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NUMERICAL SIMULATION OF THE INCREMENTAL FORMING PROCESS FOR KNEE IMPLANTS

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Summary: *The paper presents a comparison study based on the simulation by the finite element method (using the Ls-Dyna software) on three different incremental sheet metal forming process alternatives for medical implants used for the partial resurfacing of the femoral condylar surface of the knee. The paper also studies the influence of the material thickness and the punch diameters about the stress and strain distribution, the thinning of the material, the force variation and the springback of the material.*

1 INTRODUCTION

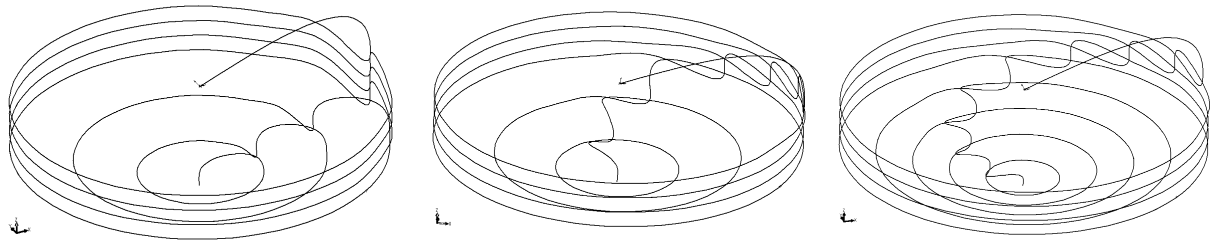
The patellofemoral resurfacing system combines intra-operative, condylar surface, off-the-shelf and contoured articular inlay components. Of these undoubtedly the most important is the condylar surface. This component is obtained in this moment from titanium alloys or Co-Cr-Mo alloys obtained by casting and then coating the undersurface of Cp-Ti as a better quality of condylar surface. There are several different types of surfaces such as the geometrical shape and dimensions that characterize a (depending on the nature and size of lesion) (Figure 1). In this paper, authors propose to examine by a numerical simulation of the newest ways to get the condylar surface and therefore to obtain the component of the titanium sheet (Ti-6Al-4V) by forming, incremental forming exactly.

(a) (b) (c)
Figure 1: Different surfaces which could be obtained by incremental forming process
(a) arthicular surface, (b) radial head, (c) finger falange base

The incremental sheet metal forming represents a complex metal forming process, at which, as compared to classical stretch forming process, the kinematics comprises beneath a movement on vertical direction also a movement in the blank's plane[1, 2]. A major advantage of this method is that the ability to program the punch trajectory can obtain different forms specific to each type of injury without the need for complicated tools[3]. We refer below only to the incremental deformation of the joint surface (Figure 1, a).

2 THE NUMERICAL SIMULATIONS

To tackle the non-linear analysis, a parameterized model, used in the analysis through the finite elements method, has been built, described through the Ls-Dyna software. The forming system that is being used as base for the numerical simulations consists of a die, blankholder and hemispherical punch. A thin sheet circular blank (D = 60 mm), placed on an active die with circular working zone is considered. There are not imposed boundary conditions, on the nodes placed on the circumference because the blankholder eliminate this necessity. Three different trajectories were been choose in order to cover the entire condylar surface. The three different trajectories followed by the punch for the numerical simulation of the incremental forming process are presented in figure 2.

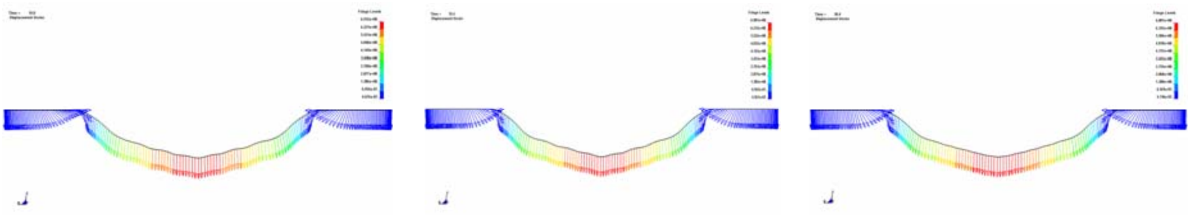


(a) (b) (c)

Figure 2: The three different trajectories followed by the punch

In all three alternatives the punch is placed asymmetrically and, in the first stage, has a perpendicular movement on the sheet level. In the second stage the punch follows a circular trajectory around the die borders. In the third stage the punch follows also a circular trajectory but the distance between the die borders and the punch and the penetration depth of the punch increase after each step in order to build the dome. For the first case (Figure2, a) the punch performs four steps on vertical direction to achieve the basic shape, and three steps for achieve the dome of punch, advancing on the vertical direction after a complete circle. (360^0). In the second case (Figure2, b) punch the difference is in that style no longer rank in the vertical direction after (360^0) but after (380^0) thus achieving 20^0 index after each circle completely. Third case (Figure 2, c) is similar to the second case, the difference consisting in that the punch goes through five steps instead of three for achieve the dome.

