THE ANNALS OF "DUNĂREA DE JOS" UNIVERSITY OF GALAȚI
FASCICLE V, TECHNOLOGIES IN MACHINE BUILDING,
ISSN 1221- 4566, 2009

ON THE CORRELATION BETWEEN THE EFFICIENCY AND THE NON-DIMENSIONAL PARAMETERS OF THE PLANETARY MECHANISMS

Prof. eng. Vasile NASUI PhD

North University of Baia Mare,
e-mail: vasile.nasui@ubm.ro

ABSTRACT

The simple planetary mechanism has kinematics advantages allowing a range of transmissions reports uncovered by any other transmissions but on the other hand they have disadvantages from the dynamic point of view for extreme cases. However, for these cases it is required the appropriate choice of the non-dimensional parameters of the devices, giving up the standard values. The paper present the results of the research regarding the identification of some parameters of control and checking to obtain the best correlation of the movements at machine tools as well as the opportunity to use planetary mechanisms. The power dissipations can be influenced a lot by the modifications of these parameters, as it resulted from the experimental researches undergone by the authors on the specialized stands for the planetary reductions gears manufactured in the series fabrication.

KEYWORDS: efficiency, non-dimensional parameters, planetary reducers, mechanical efficiency

1. INTRODUCTION

A typical feed of using the planetary transmissions in building machine tools where is the problem of correlation of several movements such situations appear very frequently. In the building of machine tools, we also find planetary mechanisms to compose or decompose movements or to simply achieve a transmissions report [10].

For the transmissions with planetary gearings, the efficiency and the specific power dissipations have a special importance. The numerous published papers have tried to achieve appropriate analytical evaluations of the efficiency taking into account the assembly of the non-dimensional parameters as well as the determination of the determination of the limits of the correlation [3].

The planetary transmissions are high technical products which have special cinematic and dynamic advantage, the best in certain area of parameter.

The simple transmissions (fig. 1) which from a cinematic point of view offer the maximum of advantages, from the efficiency point of view, it represents a maximum of disadvantage. Consequently, when designing these, taking, into account the two criteria (the kinematics and the energetic we choose compromise solutions) [1].

The specific power losses may greatly influenced by the changing of the non-dimensional parameters specific to planetary gearings. The present economic context imposes further research on the methods and the means used to conceive the products in view of a better competitiveness (fig. 2).

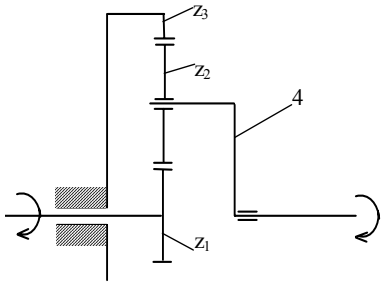

Fig.1. Simple planetary mechanism

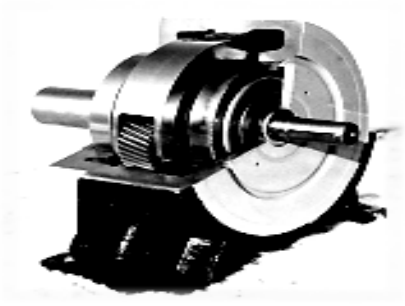

Fig. 2. The planetary reducers

Their analysis shows that the identification of a product is not previous to the coming up with a solution, but they develop simultaneously. The existing already experimented physical solutions are proposed starting from the stage of functional defining [11].

The global assembly of the finite product is differentiated in different subassemblies independently conceived, which can generate contradictions and antagonisms when reunited. Therefore we obtain in the conception stage a chain of cycles to get to the chore of the issue, to research the solutions and then to their integration within the already conceived structural elements, leading to their optimization [2].

The present researches in the field of the modern industrial acting for the machines - tools and robots use the advanced technique of the virtual modeling and experimentation. The unitary approach of the transmissions with planetary gearings matches the present tendencies of the integration of the informatics technologies in the research and the production of the rotary actuators.

The interdisciplinary approach assures the lining up to the priorities, objectives and methodology particular to the European research in this domain. On the national stage, there are little technologies dedicated to the modeling and virtual simulation for the linear electro mechanic actuators which should be turned into an instrument of simulation generalized in this case [6].

Mechanical power transmission is to be adapted from the coupling and angular speed point of view to the characteristics of the driving engine. In the harmonizing of these characteristics the planetary reducers offer the best solutions under the conditions of a high dynamics quality achievement [7].

