpose, however, it is necessary to begin with the modernization of production [6, 7].

The acquisition of new metalworking equipment is not always the most rational solution. Modernization of the equipment already in use and qualitative repair allows enterprises to obtain machines of at least [1, 8] quality. Thus, the design task of the numerical control machine is relevant.

## II. MATERIALS AND METHODS

### 2.1. Related work

Solutions for problems related to the design, modeling and writing of software for computer numerical control (CNC) and analysis of the effective operating patterns of metalworking machines have been devoted to a number of works.

In theory, the design of optimal machining cycles for numerically controlled metal cutting machines is considered in [8]. It has been determined that dynamic programming allows the improvement of an unlimited number of control parameters for all automation processes in metal cutting machines with digital control.

Construction of low-performance cutting tools The dynamic scale and static calibration of the cutting force are described on a CNC milling machine in [9]. The proposed arrangement was linked using the NI data acquisition system to measure cutting forces. The dynamometer advanced in this work is validated by conducting experimental experiments. This low-cost dynamometer is capable of measuring cutting forces in all three directions.

The structural structure of the mechanical formulations was studied in [10]. The objective of this work is to provide basic form parameters, ie, preliminary data for computer-aided design of metalworking equipment. Coding of the layout of metal-cutting machines in [11].

The processing precision adjustment is described by the offset of the programmed instrument in [12]. Based on the mathematical model of the treatment center, a method is proposed for the programmed correction of the tool and the movement of the work in the metal-controlled metal cutting machines. This method improves machining accuracy in real time.

In [13] investigates the type of correlation by changing the cutting tool geometry. A series of simulations of finite elements (FE) were performed for several different beam angles, showing a strong relationship between the triaxiality stress parameter in the deformation area and the required cutting force components.

## **2.2 Analysis of the metalworking machines features**

All the variety of equipment designed for metal processing is divided into several categories depending on its functional purpose. Each of the categories, in turn, has several subspecies [2, 4].

A group of metal working machines includes a large number of different equipment. The basis for its classification is a functional feature, that is, the type of metal processing.

According to the accuracy class, metal working machines are divided into five classes [14]:

- normal accuracy (N).
- increased accuracy (I).
- high accuracy (H).
- particularly high accuracy (P).
- extremely precise machines (E).

Depending on the application field, different mass machines are used.

Classification of machine tools by weight [4, 14]:

- Light (<1 t).
- medium (1-10 tons).
- heavy (> 10 tons).
- unique (> 100 tons).

Classification of metalworking machines by automation degree [2, 14]:

- manual.
- semiautomatic devices.
- automatic machines.
- CNC machine tools.
- flexible production systems.

Classification of metalworking machines by specialization degree [1]:

- universal. To produce a wide range of details in small batches. Used in single and batch production. Also used for repair work.
- specialized. For manufacturing large details batches of the same type. Used in medium and large-scale production.
- special. For the manufacture of a single component or single standard size detail. Used in large-scale and mass production.

## **2.3 Kinematic calculation of the main machine drive**

When developing the design of metalworking machines, the problem arises of the choice of the drive for the main movement of the machine.

The goal of the kinematic calculation is to develop a kinematic drive circuit. It is necessary to select an electric motor based on the technological capabilities of the machine being designed.

Suppose a DC motor is used in the machine drive. Speed regulation is a forced change in the engine speed in order to regulate the movement speed of the machines and mechanisms executive bodies. The total drive control range is [1, 15]:

$$R_n = \frac{n_{\max}}{n_{\min}}, \quad (1)$$

where  $n_{\max}$  – maximum speed for specified limits of load variation on the motor shaft.

$n_{\min}$  – minimum speed for given limits of load changes on the motor shaft.

This range is the product of the DC motor control range and the stepped gearbox.

To determine the range of engine control it will be necessary to specify its size and parameters. For a given useful power, it follows [1, 15]:

$$N_{np} = \frac{N_{nom}}{\eta}, \quad (2)$$

where  $N_{nom}$  – nominal frequency of rotation;

$\eta$  – efficiency.

Thus, the adjustment range of the selected motor is [1, 15]:

$$R_{em} = \frac{n_{em,max}}{n_{em,min}}, \quad (3)$$

where  $n_{em,max}$  – nominal maximum frequency of electric motor rotation;

$n_{em,min}$  – nominal minimum frequency of electric motor rotation.