The material associated with the part's elements corresponds to a titanium alloy sheet Ti-6Al-4V. For modeling this material the Ls-Dyna material model 36 (Barlat's 3-parameter plasticity) was chosen because it can accommodate in-plane an isotropic yield behavior. We considered elasticity modulus is E = 118 GPa, Poisson's coefficient is ν = 0.34, density ρ = 4,428 g/cm3 while the flow stress is σ_Y = 365 MPa, strength coefficient K = 438 MPa and hardening coefficient n = 0.45. A value of the friction coefficient of 0.075 was used. Following the performance numerical analysis it was found that if the first type of trajectory (Figure 2, a) because the punch motion run vertical penetration appear irregularity in that area. So if the first type of trajectory as in the case of the second type of trajectory (Figure 2, b) is observed and a radial marks because of the number of radial steps was small (3). This radial mark is blurred in the case of the third type of trajectory (Figure 2, c). These observations can be identified in Figure 3 where the nodal displacements are shown on the vertical direction corresponding to the three types of trajectory above mentioned.



(a) (b) (c)

Figure 3: The nodal displacement on Oz direction for the three different trajectories followed by the punch

Based on the above mentioned, we chose to vary the material thickness and punch diameter for the third type of trajectory (Figure2, c). Two different values of the hemispherical punch diameter (d = 4 and 6 mm) and two different initial thicknesses of blank (t = 1 and 1.2 mm) are taken into consideration. The geometric data that were kept constant, were the diameter of the blank, the die radius and the clearance between punch and die edge. Four separate different analyses were performed. The numerical results of the simulations were centred on the determination the equivalent Von Mises stress, the thinning of the sheet (Figure 4), the principal strain (Figure 5), the springback (Figure 6), the forces on the processes (Figure 7) and the manner in which these are influenced by the geometrical parameters that were varied.

The numerical results for the analyzed parameters are presented in Table 1. Figures 4 … 7 shown the results obtain from the case no. 2 (t = 1 mm, d = 6 mm).

Case no.	Input data		Output data						
	t	d	Equivalent stress	Principal strain	Thinning	Springback	F_x max	F_y max	F_z max
	[mm]	[mm]	[MPa]	[mm/mm]	[%]	[µm]	[N]	[N]	[N]
1.	1	4	315.68	0.29	28,72	2.13	377,1	356,6	1066
2.	1	6	276.92	0.22	23.62	2.99	337,5	324,4	1053
3.	1.2	4	305.2	0.26	27.56	2.23	457	435,1	1337
4.	1.2	6	272.3	0.18	23.13	3.14	398,2	382	1316

Table 1: Numerical results for all the four analyzed cases

3 CONCLUSIONS

The main conclusions can be drawn following numerical simulations presented in this paper are primarily related to how is the distribution of the characteristic data. It is noticed that the maximum value for stress and strains principal or equivalent and also for thinning to appear across the punch trajectory on the circle circumference with the bigger diameter.

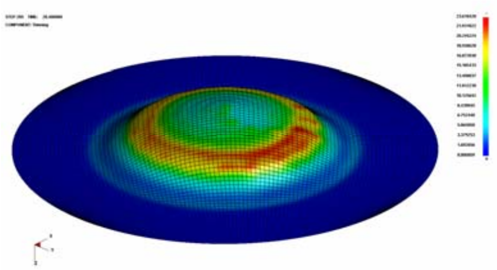


Figure 4 The thinning variation for case no. 2

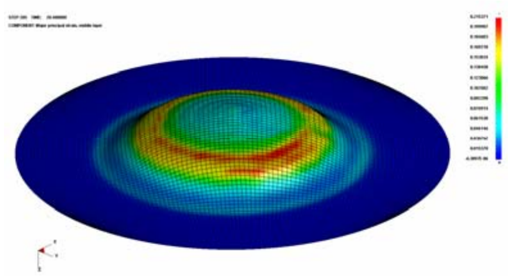


Figure 5 The principal strain variation for case no. 2

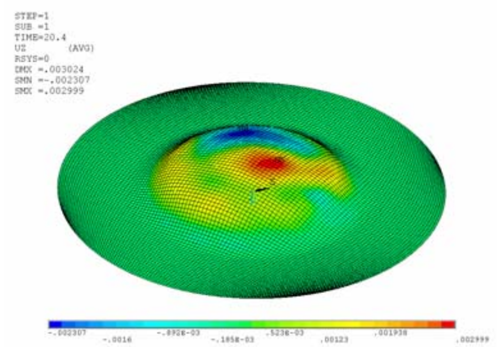


Figure 6 The springback variation for case no. 2

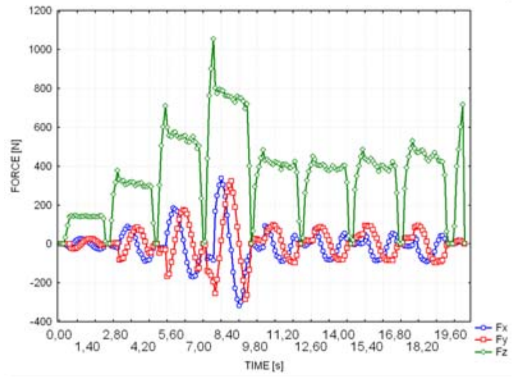


Figure 7 The force on x, y and z direction for case no. 2

Other conclusion is that the number of steps on the vertical and radial direction is much greater increases part accuracy obtained. For the same reasons it is recommended indexing position to punch ingress. The maximum principal strain, equivalent stress and thinning significantly increases with decreasing diameter punch and are less influenced by the thickness of the material. Springback increases with the increasing of the punch diameter and the forces in the process increase with increasing material thickness and slow decreasing of the punch diameter.

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