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# CALCULATION OF THE CONTACT SURFACE IN THE ORBITAL DEFORMATION OF THE CYLINDRICAL WORKPIECE

**Sorin Dumitru GROZAV, Vasile Adrian CECLAN, Gabriel Nicodim CIUSCA**

***Abstract:*** *In this paper has focus on the geometric characteristic of the contact contour between the upper die and the cylindrical workpiece. The correlation curves of the rate of the contact area (λ) and the angle subtended by the contact arc (αAB) with respect to the spiral feed (Sθ), rocking angle (θ), and the radius of the workpiece (R) have been drawn. Has been discussed the effect of the relative spiral feed (SR) on the configuration of the contact contour and the magnitudes of λ and αAB. Finally, has been presented the minimum relative spiral feed necessary for full-deformation.*

***Key words:*** *orbital deformation, contact, contour*

## 1. INTRODUCTION

Orbital deforming it is an unconventional forming technology of metals, having as a particular the fact that applying in a convenient way the forming pressure; it is obtained a considerable reduction of forming pressure for the same forming straight. The principle of orbital deforming was patented in 1910, but his extension began in the last 25 – 30 year, after the apparition of the machines able to realization of this operations. This method is based on the principle that the pressure is not applied on the whole surface of the work piece, and it is applied only a 20 – 30 of it. This it is show in the figure 1.

The pressure application zone is variable in time, because the pressure is moving on the surface of the work piece with a constant frequency of 150 – 200 cycles/min. The most important traits of this method, having as result a sequential penetration of the pressure in every parts of the work piece surface are: the wobbling motion of the tool together with the superior tool reported to the vertical axes, and the four moves of that.

The determination of the tools track which is the most suitable for the work piece is important for metal flow in the tool. A similar influence has and the choice of the wobbling limit angle has the same influence as forming pressure.

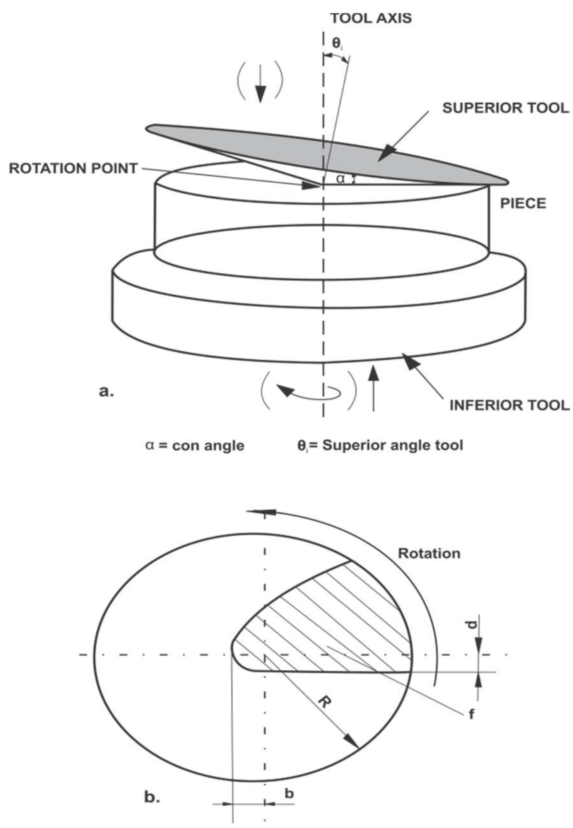



Figure 1. Orbital deformation of a cylindrical workpiece [4],[7]

If the deformation of the conventional, inter-acting with the tool on its entire front surface of preform, when deformation orbital focus of deformation is located at any stage of the process (the shaded area in figure 1 b).

The initial preform, having usually formed of a cylinder or ring, is seated in lower die which is vertically oriented axis of symmetry. The upper die having the conical shape of the roller is inclined from the vertical by an angle $\theta$.

The upper die must be so positioned that the apex of the cone to be located always on the axis of symmetry of the lower die, which is the central axis of rotation.

Changing the shape of the preform is carried out by oscillating the upper die around the central axis of rotation and the vertical movement of advance, either the upper die to the lower die, or vice versa. In any case, the tip of the cone, which is always fixed, becomes the pivot point of the upper die. Kinematic point of view it is a rigid fixed.

