International Students Olympiad in Extrusion Technologies

Reference report

Participant 164-10

2023

Outline

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1. Task

A profile extrusion company received an order to produce a **30** tons batch of hollow aluminium profile (Fig.1) from **AA6063-T5** alloy. A press for direct extrusion was chosen to fulfill the order. There is **1** extrusion line available at the facility with a container diameter of **150 mm** and nominal press load of **14 MN**.

There are 2 **special requirements** for the profile:

1) all welding seams should have structural welded bondings (see more in QForm Extrusion Users manual - *Users manual > Extra package of standard subroutines > Welding quality*).
2) Streaking line should not be present in the area of screw slot (see more in QForm Extrusion Users manual - *Users manual > Extra package of standard subroutines > Streaking lines analysis*).

Using simulation of profile extrusion process, develop a die set design required to complete the order and choose technological parameters of the process.

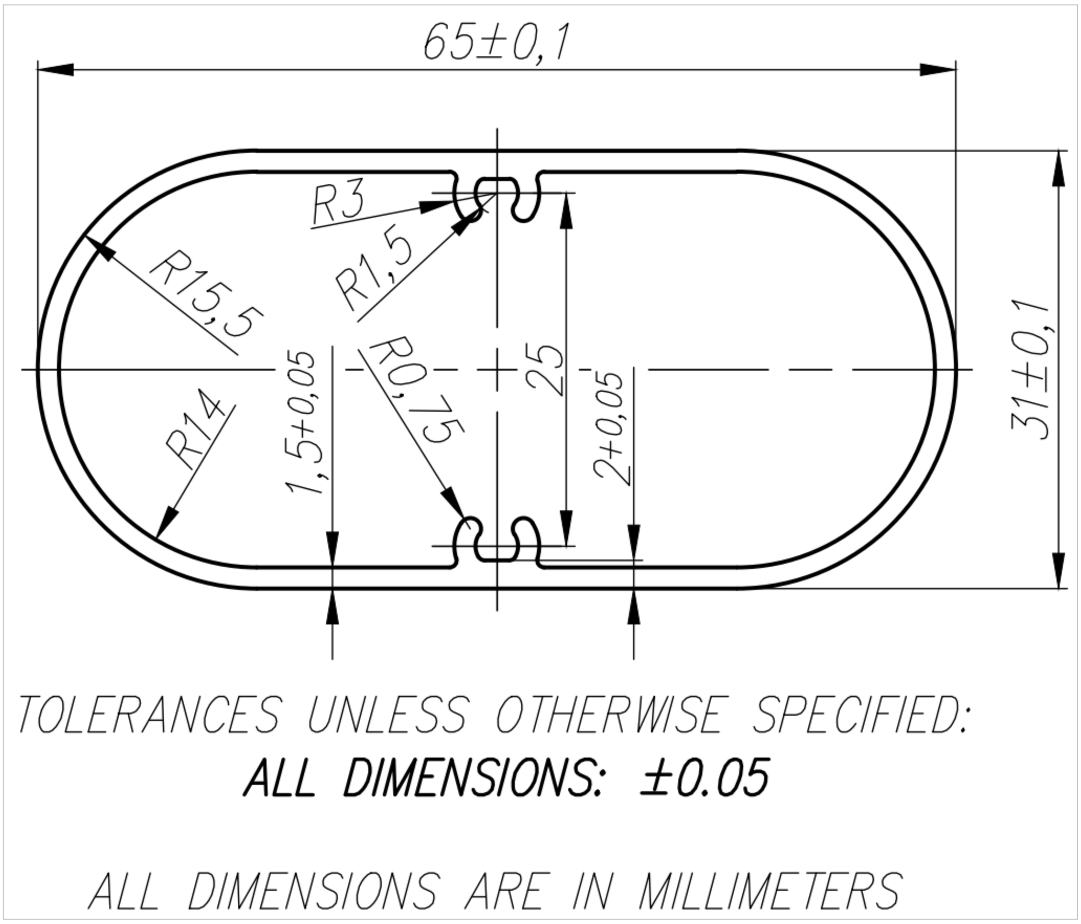

Fig.1. Profile

<u>Please note!</u> Profile dimensions are presented as for <u>hot profile</u>. So, participant doesn't need to calculate die orifice based on cold profile dimensions and thermal expansion coefficient. To achieve the requirement of tolerances on the profile, participant should achieve the following goal: hot profile dimensions in **QForm Extrusion** should be in tolerances indicated on profile drawing.

We recommend to use ¼ symmetrical model to save your time. **<u>Note</u>:** welding quality cannot be assessed using the respective subroutine in case when welding seam is located on symmetry plane. Make sure that welding quality is good enough or use half of the model instead of quarter.

Dxf-file of hot profile is in the attachment.

Task notes

Create a report containing description of task execution, process simulation and steps of results analysis including calculations and technology verification. Use **QForm Extrusion** as a tool for assessment and justification of the proposed technology.

Quality, reliability and reasonability of approaches used to solve technological problems have an influence on the final mark, taking into account the following criteria:

- balance of material flow and lack of profile intersection with die set
- adjustment of extrusion temperature-velocity mode
- profile orientation on the die face
- adjustment of extrusion load mode (selection of billet length)
- analysis of die stress-strain condition
- productivity rate of the proposed technology (number of profiles extruded simultaneously and weight of profile per 1 press stroke)
- transversal seam length value and welding quality estimation of longitudinal seam
- streaking lines analysis and suggestion of defect elemination
- universality of proposed components of support tools
- analysis of potential extrusion defects; prediction and elimination
- suggestion of appropriate heat treatment

6 hours provided to design the technology, to simulate it and to create a report using a text editor.

At the end of the work create an archive (use special number provided by committee to name the archive) including the report and resulting simulation files of a single final version of technology. Report title and QForm files have to contain your special number. Name of participant shouldn't be specified.

Additional data

Die set length – **125 mm**
Die set diameter – **250 mm**
Bolster length – **150 mm**
Bolster diameter – **360 mm**
Pressure ring inner diameter – **250 mm**
Material conditions – **T5**

Other requirements – according to local standards

2. Die set design

The count of die orifices **n** is determined by the extrusion ratio $\boldsymbol{\lambda}$, which should be in the interval between 30 and 80 units.

Extrusion ratio:

$$\lambda = \frac{F_{cont}}{n \cdot F_{prof}} \qquad (1)$$

$F_{cont} = \frac{\pi \cdot {d_{cont}}^2}{4} = \frac{3{,}14 \cdot 150^2}{4} \approx 1{,}767 \cdot 10^4\ mm^2$- area of the container cross-section

$F_{prof} = 264{,}569\ mm^2$- area of the profile cross-section

With a given container diameter the extrusion ratio will be:

$$\lambda = \frac{F_{cont}}{n \cdot F_{prof}} = \frac{1{,}767 \cdot 10^4}{1 \cdot 264{,}569} \approx 66{,}8 \qquad (2)$$

The workpiece diameter should be sufficient to insert it into the container. Also increasing billet diameter by thermal expansion and tolerances should be taken into account. Thus, the required workpiece diameter:

$$d_{wp} = (0{,}97 - 0{,}98) \cdot d_{cont} = 0{,}98 \cdot 150 = 147\ mm \qquad (3)$$

The workpiece length can be estimated by ratio $\frac{L_{wp}}{d_{wp}}$, which should be in the interval between 2-4,5 units. As an initial approximation this ratio can be taken equal to 3. In this case:

$$L_{wp} = (2 - 4{,}5) \cdot d_{wp} = 3 \cdot \approx 440\ mm \quad (4)$$

The length of billet can be increased but it could result in very high extrusion load. So, the billet length can be specified via adjustment of temperature-velocity mode considering the maximum press load.

