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STRUCTURE ANALYSIS OF MOULD PARTS MADE OF MATERIALS FOR SOFT MOULDS

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Abstract: *The paper deals with structure analysis of mould parts made of materials for so called soft moulds. Soft mould is mould intended for small-lot and piece production. The gap in division plane causes increasing of loading space resulted in product without required dimensions (accuracy). The designing stage of mould is important to find final deformation of mould parts from applied load. The paper analyzes the three chosen materials suitable for soft moulds.*

Key words: *mould, gap, division plane, accuracy, material, deformation.*

1. INTRODUCTION

The aim of soft moulds is usage for small-lot and piece production. It provides different approach for their designing regarding to manufacturing of mould itself. The classic material for moulds is tool steel regarding its properties as strength, wear resistance resulting in dimensional stability. [3] But in case of soft moulds repeatability of production is not so important. The soft mould is designed for several pieces of moulding. The disadvantage of tool steel is its machinability and usage of more quality tools. [4] It causes the higher expenses for production of mould.

The aim of our research is to find the material with good machinability and low expenses for production of mould provided the accurate presswork and not at least the flexibility of production of different moulds. The flexibility can be improved by unit construction mould, modified tools, system of geometry generation and its control.

2. MODEL DESCRIPTION

Structural analysis was made for mould geometry and its dimensions for three different materials of mould. The aim of structure analysis was to find the gap in plane of division for different materials and pressure forces, displacements and stresses.

2.1. Model and boundary conditions

Model consists of lower part of mould with loading space and upper part. The inner pressure in loading space is p = 150 MPa ×1.2 = 180 MPa where constant 1.2 is coefficient of safety. It is the maximum value of pressure used in computation. The plane of division is modelled as contact plane with coefficient of friction 0.02. The pressure force is modelled as force distributed on surface. The important is fact that the pressure in contact plane of piston and upper mould part is not distributed uniform but parabolic. Its maximum value is in the middle of plane. Regarding mentioned fact the piston is involved to model. The piston is joined with upper mould part and they form the one unit. The uniform distribution of pressure force is applied to upper piston plane. The model is described in Fig. 1.

2.2. Pressure force

The minimum pressure force can be computed from static equations where force from inner pressure has to be in equilibrium with pressure force.

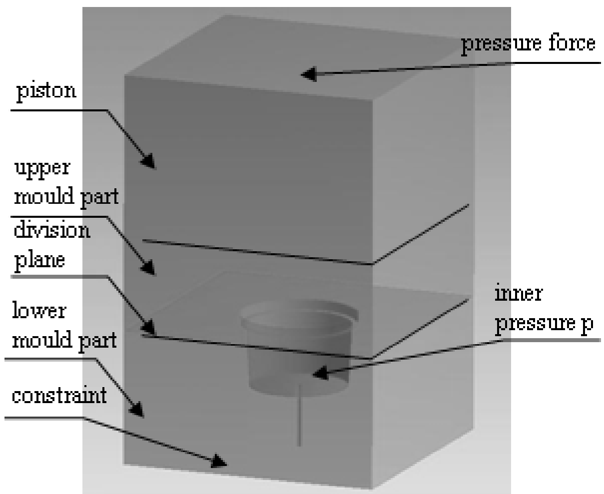

Fig. 1. Model and boundary conditions.

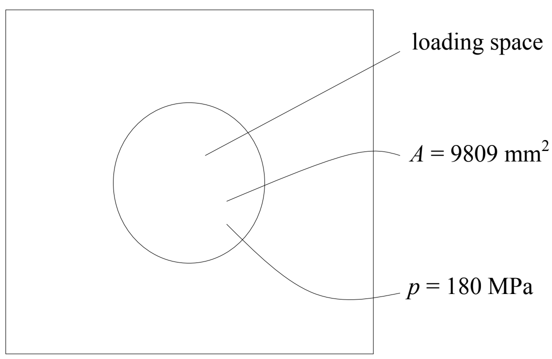

Fig. 2. Loading space plan projection.

