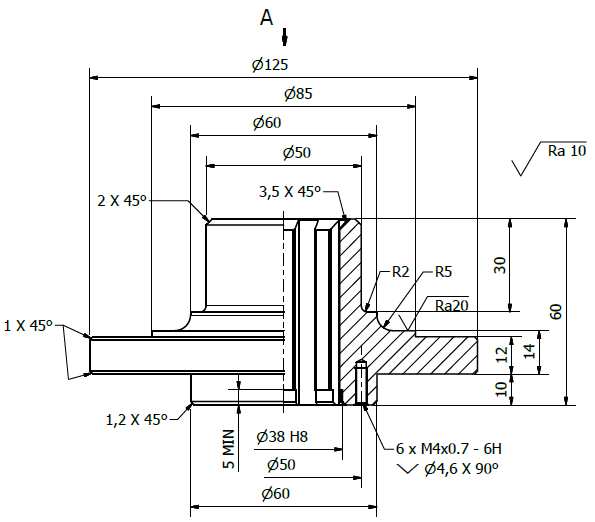
**The International Students Olympiad in Hot Bulk Forging Technologies**

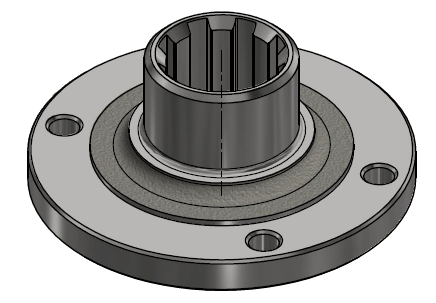
**CODE** 0210

28.04.2017

**1. Introduction**

The goal of the work was to design and optimize the "Coupling" forging technology based on QForm v8 numerical simulation.

Drawing of the final part (after machining)  


3D visualization of the final product

**2. Information about manufacturing details**

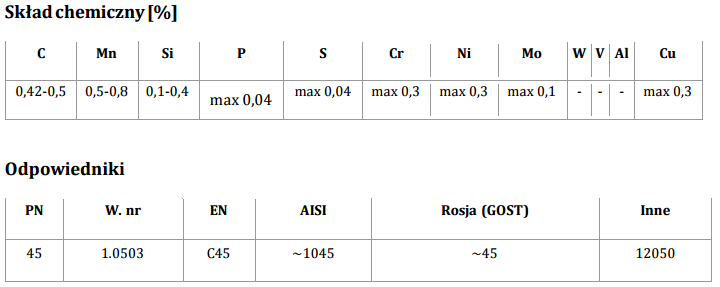
1. Number of parts in one order: 30000
2. Available forging equipment:

* hydraulic press (10 MN, 10mm/s)
* steam-air hammer (2t, 50 kJ)

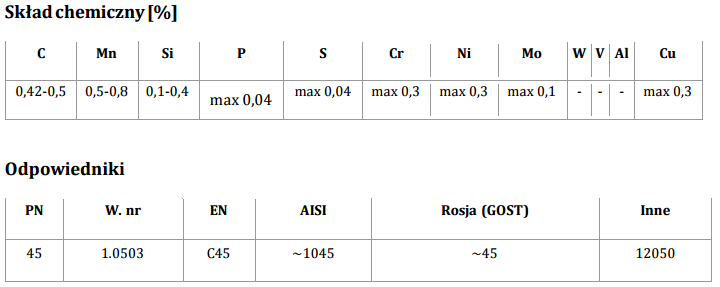
Taking into consideration a shape and number of parts the steam-air hammer was chosen as a machine to forging process execution. This choice is better from economical point of view because of higher velocity of the machine.

**3. Designing of forged part**

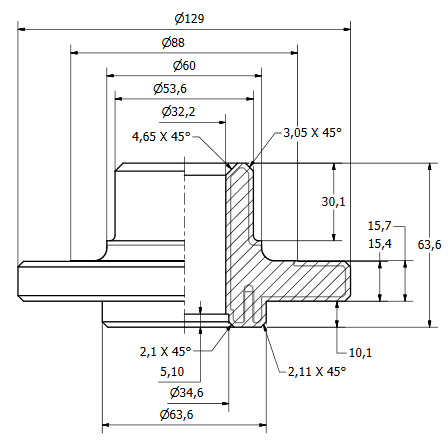
* Axisymmetric type of the part
* Material: C45 carbon steel
* Chemical composition:



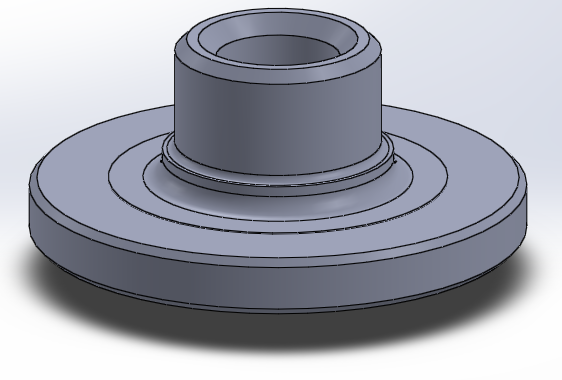
* Symbols:

(Reference #1)

Drawing of the part with allowances to machining   
(general tolerance +-0,3 mm)



Visualization of the part before machining



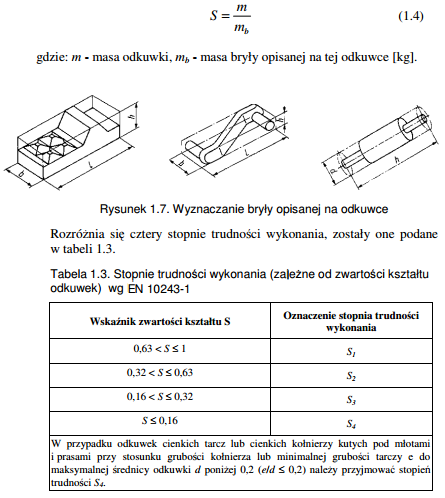
Details about the product:

* Volume: **269396.97 mm3**
* Mass: **2115 g**
* Volume of the enveloping body of the part: **831239.97 mm3**
* Mass of the enveloping body of the part: **6525 g**

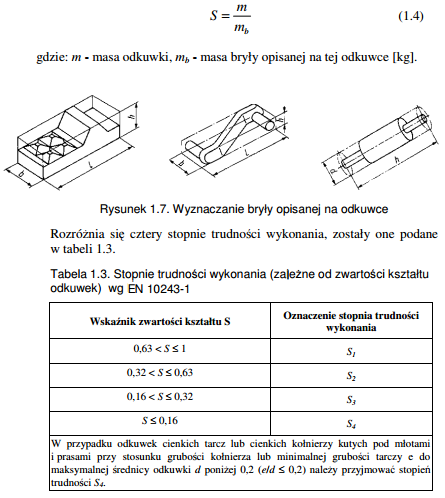
Based on the norm EN 10243-1: 1999 for the hot closed die forging made of carbon and alloy steel **forging grade F** was chosen - an adequate standard of accuracy for the majority of applications.

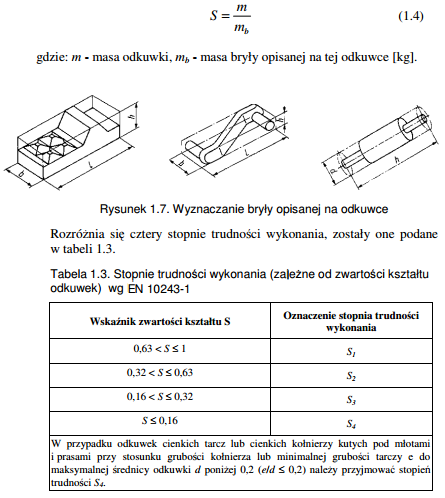
**Category of steel - M1** (steel with carbon content not more than 0,65% and total of specified alloying elements (Mn, Ni, Cr, Mo, V, W) not more than 5% by mass.

**Shape complexity factor -**  S



m - mass of forging, mb - mass of enveloping shape

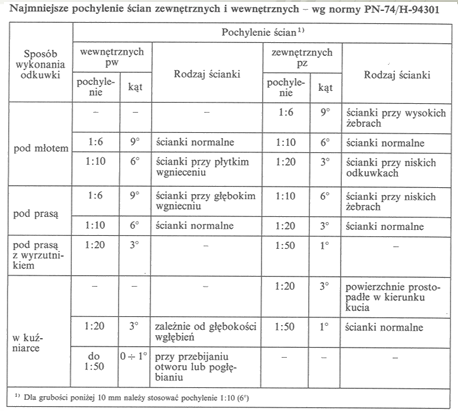




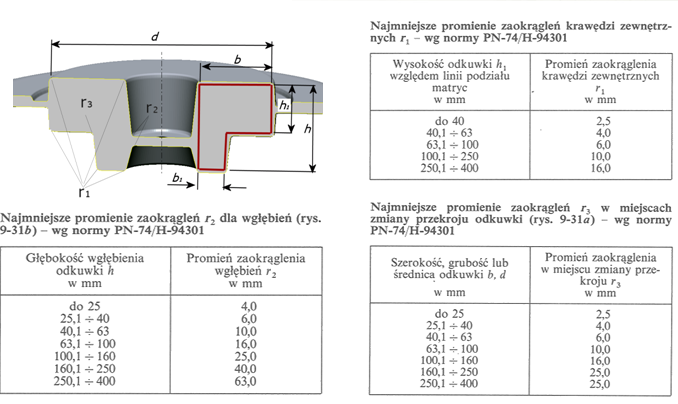
S=2115/6525= 0,33 - shape complexity factor S2

