Mechanism designs adapted to 2D technologies

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Abstract. A significant reduction in the cost of manufacturing machines and various mechanical systems can be achieved by adapting their designs to 2D technologies. The article is devoted to the development of appropriate designs of centroid mechanisms, namely, spiderless planetary transmission and planetary rotary hydraulic machines.

1. Introduction
Modern mechanical engineering is built mainly on technological operations related to metal cutting. In addition to the costs of numerous machining facilities and tools, this requires the presence of a large number of skilled workers. As a result, the cost of products manufactured using traditional technologies is high. A fundamentally new, breakthrough solution is the use of 3D printers. However, such technologies are only in their infancy. Currently, 2D technologies exist and are actively developing, in particular laser and hydroabrasive cutting of sheet material. These technologies are characterized by high productivity, degree of automation and accuracy of processing, but practical application has so far been found mainly in procurement operations. The reason is that when manufacturing machines whose designs are designed for traditional mechanical processing, the number of operations carried out using 2D technologies is very limited. A significant reduction in the cost of manufacturing machines can be achieved by adapting their design to 2D technologies.

2. How mechanisms adapt to 2D technologies
The adaptation of machines and mechanical systems to 2D technologies will consist in meeting a number of requirements:

• most (and better all) parts of the mechanism should be flat;
• it is necessary to strive to ensure that the maximum number of dimensions of parts (including the most accurate ones) is provided by a sheet cutting operation;
• it is advisable to make the links of the mechanism in the form of a package of corresponding disks. By the way, in addition to meeting technological requirements, this will help compensate for errors in the manufacture of parts due to their self-installation.

Centroid mechanisms are suitable for such adaptation. From these positions, two groups of mechanisms are studied:

• spiderless planetary transmissions;
• planetary rotary hydraulic machines.
3. Planetary mechanisms and spiderless planetary transmissions

Planetary mechanisms contain central gear links and several satellites. Thus, most of their parts are flat gears. The share of such parts in the so-called spiderless planetary transmissions is even greater. In the simplest cases, the spiderless planetary transmissions may consist of gears alone, some of which are provided with elements for removing torque therefrom. Such a gear in figure 1 [1] is used in the mechanism for changing the tilt of the car seat. In it, all parts are made using 2D technologies.

For adaptation, the whole range of known and fundamentally feasible spiderless planetary transmissions [2-6] can be considered. Methods of parametric calculations [7,8] have been developed for such transmissions. The model of one of the new spiderless planetary transmissions [9], the parts of which are made by laser cutting, is shown in figure 2.

A niche that can be occupied by planetary gears manufactured using 2D technologies are short-term drives for which compactness and minimum cost are most important.

4. Planetary rotary hydraulic machines

Hydraulic displacement machines are widely used in mechanical engineering. Currently used varieties of such machines have their advantages and disadvantages. Among positive displacement hydraulic machines, rotary pumps and engines containing a planetary mechanism in which variable volumes...
enclosed between central gear wheels and floating satellites operate have long been known. The central wheels can be both round and non-circular. The principal advantages of planetary rotary hydraulic machines are a large useful volume of working cavities, the absence of loaded sliding pairs, and insensitivity to tooth wear. The main reason why such hydraulic machines have not been widely used to date is the difficulty of manufacturing gears with inner and non-circular teeth. Using 2D technologies eliminates this problem.

Optimal structures of planetary rotor mechanisms were searched [4]. As a result, diagrams with round (figure 3) [5] and non-round (figure 4 and figure 5) [6] wheels are obtained, the feature of which is the same number of teeth of both central wheels. Compared to the existing ones, the new schemes have a simpler design and a larger useful volume.

**Figure 3.** Planetary rotary hydraulic machine with round gear links: 1, 2 - central gears; 3 - satellites.

**Figure 4.** Planetary rotary hydraulic machine with non-circular gear links: 1, 2 - central gears; 3 - satellites.
5. Conclusions
Existing technologies make it possible to manufacture gear links of a hydraulic machine from steel. Such structures are capable of withstanding a pressure of 50-100 atmospheres. This, for example, will create a range of drilling pumps, which will be 3-5 times more compact and 5-10 times cheaper than the currently used plunger and piston pumps. Other possible applications of planetary rotary hydraulic machines: pumps for pumping oil and fuel oil, dosing pumps for various liquids, pumps and motors of hydraulic drives, pneumatic motors, vacuum pumps of low vacuum.

The analysis of the possibilities of adapting to 2D technologies of many flat mechanisms that are not centroid is also very relevant.

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