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STRUCTURE CREATION OF FLEXIBLE CONSTRUCTIONS OF MOBILE WORKING MACHINES

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Abstract:
Experience in the area of development and production of flexible modular constructions of mobile working machines support their effectiveness and competitiveness. Modular solutions of multiple machine types, or their building sequences based on architecture of a mutual platform simplify the process of their development and production and also integration into logistic chain of a production company. Creation of a mutual platform is then an effective tool every producer

Key words:
flexible modular structure, mobile working machine, coefficient of modular structure, modularity ratio, platform

1. FLEXIBLE CONSTRUCTIONS OF MOBILE WORKING MACHINES

The newest knowledge in the area of an effective production of products with respect to constantly changing requirements on their function, use, properties and competitiveness on a relatively saturated market indicate the need of such a structure of products, which enable their relatively fast development reacting on immediate needs of users. So called flexible modular constructions comply with such requirements, enabling creation of needed products in a short time in needed range and variants [1].

Modular constructions of products are assembled from unified basic building modules, which are in various extent and composition used in broad spectrum of variants [2]. Effectiveness of this method lies in suitable grouping into an architecture, which is repeatedly applied in the form of a structural basis for particular type of products. Such a structural basis is called a platform. By a consecutive adding of further modules assuring functionality, a new variant of a product is created with required functional properties. This architectonic philosophy of a product creation is depicted in the Fig.1.

Attributes of such methodology of products development are mostly used in production of personal automobiles but its principles are used also in the area of mobile working machines. These create a broad range of products determined for realization of various working technologies in various size classes or sequences.

Production effectiveness of such products (whether a production sequence or a production program) can be expressed by modularity ratio [2]. Modularity ratio determines degree of use of particular unified building modules in creation of particular variants of products. A platform is then the basis of main building modules which occur only in one variant and are used in all products [3], [4], [5]. Modules, which create final machine assemblies, can generally be separated into three groups, Fig.2. Explanation follows in the text.

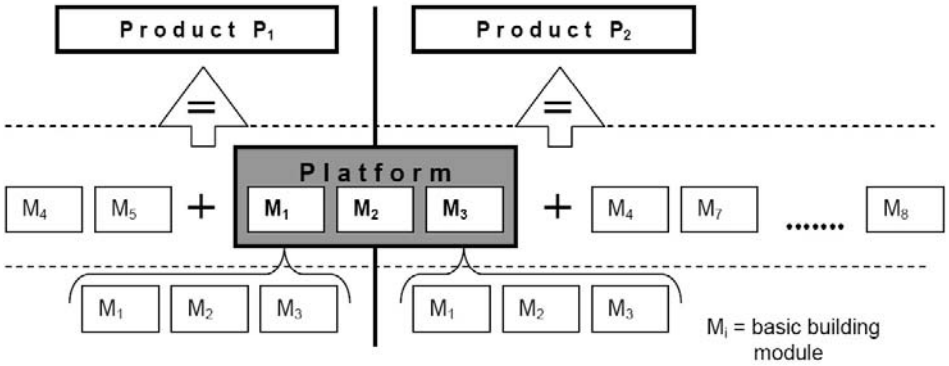


Figure 1. Modular structure and a platform depiction

2. ARCHITEKTONIC STRUCTURE OF MOBILE WORKING MACHINES

Architecture of modular creation of mobile working machines with a common platform is demonstrated in Fig.2. A typical sign for this group is that at least one working technology is common for all these machines. Let us consider the group G4, Fig.3. of four machines: Excavators, Loaders, Manipulators and Fork lift trucks. In the future text and previous FIGURE 2 we use abbreviations E for Excavators, L for Loaders, M for manipulators and F for Fork lift trucks. Mutual working technology for all these machines is manipulation with material.

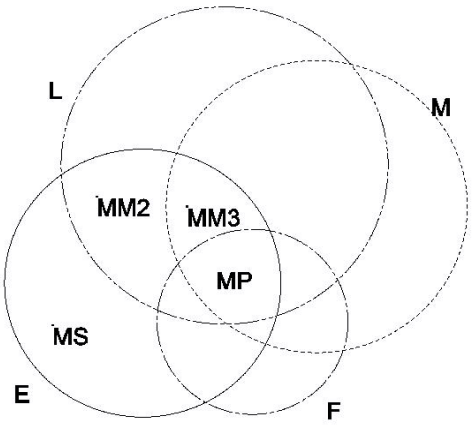


Figure 2. Classification of modules of the group E, L, M, F (E-Excavators,L-Loaders,M-Manipulators and F-Fork lift trucks)