The range of the gearbox can be determined by the formula [1, 15]:

$$R_b = \frac{n_{em,min}}{n_{min}}, \quad (4)$$

Therefore, the overall control range can be written in the form [1, 15]:

$$R_n = R_{em} \cdot R_b. \quad (5)$$

For the selected values of the motor control range  $R_{em}$ , the geometric series denominator  $\varphi$ , the conditional number of electrogroup steps  $R_{em}$  will be [1, 15]:

$$p_{em} = 1 + \frac{\lg R_{em}}{\lg \varphi}. \quad (6)$$

The number of gearbox stages is determined from [1, 15]:

$$z_b = \frac{\lg(R_n \cdot \varphi)}{\lg(R_{em} \cdot \varphi)}. \quad (7)$$

Consequently, the conventional number of drive speed stages is [1, 15]:

$$z_{em} = p_{em} \cdot z_b. \quad (8)$$

Suppose, a split drive with a speed box representing a double search is adopted. Such a search can be used as a multiplier mechanism for cutting multi-threaded threads and threads with large steps. With this in mind, we can write the drive formula in the following form [1, 15]:

$$z_n = p_{em} \cdot p_1 + p_{em} \cdot p_1 \cdot p_2 \cdot p_3 + p_{em} \cdot p_1 \cdot p_2 \cdot p_3 \cdot p_4 \cdot p_5. \quad (9)$$

In strict accordance with the approved structural formula, it is possible to plot the rotational speed of the drive (Fig. 1) with infinitely variable spindle speeds in the ranges,  $R_1$ ,  $R_2$  and  $R_3$  [1].

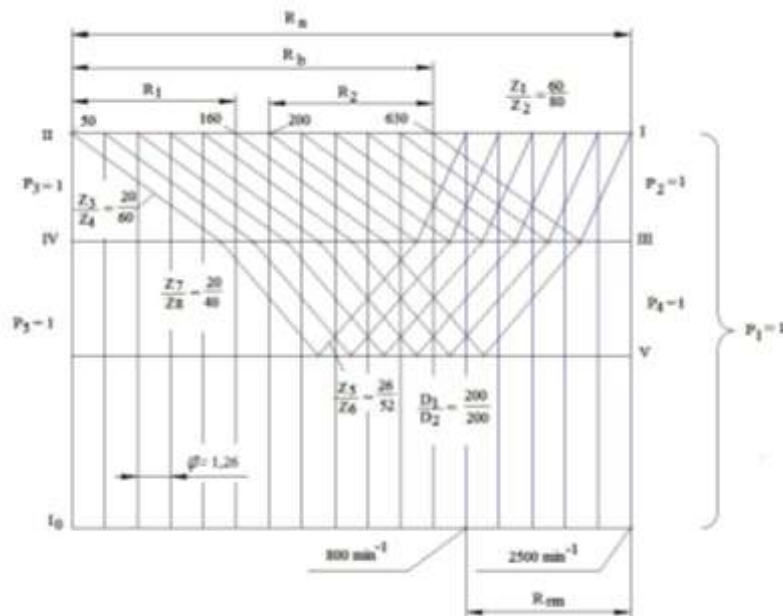


Figure 1: Schedule of rotation frequencies

In the middle of the control range between the frequencies 160-200 and 630-800, a gap is allowed due to a reduction in the number of gearbox stages. If it is necessary to exclude the lack of property, the DC motor can be used with the same capacity, but with a greater control range  $R_{em} = 4$ .

The kinematic scheme of the drive (Fig. 2) gives the following two transfer ratios:

$$i_{n1} = \frac{z_1}{z_2} \cdot \frac{z_3}{z_4} \quad (10)$$

$$i_{n2} = \frac{z_1}{z_2} \cdot \frac{z_5}{z_6} \cdot \frac{z_7}{z_8} \cdot \frac{z_3}{z_4} \quad (11)$$