The overall view of die set is shown in figure 2. Since the die set has two planes of symmetry, in order to minimize the simulation time in QForm Extrusion, one fourth of the geometry will be used.

The circumscribed diameter of feeders should not be bigger than $0{,}9 \cdot d_{cont}$ to minimize flowing of billet skin, which contains surface defects and industrial lubricant. That is why it is received equal to 135 mm. After first simulation the volume of metal that goes through particular port was analyzed and changed to achieve stable flow of the profile.

It is better to place the webs in the corners of the profile, since in this case the weld seam will be less visible. However, if the analysis of the durability of the tool shows poor results, then the design of the webs should be changed by adding, for example, additional webs in the center of the mandrel.

The height of the welding chamber as a first approximation is assumed to be 15 mm. However, it can be increased in the future if the quality of the weld is not structural. An increase the height of the welding chamber will influence to pressure inside it, as well as to an increase in welding time, which will positively affect on the quality of seams.

The prechamber height is accepted as equal to 5 mm.

The height of the bearings is assumed as constant and equal to 6 mm. In this case, the deformation of the core along the Z axis is taken into account by increasing the height of the core's bearing relative to the die entry by 0.5 mm.

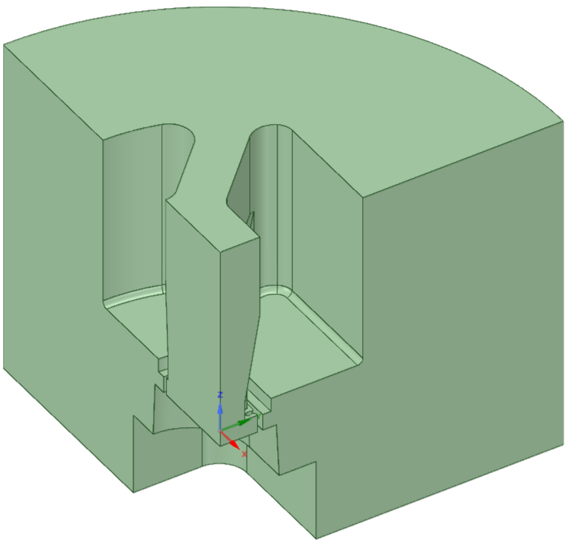

Fig. 2 First die set

The bolster height is assumed to be equal to 150 mm. The contour of its hole is made in the form of a round in order to simplify manufacturing and unification. The geometry of the bolster is shown in fig.3.

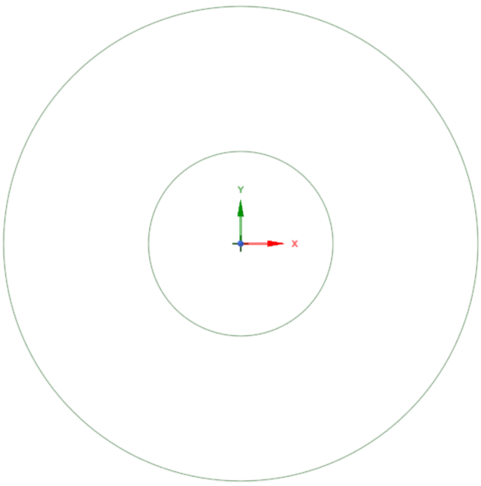

Fig.3 Bolster geometry

Process parameters are specified in the tables 1-3.

Table 1

	Diameter, mm	Length, mm	Geometry type
Container	150	-	-
Billet	147	440	-
Die set	250	125	3D
Die holder	360	-	-
Bolster	360	150	2D
Pressure ring	250	-	2D

Table 2

	Temperature, ℃	Material
Billet	480	AA 6063
Die set	450	H13 for extrusion
Bolster	150	
Ram	420	
Container	420	

Table 3

Ram velocity, mm/s	5

3. QForm Extrusion simulation

Before starting the simulation of process, a finite element mesh should be created by using the QShape editor. For correct calculation, it is required that there are at least three finite elements in the profile section (fig.4).

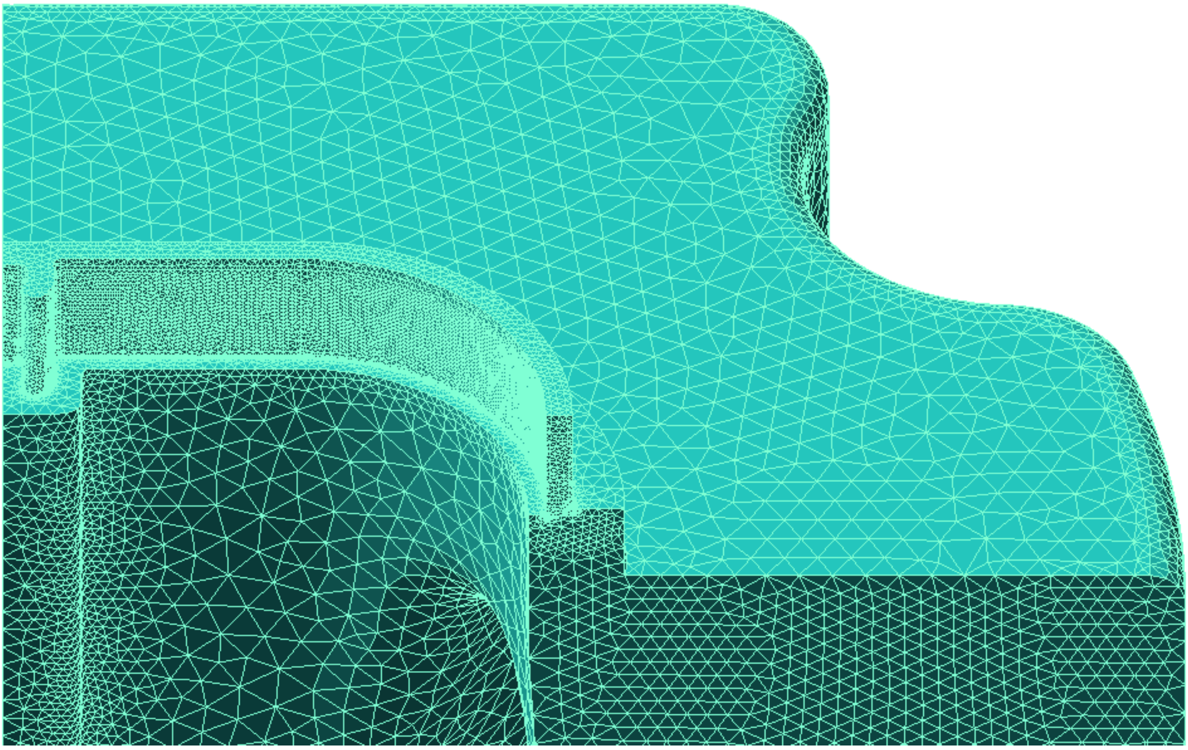

Fig.4. Finite element mesh

The first design

The simulation showed a large instability of the flow, as can be seen from the field "Velocity deviation" in fig.5. The intersection of the profile with the tool was also detected (fig.6). In cases where contact with the tool occurs in a fast-flowing area, it can help by slowing down the fast sections. However, if contact is observed for a slow section of the profile, this only complicates the situation and increases the chance of reject. Therefore, it is better not to allow contact with the tool at all.