Planetary gearboxes have a special importance within powerful modern transmission owing to the advantages they present concerning the kinematical and dynamical performances as well as the possibility of automating the orders. These are constructions of gearboxes with a complex structure and the kinematics structural synthesis methods of these transmission use planetary mechanisms of special construction [12].

Planetary gearboxes have a special importance within powerful modern transmission owing to the advantages they present concerning the kinematical and dynamical performances as well as the possibility of automating the orders. These are constructions of gearboxes with a complex structure and the kinematics structural synthesis methods of these transmission use planetary mechanisms of special construction [12].

Planetary gears trains take a very significant place among the gear transmissions which are used in many branches of industry, in the field of machine-tools and robots have an essential importance these of programmed position [13].

Planetary transmission made planetary reductions gears can be used both in the case of a gear box of the 2 type planetary group, or in the 3 type planetary group (made of two or three planetary units) with a large possibility of getting a great number of transmissions rations (fig. 3).

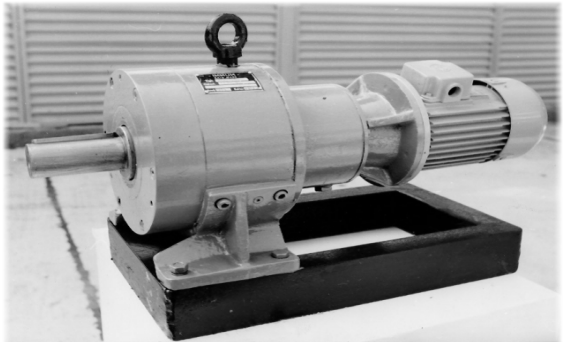

Fig. 3. Planetary train gear

We also present experimental contributions of the authors regarding efficiency calculation, after research on specialized testing stands of producers of planetary reducers in series, confirming the accordance with theoretical deductions (fig. 4).

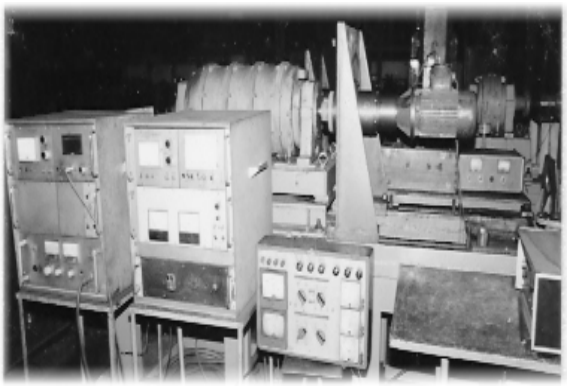

Fig. 4. The trial stand of the planetary reducers

2. NON-DIMENSIONAL PARAMETERS SPECIFIC TO PLANETARY GEARINGS

The parameters of the planetary gearings have a rather great influence on the specific powers losses. Thus, the decrease in the rolling height of the tooth head by changing the coefficient of the reference head height and of the specific profile shifts leads to the decrease in the power losses [4].

This decrease is limited by the decrease in the coverage degree as it can be observed in figure 5. At the same time to obtain of a smaller power a larger numbers of teeth for the two dented wheels. Another parameter that influences greatly the specific power losses is the gearing angle. Thus, when this angle

increases by 20 or 30 % the power losses decrease by 26 %. This is limited by the danger of point sharpening [14].

In the case of the gearings, the specific power losses are influenced by their dimensions, by the type and the size of the loadings and by the relative shifts. Thus, in the case of the bearings, to reduce these losses it is recommended to choose those types with a capacity of large loading, because thus smaller diameters are obtained for the same weight, although the moment of friction will decrease in this way [4].

Therefore, the linear contact bearings are preferred to those with pointed contact because they have a corresponding smaller friction coefficient [10]. The friction coefficient can be influenced by the adequate choice of the lubricant, taking in to account the regime temperature of the transmissions.

The power losses resulting from the friction between the moving machines and the lubricant are influenced by their shape and speed. On the basis of the researches it resulted that these losses are fewer than 10% out of the whole of the specific losses in the case of the adequate choice of the satellites of the planetary mechanisms get as little as possible in the oil bath in inferior position [15].

Also, the most precise teeth and assembly as well as the decrease of the quality of the tooth surface lead to a decrease of the energy losses.