Special characteristics of this method, having resulted in a gradual penetration of the surface pressure in every place the processed material are:

- the oscillation of the die-holder with the upper die with respect to the vertical axis;
- four or more different movements thereof. In this way the kinematic conditions become more complex.

Thus, at any given time a portion of the volume part is in the focus of deformation. Due to the oscillating movement of the upper mould and the advance due to axial deformation zone is dynamic. It moves the propeller downward sweep the front surface of the workpiece and approaching nearer to base the preform. Penetration depth of deformation on the preform height depends specifically track configuration and the actual amount of process specific parameters.

## 2. CALCULATION OF THE RELATIVE SPIRAL FEED

### 2.1 Experimental research

In order to be able to operate with maximum efficiency the facilities offered by this new and wider technology, it is necessary to study the flow of the material and the distribution of deformations in the volume of the orbital deformed blank, necessary for the design of a correct orbital deformation technology. [1], [2], [7], [8] For the study of the unevenness of the deformations at the orbital deformation we worked with lead cylindrical specimens with different ratios between height (H) and diameter (D): H / D = 0.2 ..... 2. We have drawn on the lateral surface a network of equidistant lines parallel to the base of the specimens, and on the front surface they have drawn equidistant concentric circles. For the modification of the parameters of the networks after the orbital deformation we could characterize the distribution of the deformations and the flow of the material. The experiments were performed on a Polish orbital PXW100 deforming machine, which can develop a 1600 KN axial force (Fa) with an oscillating angle of the upper tool of $\gamma$ = 20 at a oscillation frequency of 200 oscillations / min. This press carries out four types of movements [1],[2],[4].

### 2.2 Experimental results

When a cylindrical workpiece is upset during orbital deformation, the equation of the conical surface of the upper die in coordinate system x’y’z’ is

$$x'2+y'2-z'2\ ctg2\theta = 0 \quad (z'\geq 0) \qquad (1)$$

where $\theta$ is the rocking angle of the upper die (Fig. 1). Rotating anticlockwise the coordinate system by an angle $\theta$, the conical surface becomes

$$y2-2xzctg\theta+z2(1-ctg2\theta)=0 \qquad (2)$$

In addition to rocking of the upper die there is an axial feed of the workpiece. Therefore, the workpiece is upset to form a spiral surface. It is assumed that the speed of revolution of the upper die is n (rpm), the feed velocity of the workpiece will be v (mm/s).

Let the horizontal generatrix of the upper die be the x-axis and the vertex be the origin of coordinates. The spiral surface of workpiece can be expressed as:

$$z = (1- \Phi T/2x\ ) S\theta \qquad (4)$$

$$x = r \cos\Phi T \qquad (5)$$

$$y = r \sin\Phi T \qquad (6)$$

where $\Phi T$, r, R are polar angle, polar radius and the radius of the worpiece respectively.

Substituting equations (4),(5) and (6) into equation (2), we have:

$$\sin2\Phi Tr2 - 2\cos \Phi Tctg\theta(1 - \Phi T/2x\ ) S\theta r +$$

$(1–ctg2\theta)(1–\Phi T/2\theta)2S\theta$ (7)

This is the polar equation of the contact contour between the upper die and the workpiece during orbital deformation. Let :

$A = \sin 2\Phi T$

$B = 2 \cos\Phi T ctg\theta\ (1- \Phi T/2x\ )\ S\theta r$ (8)

$C = (1 – ctg2\theta)(1-\Phi T/2x)2S\theta$

$R = (B + B2 – 4AC)/2A$ (9)

If Sθ, θ and R are given, by means of a computer, we can draw the contact contour during orbital deformation. (Fig. 2)

