Edward CHLEBUS, Bogdan DYBAŁA, Tomasz BORATYŃSKI

Institute of Mechanical Engineering and Automation
Technical University of Wrocław, Poland

CAD SYSTEM FOR DESIGNING GUIDING UNITS OF MACHINE TOOLS

The paper presents the structure of a CAD system for designing guiding units of machine tools. All software modules of the system are characterised. Example screen images show the contents of a database of typical guideline units. Example results of calculations for a selected guideline system are presented.

1. INTRODUCTION

Machine manufacturing technologies through the use of CIM techniques lead to automated production. Automated production is more efficient, accurate and allows more diverse products, in other words "is flexible." These trends call for a new approach to the process of machine design as a manufacturing machine is one of the basic elements of an automated flexible manufacturing system. It concerns both the methodology of the design and the means supporting it. The means are mainly possibilities created by the CAD technology. Effective use of the CAD technology requires that it should also support the preliminary step of forming a machine structure. The substantial property of the CAD software being presented should be the automation of routine tasks and forming a machine structure with the help of rich data bases, knowledge bases and parametric graphical libraries of standard elements and units of machines.

Guiding unit is one of the most significant structural units of a machine and particularly of a machine tool. An example diagram showing phases of selection of a type and macrogeometry of guiding units is presented in fig. 1. Guiding units must meet very high requirements, the most important are:

- high stiffness, accuracy and reliability,
- simple assembly and adjustments,
- silent running,
- low cost.

As research and experience show these requirements may be met by rolling guiding units, widely used in machine tools and NC machines.

