Abstract: The article represents the Scientific States of Mechatronic Manufacturing Systems (MMS) with usage of automatically interchangeable and renewable aggregate and modular units as Scientific Direction of Research to Manufacturing Systems. A modular units changing of variable structural levels is the main property of Constructive Transformation and exploitation parameters. It is shown the MMS advantage over to contemporary Flexible Manufacturing Systems. Mechatronic Manufacturing System with usage of automatically interchangeable and renewable modular units is a self-controllable and self-regulable System wherein the basic properties are: changing of multilevel System Structure consist of mechatronic modular units and mechanisms, interunits and interelement connections and coherencies with the goal of functioning in changing production exploitation time cycle.

KEYWORDS: MECHATRONIC MANUFACTURING SYSTEMS, INTERCHANGEABLE MODULAR UNITS, FLEXIBLE MANUFACTURING SYSTEMS, MULTIVARIANT MANUFACTURE, RMS CONSTRUCTIVE TRANSFORMATION

1. Foreword
The rate of contemporary Manufacture development is defined by the point that cycling of Technology renewal and changing of Manufacture Development strategy must embrace the very short time period. In general statements of Machine Building development in Russia machine systems always was the basic characteristic of the equipment in Manufacturing Systems and especially in the branch of industry – Machine Tool Building.

The last years in the world practice of Manufacture Development are dynamic period of Multivariant Manufacture (MM) establishing, differed of various structure and interrelations for all material, informational, production flows. This period is characterized by the fact that predominant development strategies of every separately production type (kinds): Mass Production (for example, in motor – car industry) designated for constant multiyear output of single model products, then Large – Series, Serial Productions outline its usefulness and in conditions of severe competition on market of product realization and sale these Productions are transformed in to development strategy of Multivariant Production, i.e. Production of variable type from Mass to Individual is created with application Mechatronic Manufacturing Systems (MMS).

The Multivariant Manufacture with MMS is a common direction of Flexible Manufacture transformation in the highest Production Capacity Manufacture which for program and value product output may be changed in limits distinguishing in contemporary conception, from Mass to Individual Production integrating the most productivity Transfer Line properties of Mass Production and the Flexibility in the conditions of multinomenclature machining.

Fig.1. The Multivariant Manufacture (MM) Space with the Working Positions of Mechatronic Manufacturing Systems (MMS)

2. Decompositional and Compositional stages of Multivariant Manufacture Simulation
In completion processes of simulation Multivariant Manufacture there are defined the main tasks of compositional simulation in cycle of MMS transformations: modeling space formation, formation of Machine Systems, structure forming and their functional properties. There are two Simulation stages: Decompositional and Compositional stages of Multivariant Manufacture Simulation with Mechatronic Manufacturing System.

The Decompositional Simulation involves the next processes in MMS Transformation and creation cycle: degeneration or changing of MMS interelement coherences and connections with performance ending of production order and olden production program and it is performed definition of elements and interelements coherences. The input bank data for formation of technique decisions array, for new created Manufacturing System, for new products is prepared. Accordingly there are defined: 1) necessity and possibility of interelement coherences destruction with possibility of autonomous setting and elements array receiving; 2) possibility of formation both MMS elements array and interelements coherences array of various hierarchy levels for new Composition cycle; 3) possibility of hierarchy levels formation for MMS subsystems. In completion processes of Decompositional simulation there are defined the main tasks of compositional simulation. The main tasks of compositional simulation, the decision of which is performed in MMS transformation cycle, are 1) formation of modeling space; 2) MMS Structural composition formation and its functional properties in composition process. The compositional simulation process on space of elements and interelement coherences generate the subsystems of technique decisions, technique decisions realization, optimization synthesis and choice optimal decisions are performed.

The space multifunctional model is revealed by formation model of multivariant combination of MMS structural compositions and respective technological processes. To each compositional forming in generation field will be correspond uniquely the elements and interelements coherences occupied the finite field of compositional space. The model generate possible variation of compositional forming both on variety of elements and interelements coherences per each coordinate and on elements sets and coherences variety of coordinate system.

In this respect informative properties of modeling space, performance of element processes with transmission and transformation of elements and process formation correspond to performance of composition processes with generation of structural formations.