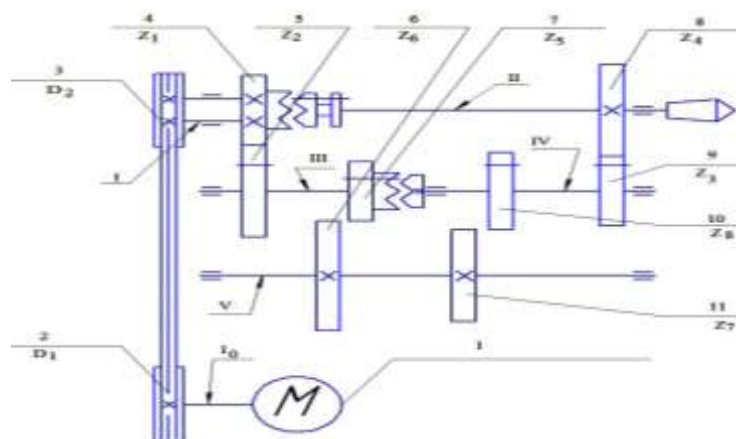


Figure 2: Kinematic scheme of the drive

Therefore, using the search as a step increment step, it is possible to extend the steps (moves) range of the threads provided by the feed drive by 4 and 16 times.

The minimum spindle speed is carried out by the chain:

$$n_{\min} = n_{em\min} \cdot \frac{D_1}{D_2} \cdot \eta \cdot \frac{z_1}{z_2} \cdot \frac{z_5}{z_6} \cdot \frac{z_7}{z_8} \cdot \frac{z_3}{z_4} \quad (12)$$

At the same time, the spindle calculated frequencies  $n_{cal}$  with respect to the frequencies accepted by the normal  $n_{nor}$  is within:  $[\Delta n] = \pm(1,26 - 1) \cdot 10\%$ .

The error is calculated by the formula:

$$[\Delta n] = \frac{100 \cdot (n_{cal} - n_{nor})}{n_{cal}}, \quad \% \quad (13)$$

The maximum speed is obtained directly from the electric motor, bypassing the bulk device:

$$n_{\max} = n_{em.\max} \cdot \frac{D_1}{D_2} \cdot \eta \quad (14)$$

The deviation of the obtained actual spindle rotational frequencies from the specified ones is within the permissible limits

### III. RESULTS

#### 3.1 Modeling of the tool holder mounting

At the heart of modern design tasks lies CAD, CAM, CAE system. UNIGRAPHICS NX 7.5 is a software tool that can speed up the marketing time of a new product, improve its quality, reduce costs, and enable us to reuse the accumulated knowledge and experience in product creation and manufacturing processes to improve innovative processes.

To create an item in UNIGRAPHICS NX 7.5, you must create an empty diagram for this part. Then you need to create a two-dimensional drawing for the part that was created. Then, using the lines, we create a diagram and to create the swallowtail element, we set the gradient angle by  $45^\circ$  (Fig. 3).

