THE ANNALS OF „DUNĂREA DE JOS" OF GALAŢI
FASCICLE V, TECHOLOGIES IN MACHINE BUILDING, ISSN 1221-4566
2002

New Consideration Regarding The Grinding Of The Polyeccentrical Surfaces

Eugen GHIŢĂ, Daniel GHIŢĂ
University "Dunărea de Jos" of Galaţi

Abstract: *R. Musyl, professor at the Technical University from Graz, defined the curves and the polyeccentrical surfaces in 1940. These surfaces are ordinary called "polygonal" and today they are standardized in Germany, and probably in other country. The authors consider that the naming is confused and wrong, proposing the naming: surfaces or polyeccentrical curves, having as a base a series of original consideration relative to this.*

The polyeccentrical curves are the gevolvents of some hypocycloids extreme stellated and regulated

The grinding of these surfaces is the most important technological problem. Today the machines of grinding are built only having as a base the licensed principle of professor R. Musyl. This principle is relative simple. But brings to a construction extremely complex and expensive. In this paper there are presented the theoretical considerations that may bring to a great simplification of the principle of building machines for grinding these surfaces. The application of this principle could determine the simplification of these machine tools. This way the using of these surfaces could extend easier in more applications in the machine building.

Key words: *grinding, machine tools, polyeccentrical surfaces.*

1. Introduction

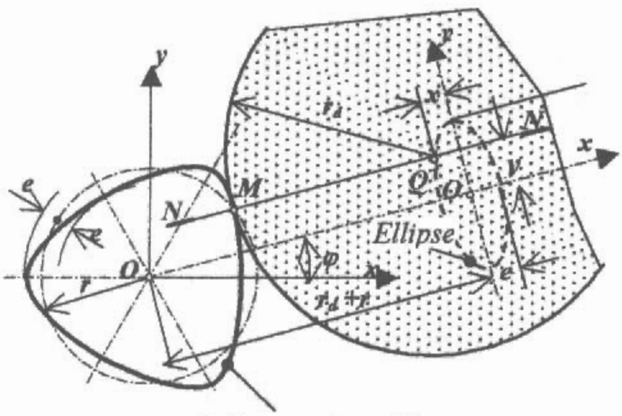
The polyeccentrical surfaces are ordinary known as *polygonal surfaces*, something we consider wrongly and confuse. It is wrong because the notion of polygon defines a shape with more angles that is not true in our case. Then, the polygonal surfaces are already known and used in the machine building, they being composed from more plane, equidistant surfaces. That's why when it is used the notion polygonal surfaces appear the relative confusion of the surfaces it refers. Even more, there are some other polygonal surfaces, those *K*, sinoidales, connected, etc. Consequently, in our works is proposed the generic name of polyforme surfaces for all these surfaces with a periodical profile and some other different naming, all of them with the prefix poly- for each distinct category.

The polyeccentrical surfaces are standardised in *Germany* concordant with *DIN 32711* (those ones with section having tree periods, called type ***P3 G***) and *DIN 32712* (those with four periods, called type ***P4 G***). These standards are recognised and took over also in other countries, in *USA*, too.

At the moment, the processing of the polyeccentrical surfaces is based almost exclusively on the grinding machines as Polygon, realised in series by Fortuna firm from Stuttgart Germany. In these machines are grinding the exterior and interior polyeccentrical surfaces or are outlined the tools as brooches to processing of the boring at this type.

The construction of grinding machine Fortuna – Polygon has as a base the principle of construction patented in 1940 by the professor R. Musyl from the Technical University from Graz, Austria. The construction of the machine is based on a mechanism that determines an elliptical movement of the centre of the grinding wheel, correlated with a uniform movement of rotation of the grinding piece, *fig. 1*. The report of the dimensions of the semi axes of the ellipse and the report between the revolution of the movement on the ellipse and the revolution of the piece, it is proved that it has to be equal with the number n of periods of the polyeccentrical surfaces.

Although in principle the engendering mechanism of the elliptical trajectory is simple, actually we observe it requires a complex construction, having very much mechanical components, complicated, hard to be done. That's why these grinding machines are very expensive. That's why we can appreciate that probably the costs imposed by acquisition represent the most important obstacle regarding the extension of using these surfaces.



