JIG AND FIXTURE CAD/CAM SYSTEM

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Abstract

Development of CAD/CAM systems for workpiece jig and fixture has to rely on a general-purpose CAD system, such as an AutoCAD system comprising the needed standard interfaces. So it is relatively easy to change types of the underlying CAD system and the computer. The design process is helped by a 3D functional model. This so-called Jig & Fix CAD system is an open system constructed of a modular (unified) set of 3D elements, permitting to change the set of elements, the database and the manipulation set. This CAD system may be of help in factories in the design and manufacture of NC, CNC machine tools and production cells, as well as in concluding contracts, and in tender transactions.

1. Introduction

In machine industry, even small firms want CAD/CAM systems to help design and manufacture. In these categories of problems, no complete and efficient solution may be expected either

— from turn-key or
— from general-purpose CAD systems.

Our research work has been essentially intended to help designing workpiece clamping fixtures, which are of outmost importance in machine tool manufacture. This R & D project had been funded by the Development Institute of the Machine Tool Works Co. (SZIMFE Rt.) as part of a wide-range industrial automation project, run in the past five years.

The essential problem was to develop a CAD system for the VUNAR SUS 50 technological set of about 800 different 3D elements (of about 100 subtypes) to efficiently help design of workpiece holding-orienting fixtures.

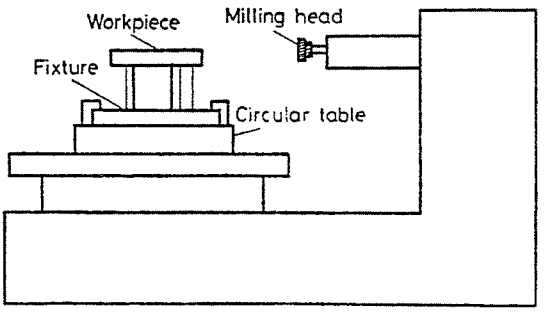

Fig. 1. Connection between workpiece, clamping fixture and milling machine

Basic requirements were:

— to develop a *comprehensive functional modelling system* for any object in the CAD system — workpiece, base plate, pallet, modular fixture elements (Fig. 1);
— *workpiece modelling by envelope surfaces,* for any working phase (clamping), defining zones on the workpiece (envelope) surface;
— *development* of an *efficient, interactive* and *functional design method* for constructing and modifying clamping fixtures;
— easing *impact problems* between machining tool (machine tool) and clamping fixture;
— as well as *generation of a list of pieces* and of documentation for the designed fixture.

A further purpose was to effectively help — not only the fixture design work but also:

— the processes of technical offer making, of tender transaction for new products such as NC, CNC and other machine tool products (e.g. manufacturing cell) by reducing the minimum set of elements needed for assembling the main pieces;
— reduction of design time and costs of assembling main pieces of the ordered new machine tool products.

In conformity with these requirements, a "Jig & Fix" design system has been developed for workpiece clamping fixtures, likely to be adaptable to the increasingly applied flexible manufacturing systems (FMS) as basic element of a fully automatic palleting system.

As a set of elements for the Jig & Fix workpiece clamping fixture CAD system, the technology system SUS 50 of the VUNAR Co. has been chosen, permitting different trends of prospective further developments, computer assistance of designing fixtures with other systems of modular element sets.

2. General directives of developing milling fixtures for clamping box-type workpieces

In up-to-date machine production, drilling-machining in NC machines is made by means of fixtures composed of elements adapted to the actual workpiece.

In manufaeturing by means of NC machines, the fixture as a production tool has a double function:

— positioning of the workpiece (impact, orientation);
— safe fastening of the workpiece in the given position against machining forces, moments.

Fixtures composed of unified elements (EÖK) are expected:

— to safeguard a constant machining spot within the tolerance (exchangeable manufacture);
— to ensure safety of either the workpiece or the fixture from deformation due to machining forces (stiffness);
— to make manufacture as economical as possible.

Factors affecting the construction of the fixture are shown in Fig. 2.