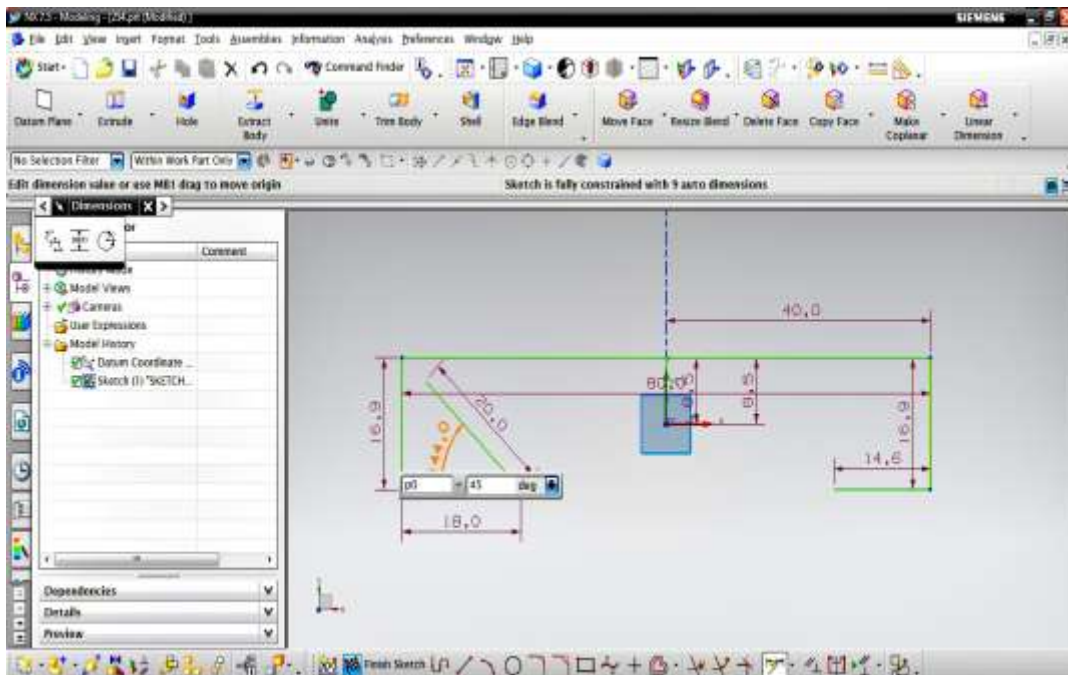


Figure 3: Creating a dovetail element

To cut off unnecessary lines, you can delete them using the special Quick Trim tool, the truncated line is highlighted in orange (Fig. 4).

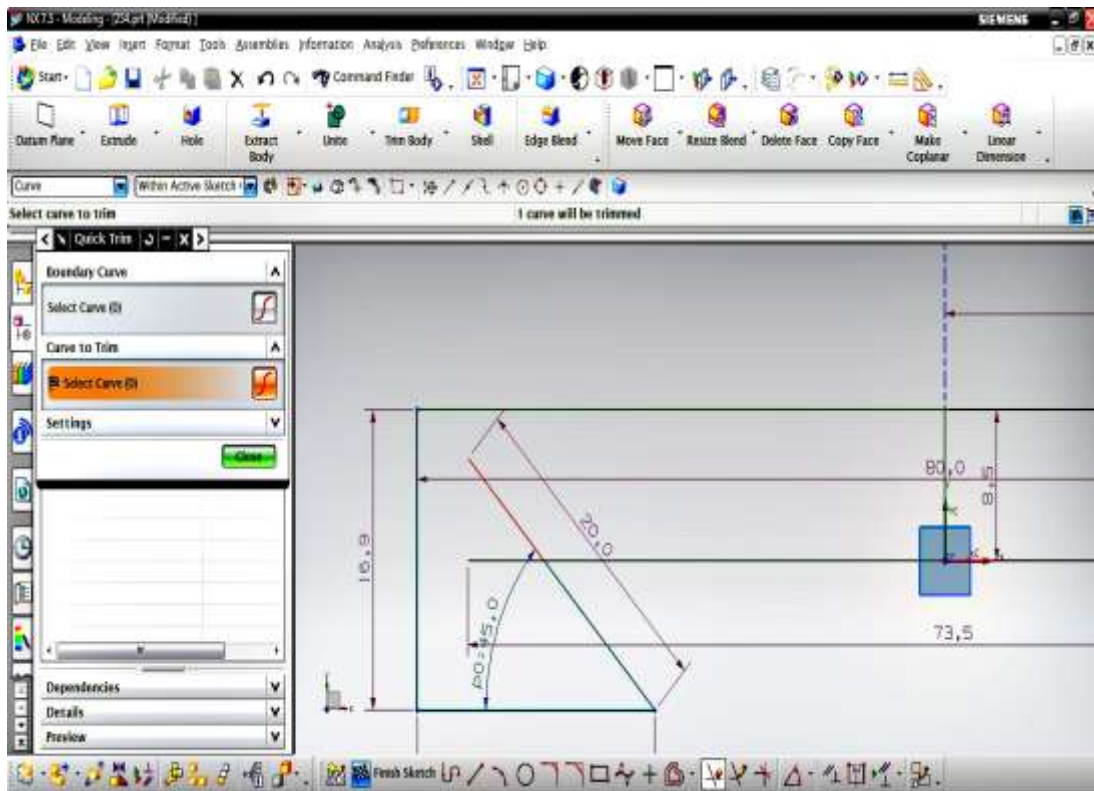


Figure 4: Quick Trim Tool

Next, you need to create holes on the side edge of the detail for this you need to create a sketch on the same face (Fig. 5).

