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THE CONCEPT OF THE STEP-BY-STUDY EVOLUTION OF SPINDLE MOTORS USING VENN-EULER DIAGRAMS

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ABSTRACT

The evolution of creation and improvement of rotary drives of the main movement with their translational movement, beginning with aggregate machines and finishing with modern intelligent motor spindles for CNC machines is traced. Symbols for the circuit image of motor spindles are offered. Graphical representations of motor-spindle hybrids of different level of crossing using Venn-Euler diagrams are presented.

1. FORMULATION OF THE PROBLEM

In order to ensure high-speed (HSC - High Speed Cutting), high-performance (HPC - High Production Cutting) and precision (High Precision Cutting) processing of parts [2, 3] in the main motion drives of CNC machine tools, electromechanical main motion drives of the type motor-spindle (M-S) [6, 10-12], where the spindle is a rotor with supports that have air or liquid cooling. The existing M-S provide only rotation for the main movement, and for translational movement along the controlled coordinate, additional drives are used that are not aligned with the axis of the spindle, this limits their functionality. Non-self-acting and self-acting power heads of aggregate machines became the prototype for M-S (Fig. 1) [4].

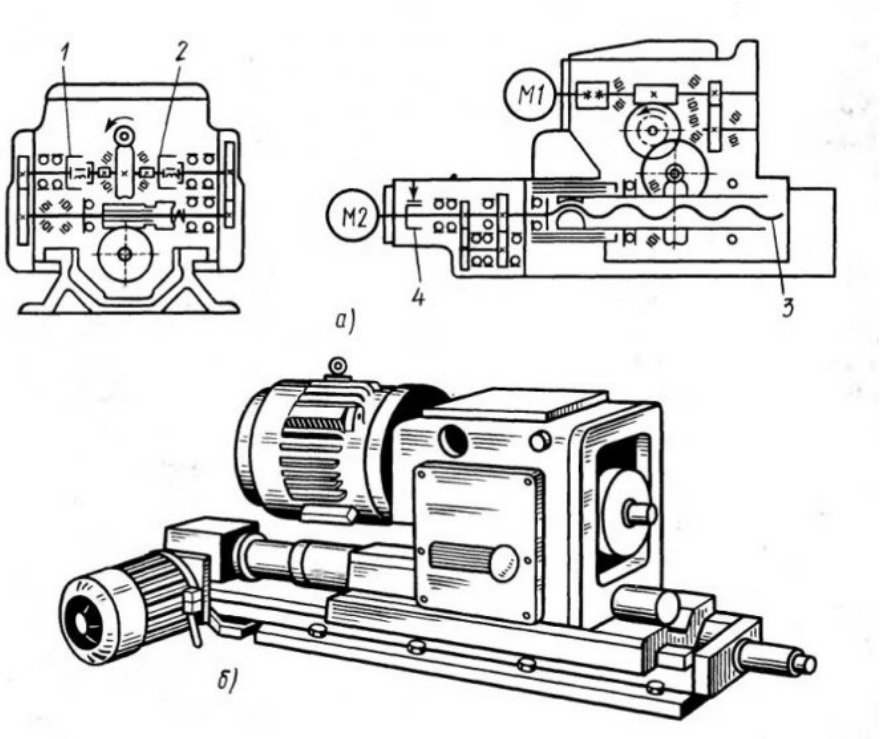

Fig. 1. Electromechanical self-acting force head: a — diagram, b — general view; M1, M2 — electric motors, 1, 2 — electromagnetic couplings, 3 — propeller, 4 — electromagnetic brakes

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2. THE MAIN TASK AND THE OBTAINED RESULTS

The use of non-self-acting M-S shortened the kinematic chains, reduced the dimensions of the main motion drive and made it possible to ensure rotation frequencies in lathes up to n=10-20 thousand rpm, and in drilling-milling and grinding machines up to n=100-200 thousand rpm /min and above. Therefore, they began to be widely used as modules in machines of various purposes, and to ensure feeds, a separate translational drive with guides, for example, a screw, not coaxial with the axis of the spindle, which increases dimensions, metal consumption and labor costs during manufacture, is used. In addition, when processing on machines with parallel structure mechanisms (MPS) [5] parts with many holes in different planes (cases, board, etc.) and at different angles, the use of non-self-acting M-S requires moving the moving platform together with the non-self-acting M-S, which limits the speed and acceleration of moving parts due to excess masses and dynamic loads. Combining two drives into one coaxial unit for self-acting M-S significantly reduces dimensions and metal consumption, excludes guides and distortions from additional moments, increases speed and acceleration. The need for further improvement, the development of design methods and the search for new solutions for intelligent self-acting M-S of the Smart Spindle type [7] determine the relevance of research using hybridization [9]. For the graphic representation of the M-S schemes, conventional designations of the components are proposed, namely (Fig. 2): the main movement-rotation of the spindle n, the longitudinal feed drive, the clamping mechanism, which provides the radial clamping force of the object (part, tool) F, U control systems for the intellectualization of the M-S work process.

