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MECHANICAL TRANSMISSIONS FOR ACCURATE DISPLACEMENTS

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ABSTRACT: *In technical literature, the accurate displacements or positioning transmissions are not usually presented separately. This work presents mechanical transmissions classification criteria and accurate displacement transmissions as well. It also presents constructive solutions, advantages and drawbacks of different accurate displacements transmissions.*
Key words: Mechanical transmissions, *accurate displacements, cycloidal gearing, roller gearing.*

1. INTRODUCTION

Worldwide, accurate displacements mechanical transmissions are utilized in different top interest areas, such as: robots, machine-tools, aeronautics, transportation, precision mechanics, precision mechanisms, devices and gauges, thermal treatments etc.

These transmissions have the purpose to achieve accurate displacements (positioning) for translation and rotation movement. Besides the increased final product quality, the purpose is to improve robustness and functionality of these accurate displacements systems, simplicity, reduced size and weight, with improved functional parameters or at least comparable or even better with respect to the regular current transmission systems.

For that, we must perform the constructive and functional analysis of the mechanical transmissions for accurate displacements used worldwide in the fields mentioned above.

2. MECHANICAL TRANSMISSIONS CLASSIFICATION

2.1 Mechanical transmissions classification

Mechanical transmissions are used for motion and power transmission from motor, respectively driving shaft to the driven one.

For a complete classification of mechanical transmissions, the following criteria are used:

I. Based on the type of power transferred, there are***:***

- power transmissions;
- cinematic transmissions.

II. Based on the motion transformation:

- transmissions without motion type change;
- transmissions for rotational to translation motion transfer;
- transmissions for translation to rotation transfer.

III. Based on the type of machinery parts used for power transfer:

- gear transmissions; cam transmissions; frictional transmission;
- screw-driven transmissions;
- ball screw transmissions;
- belt drive transmissions;
- roller chain transmissions;
- lever mechanism transmissions.

IV. Based on the motion precision:

- general mechanical transmissions;
- accurate displacements mechanical transmissions.

V. Based on construction type:

- direct or without auxiliary element (gears, frictional etc.)
- indirect or with auxiliary elements (roller

chains, belt driven etc.)

3. MECHANICAL TRANSMISSIONS FOR ACCURATE DISPLACEMENTS

3.1. Classification

Accurate displacements transmissions can be classified based on the following criteria:

I. Based on construction type there are:

- Gear transmissions: (fig. 1):
  - Spur gears:
    - involute profile;
    - cycloid profile;
    - with rolls (fig. 2);
  - Bevel gears;
  - Helical;
- Screw-driven transmissions (fig. 3);
- Ball screw transmissions (fig. 4);

II. Based on the motion type of the driven element:

- rotational motion transmissions (fig. 1, a, 2, a);
- translation motion transmissions (fig.1, b, 2, b, 3, 4).

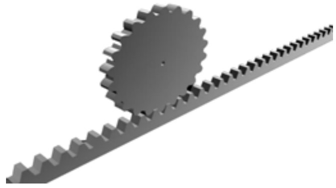
Figure 1,c presents the kinematics diagram of a robot Acma S18 and figure 1,d presents kinematics diagram of a mechanical transmission used to drive the orientation mechanism 4, made out of external spur gearing z_1-z_2, conical gearing z_3-z_4 and notch belt transmissions z_A-z_B and z_C-z_D, [1].

The advantages of gearing transmissions are: constant gear ratio; reliability and durability; reduced size; can transfer mechanical power within a large range of speeds and gear ratio; high efficiency (up to 0,995); can provide translation and rotation as well; there is no speed limit (for precision motion application); easy maintenance; interchangeable components; easy to adjust backlash;

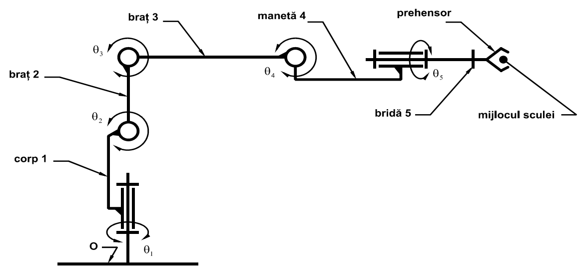
The drawbacks of gearing transmissions are: it requires very high manufacturing and assembling accuracy; noisy at high speeds; the speed ratio is limited due to the integer number of teeth; it requires enclosed areas, need sealing from external environment (to avoid wearing due to dust and other impurities).

Figure 2,a and b presents two roller transmissions for rotation and translation respectively, produced by NEXEN, SUA [.