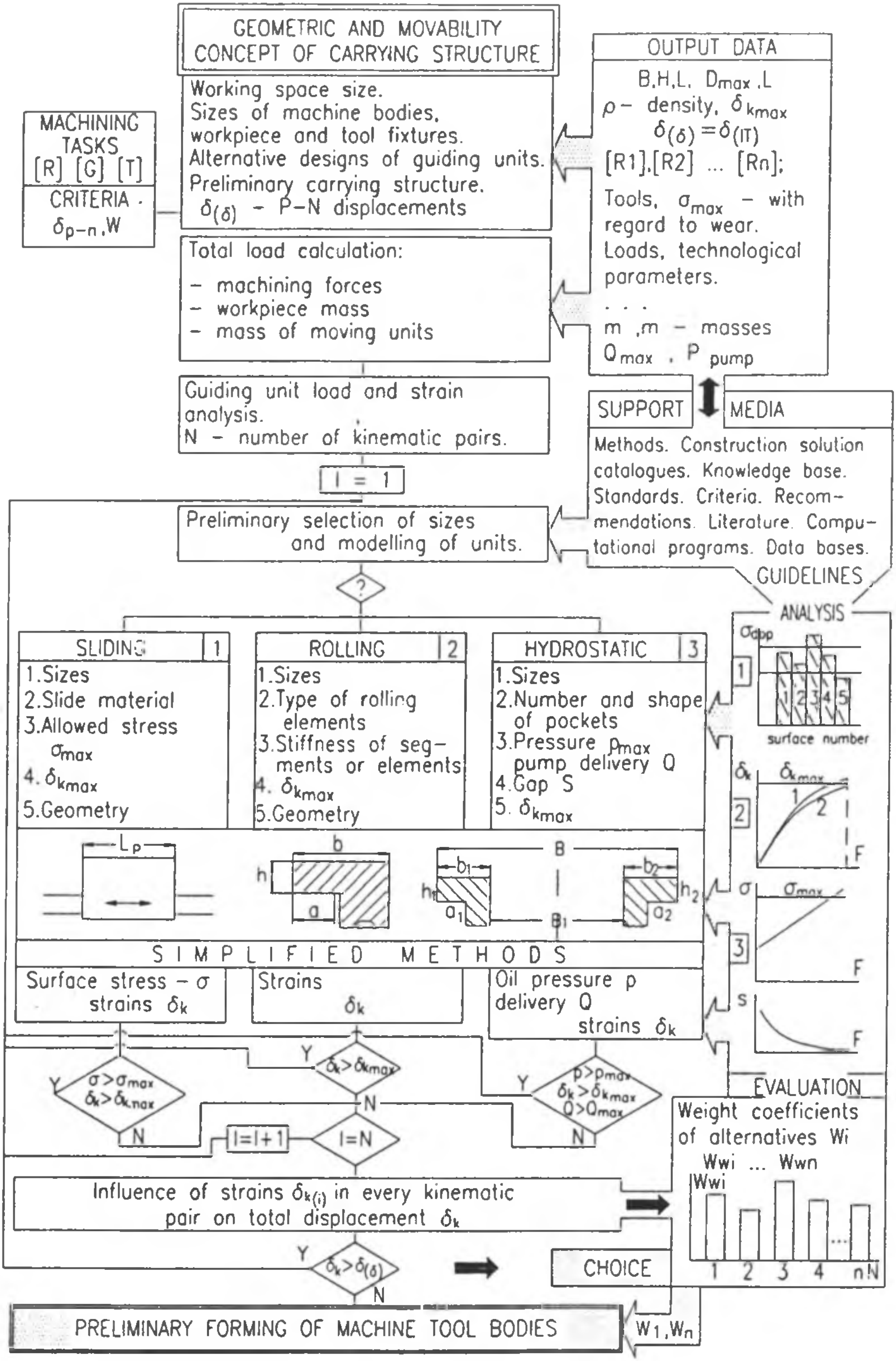

Fig. 1. Selection of guiding units

A research team at the Institute of Mechanical Engineering and Automation of the Technical University of Wrocław started a project on a CAD system for designing moving units of machine tools based on rolling guiding units. The project started from development of a structure and contents of data bases and graphical libraries of construction elements used in rolling units. In these units active loads are carried by balls or rollers, depending on the design. Although this type of units has become a standard construction element in modern machine tools there is a lack of effective methods supporting their selection during forming of design solution with a CAD system.

Therefore the methodology and software for active forming of rolling guiding units being developed, together with the data bases and the libraries of functional components, should enable effective design of guiding units of machine tools. The linked computational modules should also enable the analysis and estimation of the influence of construction factors introduced in the design (type and size of rolling units, magnitude of external loads, point of application of external loads and spacing of the guiding units) on the displacement of selected points of the construction. Fig. 2 presents a general structure of the CAD system for designing moving units of machine tools.