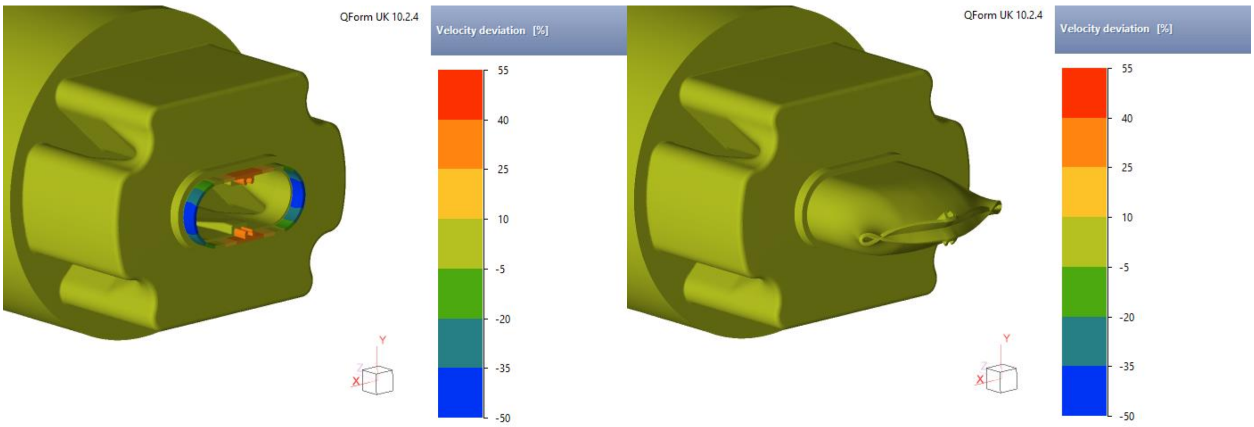

Fig.5. Unstable profile flow

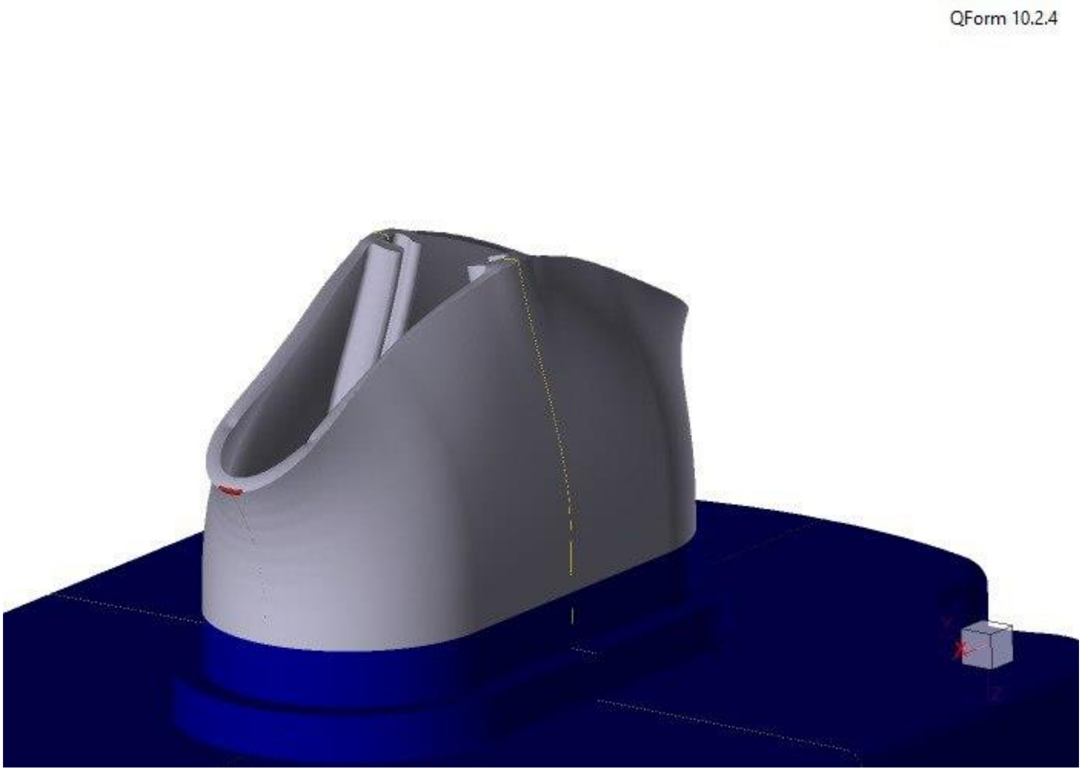

Fig.6 Intersection with tool

Optimization of the flow can be achieved by changing the design of feeders and prechamber.

X, Y, Z displacements are shown in fig.7-9.