The proposed conventional designations can be used on the basic kinematic diagrams of machines in addition to the existing designations for greater specification. The process of searching for hybrids of self-acting M-S with clamping mechanisms (**n**, **s**, **F**) can be represented graphically using a three-level crossing model (Fig. 3), which corresponds to the ratio 1_3 (**nsF**), 2_3 (**ns**, **sF**, **nF**), 3_1 (**n**, **s**, **F**) and the three-level Venn diagram (Fig. 4) [1].

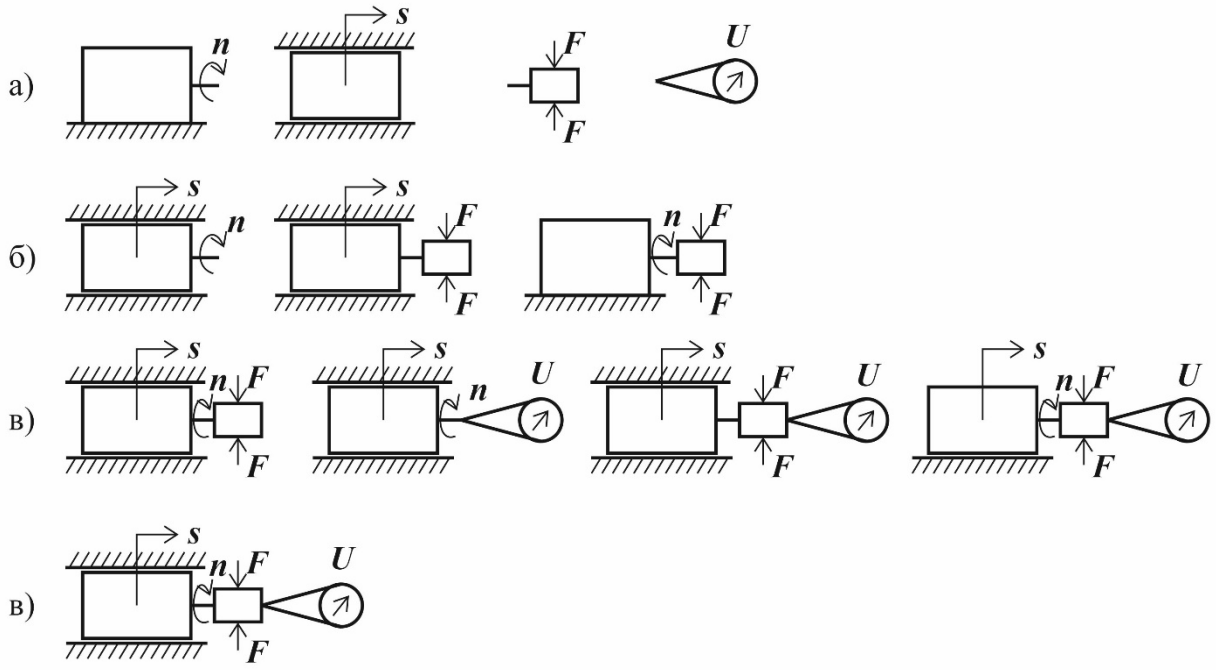

Fig. 2. Conventional designations for M-S: a-individual components; b-hybrids from two components; c-hybrids from three components; d-hybrids from four components

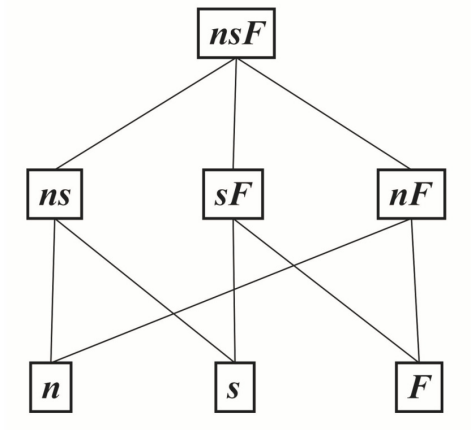

Fig. 3. Graphic representation of the creation of hybrids of self-acting M-S with clamping mechanisms