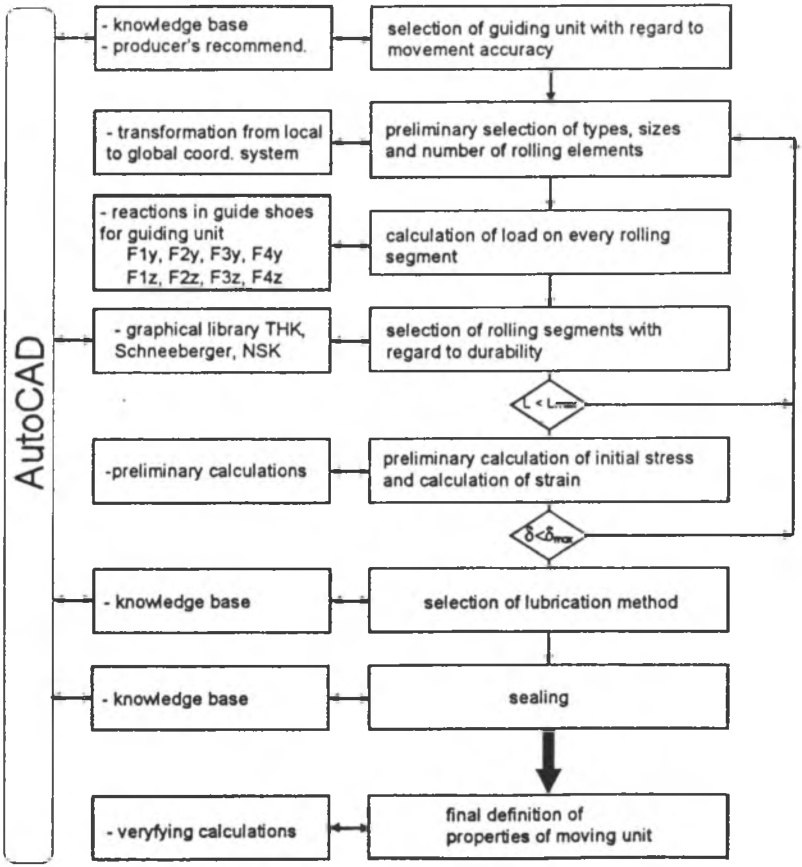

Fig. 2. Structure of the system for designing moving units of machine tools

2. SELECTION OF ROLLING GUIDING UNITS

Range of machining tasks, size and mass of workpieces determine a geometric and movability structure of a machine tool, spatial position of guiding units, type of guiding units and their properties. External loads, type of their carrier in individual kinematic pairs and movability requirements are the basis for selecting a construction solution.

As mentioned before in the first phase of design simplified methods are used. They support designer's decisions on a concept and a construction solution. During the design of rolling guiding units the simplified method is based on a **wear model** using an index of the guiding unit's durability. The index L is expressed as

$$L = \left(\frac{C}{P}\right)^{\frac{10}{3}} \text{ [km]}$$

where: C -- dynamic load capacity,
P -- maximum reaction force on the guide shoe [N].

In the preliminary design of the rolling guiding units the designer, as in the selection of rolling bearings, selects rolling units that meet given functional requirements. The rolling units determine not only accurate movements of the slide, but also the accuracy of the positioning, very important in machine tools.

With this in mind a CAD system integrated with the **AutoCAD** package was developed. The system helps to select rolling guiding units for movable units of machine tools. The most important module of the system is a parametric graphical library of rolling guiding units.

Below are described successive phases of design of rolling guiding units with example screen images:

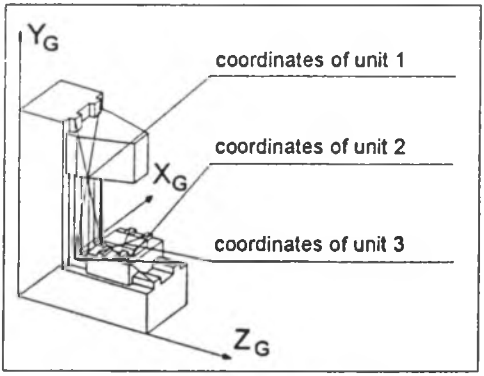

Fig. 3. Location of guiding units in the machine tool construction system

- Alignment of axes of the global coordinate system in the machine tool construction system according to the ISO standard.
- Positioning of guiding unit in the machine tool construction system (fig. 3) and positioning of kinematic pairs. Coordinates of centres of the pairs are origins of local coordinate systems. Selection of guiding units in local coordinate systems is described by the algorithm in fig. 1. Calculations are executed for every guiding unit and if data required for the calculations were defined in global coordinate system, they are transformed into every local coordinate system.

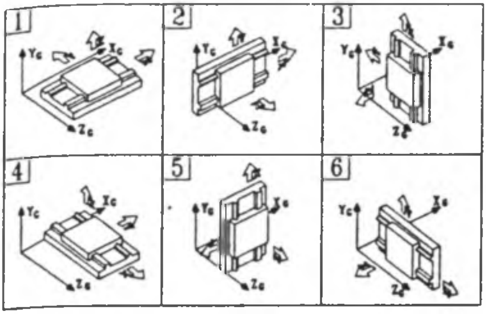

Fig. 4. Location of guiding units in the machine tool global coordinate system

- Alignment of axes of local coordinate systems of every guiding unit in the global coordinate system (fig. 4). According to sense and direction of the movement of the guiding unit the orientation of the rolling units is selected from six possible combinations. The direction of the movement determines the orientation of the X axis of the local coordinate system, the orientation of the other two axes are determined according to the ISO standard.

