OPTIMAL DESIGN OF PREFORM GEOMETRY AND TRIBOLOGICAL CONDITIONS IN CAN FORMING

Tomaž Rodič[a], Domen Cukjati[b] and Igor Grešovnik[b]

[a]Faculty of Natural Sciences and Engineering, University of Ljubljana,
Aškerčeva 12, 1000 Ljubljana, Slovenia
e-mail: tomaz.rodic@uni-lj.si web page: http://www.uni-lj.si

[b]C3M d.o.o., Centre for Computational Continuum Mechanics,
Vandotova 55, 1000 Ljubljana, Slovenia
e-mail: domen.cukjati@c3m.si web page: http://www.c3m.si
e-mail: igor.gresovnik@c3m.si web page: http://www.c3m.si

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Abstract. *This article is concerned with mechanical shaping of food cans. One of the problems related to this technology is that edges of cans are in general not flat after forming, which causes severe problems for seaming. The forming process must therefore be carefully optimised to achieve desired shapes. In this work three technological options to overcome the problem are investigated numerically. The options are: optimisation of preform design, optimisation tribological conditions between can body and individual segments of the tooling system as well as kinematics of the tooling segments. Numerical analyses show that preform design offers the highest optimisation potential. For preform shape optimisation a very efficient algorithm has been developed which enables effective minimisation of objective function.*

1. INTRODUCTION

Market demands in packaging industry force can manufacturers to produce beverage and food containers in variety of attractive shapes. This places a considerable pressure on shaping technologies to enable economical large-scale production. One of the problems associated with complex 3D shaping is that edges of cans after forming are not flat which causes severe problems for seaming. This can be observed in Figure 1 where a cylindrical preform with initial height of *100 mm* has been deformed to a 3D shape. The resulting difference between the highest and lowest point on the edge is about *3mm* which is not acceptable for seaming. Thus, straightforward application of shaping technology is not applicable and the process must be carefully optimised with respect to preform shape, tribological conditions and kinematics of the tooling system in order to enable successful production.

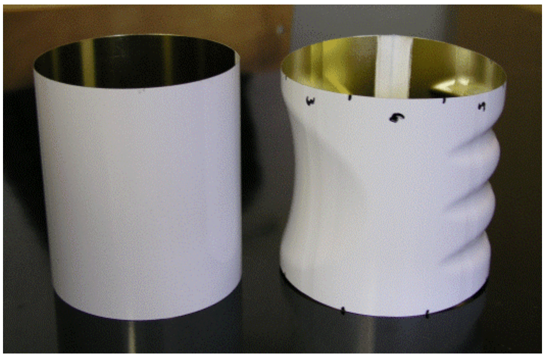

Figure 1: Can body before and after forming.

2. OPTIMISATION ENVIRONMENT

In order to reduce expensive industrial trials numerical optimisation procedures have been set up. For numerical simulations of the can forming process the finite element system *ELFEN*[1] has been applied by considering large strain and deformation theory, elasto-plastic constitutive relations for steel sheet, Coulomb's frictional model between rigid tool segments and deformable can body and implicit time integration scheme.

The simulation system was connected with the optimisation shell "*Inverse*"[2-4], which controls execution of numerical analyses in parametric studies and automatic optimisation. Its open architecture centred around an interpreter enables connection with different auxiliary and simulation programmes and sufficient flexibility at definition and solution of complex problems. Beside the solution of practical problems, the shell serves as supporting environment for development and testing optimisation methodologies.

The shell has been applied as a versatile tool for optimisation of different technological parameters including preform shape, tribological conditions and kinematics of tool segments.

3. PROBLEM DESCRIPTION

The mechanical shaping of the can body is achieved by segmented tooling system as shown in Figure 2. Individual tool segments 1-4 move in the radial direction. During the forming process the edge A-B of the can body is deformed. The aim of our study is to investigate how different technological parameters influence deformation of the edge and in particular how to minimise the difference between the lowest and highest point on the edge after forming. Because of the symmetry, only one quarter of the geometry has been considered in our computations.

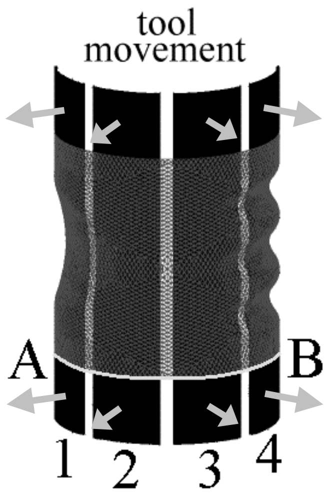

Figure 2: Mechanical shaping of can body

4. PREFORM DESIGN

One way of achieving the desired shape of the can after forming is to optimise the preform shape. An efficient algorithm has been set up for iterative updating of preforms. These were evaluated as a function of deformed configuration computed in the last available iterate.