The compositional space in initial stage is Decompositional space, transformed in simulation process and is revealed by technique decisions space. The Compositional simulation process on elements and interelements coherences space forms the technique
decisions subsystems. There are performed the technique decisions generation, optimization Structural and Parametric synthesis then the extraction of optimal decisions.

The processes of MMS technique decisions formation and generation are automatized in real time. In this case there are performed Structural and Parametric synthesis, involving Aggregation, Composition, cyclogram process, analysis and choice of decisions on each step of structural compositions formation. This way allows to model Technology and Manufacturing System, started from elemental level and finished to integrated system of technological process and Manufacturing System amidst Manufacturing Medium and conditions which superimpose the limitations, regulate input of criteria to all extent of synthesis control process.

3. Multivariant Manufacture properties and Constructive Transformation

For decision technique – exploitational problems defining usage of Multivariant Manufacture the main requirements may be formulated, fig.1.


2. Automatic changeover, tool changing are additional and auxiliary processes. Necessity of modular units usage with automatic regulation and tools changing, also tools and units changeover are defined in the process of technological process changing.

3. The Multivariant Manufacture must be characterized by presence of quick – changing and automatically changing aggregates and modular units of various functional and technological destination with possibility of automatic formation of various hierarchy level and with possibility of formation work zone for machining and allocation place in production area, fig.2 [22].

4. Providing the required production capacity with changeable nomenclature and product year program with achievement of the best work – pieces quantity, intended by documentation.

5. Functioning and control of Manufacturing System in the conditions of guaranteed exploitational reliability and working ability in the whole period of program performance. The support and regeneration of working ability are provided with automatic modular unit changeability on various hierarchy levels with possibility of automatic tools changeover and regulation.

Multivariant Manufacture obtains the following variable properties. 1. The volume of space filling or the part space and its variation corresponds to nomenclature and production program, to technique – exploitational parameters. 2. Automaticization level of unit content changing is defined by transformation on various levels of structural hierarchy. 3. In the process space transformation the changing of functional destination and technique – exploitational parameters and also the redistribution of space volumes and production area are performed. 4. It is allowed Constructive Transformation and functioning in three regimes: a – Full Transformation Regime (FTR); b – Partial Transformation Regime (PTR); c – Automatic Changeover and readjustment Regime (ACR) of tools and units. The Partial Transformation Regime (PTR) may be named as Units Rejuvenation Regime (URR). The regimes PTR, URR are necessary for exploitational process in the case of moral aging units and partial loss of working ability.

Within the limits of every transformation cycle, fig. 1, the Restructuration is defined by changing of technique – exploitational parameters. The technique – exploitational parameters such as the Production Capacity, Reliability, Flexibility are established and controlled then it is generated the sequence of multilevel connections revelation among units, bearers, between of the formed structural subsystems on various hierarchy levels.

Main investigations of creating and applying Multivariant Manufacture in Russia have been designed primarily by scientific school of Togliatti State University with a long history of researches [14,18,19] since the beginning of 80 years of 20 century. Scientific priorities are confirmed in more than 100 scientific publications and monographs, including more 30 inventions and patents.

Multivariant Manufacture constitute the main field of contemporary Manufacture development, which could not only be readjusted and have automatic mechanisms for tools changing, but might automatically change Construction and Structure in real time on base application of automatically interchangeable and renewable aggregate and modular units

Mechatronic Manufacturing Systems (MMS) and Multivariant Manufacture (MM) with usage of automatically interchangeable and renewable aggregate and modular units as Scientific Direction of Research to Manufacturing Systems, in our investigations these MMS are named as Reconfigurable Manufacturing Systems – RMS.

4. The difference in RMS terminologies of Mechatronic Manufacturing Systems

The difference in terminology was that we in Russia have been called in the early 80’s Automatic Systems with automatically changeable units, with variable Construction and Configuration, where the main feature was established as Reconfiguration and its synonym Reconfiguration because much later, the Michigan University (USA) have been fulfilled extensive experimental research on the level of U.S. national policy of development Reconfigurable Manufacture. In our terminology - Multivariant Manufacture.

The problem in matters of terminology was that in English there was no correspondence to translate from Russian "Componation [komponovanie]", "Componatics [komponetika]" as science in English. If the word in Russian "структура [struktura]" is in English language completely identical and translate as "Structure", then the word "[komponovka]" in English there was no one correspondence with the semantic word. To English word "Reconfigurability" more closely corresponds the words in the technical translation into Russian as "Rearrangement, Reinstalling, Resetting." In the Russian translation "Reconfigurable" has several meanings: "Readjusted", "Variable Configuration".