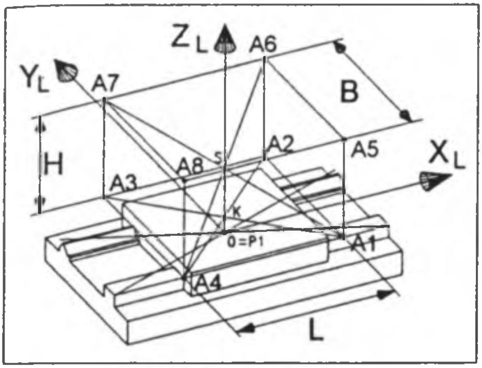

Fig. 5. Defining working space

- Defining the working space (fig. 5) and its position relatively to the work table of the machine tool or the workpiece fixture (according to the given range of workpieces). The program allows specifying the working space in the global or any local coordinate system. Defining the working space is possible in three ways:

- width B, length L and height H of the space and coordinates of the center of the space S_X, S_Y, S_Z,
- width B, length L and height H of the space and coordinates of the center of the bottom plane of the space K_X, K_Y, K_Z,
- coordinates of two points of any diagonal of the space, for example A_{1X}, A_{1Y}, A_{1Z} and A_{7X}, A_{7Y}, A_{7Z}.

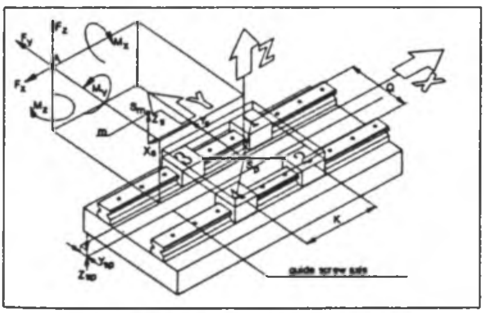
Fig. 6. Defining the vector of external load

After specifying the data the program calculates coordinates of all points (A_1, A_2, ..., A_8) and transforms them into the global coordinate system. In these points components of external load forces will be applied (fig. 6). The components will be calculated from active components of machining forces, mass forces and inertial forces.

After constructing geometric models of all guiding pairs the rolling guiding units are selected with regard to external loads and defined working space. The units will carry active and passive working loads. The units are selected from graphical libraries developed in AutoCAD [1]. Example data for typical guiding units from Schneeberger, THK and NSK are presented in fig. 7, 8 and 9 [3], [4], [5].

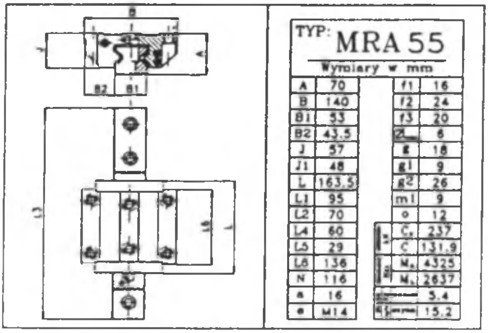

Fig. 7. A guideline unit from Schneeberger

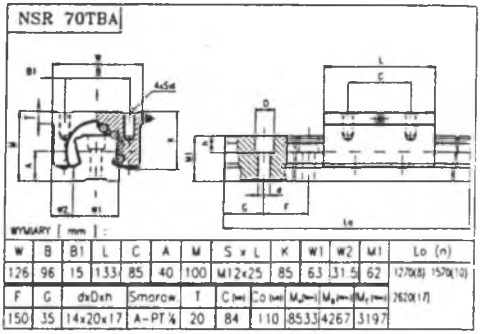

Fig. 8. A guideline unit from THK

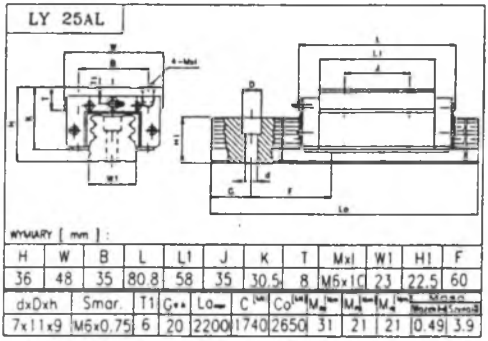

Fig. 9. A guideline unit from NSK

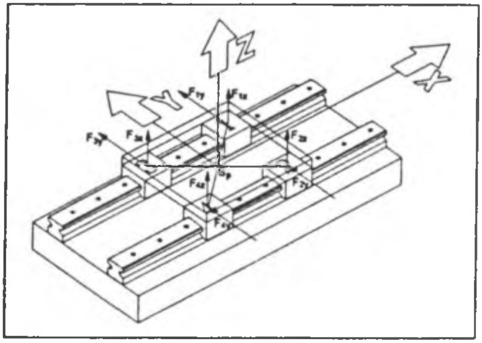

Fig. 10. Loads on all guide shoes

Next phases in design of guiding units are:

- Transformation of forces, moments and coordinates from the global coordinate system into local coordinate systems of every guiding unit in order to calculate reaction forces in successive rolling units.
- Selection of type and size of rolling units for a given type of guiding connection with regard to data combining durability and dynamic load capacity, which are contained in the data bases.

After completing the computational model the loads and strains of successive moving pairs are calculated in their local coordinate systems. This process required developing an appropriate computational method. It calculates:

- loads in every rolling unit F_{1Y}, F_{2Y}, F_{3Y}, F_{4Y}, F_{1Z}, F_{2Z}, F_{3Z}, F_{4Z}, example results are presented in tab. 1,

- static strains in these units (fig. 11),
- displacements at selected points from the working space (fig. 12).

Zestawienie danych i reakcji w prowadnikach Prowadnicy 1

Sily skrawania	Fx= -3000.0,	Fy= -700.0,	Fz= -500.0
Momenty skrawania	Mx=-10000.0,	My= 0.0,	Mz= 0.0
Wspol. srodka ukladu LUW	Xgp1= 0.0,	Ygp1= 0.0,	Zgp1= 0.0
Przesuniecie osi LUW od osi sruby		Ysp= 70.0,	Zsp= -50.0
Rozstaw prowadnikow K i prowadnic Q		K= 500.0,	Q= 400.0

Sily masowe			Wspolrzedne masowe		
Fmx1=1200.0	Fmy1=0.0	Fmz1=-1962.0	Xm1=-105.0	Ym1=175.0	Zm1=195.0
Fmx2=0.0	Fmy2=0.0	Fmz2=0.0	Xm2=0.0	Ym2=0.0	Zm2=0.0
Fmx3=0.0	Fmy3=0.0	Fmz3=0.0	Xm3=0.0	Ym3=0.0	Zm3=0.0
Fmx4=0.0	Fmy4=0.0	Fmz4=0.0	Xm4=0.0	Ym4=0.0	Zm4=0.0

Xag, Yag, Zag - Wspolrzedne strefy obrobki (A1,...,A8) w ukladzie GUW
Xal, Yal, Zal - Wspolrzedna strefy obrobki (A1,...,A8) w ukladzie LUW

Zestawienie sil na kierunkach Y, Z w ukladzie LUW w czterech prowadnikach

	A1	A2	A3	A4	A5	A6	A7	A8
Xag	-230.0	-230.0	0.0	0.0	-230.0	-230.0	0.0	0.0
Yag	0.0	300.0	300.0	0.0	0.0	300.0	300.0	0.0
Zag	280.0	280.0	280.0	280.0	0.0	0.0	0.0	0.0
Xal	-230.0	-230.0	0.0	0.0	-230.0	-230.0	0.0	0.0
Yal	0.0	300.0	300.0	0.0	0.0	300.0	300.0	0.0
Zal	280.0	280.0	280.0	280.0	0.0	0.0	0.0	0.0
F1y	-350.0	550.0	389.0	-511.0	-350.0	550.0	389.0	-511.0
F2y	-350.0	550.0	389.0	-511.0	-350.0	550.0	389.0	-511.0
F3y	0.0	-900.0	-739.0	161.0	0.0	-900.0	-739.0	161.0
F4y	0.0	-900.0	-739.0	161.0	0.0	-900.0	-739.0	161.0
F1z	204.8	17.3	-97.7	89.8	-880.2	-1067.7	-1182.7	-995.2
F2z	598.2	785.7	670.7	483.2	3.2	190.7	75.7	-111.8
F3z	-1829.2	-2016.7	-1901.7	-1714.2	-1234.2	-1421.7	-1306.7	-1119.2
F4z	-1435.8	-1248.3	-1133.3	-1320.8	-350.8	-163.3	-48.3	-235.8
MAX	-1829.2	-2016.7	-1901.7	-1714.2	-1234.2	-1421.7	-1306.7	-1119.2