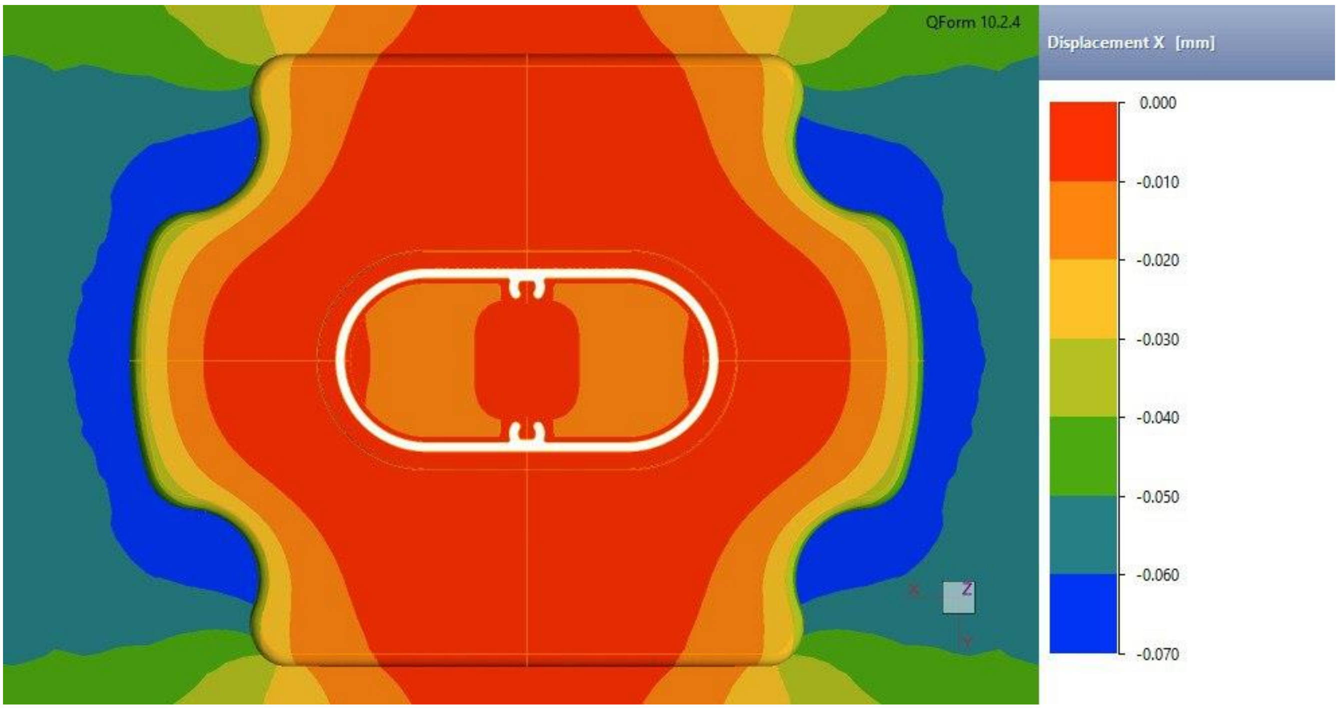

Fig.7 Displacement X

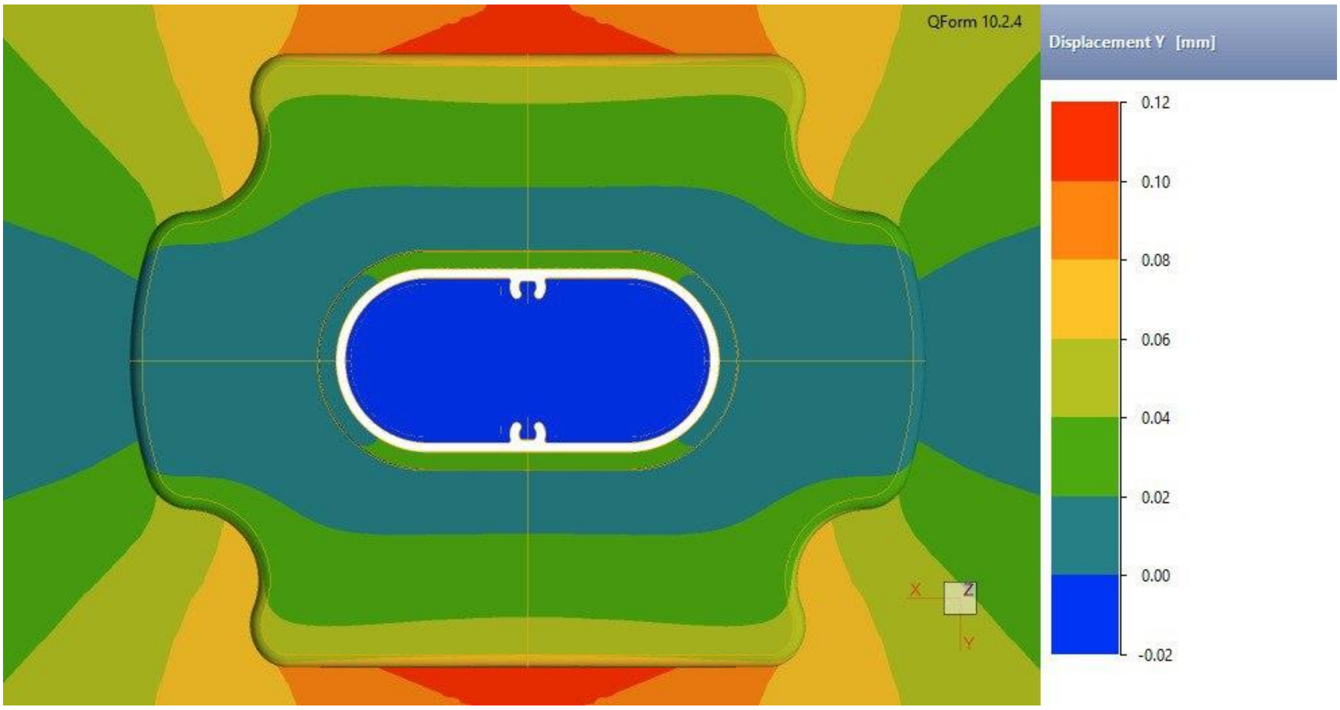

Fig.8 Displacement Y

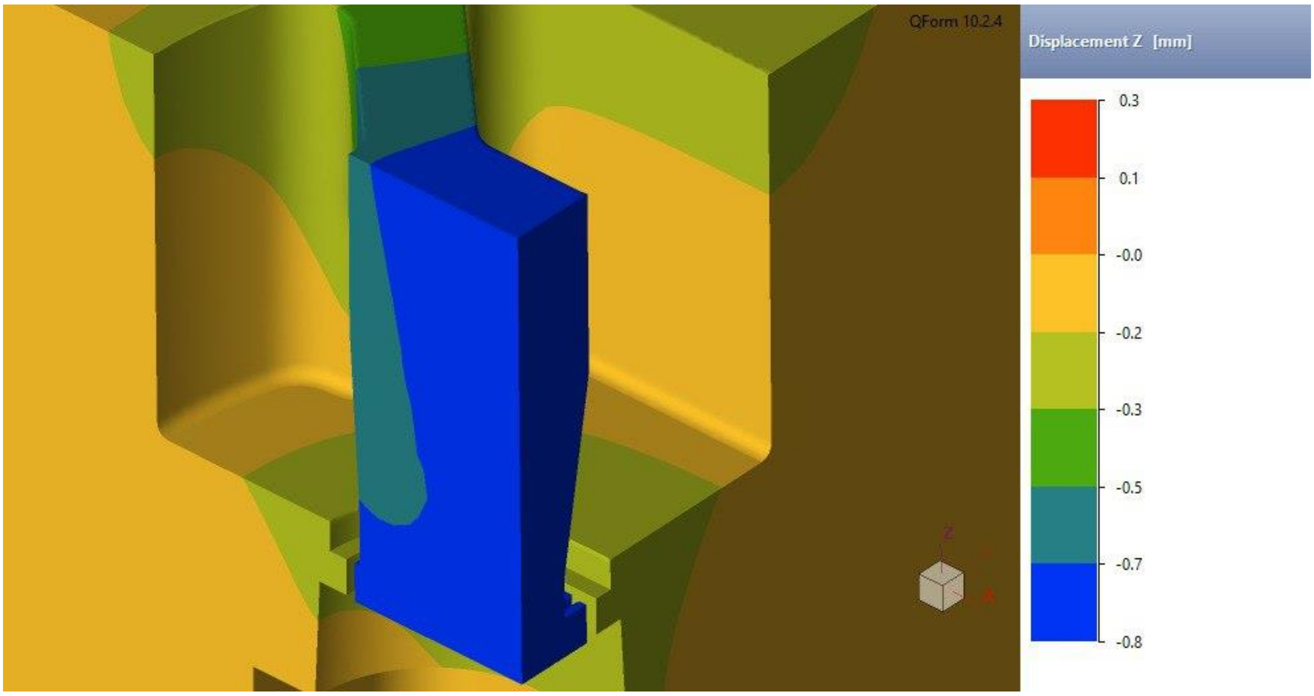

Fig.9 Displacement Z

The most dangerous zones of the tool are the zones under webs, where, due to large values of effective stresses and prevailing tensile stresses, destruction occurs (fig.10-11). Due to the achievement of the stress intensity of the yield strength of the material under the Mises plasticity condition, plastic deformation occurs. And because of the tensile stresses that can be detected using the medium stress field, cracks appear.