Also there aren’t found accordance of word "компонетика – [komponentika]" as science in English. If to conduct the correspondence of words in Russian: 1) “компоновать [komponovat]”, 2) “компонование [komponovanie]”, 3) “компоновка [komponovka]" that is probably to receive the words translation in English, offered by us, as 1) "companion", 2) "componation", 3) "componatics".

Then the words in Russian: 4) "перекомпоновывать (or пере-компоновать) [perekomponovat]", 5) "перекомпонование [perekomponovanie]", 6) "перекомпона [perekomponovka]", 7) "перекомпонуемый [perekomponuemyi]", 8) "переконфигурировать (or реконфигурировать) [perekonfigurirovat]", 9) "реконфигурация [rekonfiguratsiya]", 10) "реконфигурируемые [rekonfiguriyemiy]" will be able to translate in English as 4) “Recompate”, 5) “Recompation”, 6) "Recompations", 7) “Recompatable” or “Recompatic”, 8) "Reconfigure", 9) "Reconfiguration", 10) "Reconfigurable".

Fig.2. The Working Position of Recompanatable Manufacturing System (RMS) with automatically interchangeable modular units on Space of Multivariant Manufacture
If in relation to Flexible Manufacturing Systems (FMS) for Recomponatable Manufacturing Systems (RMS) a distinguishing features are Recomponatability, Recomposition based on the automatically exchangeable units and modules at different levels of structural hierarchy [14,18,19]. As we know these properties are not relate to Reconfigurable Manufacturing Systems [9].

In general statements of Machine Building development in Russia the Machine System Componatics Theory was always of basic characteristic for the Manufacturing Systems Equipment and especially at the branch of industry – Machine Tool Building. The Componatics Theory in conjunction with the Kinematic Structures Theory of Machine Tools, Automatic Lines and Systems have been received the full development in the Soviet Union, ranging from 40 - 50 of the 20 century. Main provisions in the Componatics Theory and Kinematic Structures Theory have been developed by famous Russian scientists such as: Vladzevsky A. P., Vragov U. D. [21], Artobolevsky A. L., Artobolevsky L. I. [2], Kucher L.M., B. Boguslavsky B. L. [5], Shaumyan G.A. [10], Pronikov A. S., Volchkhevich L.I. [11], [31], Erpsher Y.B., Dashchenko A.I. [8], Cherpakov B.I. [7], Averiyanov O.I. [1] and others. Significant contribution to issues of analysis and choice of Componatics have made Vragov U. D [21]. The initial stages of developing the theory and creation of Recomponatable Manufacturing Systems were included in the works Boytsov V. V. [6], Shaumyan G. A. [10], Volchkhevich L. I. [11], [20], Artobolevsky L. I. [2], Biyskiy D. Y. [2] in 60 - 70 years and other native scientists. Monograph Vragov U.D [21] is a fundamental scientific work, which focuses on the Componatics basics as a common teaching Structure and Componatics Transformation of Manufacturing Systems .There are considered several stages of Componatics formation: technological, coordinate, basic, structural. Unified theory of technological, coordinate, basic and structural Componatics is considered as a general scientific direction for the theory of Componatics and Componentry.

The notion of "Reconfigurable System", i.e. System with altering Configuration relates to a change of Configured System State, Configuration changing of Manufacturing System, tools change-over, to changing of outer exterior or visage RMS.

In this regard, in contrast to the Reconfigurable Systems the Recomponatable System parameterization has distinct restructral, functional, technical – operational differences from the Flexible and Reconfigurable Manufacturing Systems.

5. The definition and purpose of Recomponatable Manufacturing System

Recomponatable Manufacturing System (RMS) is a self-controllable and self-regulaable Mechatronic Manufacturing System, the basic properties of which are: changing of Componation and Construction, multilevel Structure of mechatronic modular units and mechanisms, fig.3, interunits and interelement connections and coherences with the goal of functioning in changing production exploitation time cycle. RMS is characterized as a complex of controlled, automatically exchangeable technique and auxiliary facilities, automatically composated and organized on Multivariant Manufacture with multilevel Structure [12,14,18,22]. When the Componatic and Structural transformation cycling is submitted to cycling of production, preparation and new product manufacturing. In transformation cycle RMS is organized and optimized in Componatics and Structure on time period limited by production. Recomponation and Reconstruction (for example, with application of Robotic Machine, fig.4 [22]) becomes a necessary RMS flexibility property to change and transform the Componation and Construction, fig. 2,3, in the process of Multivariant Manufacture structure changing in correlation with technological process Structure Transformation of work pieces production. Recomponation is directed at of RMS Componatics changing, respective space allocation, automatic units basing and clamping. In RMS composated status a Production process is performed.