$F = pA$ = 180 MPa × 9809 mm^2 = 1 765 620 N = 177 tone, where F is pressure force, p is inner pressure and A is area of loading space plan projection.

The value of loading space plan projection is obtained from Pro/Engineer. By reason of minimize the gap in division plane, the larger pressure force is applied. The computations are made for pressure force 2 MN (200 tone), 2.2 MN (220 tone) and 2.5 MN (250 tone).

2.3. Materials applied to mould model

The materials and their material properties are listed in table 1. The tool steel is present material and another two kinds are suggested materials.

Böhler M200 is Cr-Mn-Mo alloyed steel. The machinability of Böhler M200 is excellent.

Alumec is high strength alloy with excellent machinability for high speed cutting, shorter cutting time and lower costs for machining. Its low density allows easy manipulating with mould. The high heat conductivity of Alumec enables the shorter technological process.

MoldmaxHH is high strength beryllium bronze with good machinability and excellent heat conductivity that is 3-5 times higher as that of ordinary tool steel. It allows effective heat flow from loading space. The problem of moulding deformation due to heat accumulation is cancelled. It shorts the technological process even in case of combination with tool steel.

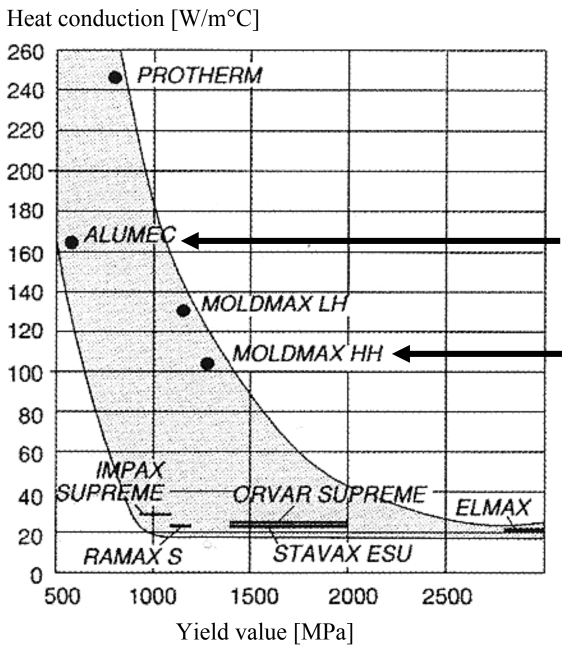

Fig. 3. Materials of mould.

Table 1

Properties of materials

Material	Modulus of elasticity [10^5 MPa]	Poisson's ratio	Yield value [MPa]
Böhler M200 (tool steel)	2.1	0.3	650
Alumec (aluminium alloy)	0.72	0.33	485
MoldmaxHH (beryllium bronze)	1.03	0.34	970

2.4. FEM Model

The mould was analyzed by classical Finite Element Method. The analysis was static. 10-noded quadratic elements were used for discreditation of mould model (Fig. 4). The accuracy of solution was satisfied for 36 554 nodes and 109 662 degrees of freedom.

The model is divided into two parts – the upper part of the form (Fig. 4) to which the piston is merged and the lower part of the form (Fig. 5) into which the upper part fits. The parts are initially configured with very small gap between them in the division plane, because the meshing algorithm would else join the nodes on the contact surfaces and treat the model as one piece. Thus the gap was necessary to avoid inconsistent contact conditions.

Contact between the parts of the mould form was modelled as a frictional surface contact using penalty method. [2] Stabilisation of the stiffness matrix was also incorporated for the former steps for the condition of the model with the gap or else the displacements could be very large. As soon as the contact occurs the method is stable and the forces acting on the form result in equilibrium. For better convergence of the solution the applied pressure force was ramped and was increasing in small steps. This improves among other thing the swiftness of the solution so the time required to reach equilibrium in each step is shorter and the solution is more stable.

