Selection of Locators in Automated Design of Fixtures for Locating Workpieces During Machining

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Abstract - **Using the systematic approach, the possible basing schemes of the workpieces in the machining attachments have been discovered and systematized with a view to their use in automated design. The analysis shows that the use of the proposed systematization in computer-aided design is significantly more rational, since the structure reflects the sequence of choice of the optimal basing scheme - analysis of the theoretical basing scheme, analysis of the geometry of the workpiece, formation of the possible list of the basing schemes. An analysis was performed with the help of which the criteria for geometric compatibility were revealed, allowing to make a choice of a basing scheme, satisfying the geometric shape of the workpiece. An algorithm for selection of locators has been developed. The development is part of a system for automated design of fixtures for locating of workpieces during machining.**

Keywords - locating of workpieces; fixtures; basing schemes; locators; computer aided design.

I. INTRODUCTION

The development of systems for automation of engineering work has necessitated the development of systems for automated design and in particular fixtures for locating workpieces, which include newer tools, libraries, functional applications and levels of integration.

Compared to manual design, the use of CAD /CAE systems makes it possible to reduce manual labor and increase the quality of design, but does not allow complex automation, as the key stages (choosing the optimal scheme of basing (SB), calculating clamping forces, selection of construction of the locators) is done manually [1] - [5].

One of the most complex tasks in the automated design of fixtures is the selection of an optimal scheme of basing the workpieces, so *the purpose of this work is to systematize the possible schemes of basing and selection of locators in order to use them in automated design.*

II. GENERAL REGULATIONS

- *Systematization of the schemes of basing the workpieces*

The analysis of the existing systematizations of the possible schemes of basing shows that the most rational is the one proposed in [6], in which several possible realizations correspond to one theoretical SB, the number of which depends on the geometric shapes of the surfaces used for location technological bases (LTB).

Since the workpieces are based on planar (P), external (Cl^e) and internal (Cl^i) cylindrical, external (Cn^e) and internal (Cn^i) conical surfaces, different combinations of geometric shapes of the base surfaces are obtained (PPP, $PPCl^e$, etc.), occurring in practice, and a different number of realizations of SB from these combinations. Moreover, several possible combinations of geometric shapes of workpiece surfaces, used for LTB, correspond to a theoretical SB [6],[7].

The workpieces are based on one or several LTB, one of which is the main, providing the best orientation of the workpiece, depriving it of three (main plane LTB), four (double guide LTB) or five (support guide LTB) degrees of freedom.

A surface ensuring a stable position of the workpiece in the fixture is chosen as the main base. The relatively largest surface area of the workpiece is chosen.

The main LTB, depending on the degrees of freedom taken away and their symbols are given in Table 1, and the most frequently used locators - in Table 2. According to the number of deprived degrees of freedom and the geometric shape of LTB, locators are grouped as shown in Table 3.

TABLE 1 TYPES OF LOCATIONS ON TECHNOLOGICAL BASES

Geometric shape of the surface	Deprived degrees of freedom	Name	Definition
Plain (P)	3	main (primary)	MP
	2	guide	G
	1	support	S
Cylindrical (Cl)	4	double guide	DG
	3	main	MCl*
	2	double support (centering)	DS
	1	support	S**
Conical (Cn)	5	support guide	SG
	3	support centering	SC
	2	double support (centering)	DS***
Spherical (Sp)	3	triple support	TS
* When using a floating (self-locating) long V-blok [8]			
** When using a floating (self-locating) short V-blok			
*** Floating center or movable rear center			

Combining the possible LTB with the possible used locators, the possible schemes of full basing were obtained (Table 4) [8].

The choice of LTB for a particular operation depends on various factors. Thus, the use of this systematization in computer-aided design is significantly more rational, as its structure reflects the sequence of selection of optimal LTB - analysis of the theoretical LTB, analysis of the geometry of the workpiece, formation of a possible list of LTB.

If the described system is applied to a specific workpiece, it is noticed that not all SB are applicable, which is determined by the geometric incompatibility of the workpiece and locators, which implement it. An important role is played by the geometric characteristics of the

workpiece: the presence of stamping or casting slopes; location of the bases of the workpiece, not allowing the implementation of the selected combination of locators, etc.