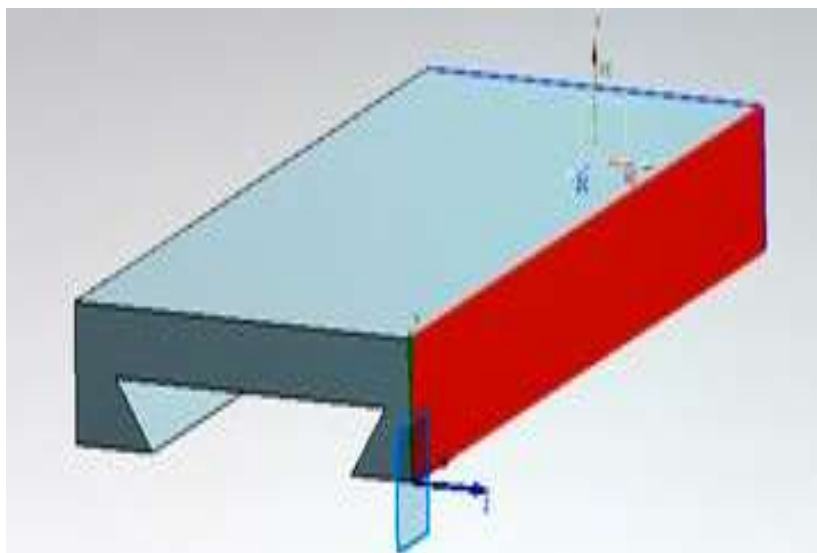


Figure 5: Creating a sketch for holes

To begin with, we simply create holes of the appropriate diameter. After the sketch is created, we use the Extrude function, only in contrast to the extrusion operation, now in the Boolean column we specify the logical operation of Subtract (Fig. 6).

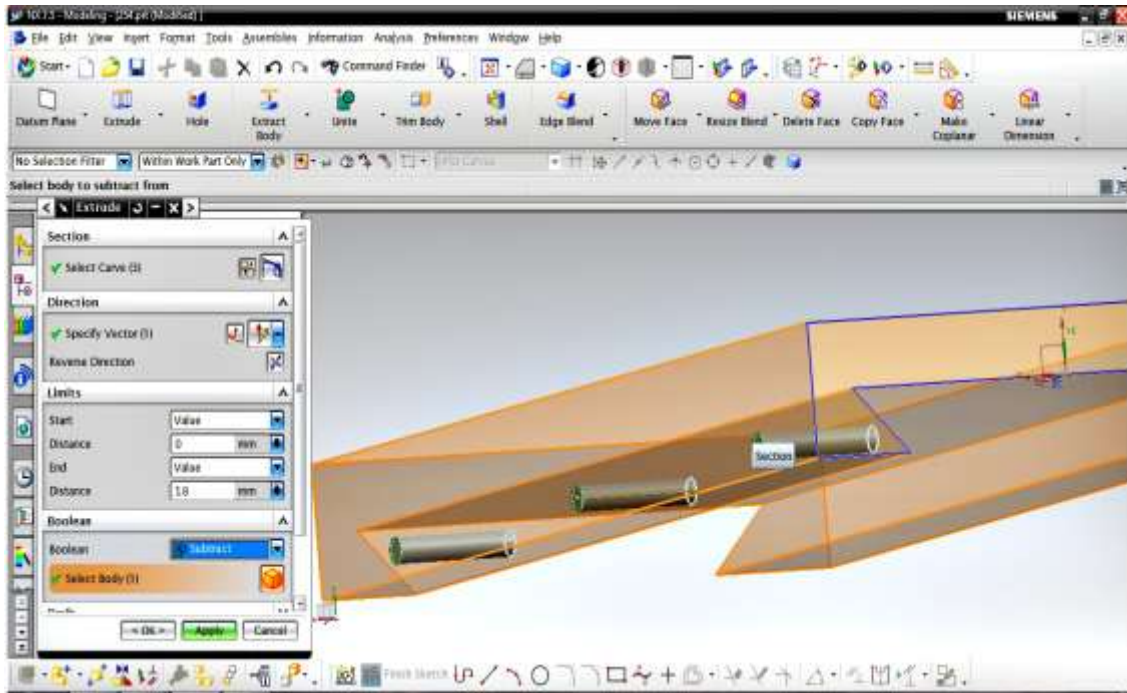


Figure 6: Using the logical operation Subtract

### 3.2. 3D model of machine assembly development

To start creating an assembly in UG NX 7.5, you need to open the used details, for this go to: File – Open and open the required file. After opening all the details needed to create the assembly, you need to go to the assembly window: window – Sborka.prt (Fig. 7).