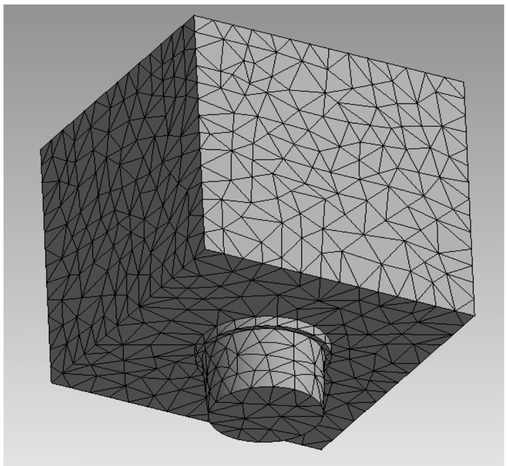

Fig. 4. Model mesh of upper part.

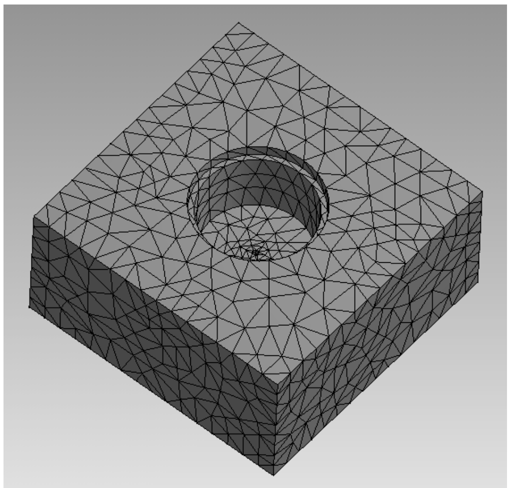

Fig. 5. Model mesh of lower part.

3. RESULTS

Figure 6 depicted the three places of evaluation of displacements: gap in division plane, the place of maximum displacement on the bottom and side of loading space.

From Figs. 7–9 the difference in deformation (displacement) of loading space is visible. The deformation is zoomed 100 times. The arrows point to maximum deformation.

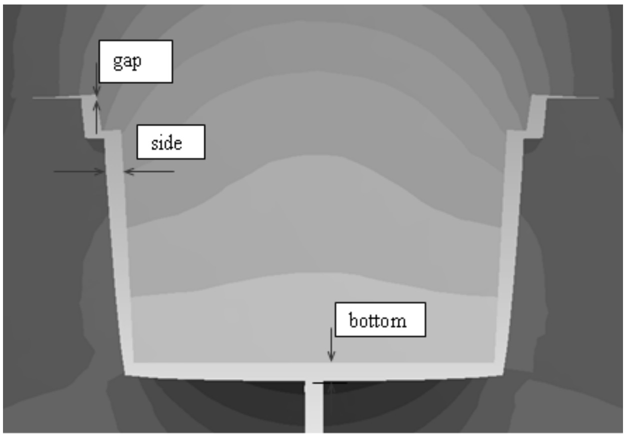

Fig. 6. Places of evaluation of displacements (zoom 50-times).

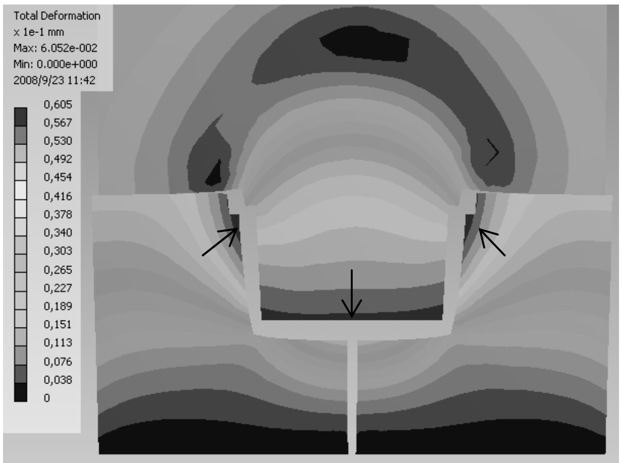

Fig. 7. Total deformation – Böhler M200, $F = 200$ t.