TABLE 2 LOCATORS

Locators	Definition
Support (cylindrical or flat)	S
V-block long	V_l
V-block long floating	V_{lf}
V-block short	V_s
V-block short floating	V_{sf}
Pin cylindrical	P
Diamond pin cylindrical	P_d
Cylindrical mandrel	M_c
Diamond mandrel cylindrical	M_{cd}
Taper mandrel	M_t
Bushing cylindrical long	B_{cl}
Bushing cylindrical short	B_{cs}
Taper bush long	B_{tl}
Taper bush short	B_{ts}
Centre hard	C_h
Centre rotating	C_r
Centre floating	C_f

TABLE 3 APPLICATION OF LOCATORS

Geometric shape of LTB	Deprived degrees of freedom				
	5	4	3	2	1
P	-	–	S	S	S
Cl^e	-	V_l, B_{cl}	V_{lf}	S, V_{lf}, V_s, B_{cs}	S, V_{sf}
Cl^i	-	M_c	C_h	P, M_{cd}, C_f	P_d
Cn^e	B_{tl}	-	B_{ts}	-	-
Cn^i	M_t	-	C_h	C_f, C_h	-
Sp	-	-	S	-	-

When choosing the construction of locators should take into account the criteria:
• theoretical scheme of basing;
• type of locators;
• shape of the surface used for LTB;
• quality of the surface used for LTB (rough, finish, presence of casting or stamping slopes);
• maintainability;
• possibility to combine with another locator.

• *Algorithm for automated selection of locators*

The choice of the construction of the locators is made according to the scheme shown in Fig. 1, systematizing the construction of the locators according to the above criteria.

TABLE 4 POSSIBLE SCHEMES FOR BASING OF THE WORKPIECE

Theoretical SB	Surfaces	Realizations	Theoretical SB	Surfaces	Realizations
MP + G (DS) + S	PPP	SSS	DG + S + S (DG + G)	Cl^ePP	V_lSS
	$PPCl^e$	SSS			$B_{cl}SS$
	$PPCl^e$	SSV_{sf}		Cl^ePCl^e	V_lSS
	$PPCl^i$	SSP_d			$B_{cl}SS$
	PCl^eP	SSS			V_lSV_{sf}
		$SV_{lf}S$			$B_{cl}SV_{sf}$
		SV_sS		Cl^ePCl^i	V_lSP_d
		$SB_{cs}S$			$B_{cl}SP_d$
	PCl^eCl^e	SSS		Cl^eCl^e	V_lV_s
		SV_sS			$B_{cl}V_s$
		$SB_{cs}S$			V_lS
		SSV_{sf}		$Cl^eCl^eCl^i$	V_lSP_d
		SV_sV_{sf}			$B_{cl}V_{sf}P_d$
		$SB_{cs}V_{sf}$			$V_lV_{sf}P_d$
	PCl^eCl^i	$SS\ P_d$			$B_{cl}SP_d$
		$SV_{lf}P_d$		Cl^eCl^i	V_lP
		SV_sP_d			$B_{cl}P$
		$SB_{cs}P_d$		$Cl^eCl^iCl^i$	$V_l\ P_dP_d$
	PCl^iP	SP_dS			$B_{cl}P_d\ P_d$
		$S\ M_{cd}S$		Cl^iPP	M_cSS
	PCl^iCl^e	SPS		Cl^iPCl^e	M_cSS
		$SM_{cd}S$			$M_cS\ V_{sf}$
		$SM_{cd}V_{sf}$		Cl^iPCl^i	M_cSP_d
		$SP\ V_{sf}$		$Cl^iCl^eCl^i$	M_cSP_d
	PCl^iCl^i	SPP_d			$M_cV_{sf}\ P_d$
		$SM_{cd}P_d$		Cl^iCl^i	$M_c\ P$
		$S\ C_fP_d$			$M_c\ M_{cd}$
SG + S	Cn^eP	$B_{tl}S$	SC+DS+S	Cn^iCn^iP	C_hC_hS
	Cn^eCl^e	$B_{tl}V_{sf}$			$C_f\ C_f\ S$
	Cn^eCl^i	$B_{tl}P_d$			
	Cn^iP	M_tS			
	$Cn^i\ Cl^e$	M_tV_{sf}			
	Cn^iCl^i	M_tP_d			