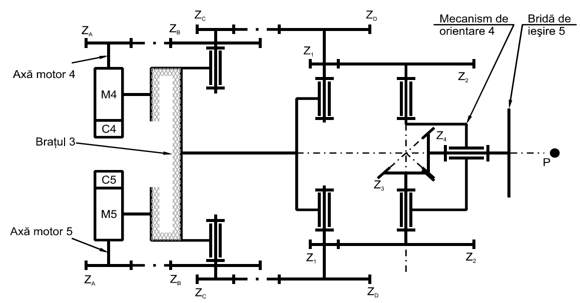
a.



b.

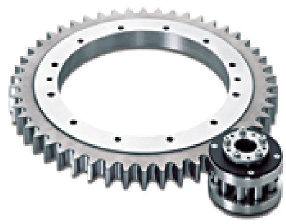


c.



d.

Fig. 1. Mechanical transmissions for accurate displacements with spur gears



a.

b.

Fig. 2. Rotation and translation roller transmissions

The advantages of these transmissions are: realize translations and rotation motions as well; there is no speed limit (for precision motion application); easy maintenance; easy and quickly worn out components interchangeability; high durability; simple backlash tuning.

The drawbacks of these transmissions are the manufacturing very tight tolerance, and high cost.

In figure 3 is presented a screw-driven transmission, for which the two-piece nut construction and adjustment allowance, permits elimination of axial backlash.

The ball screw transmissions are presented in figure 4, for which the solution for backlash elimination is identical with the one used for regular screw-driven transmission.

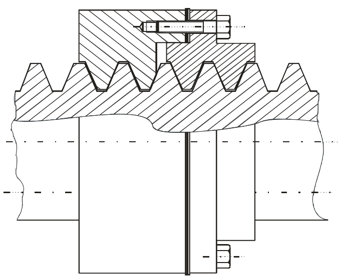


Fig. 3. Screw-driven transmission

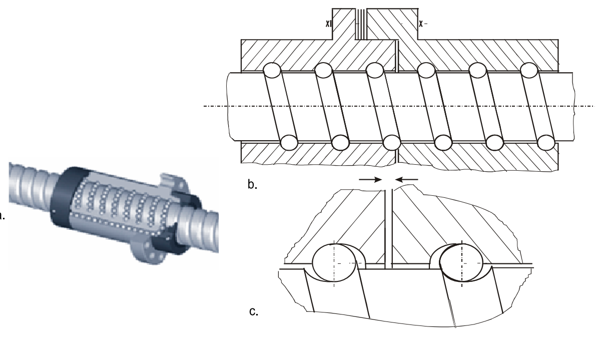


Fig. 4. Ball screw transmission

It is utilized for transmissions with high requirements for cinematic precision over time, high efficiency, reliability, high precision mechanisms, subassemblies of automated machine-tools etc. The large scale usage is limited by complex manufacturing, which leads to a higher price.

The advantages of these transmissions are: small friction losses, higher efficiency; the nuts can be made to be pretension when assembled, eliminating the axial backlash, so creating a high functional precision (fig.4, b and c).

The drawbacks of these transmissions are: high price; high manufacturing precision; the speed is limited by screw resonance frequency; requires lubrication, otherwise the durability decrease by 90%; requires extra maintenance; it can be utilized only for rotation to translation transformation and for transforming the translation into rotation motion.

For precision motion mechanical transmissions, the basic functional parameters, as defined by general mechanical transmissions, the transfer motion law is a very important parameter for movement precision and location precision of the driven element. This location precision is influenced:

· dimensional accuracy of the parts defined by designed dimensional tolerance, surface finish and geometrical tolerance accordingly with the scope of the project;

· the elimination or reduction of the backlashes.

3.2. Constructive solutions, utilization areas

3.2.1. Involute gearing

The constructive parameters are dependent on construction approach, which is depended on the functional and constructive project requirements: the power to be transferred, the input shaft angular velocity, the gear ratio or first order transmission function, the angular or linear velocity of the driven element, and the space constraints if required. All this have direct influence over constructive solution and over constructive parameters. An example of constructive solution is shown in figure 5 [2], which is a mechanical transmission with gears for actuation of the orientation mechanism 4 of Acma S18 robot. Its cinematic diagram was shown is figure 1, c and d. The gearing used in this case are spur gears with involute tooth profile, and conical gears with straight teeth.