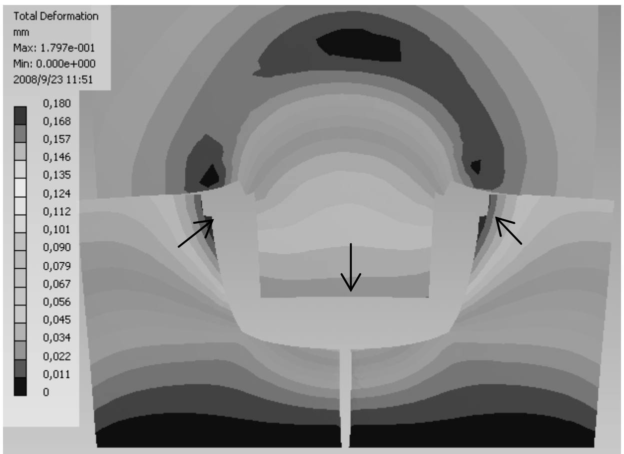

Fig. 8. Total deformation – Alumec, $F = 200$ t.

Fig. 10 describes the distribution of von Mises stress in lower mould part. The arrows point to maximum von Mises stress.

Presented results are for static analysis and for dynamic injection the results can be a bit different.

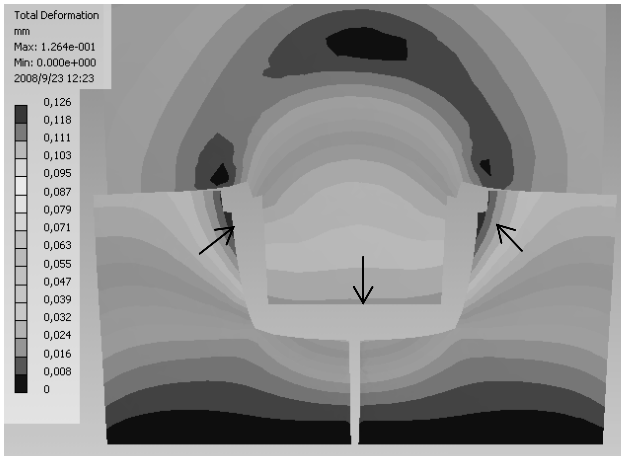

Fig. 9. Total deformation – MoldmaxHH, $F = 200$ t.

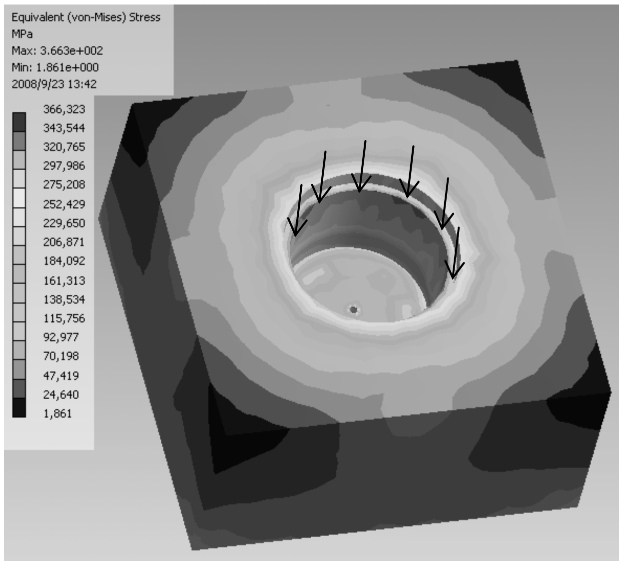

Fig. 10. Stress von Mises – Böhler M200, $F = 250$ t.