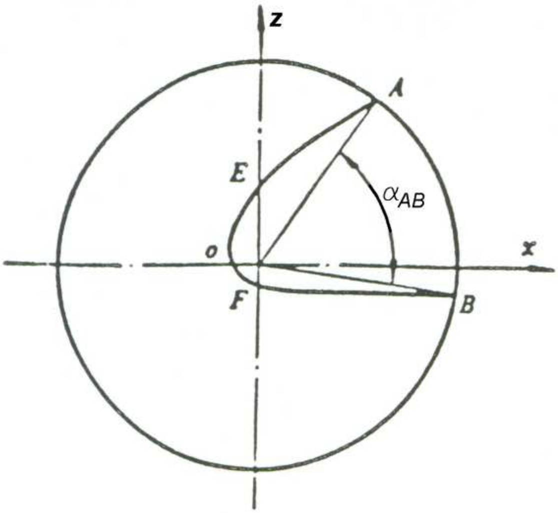
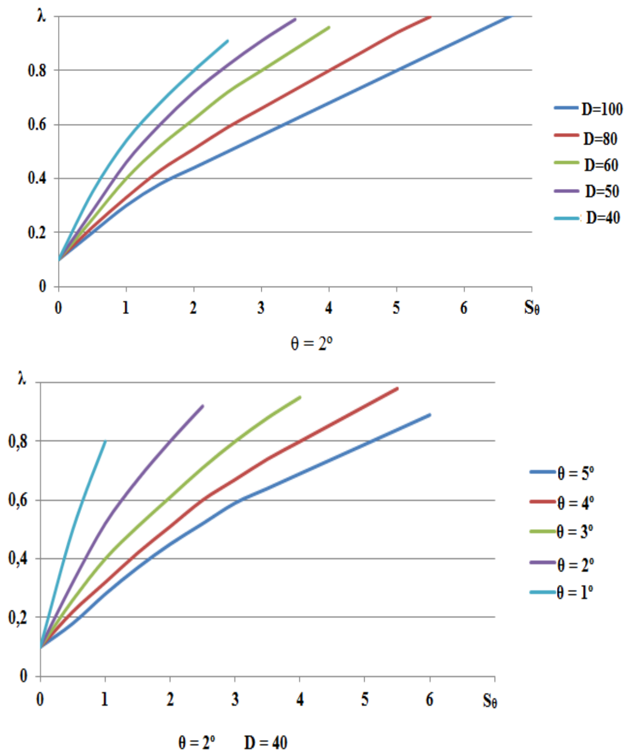



Figure 2. Contact contour during orbital deformation [4], [7]



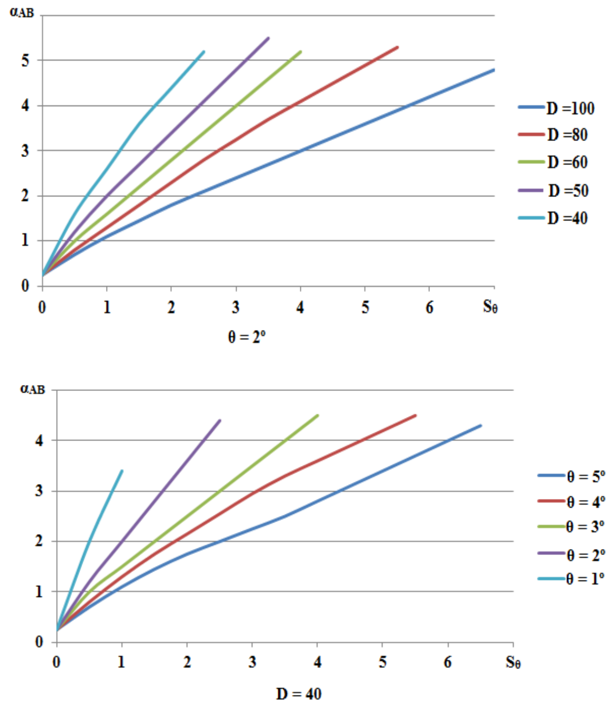




Figure 3. The correlation curves of λ , $\alpha_{AB}$ with respect to $S_\theta$, θ, and R for θ = 2° and D = 40 mm [4], [6], [7]

At point C between A and B, shall have:

TC = x, YC = 0, ZC = Sθ/2

Substituting these values into equation (2) then we obtain

$X_C = ¬- S_\theta / 2ctg\ 2\theta$ (10)

As a mater of convenience, calculation can be started from the point C, and incremented by 0,5°.

Let T = x→0, up to point A, where the corresponding $r_A = R$.