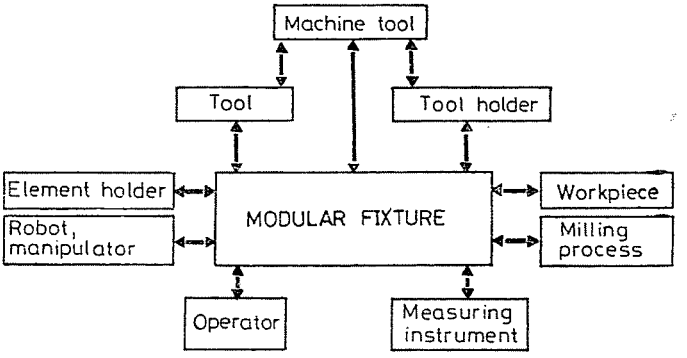

Fig. 2. Factors affecting the construction of the fixtures

Machine tool table dimensions, displacement ranges, table grooves are determinant for the size, number, orientation of mountable fixtures. During operation, a fixture must not collide against machine parts. The tracks of tools controlled by an NC program are off-limits for the fixture, to avoid collisions. Here often the size and machining track of the tool holder (e.g. drill chuck) are the limitations. For milling tools, also overrunning and running out have to be reckoned with.

The EÖK element system is often a restriction depending on the element type, set of dimensions, construction, in particular, for VUNAR systems of relatively few kinds of elements.

Based on the dimensions of the clamping parts of *robots, manipulators,* the tracks of clamping and attached robot arms have to be reckoned with in feeding, also off-limits to avoid collisions.

Size, shape, allowances, surface roughness, material, wall thickness, etc. of the workpiece (pre-product) are fundamental starting points for fixture design. A characteristic feature of the workpiece is the readiness degree, in this relation, knowledge of technology order, order of operations, operating overtaking order as well as of milling data for fixture operations, is needed.

Knowledge of the *milling process* is of importance for tool tracks, milling forces, moments, process effects (e.g. vibrations, action of cooling-lubricant fluid).

Man with his experience and knowledge affects fixture design, assemblability, applicability on the one hand as fixture designer, and on the other hand as fixture assembler.

Correct choice and accuracy of *measuring instruments,* and correct adjustment of fixtures are fundamental for the accuracy of manufacture in the fixture.

3. Simplified process of fixture design

Concerning the fixture system VUNAR SUS—50, fixture design is conditioned by:

- — database comprising base plates, locating elements, fasteners, accessories and required parameters, fast selection on menu principle, display of 3D hidden line images;
- — database comprising ultimate values, value ranges, grades, increments for fixture elements.

Steps of fixture design are as follows:

1. Based on the real workpiece drawing, generation of the workpiece model in Jig & Fix system, indicating surface elements to be machined, and bases (zones).
2. Base plate selection (preliminary).
3. Selection of fixture elements, part units for location.
4. True to size/place coordination of workpiece functional places and locating fixture elements on the base plate.
5. Selection of clamping elements.
6. Coordination of clamping elements with elements arranged according to 4, with marked workpiece surfaces.
7. Orientation of locating and clamping elements to T-grooves or to base plate side.
8. Possible modification of element position depending on 7.
9. Final base plate selection depending on 7 and 8.
10. Display of envelope tracks of tool movements.
11. Impact testing.

12. In case of an impact, workpiece model refinement or changing or shifting of fixture elements.
13. View dimensioning.
14. Labelling.
15. List generation.
16. Plotter documentation.

Rules for assembling the fixture are as follows:

— Centroid of the entire fixture with workpiece should be as deep as possible compared to the base plate.
— The fixture consists of as few elements as possible to increase stiffness, hence accuracy, and to reduce assembly time.
— Elements should be as uniform as possible to accelerate fixture design and to ease assorting of elements.
— Fast clamping elements are to be applied (automation).
— Easy and fast clamping and release of workpiece has to be provided for (automatic, robotized feed).

4. Fundamentals of developing the Jig & Fix fixture CAD system

4.1. Underlying design philosophy

Fundamentals of developing the fixture CAD system are:

— development started from a relatively high, non-zero level;
— functions required by the fixture designer-user were developed relying on standard interfaces of a general-purpose CAD system (AutoCAD 9.0);
— professional microcomputers IBM AT were considered to offer the software services above at an adequate level to develop the wanted fixture CAD system;
— uniform database and operative storage principles were to be developed for modelling workpieces and fixture elements (sub-units).