In the case of involute gears, the functional parameters vary in a large range [1]:

· large range of power transferred;

· peripheral velocity (for 3rd precision grade): 40 m/s in case of spur gears, and 75 m/s in case of helical and bevel gears;

· maximum gear ratio: 8 for spur gears; 10 for helical and double helical gears; 6 for conical gears with straight teeth; 7 for conical gears with helical teeth.

· efficiency, if running in an oil bath: 0,96…0,98 for spur gears; 0.95…0,97 for conical gears.

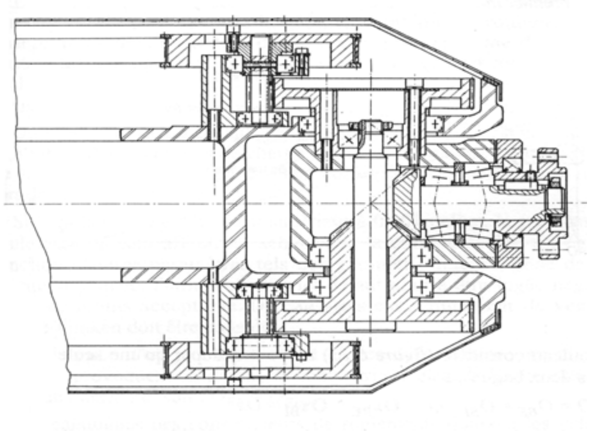


Fig. 5 Gears transmission for actuation of the orientation mechanism of Acma S18 robot

In the case of mechanical precision motion transmissions, the paramount is the precision of the motion transfer, which actually translates into precision of locating the driven element.

For involute gear transmissions, the precision of the motion transfer is dependent on the precision grade the gear is manufactured at. The precision grades and the path of contact surface finish are established by functional requirements: the power, utilization area, peripheral velocity and the maximum dynamic loads of the gearing. When the precision grade and the path of contact surface finish are established, the manufacturing technology should also be considered.

The gear transmissions functionality at required parameters demands, besides a higher precision grade (so higher cost) an adequate lubrication. Besides the requirement of being tighten, the gear lubrication is also potentially pollutant.

The backlash limits the true position of the gears, the gearing is nosy and vibe loads could aappear that influence the true position of these gears. To eliminate the backlash, special constructive solutions should be considered, which increase the friction loss, lower the efficiency, increase the noise and reduce the durability of the transmission. High speed gears are noisy.

3.2.2. Roller gearings

The roller gearing, also named pin gearing, shown in figure 6, is a particular case of cycloid gearing, the line of contact being a single arc. The pinion teeth are cylindrical (rollers or pins) and the tooth face surfaces are (rollers or pins) and the tooth face surfaces are tangent to the cylindrical surface of the pins.

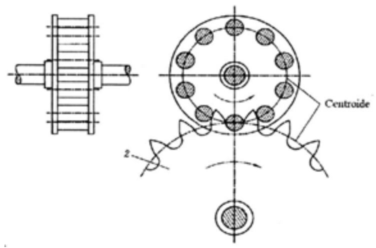
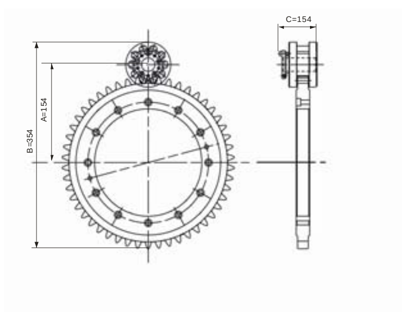
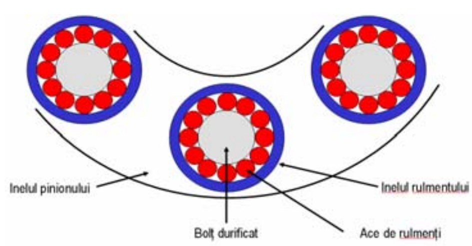


Fig. 6 Roller gearing

The roller gearing is used for crane gear assemblies, some satellite kinematic chain, in clock-work, and for precision motion transmissions made by Nexen Group, USA under the name of Roller Pinion Rotary Drive System (RPG) (fig. 7,a and fig. 8,a) for rotary motion [9], and Roller Pinion Linear Drive System (RPS) (fig. 8,b) for translation motion [8].



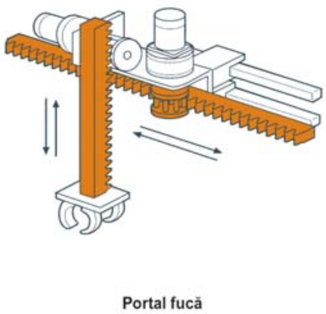
a.



b.