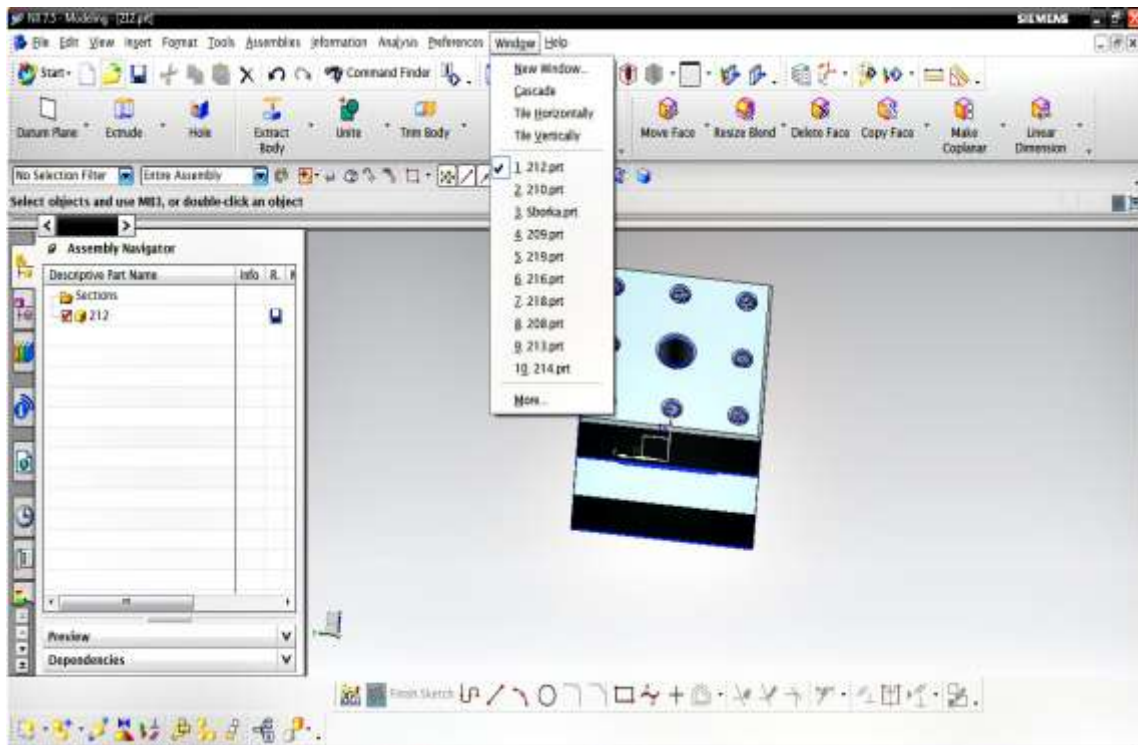


Figure 7: Switch between windows in UG NX 7.5

Then click on the button, in the lower left corner, Add Component from the list of all the details, select the required one. The Component Preview window displays the selected component (Fig. 8).