Polyeccentric profil

Fig. 1. The scheme of grinding the exterior polyeccentrical surfaces

2. Relative Consideration Regarding The Grinding Of The Polyeccentrical Surfaces

A study on this problem in [1] determined the obtaining of the following consideration:

- The polyeccentrical surfaces are used, mostly, for the assembling as shaft – hub;
- The surfaces with $n = 1$ degenerate in eccentrics, for these existing other proceedings, too, easier to be applied than using these specialised machines – tool;
- The surfaces with $n = 2$ are not functional because they auto – block;
- The interior polyeccentrical surfaces are hardly grinding, with a lot of labour, resulting extremely expensive. That's why the applying of the grinding of the operation at the series production can't be justified. That's why their finishing is realised by stitching. So if there is a technology for the grinding of the exterior polyeccentrical surfaces then, it is solved even the technology of the interior surfaces. And this, because it is possible the execution of the tools of type broach.

From what we exposed by now we can conclude that the studies in this domain may be restricted only around the problem of grinding the exterior polyeccentrical surfaces with $n = 3$ and $n = 4$.

3. Researches Regarding the Making up of New Type of Machine to Grinding Polyeccentrical Surfaces

In the remembered conditions there may be created technological equipments simpler, so cheaper. Only this way the polyeccentrical surfaces could rival with the classical assembling with keyway or longitudinal groove.

Resulted that it deserves to make up researches in order to create new technological equipments of grinding the polyforme surfaces. Because we have only the problem of grinding the exterior surfaces, we also can remark that the modification of the dimension of the grinding wheel is done slower and in more reduced limits.

We started from the hypothesis that the movement of the centre of the grinding wheel on an elliptical trajectory may be easily spoiled, approximate realised.

Such a mechanism that realises a good approximation of the quasi – elliptical trajectory was found. This mechanism realises for $n = 3$, the trajectory having the following parametrical equation:

$$x_1 = -e.\cos 3\psi,$$
$$y_1 = 2a + 3e.\sin 3\psi - 2\sqrt{a^2 - e^2.\cos^2 3\psi} \qquad (1)$$

Where:

- a is a constructive parameter of the mechanism and ψ is the angular variable, respectively it is the angle of rotation of the machining piece;

The parametrical equation of a point M from the polyeccentrical profile having $n = 3$ (*fig. 2*) are:

$$x_M = r.\cos\varphi + e.\cos 4\varphi - 2e.\cos 2\varphi,$$
$$y_M = r.\sin\varphi + e.\sin 4\varphi + 2e.\sin 2\varphi. \qquad (2)$$

Where:

r is the medial ray of the profile and φ angular variable, respectively it is the angle of rotation of the machining piece.

The equation of the normal $N - N$ at the polyeccentrical profile in the point M will have the equation:

$$y - y_M = (x - x_M).\tan\varphi$$

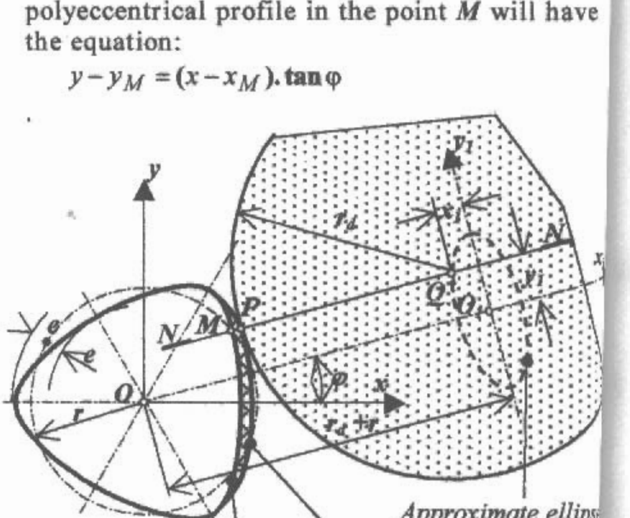


Fig. 2. The scheme of grinding the exterior polyeccentrical surfaces with the approximate method

For $\varphi = \psi$ we obtain a point Q on the quasi - elliptical curve that will have, towards the reference system xOy, the following coordinates:

$$x_Q = (r + r_d + x_1).\cos\varphi - y_1.\sin\varphi$$
$$y_Q = (r + r_d + x_1).\sin\varphi + y_1.\cos\varphi \quad (3)$$

Where: r_d is the ray of the grinding wheel.