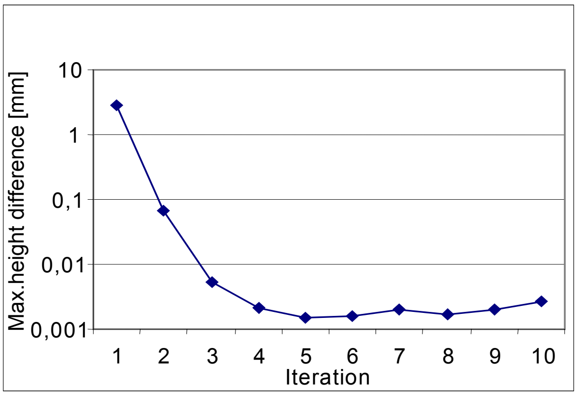

Figure 3: Minimisation of the difference between the highest and lowest point on the edge A-B

As shown in Figure 3 the convergence of optimisation algorithm was very good. In just five iterations the difference between the highest and lowest point on the edge A-B was reduced from initial 2,8 mm to 0,0015 mm. An acceptable shape of the can after the fifth iteration is shown in Figure 4. Further reductions of objective function were not possible in this case due to numerical noise associated with the applied finite element discretization.

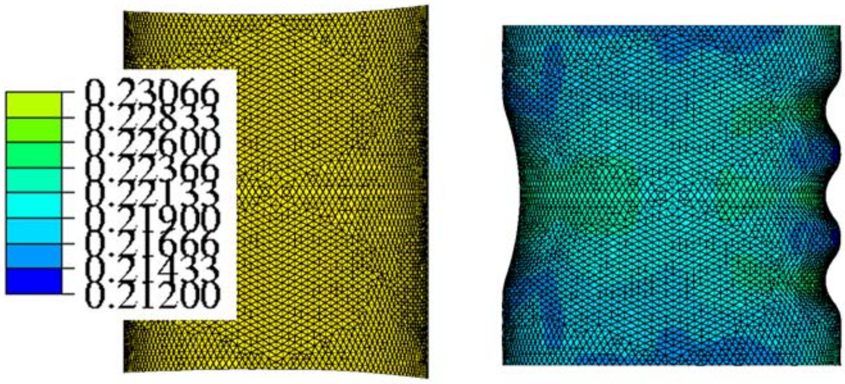

Figure 4: Optimal shapes of the can body before and after forming. The contour plot indicates thickness distribution

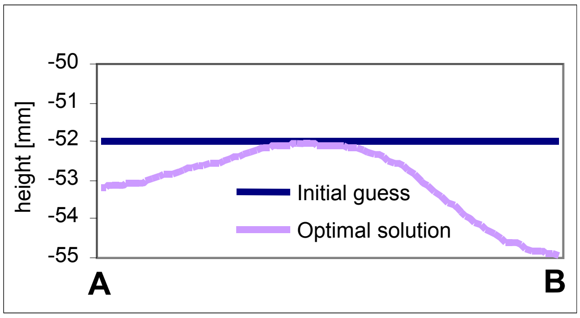

Figure 5: Height of the preform along the bottom edge A-B

Industrial implementation of shaped preforms as shown in Figures 4 and 5 is associated with extra production costs related to more expensive preparation of preforms and equipment for their positioning. Therefore an alternative means for influencing can height distribution by varying tribological conditions and kinematics of individual tool segments has been investigated.

5. VARIATION OF TRIBOLOGICAL CONDITIONS

In this section the influence of friction between the can body and tool segments is considered. For each individual tool segment the friction coefficient has been varied in the range between 0,05 and 0,3. As shown in Figure 6 and Table 1 maximal difference of height could be reduced in this way by approximately 40%. Thus, the desired shape of the can after forming cannot be achieved by adjusting only the tribological conditions. Furthermore, it would be very demanding to maintain optimal friction for adjacent tool segments in large-scale production.

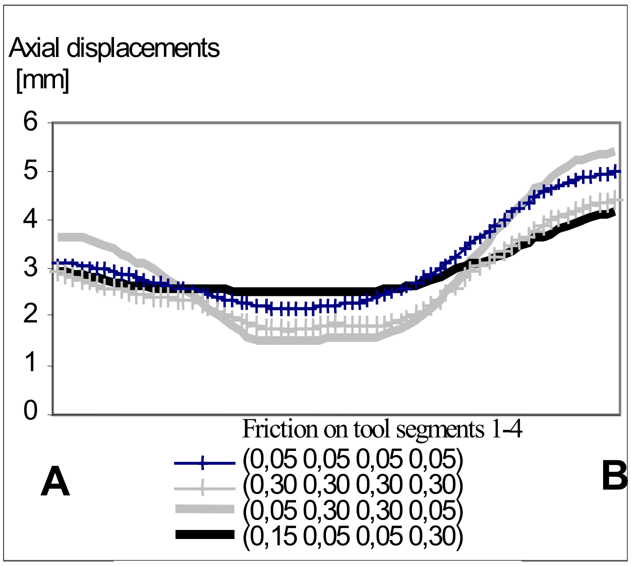

Figure 6: Displacements in axial direction along the edge for different friction coefficients applied to interfaces between can body and individual tool segments.