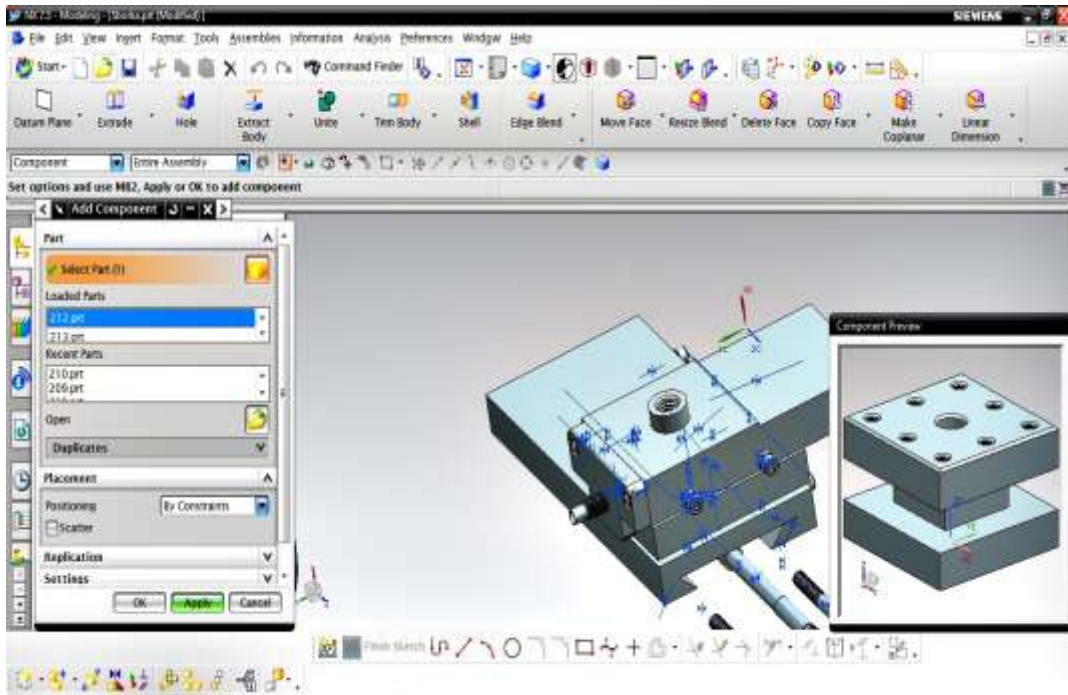


Figure 8: The window to add a detail to the assembly

Completion of adding a component is done by pressing the OK key. After that, the window for adding bindings and links between the details will open (Fig. 9).