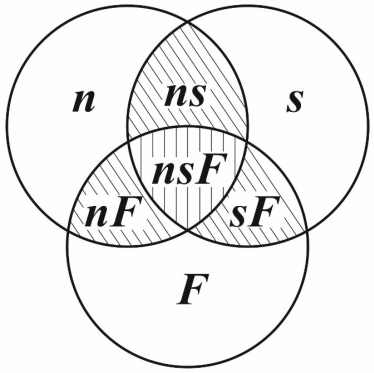

Fig. 4. Three-level Venn diagram

The process of finding hybrids of intelligent self-acting M-S with clamping mechanisms, control and measurement and mechatronic systems (**n, s, F, U**) can be represented graphically with the help of a four-level crossing model (Fig. 5), which corresponds to the ratio 1_4 (**nsFU**) 4_3 (**nsF**, **nsU**, **nFU**, **sFU**) 6_2 (**ns**, **nF**, **nU**, **sF**, **sU**, **FU**) 4_1 (**n**, **s**, **F**, **U**) and four-level Venn-Euler diagram (Fig. 6).

In recent years, dozens of patents for inventions and useful models have been obtained, as well as technical documentation has been developed and an experimental sample of a self-acting M-S has been produced based on the results of theoretical, experimental and research work carried out at KPI named after Igor Sikorsky at the Department of Machine Design in partnership with the Department of Electromechanics, which testifies to the effectiveness of the interdisciplinary approach.

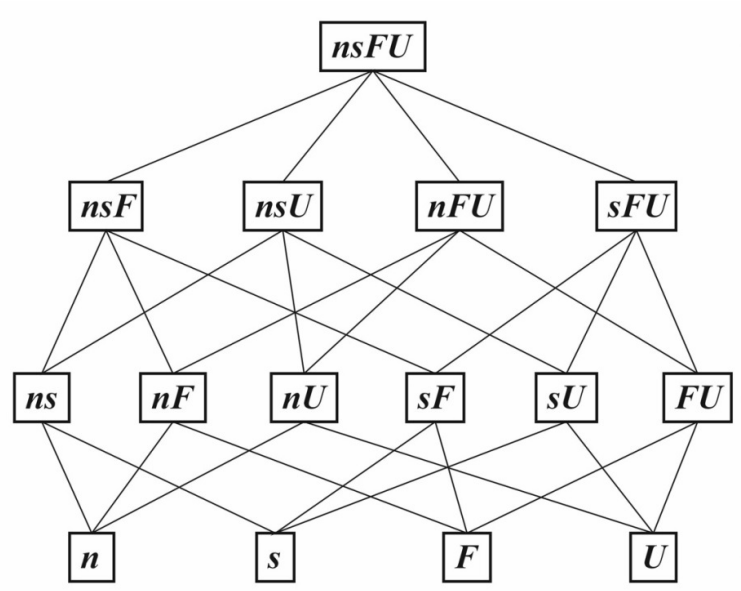

Fig. 5. Graphic representation of the creation of hybrids of intelligent self-acting M-Sh with clamping mechanisms and mechatronic systems

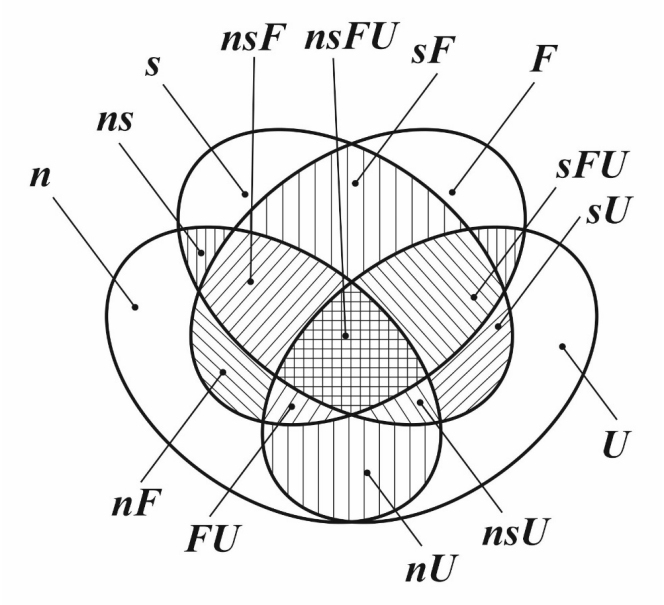

Fig. 6. Four-level Venn diagram through Euler ellipses

3. CONCLUSION

Prerequisites for the concept of creating motor-spindles on a modular basis using Venn-Euler diagrams are proposed, which greatly facilitates the search for new technical solutions at the level of inventions and useful models.

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