Fig. 7. Nexen transmission [8]

a. Synchronic transmission



b. Portal fork

Fig. 8. Nexen transmissions utilization examples [8]

The main advantage of roller gearing is avoiding tooth cutting process, because the pinion is designed as an assembly of rollers or pins installed between two discs. (fig. 6, fig. 7,a). In addition to this, Nexen transmissions have the rollers installed over hardened pins and bearing rollers, which assure the rolling motion with engaged tooth profile (fig. 7,b).

Roller pinion systems produced by Nexen, USA are used in varied areas, for rotary or linear motion. Figure 8,a shows an example of rotary precision motion system application, and in figure 8,b there is a linear precision motion application [8].

Domains for using rotary motion systems are: scanning systems; indexing systems; medical fixtures; robots; automotive; aerospace industry; semiconductors; materials.

Domains for linear motion systems are: cutting tool systems; portal systems (X-Y-Z axis); medical products; robots; automotive; aerospace industry; material manipulation.

These transmissions guarantee the following performance: backlash smaller than 3,2 μm is possible because there are always two or more rollers simultaneously contacting the driven gear or rack; very tight true position, up to ± 30μm in tangential direction to indexing circle, possible because of the highly precise manufacturing of the parts; very small velocity variation (motion irregularity); maximum peripheral velocity if indexing diameter of 11 m/s.; this transmissions are very quiet at low speed and the noise does not pass 75dB at maximum speed, which a lot lower than regular gearings; 99% efficiency, because of replacing the tangential friction by rolling friction; high stiffness; reduced maintenance; corrosion resistance; high durability; high portability factor.

3.2.3. Mechanical precision motion screw driven transmissions

Screw mechanisms serve for transforming the rotary motion into linear motion and vice-versa. They are used for adjusting of for movement (fig. 3.3).

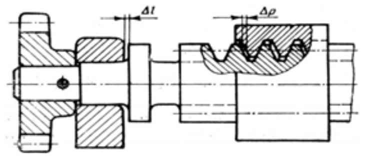


Fig. 9. Screw mechanisms

From constructive stand point, for screw mechanisms, attention should be paid to the measures of eliminating the backlash, which comes up when the movement direction or load direction is changed.

The backlash can be minimized by using adjusting nuts, which are made to allow controlling the clearance between screw coils and nut coils (fir. 3.3), and the complete elimination of the backlash can be made by some adjusting elements.

3.2.4. Mechanical precision motion ball screw transmissions

In the case of ball screw transmission, the kinetic elements are identical with those for regular screw driven transmissions.

These transmissions are used where high kinematic precision over time is required, as well good efficiency, dependability etc. Some examples of usage are: precision mechanisms, subassemblies for automated fixtures, direction column for automobiles, for machine-tools construction etc.

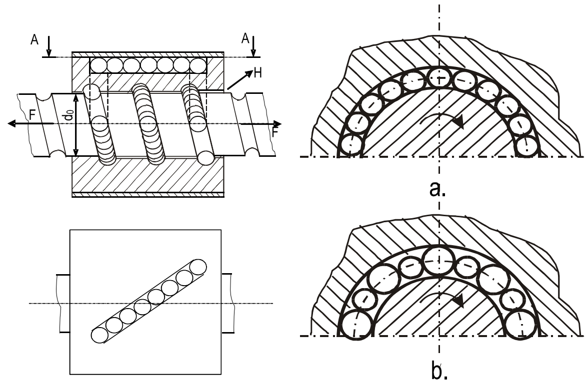


Fig. 10. Ball screw transmission

The high volume production is constraint by complex construction that leads to a higher price.

4. CONCLUSIONS

The constructive and functional parameters of mechanical transmissions used in domains that require high precision in the motion of driven element (its location control), presented in this paper, shows that there are a large variety of constructive solutions.

Among the presented constructive solutions, the most competitive from performances points of view are those produced by Nexen Group, USA [8], [9], but they need a high processing accuracy and are expansive.

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TRANSMISII MECANICE PENTRU DEPLASĂRI PRECISE

Rezumat:*În literatura de specialitate în care sunt tratate transmisiile mecanice nu sunt analizate separat cele pentru deplasări precise sau de poziţionare. Lucrarea prezintă criteriile de clasificare care pot fi aplicate transmisiilor mecanice în general precum şi celor pentru deplasări precise. Sunt prezentate de asemenea soluţiile constructive, avantajele şi dezavantajele diferitelor transmisii pentru deplasări precise.*

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