Another aspect of importance had been to develop a so-called user-interface coping with user demands, an open, extensible and modifiable menu system.

4.2. Functional mapping method for clamping fixtures composed of uniform elements

First, a functional model fitting every element of the fixture CAD system, and a method for constructing and modifying functional fixtures have been developed. A possibility had to be provided for the user-technologist designer to involve his

proper way of thinking and designing in constructing a workpiece clamping fixture for some machining (drilling, turning, milling) work (see Figs 3, 4).

In this system it is easy for the user to check whether the tool with its envelope surface described in motion collides with fixture elements or not. In the positive case the user can modify any element or unit of the fixture, or the workpiece position.

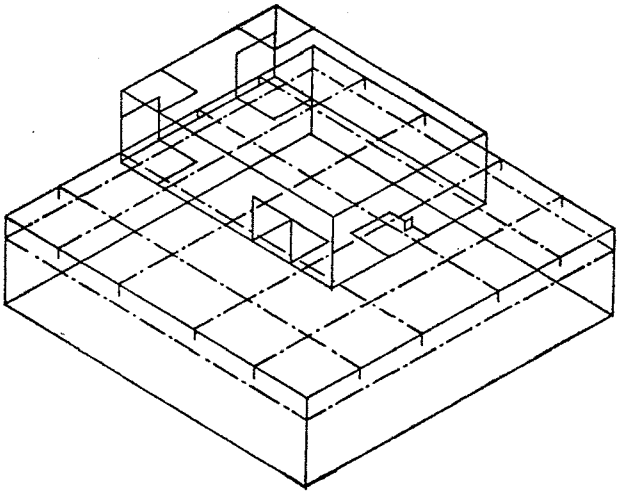

Fig. 3. Envelope surface of a workpiece with zones, and pallet (base plate) in the Jig & Fix CAD system

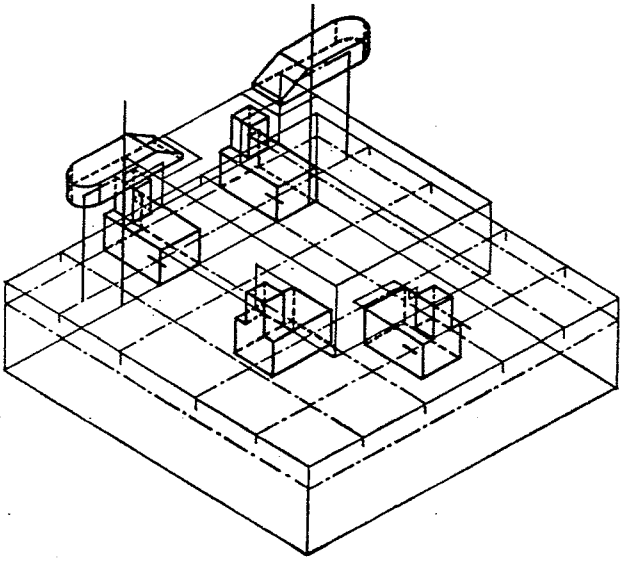

Fig. 4. A complete workpiece clamping fixture surrounding the workpiece envelope surface

This system is of help in finding the proper set of dieing or fastening, clamping elements or units for a given spacing L.

The Jig & Fix fixture CAD/CAM system has a proper relation database developed by relying on the database handling system d'ACCESS III, applying the same practically standard .DBF data format as the IBM dBASE III system. But it is a Hungarian database handling system and it is much simpler to use programs of C language than the quoted IBM or similar database handling systems.

Also programs of data change between the database handling system and the Jig & Fix CAD/CAM system, converting between formats .DBF and .DXF, have been written in MS—C 4.0 language.

It is easy for the user to extend the set of about 800 usable elements retrievable in the system database, or to retrieve a fixture defined by another designer.

It was interesting to observe the so-called multi-layer technology to be expedient for clear images and effective design manipulations.

In the system developed, the user can easily modify the menu system by means of menu-generating facilities and a user's language: AutoLISP.

In the Jig & Fix system the user may make a documentation of the wanted elaborateness, with the proper size mesh, and if needed, completed with the fully detailed list of pieces. This latter is the exact list of pieces of the designed apparatus, feasible within the system, relying on the database handling system.