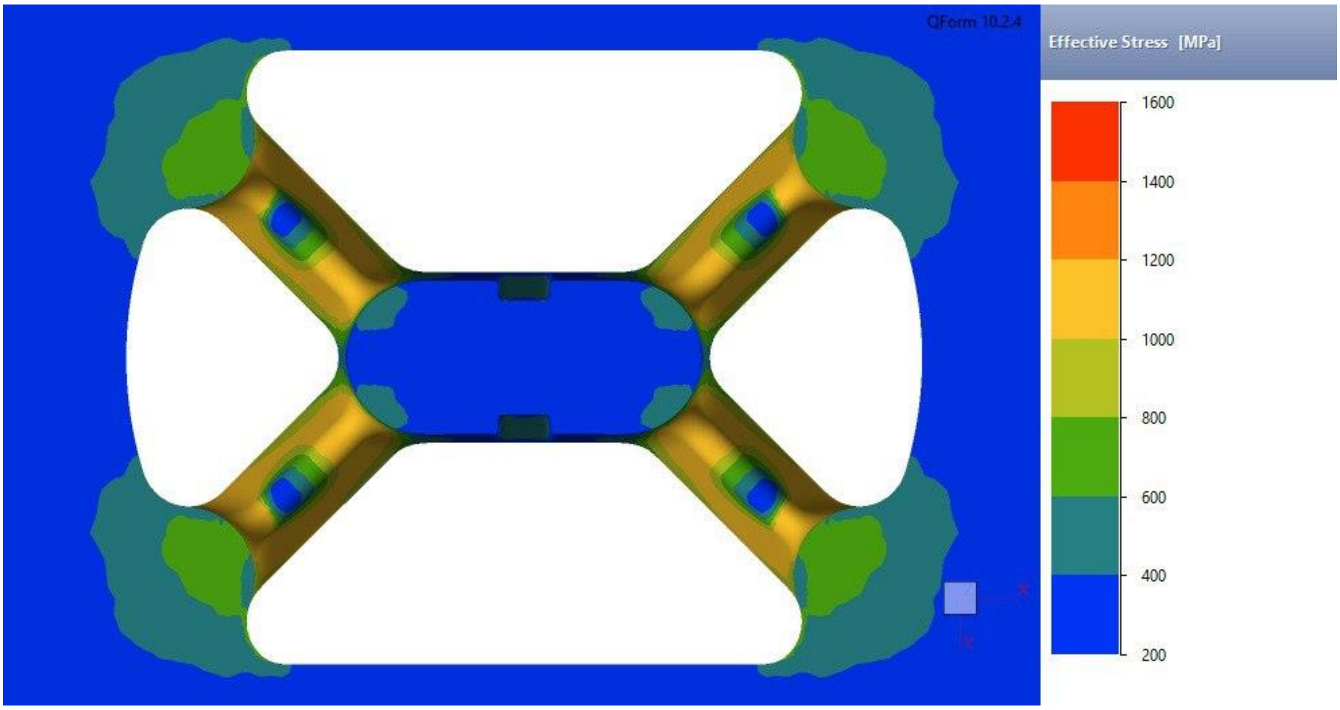

Fig.10 Effective stresses in first design

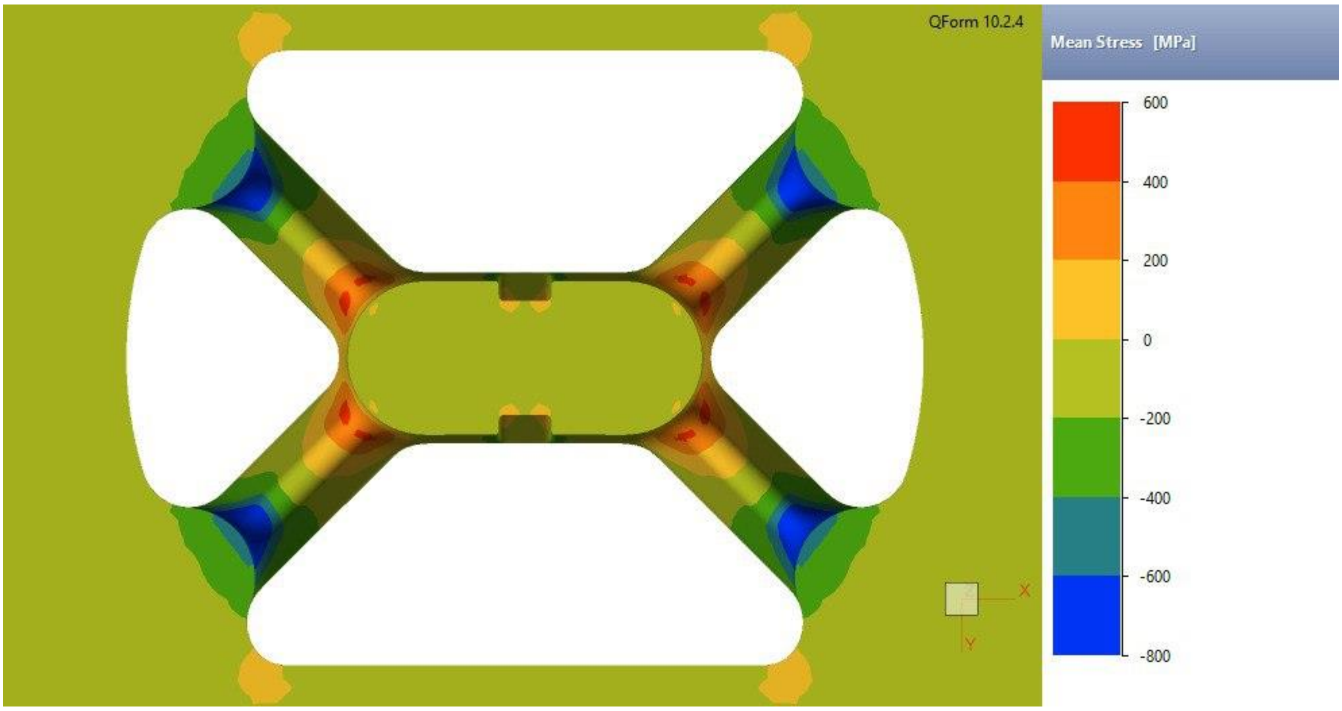

Fig.11 Mean stresses in first design

The maximum value of extrusion load for the first design was equal to 10.2 MN (fig.12) in after die filling task.

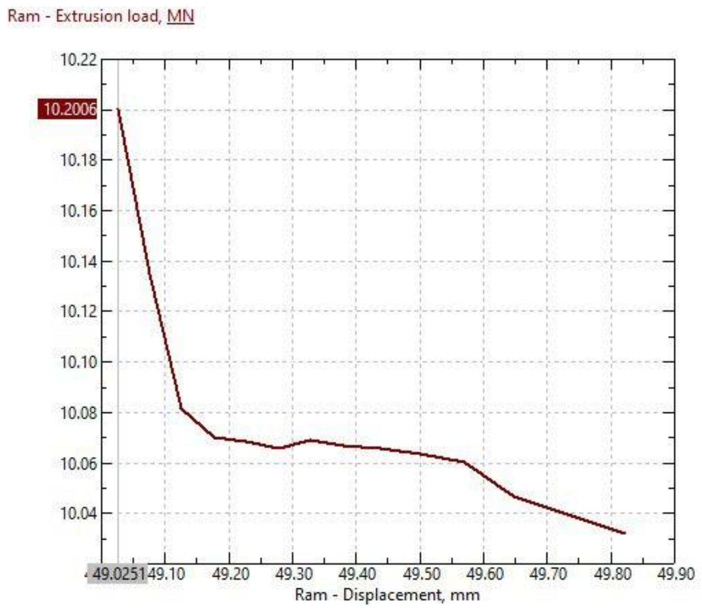

Fig.12 Extrusion load with the first die set

The second design

The view of second design is presented in fig.13.