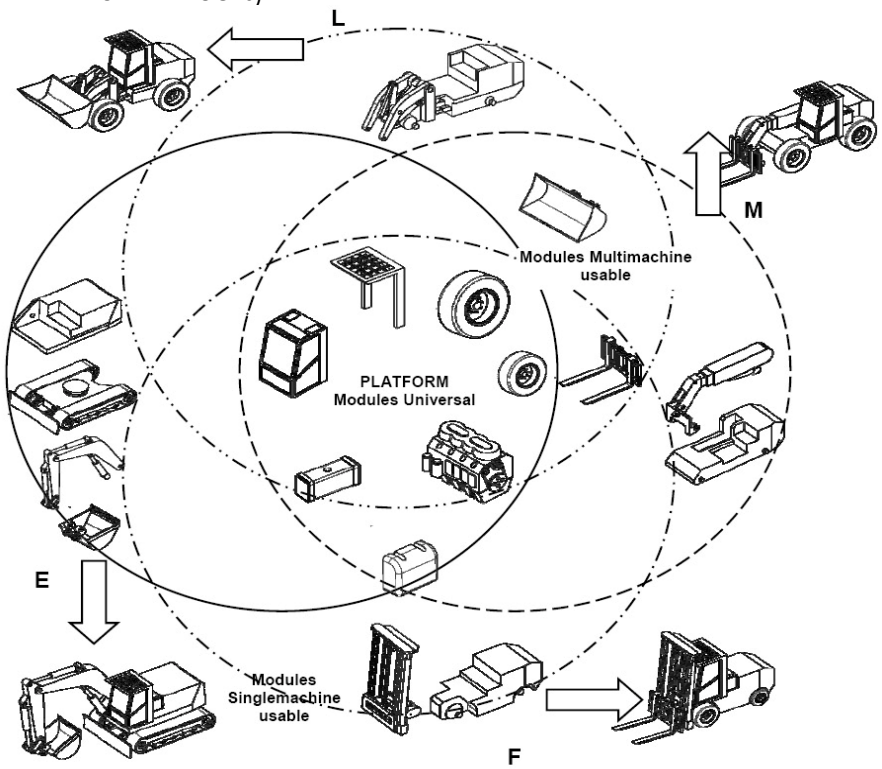


Figure 3. Architecture of creation of flexible modular assemblies of mobile working machines

For the sake of further consideration we will divide modules participating on assemblage of E, L, M, F working machines into three further groups MP, MM, MS. Description of these sets is as follows, Fig.6., 7., 8.:

-MP – set of Modules used in all 4 machines E, L, M, F. or the platform

-MM – set of Modules Multimachine usable, modules used in 3 or 2 machines. This set divides into two subsets

MM3 - modules used in 3 machines and

MM2 - modules used in 2 machines

-MS – set of Modules Singlemachine usable, modules used only in just 1 machine.

From the architectonic structure it is clear that the highest measure of modularity will be reached in the case of as broad platform as possible. Which is possible mainly in the so called universal machines (differentiating only by working tool, which is mutually exchangeable). On the contrary, low measure of modularity will be reached by minimal platform, when building modules have the character of single purpose modules, Fig.4.

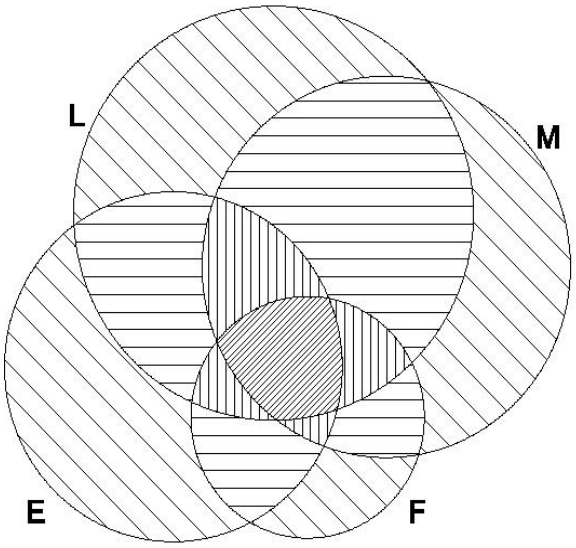


Figure 4. Graphical representation of all sets E, L, M, F and sets MP, MM3, MM2 and MS distinguished by different hatching

In the following we will describe in detail particular subsets MP, MM3, MM2 and MS.