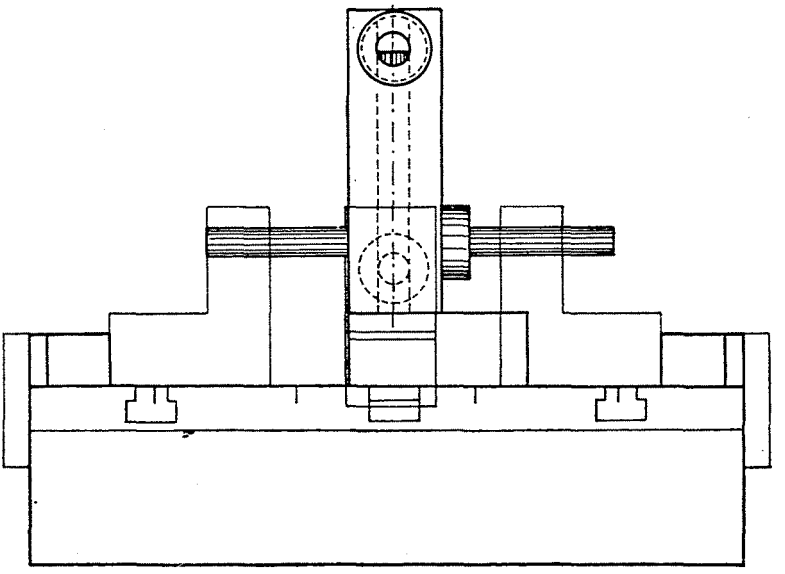

Fig. 5. Front-view design of a workpiece clamping fixture

5. Conclusions and future development

Development of the Jig & Fix fixture CAD system to the actual stage has taken about ten engineer-years. Already in this stage it can be applied to design fixtures with VUNAR SUS 50 element set, to make technical tenders, and in education (see Figs 5 to 8 made by fourth-year students at the Department of Production Engineering as an obligatory problem).

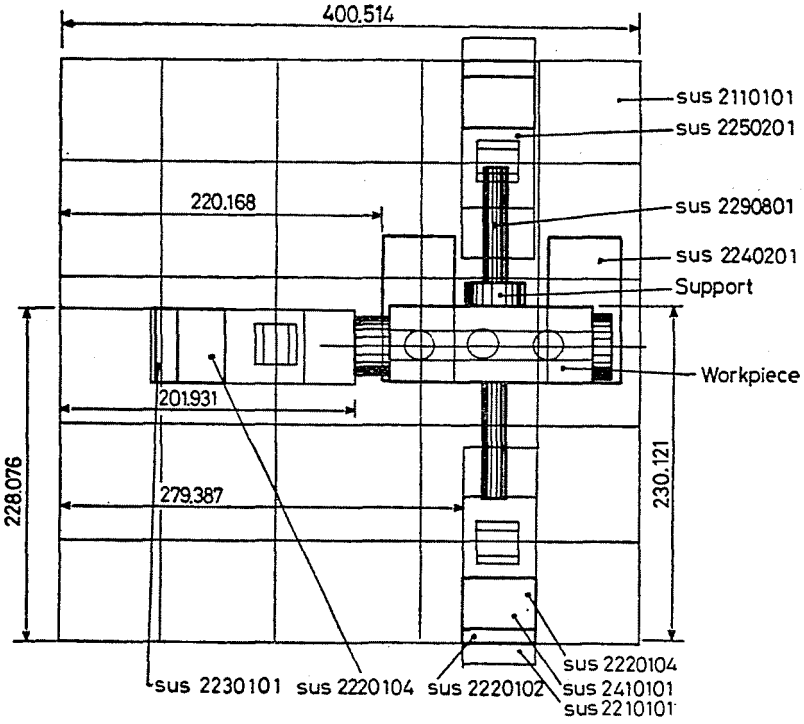

Fig. 6. Top-view design of a workpiece clamping fixture

It is an open fixture CAD system that can be developed as follows:

— it may underlie an automatic fixture assembly system;
— it may underlie another fixture CAD system relying on other modular fixture element systems; for instance, the Jig & Fix system may utilize both VUNAR SUS 100, 125, SUS—H (hydraulic) and Kontur sets of elements;
— after the needed completions, it may help fixture construction/design from any other system with a higher developed set of elements, for instance those of USP (USSR), Blüko (Blümle Co.), Roemheld systems;
— it is no problem for the user to define a proper, or a more general menu system relying on menu generation services of the basic system;

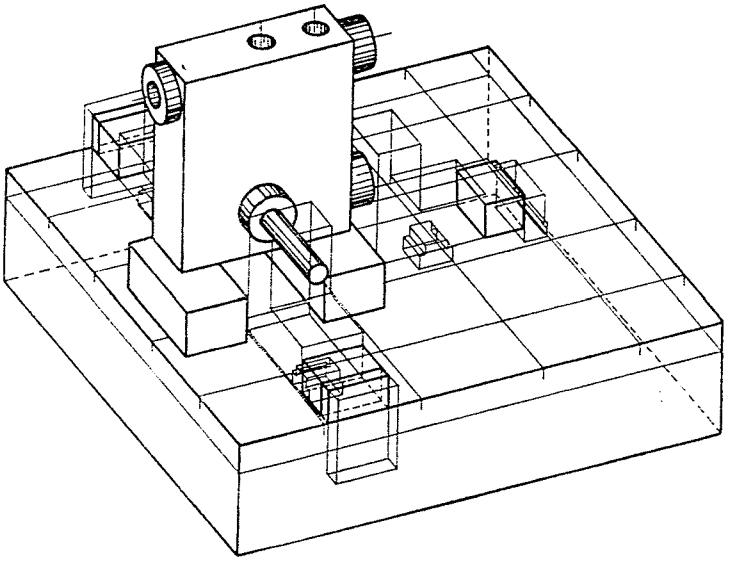

Fig. 7. Display of a workpiece clamping fixture from an arbitrary viewpoint

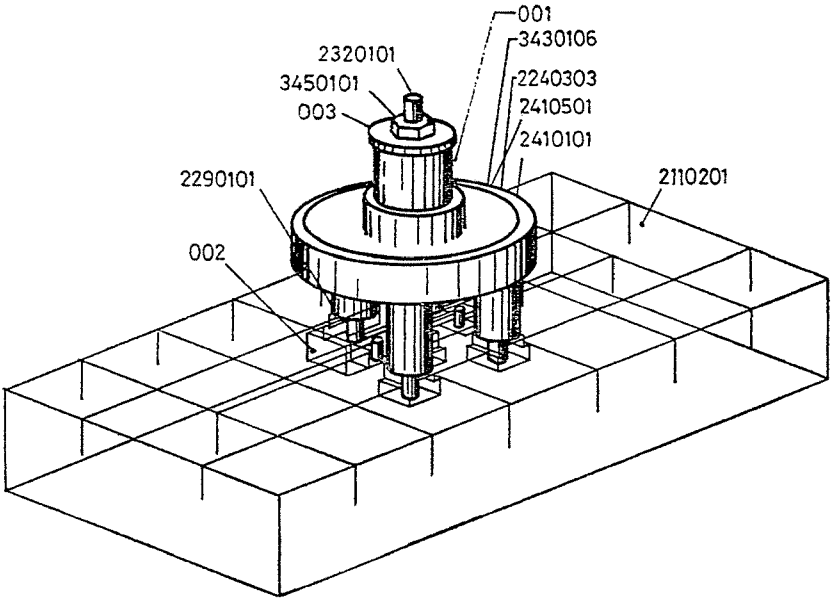

Fig. 8. An example of the combined application of different SUS element systems

— the actual system can be realized relying on other basic software or general-purpose CADD, CAD systems;
— for instance, on Cadkey, Versacad or systems Anvil, Euclid relying on Vax computers, or on Hungarian TRIOLA, BIGRAPH, etc. systems;

— utilizing standard interface facilities, it can actually transfer the developed fixture model to any CAD system with .DXF, .IGES, .DBF interfaces.

It is planned to develop another service such as to automatically suggest an assortment of dieing and clamping elements, — in knowledge of envelope surfaces of the workpiece and of clamping/dieing zones — of course, open to be revised and modified by the designer, another step towards the computer mapping of expert knowledge.

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