3. CORRELATION BETWEEN THE EFFICIENCY AND THE NON-DIMENSIONAL PARAMETERS

It is known the fact that the correlation is used in the case of stochastic relations efficiency between the analyzed phenomenon and its factors of influence. In view of the analysis of the efficiency the following stages must be observed [9]:

a) The qualitative analysis to establish of the contend of the energetic efficiency of the phenomenon and its factors of the influence i_1, i_2, $i_{3,..}$ i_n, meaning the value of the transmission ratios of the series of planetary gearing which in this respective case are 4; 5; 6; 6,14; 7; 8,2; 10 and 13.

b) The determination of the cause links and their mathematical formula, respectively of the regressive equation which in the present case can be of a parabolic type [2] approximate.

This, the overage function ξ to parabola, can be expressed by:

$$\xi = a + bz_1 - cz_1^2 \qquad (1)$$

where a, b, c > 0.

Under these conditions the maximum efficiency will be:

$$(max)\eta = \frac{(min)a + bz_1 - cz_1^2}{z_1} = min\left(\frac{a}{z} + b - cz_1\right) \qquad (2)$$

which can be expressed as:

$$(max)\eta = (max)z_1 \qquad (3)$$

It is motivated that the efficiency increases with the increase in the number of teeth of the solar pinion. If the influence of the transmission ratio is taken into considerations from the experimental researches, it results the type of functional dependence by the expression of power function:

$$y = a - bx^c \qquad (4)$$

c) Establishing the values of the equation parameters by applying the method of the smallest squares, resulting in the following relation:

$$\eta = 2 - i^k \qquad (5)$$

d) Establishing the intensity of the existent links between the efficiency and its factors of influence in order to establish essential factors by using the correlation coefficient

In each case, high values of the linear correlation coefficient were obtained. For the minimum value of η = 0, 8 of the efficiency, the correlation coefficient for the whole data set results from statistic calculations: k = 0, 01.

e) Proving the influence of the factors on the efficiency by the determination coefficient.

Having a larger number pf measurements (n ≥ 50) the calculated correlation is considered suffice if $x \geq 2m_r$, when the selection amplitude is given by the relation (6):

$$m_r = \frac{1-r}{\sqrt{n}} \qquad (6)$$

The minimum correlation coefficient is given by the relation 7:

$$r_{min} = \frac{\sqrt{n+36} - \sqrt{n}}{6} \qquad (7)$$

For n = 100, resulting r_{min} = 0,75.

By applying Fischer transformed, because

$$r_{min} \geq 0{,}5,$$

$$r = th\, z,$$

the distribution is obtained:

$$z = arcthr = \frac{1}{2} ln \frac{1+r}{1-r} = 1{,}15 lg \frac{1+r}{1-r}$$

It results $z \geq 1$, hence there is a linear correlation between efficiency and transmission ratio.

The correlation shown in this paper is done within the gearing and the generation of the planetary gearing so that the functional and the execution restrictions are observed, as they are shown in the following figure 5.

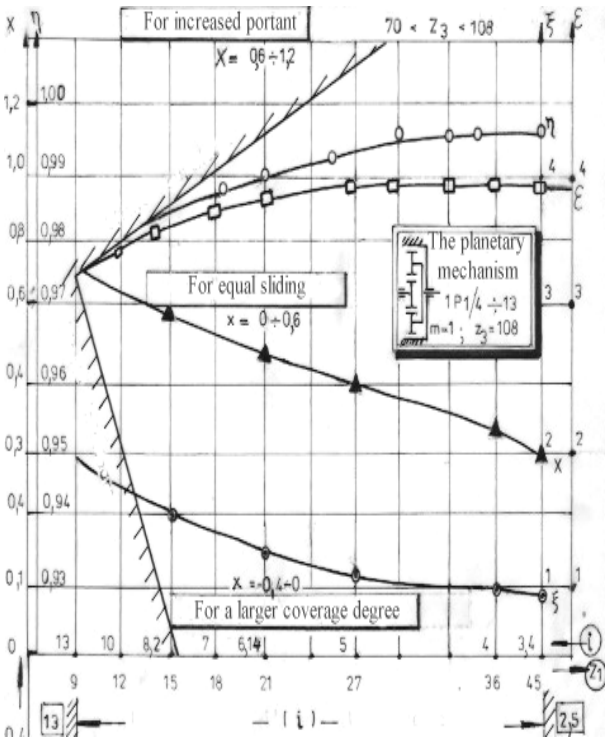

Fig. 5. Correlation between the efficiency and the non-dimensional parameters

In figure 5: z is number of teethes; ξ - degree of coverage; x - specific shift; η - mechanic efficiency; i - transmission rations.