Then let T = x→ 2x, calculation is performed up to point B, where rB = R.

The angle AB subtended by the arc αAB can be obtained simultaneously

$\alpha_{AB} = TA + 2x - TB$ (11)

The contact area involved in ACBA can be written as

$$A_R = \frac{1}{2}\cdot\int_{r_A}^{r_B} r^2 dT + \frac{1}{2}\alpha_{AB}\cdot R^2 \qquad (12)$$

The rate of the contact area ( λ ) is defined as

λ = AR / xR2 (13)

The correlation curves of λ , αAB with respect to $S_\theta$ , θ, and R are given in figure 3.

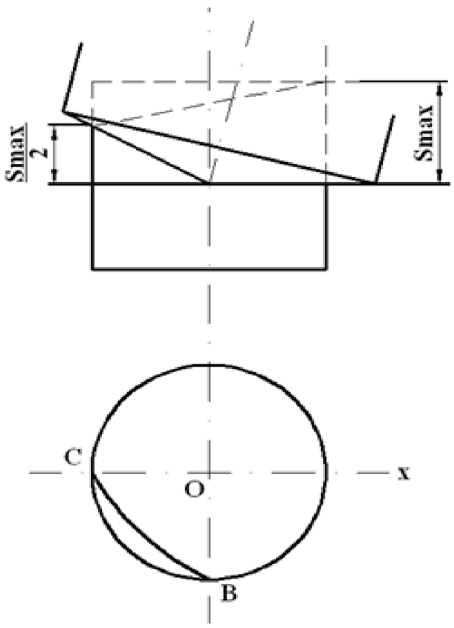


Figure 4. Rate of contact

It is clear from figure 4, when xC = -R, the rate of contact area has approximated to 100%. We can then define the spiral feed under this condition as the critical Smax.

The workpiece has been deformed entirely instead of deformed partially and the specific characteristic of orbital deformation will be lost. In this condition, from figure 5 we can obtain

$$S_{max} = 2R \, tg \, 2\theta \quad (14)$$

The relativ spiral feed is defined as

$$S_R = S\theta / S_{max} = S\theta / 2R \, tg \, 2\theta \quad (15)$$

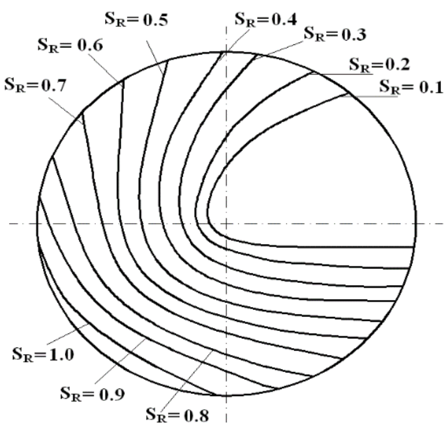


Figure 5. The contact contour [1], [4], [6]

The figure of the contact contour with different values of the relative spiral feed is shown by figure 5.

Substituting equation (15) into equation (10), we obtain

$$X_C = - S_R R \quad (16)$$

From figure 2, it is obvious that, in the point E, $X_E = 0$, $Y_E = \pi / 2$, $Z_E = ¾ \, S\theta$. Substituting these values into equation (2) we have :

$$Y_E = 3 \cdot S_R \cdot R\sqrt{1 - tg^2\theta} \approx 3S_R R \quad (17)$$

Similarly,

$$Y_F = -3 \cdot S_R \cdot R\sqrt{1 - tg^2\theta} \approx -3S_R R \quad (18)$$

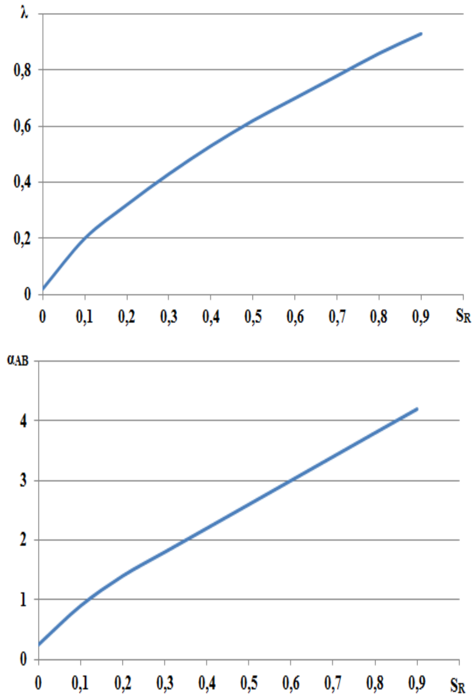


Figure 6. Correlation of λ and σAB with respect to the relativ spiral feed SR [1], [4], [5],[6]