Fig. 1. Selection of locators

```
           ┌───┐
           │ 2 │
           └─┬─┘
             ▼
internal    ◇ Type of
cylindrical   LTB ◇
   │              │ external
   ▼              │ cylindrical
┌──────────────┐  │
│ cylindrical  │  │
│   mandrel    │  │
└──────────────┘  │
   ┌──────────────┴──────────┐
   ▼                          ▼
┌──────────────┐     ┌──────────────────┐
│ V-block long,│     │ bushing          │
│ type 1       │     │ cylindrical long │
│ or type2     │     │                  │
└──────────────┘     └──────────────────┘
```

```
           ┌───┐
           │ 3 │
           └─┬─┘
             ▼
           ◇ Type of    internal
             LTB ◇      cylindrical
   external  │              │
   cylindrical│             ▼
             │       ┌──────────────┐
             ▼       │ pin          │
    ◇ Presence of    │ cylindrical  │
      casting or  Yes└──────────────┘
      stamping slopes ◇
             │No         │
             │           ▼
             │    ┌──────────────────┐
             │    │ V-block short,   │
             │    │ type 1           │
             │    └──────────────────┘
   ┌─────────┴──────────┐
   ▼                     ▼
┌──────────────┐  ┌──────────────────┐
│ V-block      │  │ bushing          │
│ short, type2 │  │ cylindrical      │
│              │  │ short            │
└──────────────┘  └──────────────────┘
```

```
           ┌───┐
           │ 4 │
           └─┬─┘
             ▼
           ◇ Type of    internal
             LTB ◇      cylindrical
             │              │
             │flat          ▼
             ▼       ┌──────────────────┐
           ┌───┐     │ diamond mandrel  │
           │ 1 │     │ cylindrical      │
           └───┘     └──────────────────┘
```