If there is the possibility to change RMS Structure, Componatics and Construction, to control by elements and coherence nomenclature then there is a possibility to control technique – exploitative parameters of Manufacturing System composated in time and space. This statement can be accepted as a basic statement for search of new technique decisions in Mechatronic Manufacturing System creation of perspective directions. Just, this statement is integrated in to context of development and structural transformation of Manufacture organization. The MMS and RMS creation process is synthesized in integrated system of automatic processes for technology design and Manufacturing System creation leading to significant reduction of production costs and to increasing of Manufacture Efficiency.

For performance of production tasks the MMS and RMS must possess the following technique – exploitative properties:

- Recomposition that is defined by automatization of space orientation and respective allocation changing, basing and fastening of units clamping during on conjoint functioning and performing of technological functions in production process;
- multilevel automatization of aggregate and modular units change in Manufacturing System Recomposition process on various levels of RMS Structural and Componation hierarchy, fig.2;
- formation of RMS Componatics with possibility of Space varying and Componation time;
- multivariate and view – changing of technological and inter - transportation flows in Componation Space of Multivariant Manufacture, view – changing of material and information flows of Production Organization and Control;
- achievement of machining processes maximum concentration with the possibility of multinomeclature work pieces machining.

The high achievement level of automatic units changing on various levels of structural hierarchy with provision of Accuracy and Stiffness parameters allow to expand the possibilities for usage of Manufacturing Systems not only in conditions of various Produc-
tion type, but also for tasks decision of automatic support and as required automatic performance renewal of Manufacturing System.

6. The increasing of RMS Life Cycle

In time of exploitation process the RMS is aged by the reason of units’ physical and moral ageing. Versus RMS with aged alive organism there is happened the die – off living cells. The RMS status (remaining able to work totally) then replaced units are renewed, Manufacturing System is decomposed and transformed from old units base on new, changing its architecture but preserving vitality for accomplishment of following technological processes.

The RMS Life Cycle must be continued even if there are happened the wearing and changing of units. Depending of physical and moral wearing of RMS units and components the unit automatic changing and rejuvenation of all RMS the changing of its architecture on Componation space is taken place. A fortiori on condition of organism there is happened the die – off living cells. The RMS status changing and rejuvenation of all RMS the changing of its architec- ture on units’ physical and moral ageing.

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RMS is automatically configured and organized into Mach- inary System so that Cyclic recurrence of Structural and Construc- tive Trans- formation is submitted to the Cyclic recurrence of produc- tion tooling and new Multivariant Manufacture. In Transformation Cycle RMS is organized in time interval limited by fulfillment of Multivariant Manufacture and production process order, by required product program and production volumes in time, by required pro- ductivity and probability of Machine System upon minimization of current and capital outlays. Automatic adjustment of function re- gimes and automatic setting – up are adaptive characteristics added to characteristics of RMS.

The received RMS technique – exploitational properties de- fined technique - economical advantages of MMS, RMS creation compared with to contemporary Manufacturing Systems (FMS, FMM, and others). First of all with RMS usage the following pro- duction problems are decided:

- flexibility increasing of Structural and Constructive Trans- formation and RMS usage in conditions of Multivariant Manufacture
- flexibility increasing of work – pieces nomenclature chang- ing, Production Capacity, exploitational reliability;
- increasing machining accuracy and Manufacturing System stiffness, decreasing cost and production area;
- improvement of working conditions and decision of ecologi- cal problems;
- possibilities increasing of aggregative regeneration of work- ing ability and rejuvenation in respect of physical wearing and moral ageing;
- decreasing of RMS cost and accordingly labor costs in com- parison with FMS.

Automation of RMS Structural and Constructive Transfor- mations is appeared as a major link of automatization development of technological preparation, production organization and control.

**Literature**

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