Figure 6 show the correlation of λ and σ AB with respect to the relative spiral feed SR respectively. For the convenience of application, we can express the relation SR=f(λ) and SR=f(σAB) with the analytical formulas by using the least square method. The process of calculating shows that, if we use the unique formulas, the calculated error of λ and σAB will be too large when SR ≤ 0,1.

## 3. CONCLUSION

So, it is appropriate to approximate the λ and σAB with two formulas respectively.

When $S_R \geq 0,1$

$$\lambda = 0,98 \, S_R^{0,64} \quad (R= 0,9997) \quad (19)$$

When $S_R < 0,1$

$$\lambda = 0,76 \, S_R^{0,536} \quad (R= 0,9996) \quad (20)$$

When $S_R > 0,1$

$$\sigma_{AB} = 3,98 \, S_R + 0,624 \quad (R = 0,9991) \quad (21)$$

When SR ≤ 0,1

$$\sigma AB = 3,42\ SR0,546 \quad (R = 0,9998) \quad (22)$$

Where R is coefficient of correlation.

When upsetting a cylindrical workpiece during orbital deformation, it is important to ensure that the length of the arc σAB to be longer than the height of the workpiece H for the benefit of full deformation. It is assumed that the ratio of the height to the diameter of the workpiece η = H/2R.

When SR > 0,1

$$\sigma AB\ R =( 3,98\ SR + 0,624)R \geq M$$

$$SR \geq 0,503\eta\text{-}0,15 \quad (23)$$

For the same reason given above,

$$\text{When } SR \leq 0,1; SR \geq 0,375\ \eta 1,83 \quad (24)$$

Equation (23) and (24) must be satisfied when the technological are satisfied.

## 4. REFERENCES


1. Grozav, S., *Studies and research on specific process parameter variation of plastic deformation thourgh cold orbital deformation*, PhD Thesis, Technical University of Cluj-Napoca, 1995
2. *Modern Polish Metalworking machines*¸Mettalurgia and Metal Forming, January, 1987.
3. Grozav, S., Achimaş, Gh., Morar, L. *Methods for the reduction of rivetting energy consumption by orbital forming*, Conf. Int. INTERPARTNER'93, Harkov, pp. 11-13 (1993).
4. Oudin, J., Ravalard, Y., Verwaerde, D., Gelin, J.C. *Force, Torque and Plastic Flow Analysis in Rotary Upseting of Ring Shaped Billets*, Int. Journal of Mechanical Science, Vol. 27, 79,No. 11/12. pp. 761-780.
5. Oudin, J., Gelin, J.C., Ravalard, Y. *Le Forgeage aves Matrice Oscillante. Applications et Developpements*, Revue Francaise de Mecanique, No. 4, 1984, pp. 201-219.
6. Sorin-Dumitru Grozav, Gheorghe Achimas, Lucian Lazarescu, Gheorghe Gligor., *The Analyse of Technological Parameters in Orbital Deformation on Contact Contour and the Relative Spiral during Orbital Deformation*, microCAD 2006, International Scientific Conference, 16-17 March 2006, pp. 73-79 section K, ISBN 963 661 711 2, si in International Journal of Plasticity, vol. 22, p. 428-438 (2006).
7. Grozav, S., *Orbital deformation*, Editura MEDIAMIRA, 2009, ISBN 978-973-713-244-4, 265 pag. (2009).
8. Sorin-Dumitru GROZAV, Gheorghe ONEŢIU, Mircea BEJAN, Mihaela SUCIU, Ovidiu-Vasile OPREA, *A model to obtain the relative spiral feed during cold orbital deformation*, Revista METALURGIA INTERNATIONAL vol XVI (2011), no. 1, ISSN 1582-2214, pag. 38- 44
9. Sinha, K.P., Prasad, S.C. *Analysis of Metal Flow During Rotary Forging*, Int. Conf. on Prod. Eng., 27th CIRP General Assembly, New Delhi, India 1977.
10. Sorin-Dumitru, Grozav; Vasile, Ceclan. "*INDUSTRIAL AUTOMATION IN THE RELATIVE SPIRAL FEED AND CONTACT CONTOUR DURING COLD ORBITAL DEFORMATION*" Supplements of the " Quality-Access to Success " Journal, Vol. 13,S5, Noiembrie 2012, ISSN 1582-2559, Pag 367-370
11. Sagá, M.; Sapietová, A.; Vaško, M.; Dekýš, V.; Kuric, I.; Čuboňová, N.: *Chosen applications of computer modelling in mechanical engineering*. Pearson UK, 2015, ISBN 978-I-78447-830-8, s. 230
12. Kosinar, M. ; Kuric, I.: *Monitoring possibilities of CNC machine tools accuracy*. In 1st International Conference on Quality and Innovation in Engineering and Management (QIEM), p.115-118, 2011, Cluj Napoca, ISBN:978-973-662-614-2
13. Jozwik, J.; Kuric, I. ; Sága, M. ; Lonkwic, P.: *Diagnostics of CNC machine tools in manufacturing process with laser interferometer technology*. Manufacturing Technology, Volume 14, Issue 1, 2014, p.23-30, ISSN: 12132489