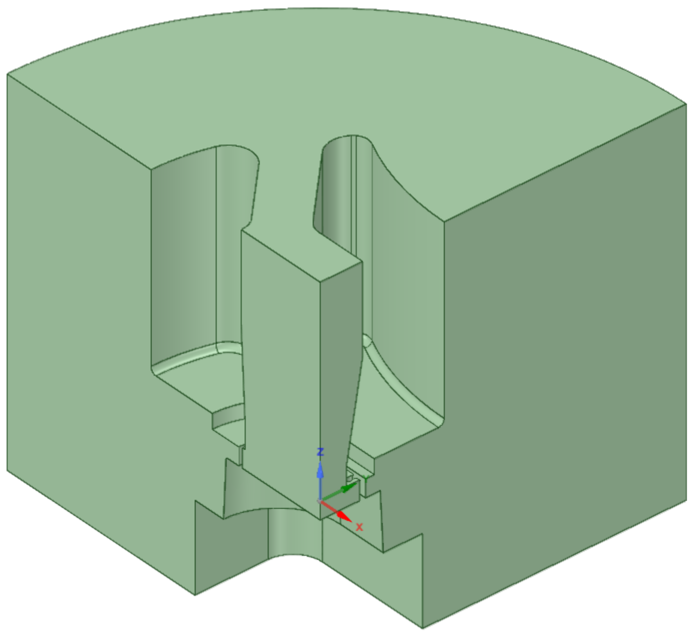

Fig.13 The second design

As can be seen in fig.14, profile flow is stable with new design of the die set.

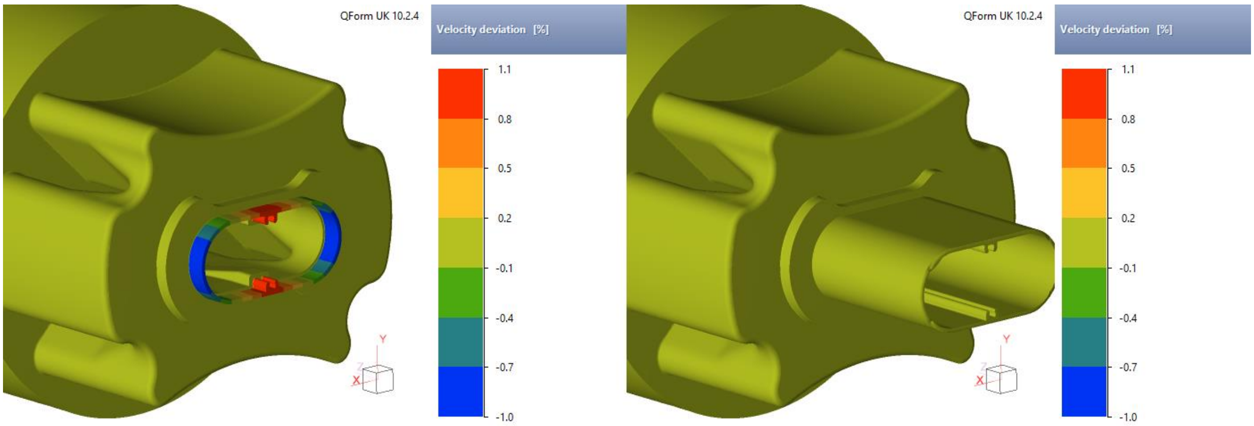

Fig.14 Stable profile flow

The whole billet task was simulated. It made possible to obtain results which should be closer to reality.

The extrusion force reached the maximum value at point 10,26 MN (fig.15) in whole billet simulation.

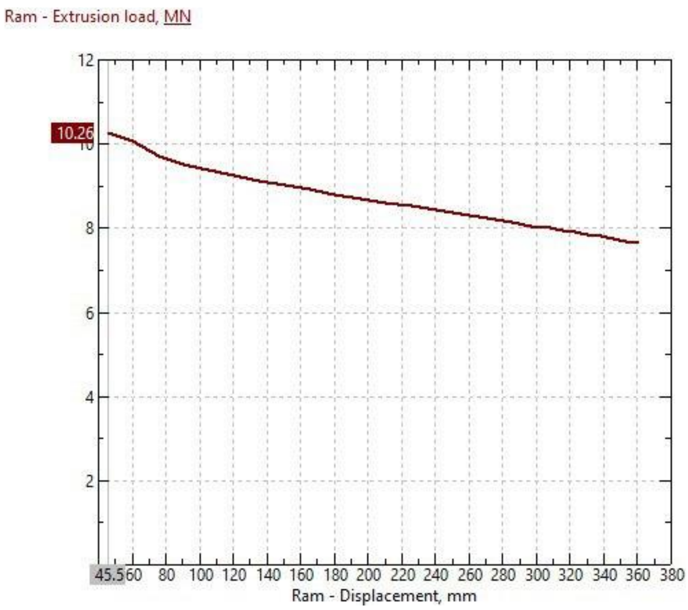

Fig.15 Extrusion load with second design

Subroutines such as tension triaxiality and plasticity status make it possible to analyze the tool in an extended way. The results of analysis are shown in fig.16-17