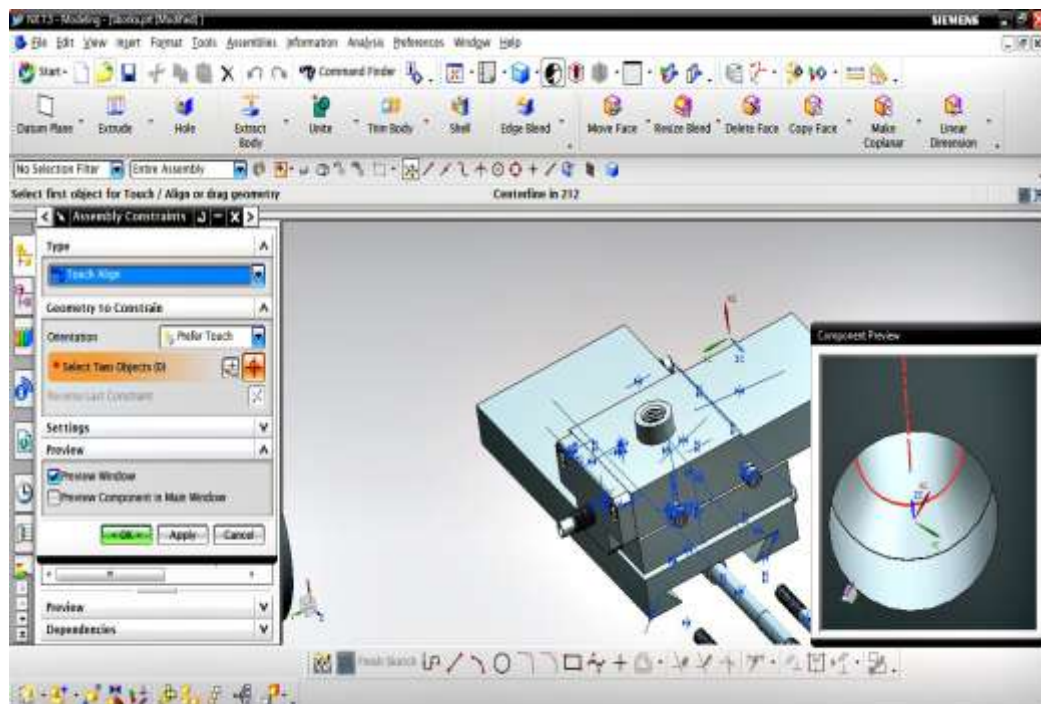
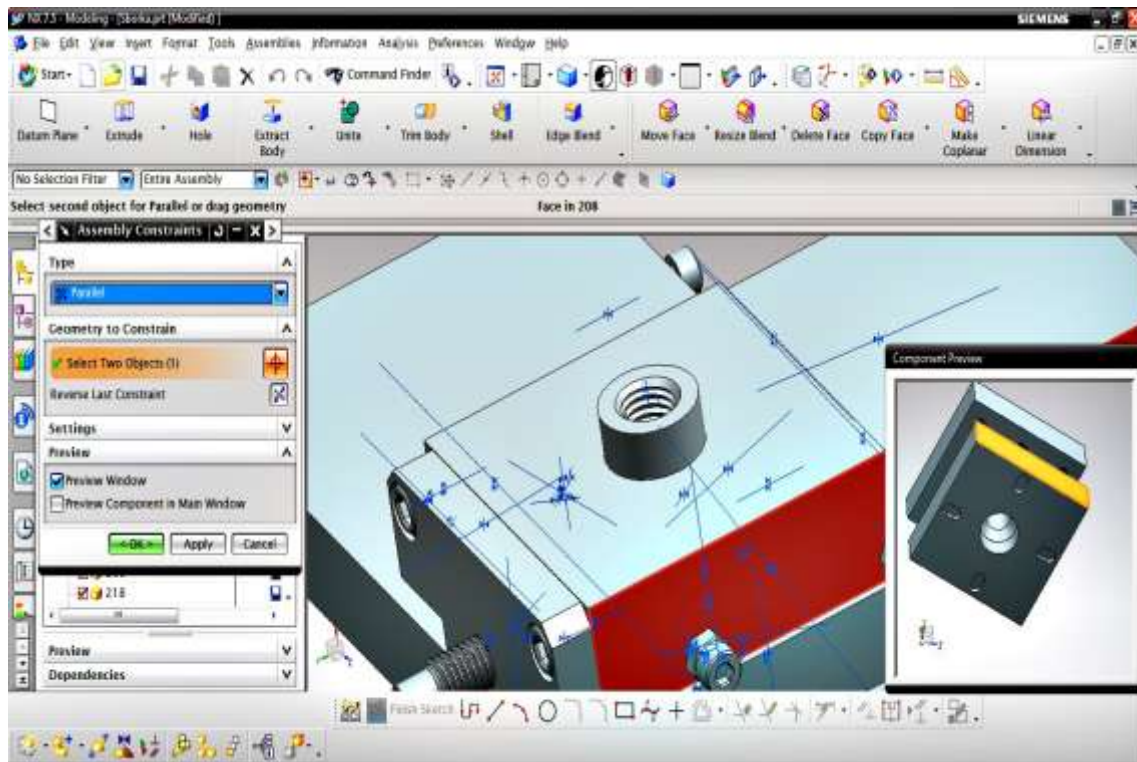


Figure 9: Specify the parallel connection

When building an assembly, each detail has its own key relationships and bindings. In this case, the tool holder installation on its "socket" is shown. A key link in this and other cases of joining details with the hole's presence is the coincidence of these holes' axes. Specify the hole's axis by hovering the cursor on the circle and then after a few seconds, click on the specified area with the left mouse button and select the (Central line) in the selected window, and also specify the center line to another detail.



Next, you need to set the alignment of the details faces relative to each other. To do this, in the Assembly Constrains window, in the Type tab, specify Paralell (Fig. 10).



**Figure 10: Specify the parallel connection**

After assembling all the machine modules, it is necessary to assemble them in one piece. The modules are assembled as well as the details, by creating links and bindings between them. After the merger, the movement, along the coordinate axes, of the entire assembly will become possible only when the entire assembly is selected, and when the single element moves, the entire module will move. The result of the assembly of all machine modules is shown in Fig. 11.



**Figure 11: 3D model of the machine assembly**

#### **IV. CONCLUSION**

The paper analyzes varieties of modern metalworking machines. The kinematic calculation of the drives of the screw-cutting lathe is considered.

As a result, the individual modules simulation was carried out and the machine assembly was realized. Thus, a detailed 3D model of the machine has been obtained, which will reduce the time for design work.

Modeling in NX will give the opportunity to achieve maximum productivity at all stages of creating structural elements of the machine.

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