The equation of the normal $N - N$, implicitly, is written as:

$$x.\sin\varphi - y.\cos\varphi + x_M.\sin\varphi - y_M.\cos\varphi = 0$$

So, the expression of the distance $d(\varphi)$ from the point Q at the normal will, have the form:

$$d(\psi) = x_Q.\sin\varphi - y_Q.\cos\varphi + x_M.\sin\varphi - y_M.\cos\varphi$$

The intersection with the approximate ellipsis is solved conditioning that the point Q to be on the normal, so it has to be solved the equation $d(\psi) = 0$.

In the *table 1* there are presented the maximal values $(D_l)_{max}$ calculated with a programme of solving the equation $d(\psi) = 0$.

We way remark that the errors depend of the size of the diameter of the grinding wheel and they are even less when the diameter is bigger. But, much more important, we may observe that the maximal errors resulted after the using of the approximate method of grinding are totally negligible, because all of them are as a size under the level of the microns. So, it results the engendering mechanism is totally acceptable, practically being as precise as the theoretical one.

This conclusion justifies the recommendation that this mechanism to be used for the making up of some special machines to grinding polyeccentrical surfaces. Because constructively it is extremely simple, it may stay at the base of the creation even of some new technological equipment, as accessories, with what to be equipped the universal grinding machines.

Even more, this mechanism proves it satisfies some other exactingness. It is analysed the way it may be realised and the grinding of the interrupted profiles with *3* and *4* periods, *fig. 3*. For the study of the errors there were still used the relations deducted anterior, but for a variation of the angle φ limited between the values $-\varphi_0$ and $+\varphi_1$ that determined in [1] as having the expression:

$$\varphi_0 = \frac{\arccos \dfrac{r - \sqrt{n^2(e^2n^2 + r^2 - e^2) + (\frac{D_a}{2})^2(1 - n^2)}}{e(1 - n^2)}}{n}$$

Table 1.

The size of the approximations resulted at the grinding with a new engendering mechanism

a = 120 [mm]							
r [mm]	*15*	*20*	*27,5*	*34*	*37,5*	*45*	*50*
e [mm]	*1,00*	*1,35*	*2,00*	*2,60*	*3,00*	*3,90*	*4,50*
r_d=100 $(D_l)_{max}$ [mm]	$4,17.10^{-7}$	$1,19.10^{-6}$	$5,60.10^{-6}$	$1,60.10^{-5}$	$2,80.10^{-5}$	$8,0.10^{-5}$	$1,47.10^{-4}$
r_d=250 $(D_l)_{max}$ [mm]	$1,78.10^{-7}$	$1,79.10^{-7}$	$2,86.10^{-6}$	$6,25.10^{-6}$	$1,10.10^{-5}$	$3,20.10^{-5}$	$5,60.10^{-5}$

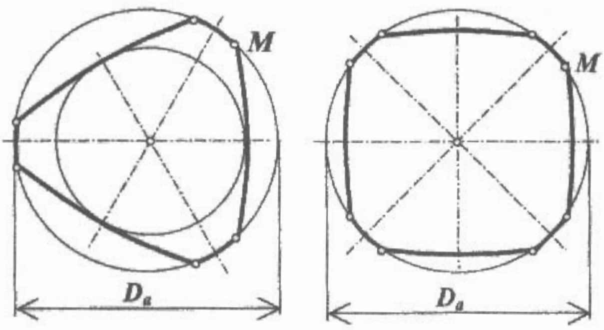


Fig. 3. Polyeccentrical interrupted profiles with **3** and **4** periods

We should remark that the engendering mechanism is used without any constructive modification even in the case $n = 4$. With other words, the approximate ellipse still rests with a report, between the great semi axis and the little one, equal with three.

Obviously that only the report between the revolution of the piece and of the eccentrically has to be modified so as the number of the periods resulted on the piece, to be equal with four.