Table 2

Comparison of displacement for different materials and pressure forces

Material	Pressure force [tone]	Gap [mm]	Side [mm]	Bottom [mm]	Max Mises Stress [MPa]
Böhler M200	200	0.02061	+0.07494	+0.09401	366.9
	220	0.01756	+0.07565	+0.09007	366.7
	250	0.01388	+0.07711	+0.08482	366.3
Alumec	200	0.05815	+0.21414	+0.25864	365.7
	220	0.04963	+0.21743	+0.24744	365.4
	250	0.03911	+0.22105	+0.23229	365.0
Moldmax HH	200	0.04019	+0.14921	+0.17714	365.4
	220	0.03419	+0.15142	+0.16935	365.1
	250	0.02692	+0.15414	+0.15889	364.7

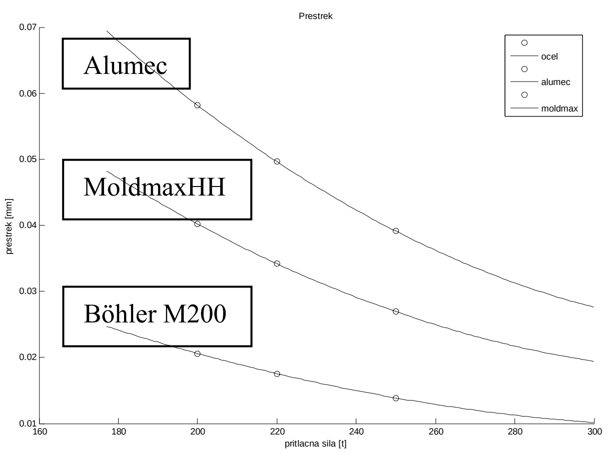

Fig. 11. Influence of pressure force on gap in division plane.

Figure 11 presents relation between pressure force and gap in division plane whereas the inner pressure *p* is constant. Naturally, Alumec has the largest gap in division plane. If we want to keep 0.02 mm gap for Alumec, the inner pressure *p* have to be lower as 180 MPa.

4. DISCUSSION AND CONCLUSIONS

The strength of all materials is suitable for moulds. The maximum stress in mould is not changing by larger pressure force. The stress in mould depends on injection pressure that is for maximum value of 180 MPa under the yield value of mentioned materials. We have to realize that the force on interface of piston and upper mould part is not distributed uniformly and its maximum value is in the middle. So the maximum wear will appear in this area. The criterion of wear is not important in our case as the soft form is intended only for several pieces of mouldings. The main criterions are accuracy of moulding and machinability of mould material.

Naturally, the very stiff material causes smaller mould deformation resulted in high-accuracy products [6]. The smallest deformations are for tool steel and also gap in division plan has required value 0.02 mm. The gap in division plane for Alumec is 2.82 times larger and for MoldmaxHH is 1.95 times larger.

The most suitable material is Böhler M200 (tool steel) because of the smallest deformations. Next to tool steel, MoldmaxHH (beryllium bronze) is suitable for larger pressure forces. Moreover, the advantage of Moldmax HH is very good heat conductivity. Alumec is not suitable for pressure force 2 MN (but lower pressure force, e.g. 0.7 MN) because of large deformation and gap in division plane that cause the low accuracy of products.

Regarding to presented results Alumec is suitable for pressure forces under 1 MN. Such pressure force causes wanted gap in division plane so as the moulding is with wanted quality but injection pressure have to be lower as 180 MPa. Concerning the mentioned facts, Alumec seems to be the best material if we concern relation: material price – material machinability. Alumec can be machined by ordinary tools in machine conditions allowing usage of larger cut depth and higher spindle speed and speed feed. The mentioned parameters of machining shorten duration of mould parts production. It is necessary to recall that not all aluminium alloys have such good machinability as chosen Alumec.

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