Fig. 1. Selection of locators (continued)

```
                  ┌───┐
                  │ 5 │
                  └─┬─┘
                    ▼
internal           ◇ Type of      flat
cylindrical          LTB ◇
   │                      │            │
   ▼            external  │            ▼
┌──────────────┐ cylindrical│       ┌───┐
│ diamond pin  │           │       │ 1 │
│ cylindrical  │           │       └───┘
└──────────────┘           ▼
                    ◇ Presence of
              Yes     casting or
               │      stamping slopes ◇
               │               │No
               ▼               ▼
        ┌──────────────┐  ┌──────────────┐
        │ V-block short│  │ V-block short│
        │ floating     │  │ floating     │
        │ beveled      │  │              │
        └──────────────┘  └──────────────┘
```
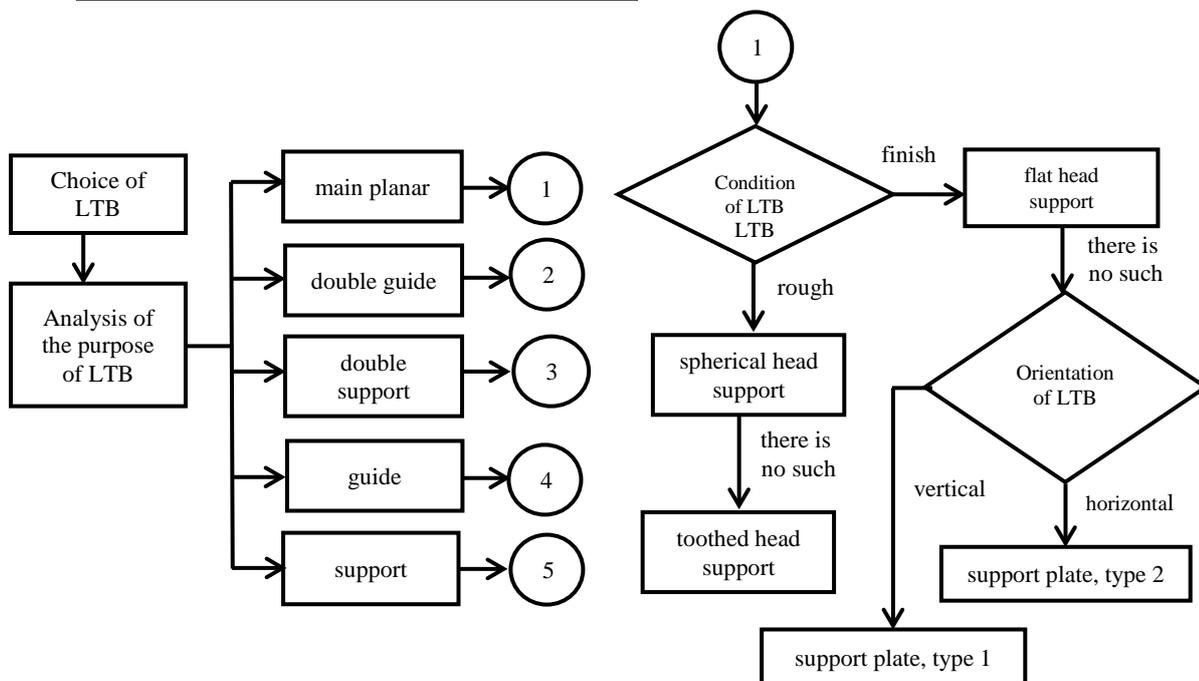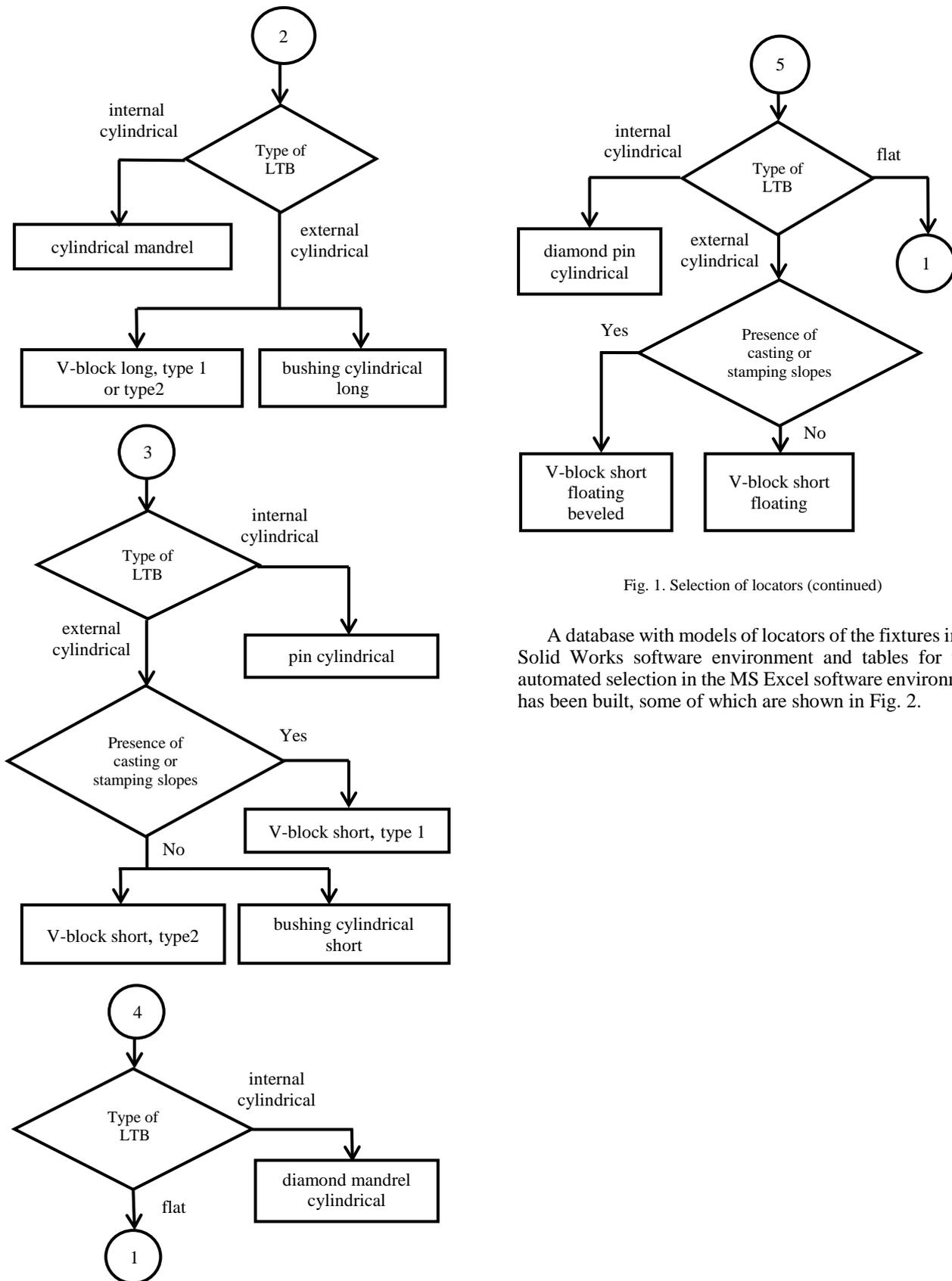
Fig. 1. Selection of locators (continued)

A database with models of locators of the fixtures in the Solid Works software environment and tables for their automated selection in the MS Excel software environment has been built, some of which are shown in Fig. 2.

Fig. 2. Tables for automated selection of locators

Fig. 2. Tables for automated selection of locators (continued)

CONCLUSION

1. Systematization of the possible schemes of basing the workpieces in the fixtures for locating during machining with a view to use and in automated design has been performed.
2. An algorithm for selection of locators has been developed.
3. A database with locators has been created and tables for their automated selection have been developed. The database allows the inclusion of new construction elements.
4. The obtained results are a stage of the development of a system for automated design of fixtures for locating of workpieces during machining.

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