14. Kuric, I. ; Košinár, M. ; Tofil, A.: *Software post-processing of data structure obtained from measuring device Ballbar QC20*. Academic Journal of Manufacturing Engineering, Volume 11, Issue 4, 2013, p.92-97, ISSN: 15837904
15. Alexandru Popan, Nicolae Balc, Alexandru Carean, Alina Luca, Alin Miron : *Research on Abrasive Water Jet Milling of the Planar Surfaces, Slots and Profiles*, Applied Mechanics and Materials, 2015/6/18, pp. 409-414
16. A.Popan, N.Balc, B.Luca, A.Popan, A. Carean: *The Accuracy of the Plastic Parts Milling Process Executed by a Six Axes Robot*, Applied Mechanics and Materials, Vol 8081/2015, Editor Trans Tech Publications, pp. 339-344.
17. Alina LUCA, Nicolae BALC, Alexandru POPAN, Vasile Ceclan, Nicolae PANC, *Improving the quality of the parts made by rapid metal casting process* Academic Journal of Manufacturing Engineering, Volume 12, Issue 3, 2014, ISSN: 15837904

**Calcularea suprafeţei de contact în deformarea orbitală a piesei cilindrice**

**Rezumat**: În această lucrare se prezintă caracteristica geometrică a suprafeţei de contact dintre matrița superioară și piesa de prelucrat cilindrică. Curbele de corelare a vitezei zonei de contact (λ) și a unghiului susținut de arcul de contact (αAB) cu privire la alimentarea în spirală (Sθ), unghiul de rotire (θ) și raza piesei de lucru (R) au fost calculate. S-a prezentat efectul alimentării spirale relative (SR) asupra configurației suprafetei de contact și a magnitudinilor lui λ și (αAB). În cele din urmă, a fost prezentată alimentarea minimă spirală relativă necesară pentru deformarea completă.

**Sorin Dumitru GROZAV,** Department of Manufacturing Engineering, Technical University of Cluj-Napoca, 103-105 Muncii Blvd., 400641 Cluj-Napoca, Romania, sorin.grozav@tcm.utcluj.ro
**Vasile Adrian CECLAN,** Department of Manufacturing Engineering, Technical University of Cluj-Napoca, 103-105 Muncii Blvd., 400641 Cluj-Napoca, Romania vasile.ceclan@tcm.utcluj.ro.
**Gabriel Nicodim CIUSCA,** Department of Manufacturing Engineering, Technical University of Cluj-Napoca, 103-105 Muncii Blvd., 400641 Cluj-Napoca, Romania.