By determining the correlation between the variation of the mechanic efficiency and the variation of the non-dimensional parameters, the energetic efficiency is high lightened.

The requirement of the correlation is that the dynamic of the mechanic efficiency out pass the one of the non-dimensional parameters.

4. SUMMARY AND CONCLUSIONS

From this paper, it results that between the mechanic efficiency and the non-dimensional parameters of the planetary gearings there are important correlation.

The efficiency can be important by special measures, such as:

- the shorting of the tooth height;
- the change of the profile shifts;
- the adjustment of a gearing angle bigger than 20^0 ;
- the choice of bearings of a large dynamic capacity and a small inner diameter;
- the use of dented wheels with the largest number of teeth.

The final solution must be checked to maintain this planetary gearing within the generation and gearing limits, to ensure the appropriate functional and manufacturing possibilities.

The methodology of mechanic dynamic modelling and that of virtual modelling which was approached led to the measure convergence to the theoretical ones which prove its efficiency and its correct choice.

In the future the researches can continue for the development of new applications on other types of mechanical transmission using this method and different modular control laboratory.

ACKNOWLEDGEMENT

The authors thank the company SC Angred SA for the help they provided by giving access to the trial stands of planetary reductions gears and by observing the researched parameters of the products in the series fabrication. The author has valued their own experience and the research was influenced by the production conditions at the firm where they worked producer of planetary reduction gears.

REFERENCES

[1]. Banica, M., 2006. *Optimizarea dinamicii angrenajelor.* Editura Risoprint, ISBN.978-973-751.385-4, Cluj-Napoca.

[2]. Bostan, I., Dulgheru,V., 1987. **,** *Transmisii planetare precesionale si armonice*, Editura Tehnicã. Bucuresti, Chişinău, ISBN.973-31-1082-5.

[3]. Cotetiu. R., 2002. *Organe de maşini,* vol. II. Cluj - Napoca, Editura Risoprint,. ISBN 973–656–290-5.

[4]. Ferguson, R J., 1983. *Short cuts for analyzing planetary gearing*. În: Machine design..Nr. 26, pp. 69 - 73.

[5]. Gillinch, G. R., 2003. *Dinamica masinilor. Modelarea sistemelor tehnice.* Editura AGIR.

[6]. Jula, A., Velicu, D., Dudita, F. s.a.., 1989. *Proiectarea angrenajelor evolventice,* Editura "Scrisul Românesc", Craiova.

[7]. Mohora, C., Cotet, E., Patrascu, G., 2001. *Simularea sistemelor de productie*. Editura Academiei Romane.

[8]. Montgomery, D.C., 1996. *Design of Analysis of Experiments,* 4th Edition, John Wiley & Sons, New–York.

[9]. Nasui, V., 2006. *Optimizarea randamentului actuatorilor electromecanici,* Edit Risoprint, ISBN.973.751.374-8, Cluj Napoca

[10]. Nãsui, V. , 2000. *Mecanism roata - cremaliera cu role*. Brevet de Inventie RO 122 226. Cl. F16 H 25/22.

[11]. Nicoara, I., 2000. *Incercarea angrenajelor* Editura Orizonturi Universitare Timisoara. ISBN-8109-25-6

[12]. Pay, E., Nãsui, V., Páy, G., 1995. *Contributions to the determination of Power Transmission Efficiency for Planetary Reducers*. In Publication of the University of Miskolc, Series C-Mechanical Engineering, vol.45, pp. 47-57.

[13]. Popa, A., 2002. *Controlul digital al sistemelor mecatronice*. Editura Orizonturi Universitare Timisoara

[14]. Rostic, B., 1994. *Multicriteria Optimization of Planetary Gear Train, London,* In: International Gearing Conference, Mechanical Engineering Publications, pp. 95-99

[15]. Vijdeluc, M., Nãsui, V., 2002. *Transmisii planetare*, Editura Risoprint, ISBN. 973.656.287-5, Cluj – Napoca.