Maxymalna sila wystepuje w punkcie A2 i wynosi -2016.7

Table. 1. Loads for all guiding units

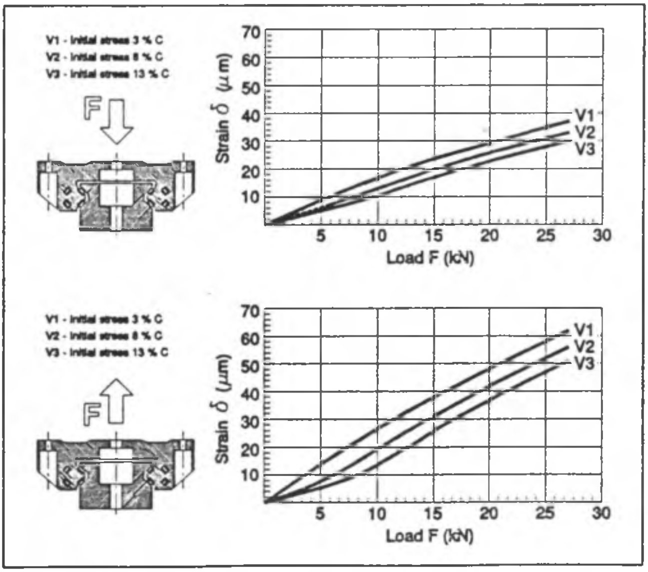

Fig. 11. Strains in all guiding units with respect to load [3]

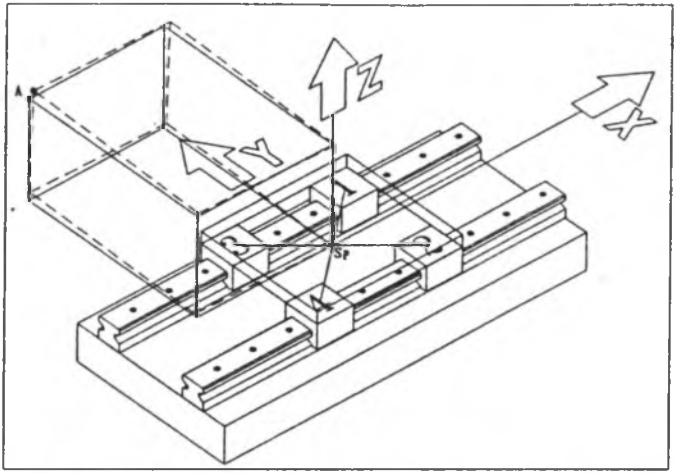

Fig. 12. Displacement of a point in working space due to the load acting on guiding units

3. SUMMARY

In the current phase of the implementation of the system a method of preliminary selection of rolling units has been developed. The units may be selected from the range offered by three companies: Schneeberger, THK and NSK. In the presented design process the selection of types and sizes of the units is based on their chosen durability period. Next phases will involve calculations of static strain in guiding units and from those - displacements in selected points from the working space. The basic criterion for estimation of a design solution of guiding units is the magnitude of these displacements and their expected effect on deviations of dimensions, shape and position of a workpiece.

LITERATURE

[1] AUTOCAD: *Podręcznik użytkownika, Wersja 12*, Autodesk Ltd., 1993.
[2] CHLEBUS E: *Podstawy kształtowania funkcjonalnych cech i własności układów konstrukcyjnych obrabiarek*, Prace Naukowe ITMiA PWr. nr 50, Seria Monografie, nr 14, Wrocław 1993.
[3] *SCHNEEBERGER Rolling Guiding Units Catalogue*, 1990.
[4] *THK Rolling Guiding Units Catalogue*, 1991.
[5] *NSK Rolling Guiding Units Catalogue*, 1989.

Revised by: Jan Kosmol