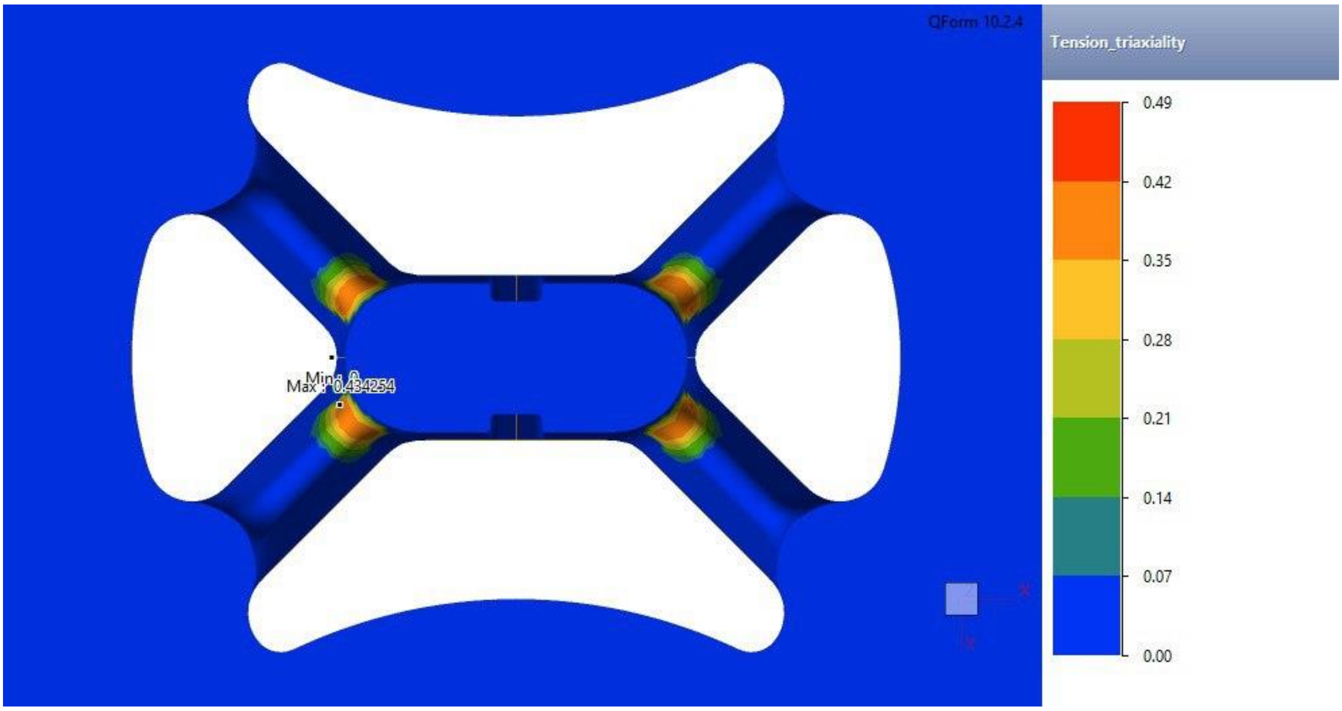

Fig.16 Tension triaxiality under webs

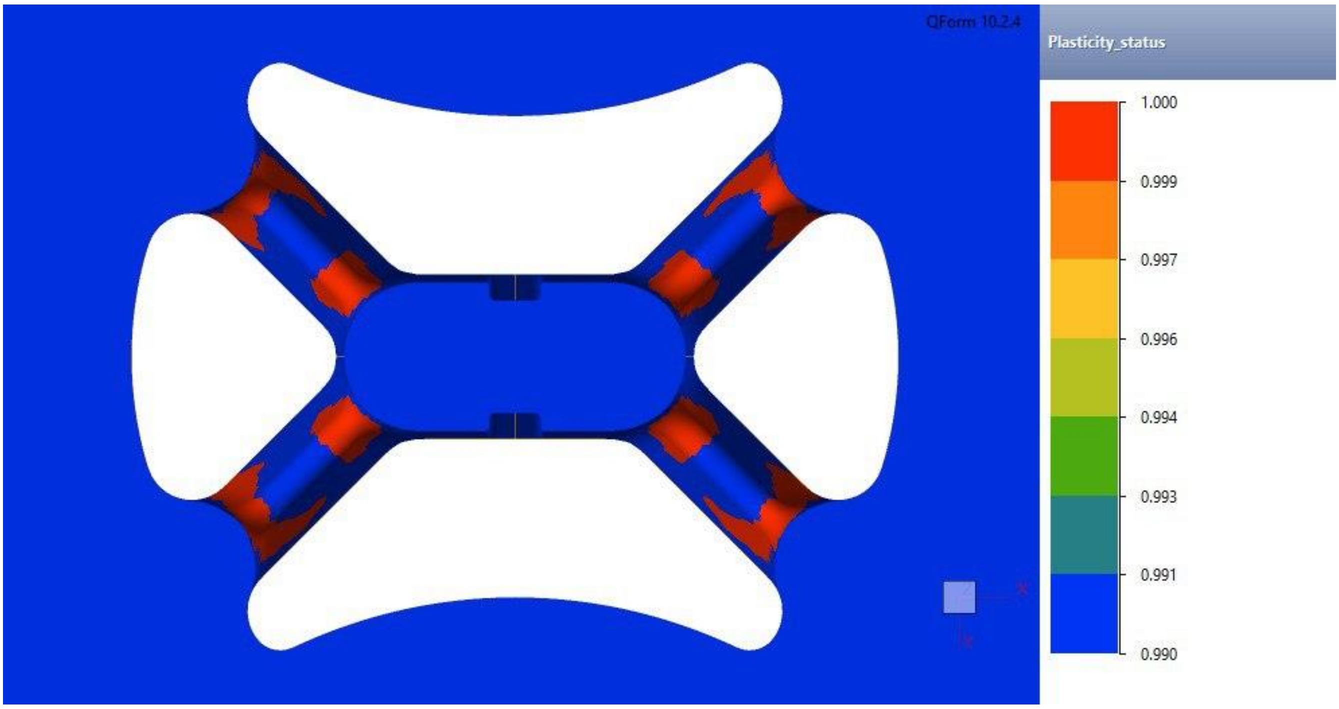

Fig. 17 Plasticity status under webs

The maximum value of the tension triaxiality field does not exceed 0.55. Based on the industrial experience of enterprises and modeling series, it is assumed that if the value of tension triaxiality is less than 0.55, then the nominal life of the die set is guaranteed. Plastic deformations do not cover the bridge in a closed contour.

It is possible to estimate the change in the thickness of the profile using the "Thickness change" field of the same name (fig.18).

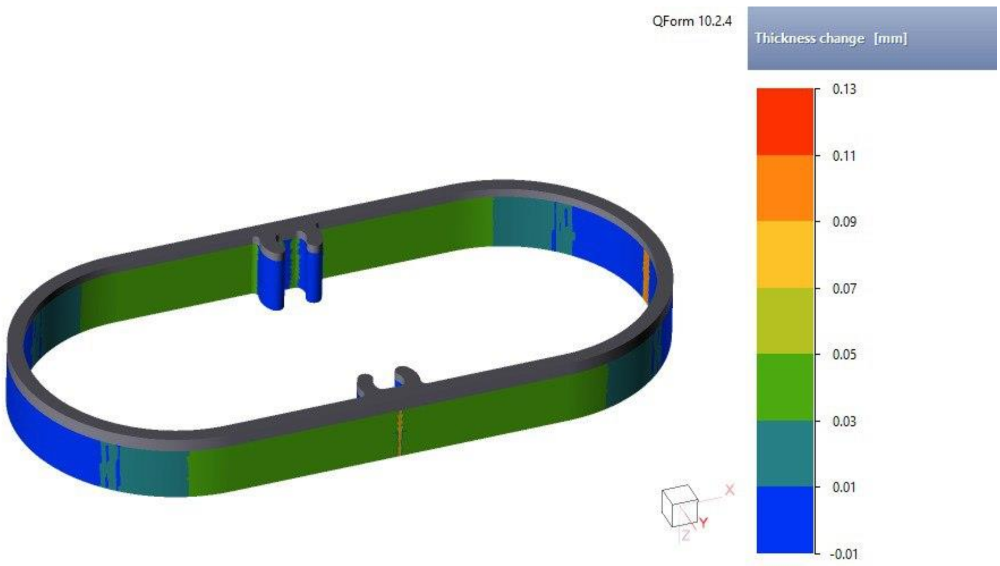

Fig.18 Thickness change

As can be seen from the figure 18, the profile dimensions are in tolerances according the drawing. However, the final dimensions of the profile depend not only on the deformations of the tool and the temperature-speed mode of extrusion, but also on the quenching process and its parameters. Let's consider that the profile quenching is perfect, then the final product dimensions are in tolerances.