Friction				Max. height difference
tool 1	tool 2	tool 3	tool 4	[mm]
0,05	0,05	0,05	0,05	2,7808
0,1	0,1	0,1	0,1	2,87007
0,15	0,15	0,15	0,15	2,89808
0,2	0,2	0,2	0,2	2,87159
0,25	0,25	0,25	0,25	2,7895
0,3	0,3	0,3	0,3	2,67111
0,05	0,3	0,3	0,05	3,92064
0,15	**0,05**	**0,05**	**0,3**	**1,65441**

Table 1: Maximal difference between the highest and the lowest point on the edge A-B after forming at different sets of friction coefficient.

6. KINEMATICS OF TOOL SEGMENTS

In order to investigate whether movement of individual tool segments has a significant effect on edge height a number of parametric studies has been performed. It has been found out that movement of tool segment 1 can have a significant effect when prescribed in different manner as movements of tool segments 2-4. This is shown in Figure 7. It turns out that the maximal difference of height along the bottom edge of the can be reduced in this way by approximately 30%.

7. COMBINED KINEMATICS&TRIBOLOGICAL EFFECTS

By combining kinematics and tribological effects the maximal difference in height can be reduced from 2,78 mm to 0,96 mm, i.e. reduction by 65% can be achieved. This is shown in Figure 8.

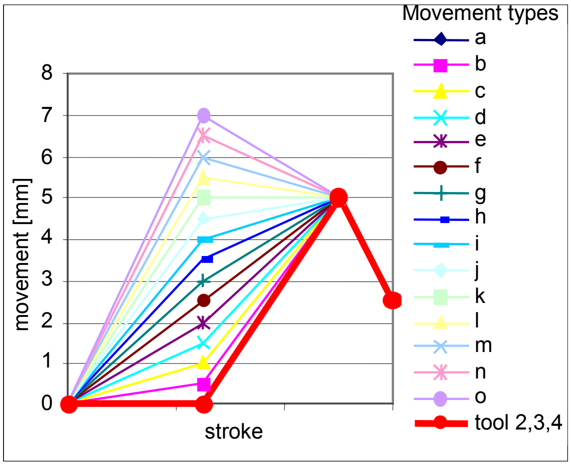

Figure 7: Kinematics of individual tool segments where equal movements are prescribed for segments 2-4 while movement of segment 1 is varied.

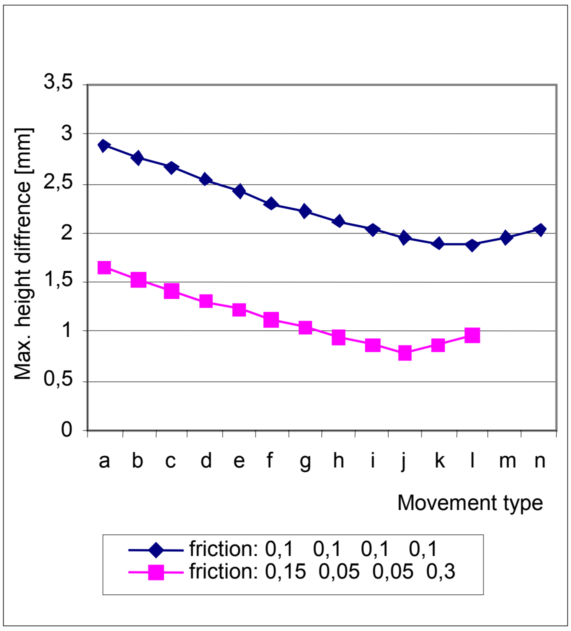

Figure 8: Flatness of bottom edge for different types tool movement with constant and variable friction conditions for individual tool segments.

8. CONCLUSION

The problem of non-uniform height of cans after shape forming has been addressed. The computations have revealed optimisation potentials for different technological options. These include optimal preform design as well as combined effects of kinematics and tribological conditions at the interface between can body and individual tool segments.

The computational system consists of finite element code and optimisation shell, which can be applied to different technological aspects. The system will be further improved and tested on complex industrial problems. A set of tools that will allow parameterisation of complex shapes is currently under development[5,6]. Other related research areas include advanced material models, efficient computation of sensitivities[7] with respect to various design parameters, robust and efficient optimisation algorithms and appropriate optimisation problems.

9. ACKNOWLEDGEMENT

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