For the group of mobile working machines denoted by E, L, M, F, the following can be supposed.

-platform MP, including modules participating on creation of all four machines E, L, M, F is defined as:

$$MP = E \quad L \quad M \quad F \qquad (1)$$

Hatched intersection represents all modules, which are building modules of all four working machines E, L, M, F. Its graphic representation is in the Fig.5.

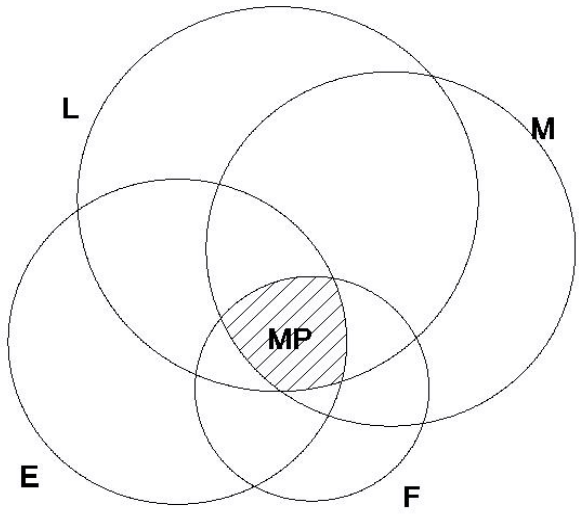


Figure 5. Graphical representation of the platform MP

Let us denote elements of the platform MP_i. On the basis of rational reasoning, so that it had a sense to speak about a platform, the set MP is not empty. Some of the hatched subsets in the following text can be empty, which but do not have any influence on our considerations about the sets MS and MM.

Representations of real cases, which can occur, can be transparently denoted by the following mathematical notation. The set MM modules, which can apply on the creation of more machines consists from two subsets. The subset MM3 of modules, which apply on the creation of three machines and the subset MM2 of modules, which apply on the creation of two machines.

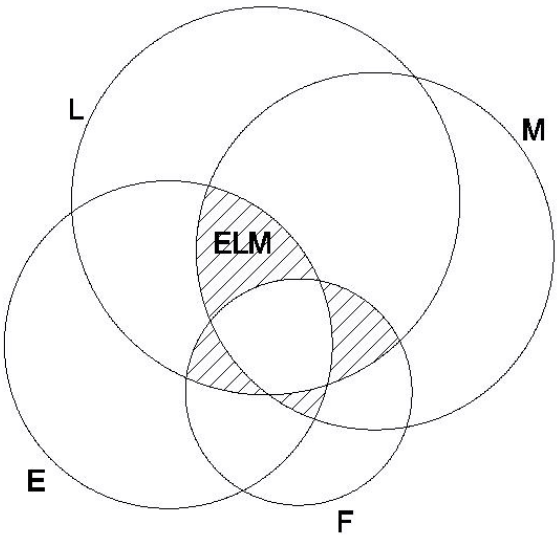


Figure 6. Graphical representation of the sets participating on three machines – MM3

Hatched sets, Fig.6. are the sets of modules, which participate on creation of three machines, they are the sets LMF, EMF, ELF, ELM, for explanation for instance ELM participates on creation of Excavator, Loader and Manipulator. Mathematical denotation is in the Table 1. Let us denote numbers of elements in these sets nLMF, nEMF, nELF, nLMF and the sum of these numbers let us denote as nMM3, what is the overall number of modules participating on three machines.

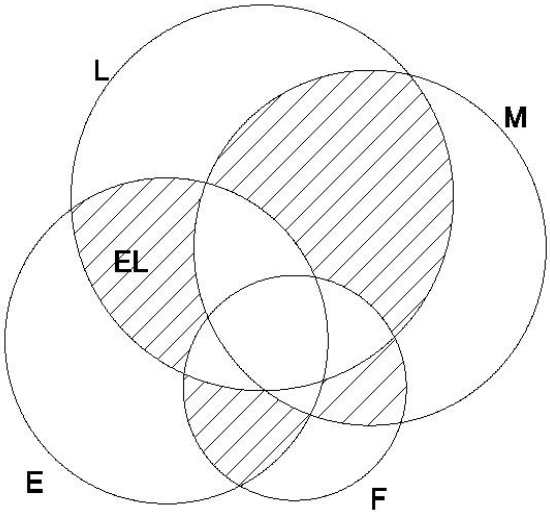


Figure 7. Graphical representation of the sets participating on two machines – MM2