That's why, for $n = 4$, the anterior relations modify, as it follows:

$$x_1 = -e \cdot \cos 4\psi$$
$$y_1 = 3a + 4e \cdot \sin 4\psi - 3\sqrt{a^2 - e^2 \cdot \cos^2 4\psi} \quad (5)$$

$$x_M = r \cdot \cos\varphi + \frac{3}{2} e \cdot \cos 5\varphi - \frac{5}{2} e \cdot \cos 3\varphi$$
$$y_M = r \cdot \sin\varphi + \frac{3}{2} e \cdot \sin 5\varphi + \frac{5}{2} e \cdot \sin 3\varphi \quad , \quad (6)$$

Using the same method of analyse anteriority presented, there were calculated the values of the errors of engendering for some cases from usual. The results of this analyse use presented in the *table 2*.

Table 2

The errors resulted at the rectification of the profiles with **3** and **4** periods

a = 120 [mm]									
n	*3*	*3*	*3*	*3*	*4*	*4*	*4*	*4*	*4*
r [mm]	*11*	*11,5*	*20*	*23*	*11,5*	*15,5*	*20*	*23,5*	*43*
e [mm]	*2*	*4*	*4*	*5*	*3*	*5*	*5*	*6*	*8*
D_a [mm]	*22*	*25*	*38*	*42*	*20*	*25*	*35*	*40*	*80*
r_d=100 $(D_i)_{max}$ [mm]	$5{,}60 \cdot 10^{-6}$	$8{,}80 \cdot 10^{-5}$	$8{,}89 \cdot 10^{-5}$	$2{,}17 \cdot 10^{-4}$	$6{,}33 \cdot 10^{-5}$	$4{,}48 \cdot 10^{-4}$	$4{,}88 \cdot 10^{-4}$	$1{,}01 \cdot 10^{-3}$	$3{,}20 \cdot 10^{-3}$

The values of the error from the *table 2* are greater than those ones from the *table 1*. But, also, their size is very reduced, being so negligible and acceptable. This conclusion is especially favourable because it brings to a simplification of the construction of the engendering mechanism and also to the adjustment activities.

Because of this satisfying result, the analysis extended also to the possibility of using this mechanism and in the case of the grinding of the interior polyeccentrical surfaces.

Applying the same considerations, the analysis will restrict only at the case $n = 3$.

For the adoption of the case from the grinding wheel r_d will be used the restriction:

$$(r_d)_{max} = 0{,}8 \cdot e \cdot (n^2 - 1), \quad (6)$$

The results presented in the *table 3*.

Table 3

The size of the approximations resulted at the grinding of the interior polyeccentrical surfaces

a = 120 [mm]							
r [mm]	*15*	*20*	*27,5*	*34*	*37,5*	*45*	*50*
e [mm]	*1,00*	*1,35*	*2,00*	*2,60*	*3,00*	*3,90*	*4,5*
$(D_i)_{max}$ [mm]	$6{,}61 \cdot 10^{-6}$	$1{,}67 \cdot 10^{-5}$	$6{,}44 \cdot 10^{-4}$	$1{,}60 \cdot 10^{-4}$	$2{,}77 \cdot 10^{-4}$	$7{,}76 \cdot 10^{-4}$	$1{,}35 \cdot 10^{-3}$

We may observe that, although the engendering errors are even bigger than in the case of grinding the exterior of the polyeccentrical surfaces, although, their size is negligible because it is under the level *1–2* μm.

4. Conclusions

The analysed mechanism, in restricted conditions corresponding to the polyeccentrical profiles with $n = 3$ and $n = 4$ periods, practically, it may satisfy all the exigencies asked to a mechanism for the finishing by grinding.

This mechanism may build the base of conception of mew technological equipments destined to the grinding of the polyeccentrical surfaces.

At this moment for this, there was initiated a programme of researching in accordance with the conception of some technological equipments adaptable on the universal machines in order to grinding roundly the exterior and the interior. In *fig. 6* is presented a general view on the sub ensemble of the engendering mechanism to such technological equipment, [1]. For grinding it is used a grinding wheel, initially having the diameter of *250* mm in diameter.