The streaking lines can be detected using the standard subroutine "Streaking lines" field (fig.19).

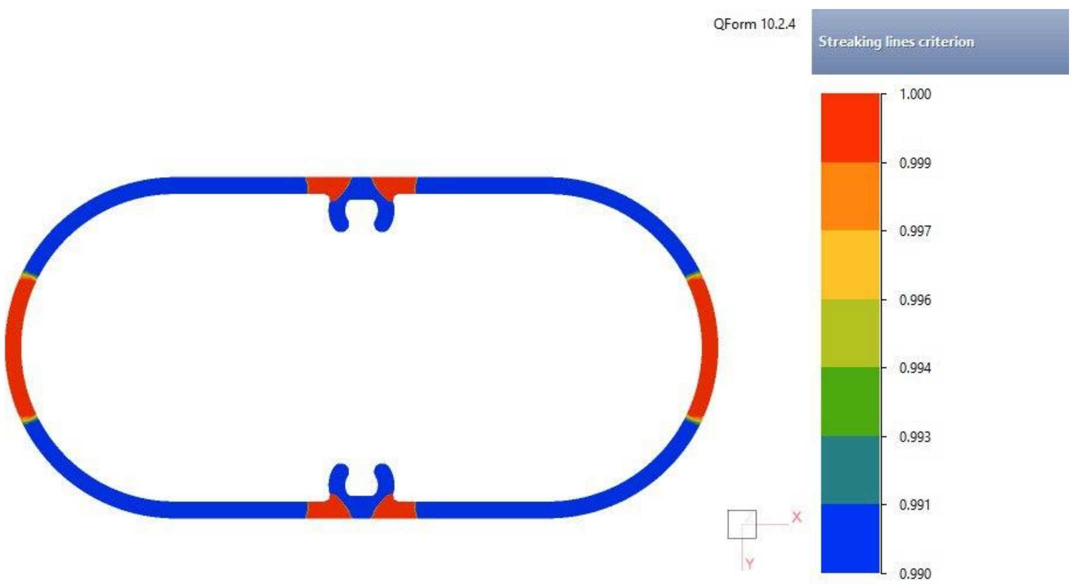

Fig.19 Streaking lines field

Profile has a structural welding as shown in fig.20.

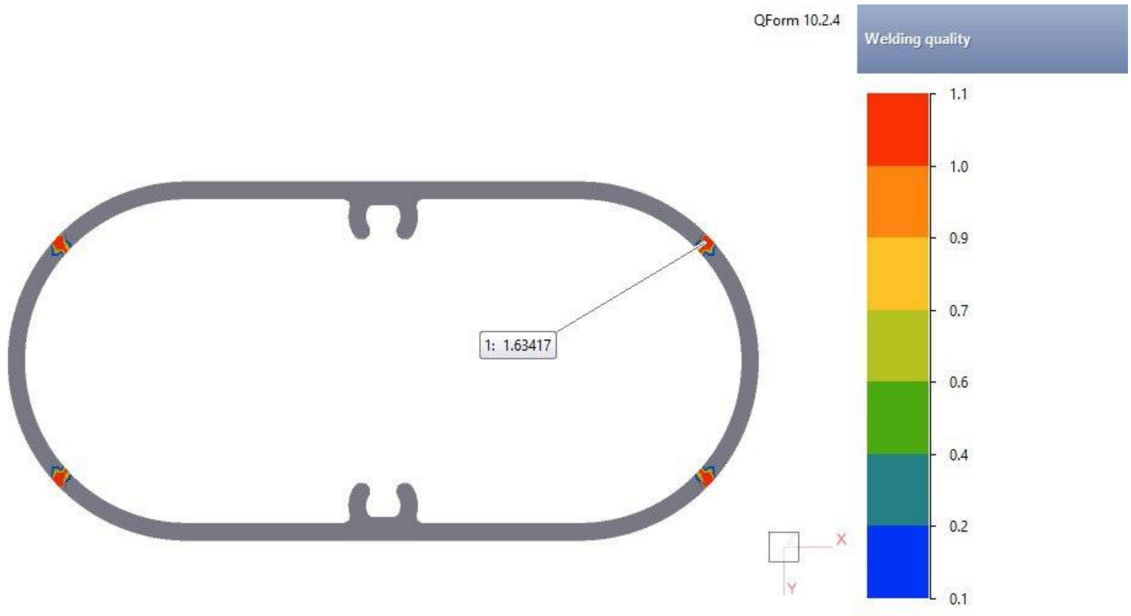

Fig.20 Welding quality

4. Industrial efficiency estimation

A mixture of two billet materials for the case of extrusion "billet on billet" is observed at a distance of 3100 mm from the stop mark, as shown in fig.21.

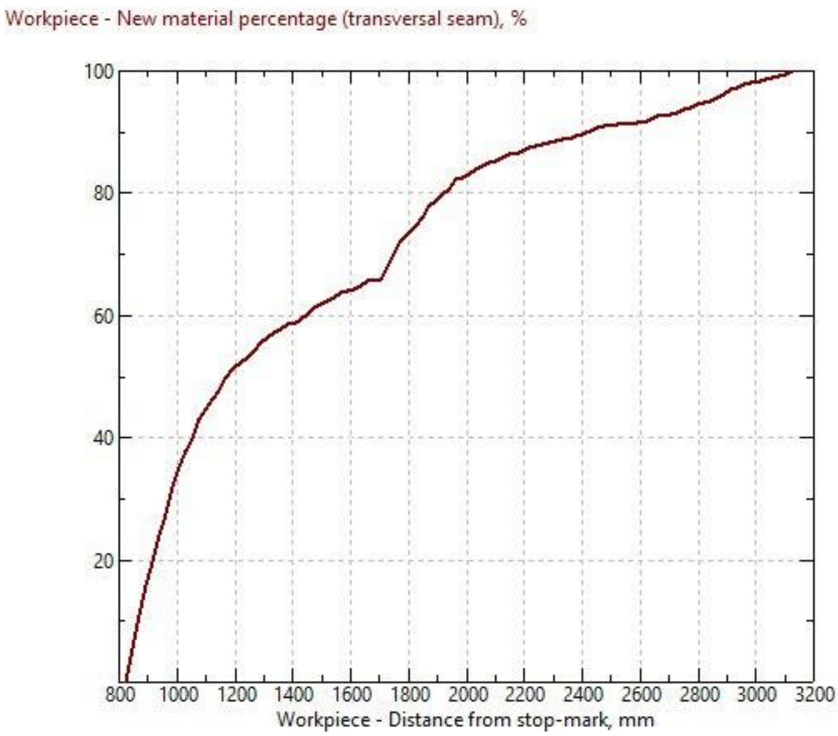

Fig.21 Distance from stop-mark

5. Final process parameters

The final parameters are presented in Tables 4-6.

Table 4

	Diameter, mm	Length, mm	Geometry type
Container	150	-	-
Billet	147	440	-
Die set	250	125	3D
Die holder	360	-	-
Bolster	360	150	2D
Pressure ring	250	-	2D

Table 5

	Temperature, ℃	Material
Billet	480	AA 6063
Die set	450	H13 for extrusion
Bolster	150	
Ram	420	
Container	420	

Table 6

Velocity of ram, mm/s	5