Hatched sets in the Fig.7. are the sets of modules, which participate on creation of two machines, that are the sets EL, EM, EF, LM, LF, MF, for explanation for instance EL participates on creation of Excavator and Loader. The set MM2 is the union of these sets. Mathematical denotation is in the Tab 1. In this case, graphical representation does not show all the six sets. Let us denote numbers of elements in these sets as nEL, nEM, nEF, nLM, nLF, nMF and the sum of these numbers let us denote as nMM2, what is the overall number of modules participating on two machines.

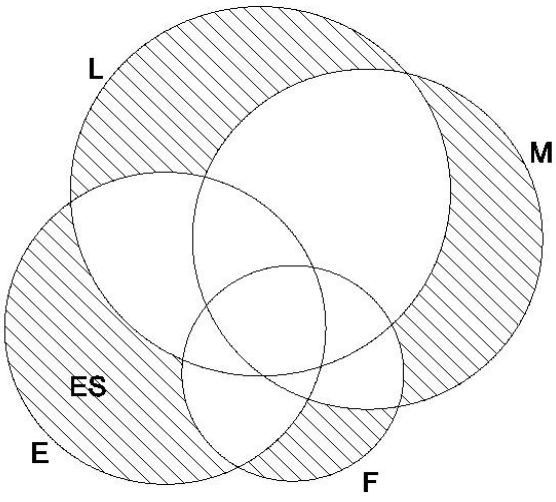
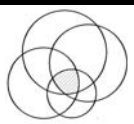
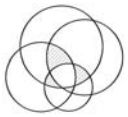


Figure 8. Graphical representation of the sets participating on just one machine – ms

Hatched sets in the Fig.8. are the sets of modules, which participate on creation of just one machine, that are the sets ES, LS,MS, FS; for explanation ES for instance participates on creation of Excavator only . Their union is the set MS. Let us denote numbers of elements in these subsets as nES, nLS, nMS, nFS and their sum let us denote as nMS.

Table 1. A transparent overview of all subsets of modules

Sort of modules		Graphical depicting	Mathematical denotation
MP			E L M F
MM	MM3		E M F - MP
			E M F - MP
			E L F - MP
			E L M - MP
	MM2		E L - (MP + MM3)
			E M - (MP + MM3)
			E F - (MP + MM3)
			L M - (MM + MP3)
			L F - (MM + MP3)
			M F - (MM + MP3)
MS			ES
			LS
			MS
			FS

Note: From the reason of a more simple denotation was in the case of sets ES, LS,MS, FS used not the same system as in the case of the sets MM3 and MM2. From the picture it is clear that the hatched subsets of E, L, M, F are the ES, LS, MS and FS.

3. COEFFICIENT OF MODULAR STRUCTURE

If we want to define coefficient of modular structure for the group E-Excavators, L-Loaders, M-Manipulators, F-Fork lift trucks, we denote the overall number of used modules:

$$nT = nMP + nMM3 + nMM2 + nMS \tag{2}$$

This number is the sum of all modules participating on creation of all 4 machines, the coefficient of modular structure can for this case be defined as follows:

$$kMS = \frac{(4.nMP + 3.nMM3 + 2.nMM2 + 1.nMS) / 4}{nT} \tag{3}$$

Strictly numerically kMS is the number from the interval (1/4, 1). Left limit ¼ of the interval would the coefficient kMS acquire for the most negative case when all the machines would be mounted from totally different modules. In such a case it would but have no meaning to talk about a platform. Right limit 1 of the interval would kMS acquire in highly hypothetical case for universal machines which would be mounted only from modules of a platform and would differentiate only by module of a working tool. After insertion of data for particular production offer, coefficient of modular structure together with modularity ratio purveys picture about extent of use of particular modules defined in part 2 and graphically demonstrated in Table 1.

4. CONCLUSION

Experience from the development of automobiles and also production of mobile working machines show, that flexible machine assemblies created on a mutual platform,

reaching relatively high modularity ratio [1], [2], can be denoted as effective and competitive solutions.

From this point of view it is then necessary that a designer in the process of machine development intentionally creates such an architectonical composition of basic building modules, which enable in frame of a building sequence of machines production as much solutions on a mutual platform as possible.

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