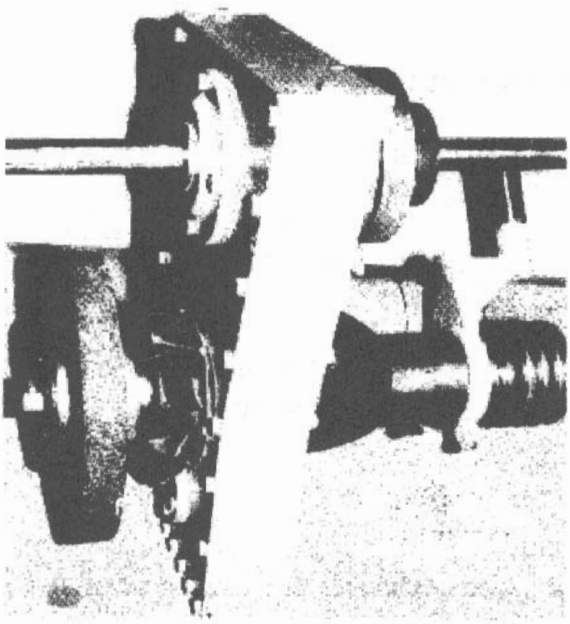


Fig. 6. *The image of the sub ensemble engendering mechanism of an experimental equipment for the grinding of the exterior polyeccentrical surfaces, adaptable on an universal machine of grinding roundly.*

5. References

[1] **Eugen GHIŢĂ**, *Contribuţii la studiul prelucrabilităţii prin aşchiere a suprafeţelor poliforme*, Ph. D. teses, University „Dunărea de Jos" of Galaţi, 1990;

[2] **Eugen GHIŢĂ**, *Teoria şi tehnologia suprafeţelor poliforme*, Editura BREN, ISBN 973-8141-07-1, Bucureşti, 2001;

[3] **Eugen GHIŢĂ, Emil ŢÂRU**, *An Approach to the Polyeccentric Surface Gearing*, The Annals „Dunărea de Jos", University of Galaţi, Fascicle V, Year XII (XVII) 1994, pp. 21-31, ISSN 1221-4566;

[4] **Eugen GHIŢĂ, Alexandru EPUREANU**, Victor POPA, *Sur la possibilité de l'approximation des profiles cycloïdal*, The Annals „Dunărea de Jos", University „Dunărea de Jos" of Galaţi, Fascicle V, Year II (VII) 1984, pp. 15-20, ISSN 1221-4566.

Noi consideraţii asupra rectificării suprafeţelor poliexcentrice

Profesorul Robert MUSYL de la Universitatea Tehnică din Graz, Austria, a definit curbele, denumite în lucrările autorului prezentei lucrări, curbe poliexcentrice. Suprafeţele care ca secţiune aceste curbe sunt standardizate în Germania cu denumirea de suprafeţe poligonale, Această denumire considerăm că este greşită şi conduce la confuzii. De aceea în lucrările autorului prezentei lucrări s-a propus pentru acestea denumirea suprafeţe poliexcentrice. În lucrare se precizează că aceste curbe sunt gevolventele unor hipocicloide extrem stelate. Rectificarea acestor suprafeţe prezintă o importantă problemă tehnologică. Până în prezent se cunoaşte doar un singur principiu de concepţie a unor maşini destinate rectificării acestor suprafeţe. În lucrare sunt prezentate consideraţiile teoretice care conduc la simplificarea principiului de rectificare a acestor suprafeţe care ar putea conduce la realizarea unor asemenea maşini de rectificat mai simple şi deci şi mai ieftine.

Nouvelle considération concernant le meulage des surfaces de polyeccentrical

Résume. R. Musyl, professeur à l'université technique de Graz, a défini les courbes et les surfaces polyeccentrical en 1940. Ces surfaces sont polygonales appelé ordinaire? et aujourd'hui elles sont normalisées en Allemagne, et probablement dans l'autre pays. Les auteurs considèrent que l'appellation est confuse et erronée, proposant l'appellation: surfaces ou courbes polyeccentrical, ayant comme base par série de considération originale relativement à ceci. Les courbes polyeccentrical sont les gevolvents de quelques hypocycloïdes que l'extrémité stellated et a réglé le meulage de ces surfaces est le problème technologique le plus important. Aujourd'hui les machines du meulage sont construites seulement ayant comme base le principe autorisé de professeur R. Musyl. Ce principe est simple relatif. Mais apporte à une construction extrêmement complexe et chère. En cet article on présente les considérations théoriques qui peuvent apporter à une grande simplification du principe des machines de bâtiment pour rectifier ces surfaces. L'application de ce principe a pu déterminer la simplification de ces machines-outils. De cette façon employer de ces surfaces a pu sortir plus facile dans plus d'applications dans le bâtiment de machine.