Based on the table below draft angles was chosen:

* internal: 9°
* external: 6°



Edge radius were chosen based on the table:

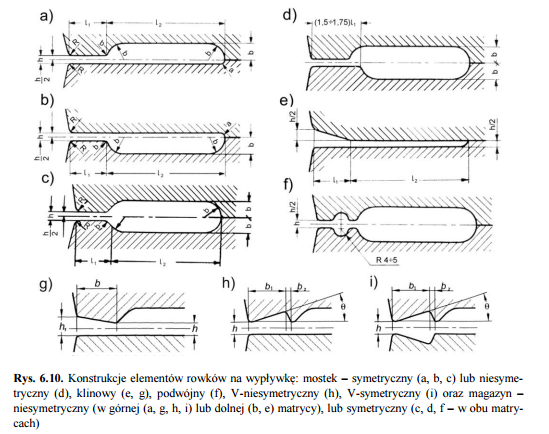


r1=2,5 mm

r2= 16 mm

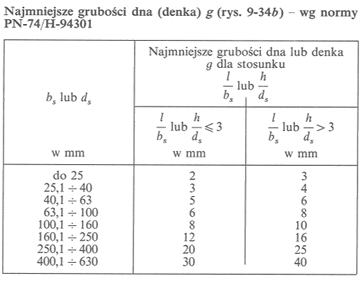
r3=10 mm

Land and gutter construction:



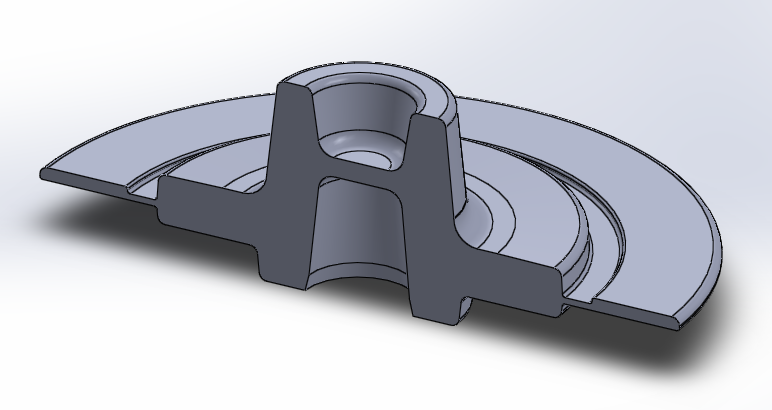
* Construction type**: a,**
* Geometrical details: **h=2 mm; l1=10 mm; l2=28 mm; R=1,5 mm; b=4 mm**

Bottom construction and position:



Flat bottom of the width equal to **6 mm** was chosen

3D geometric model of forged part (cross section)

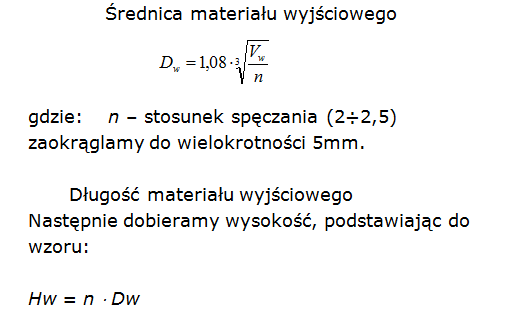


Mass of forged part (with a flash): **2516 g**

Volume of forged part (with a flash): **320478 mm3**

Workpiece geometry

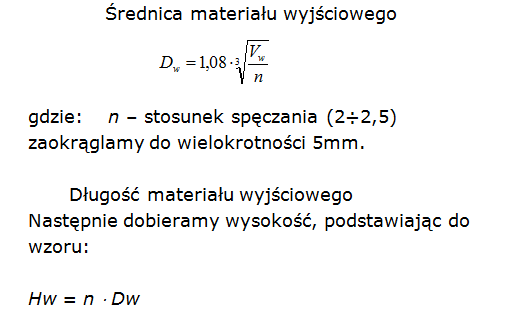
Diameter of the workpiece



n - upsetting coefficient (h0/d0 = 2 - 2,5)

Assumption: n = 2,4

Height of the workpiece



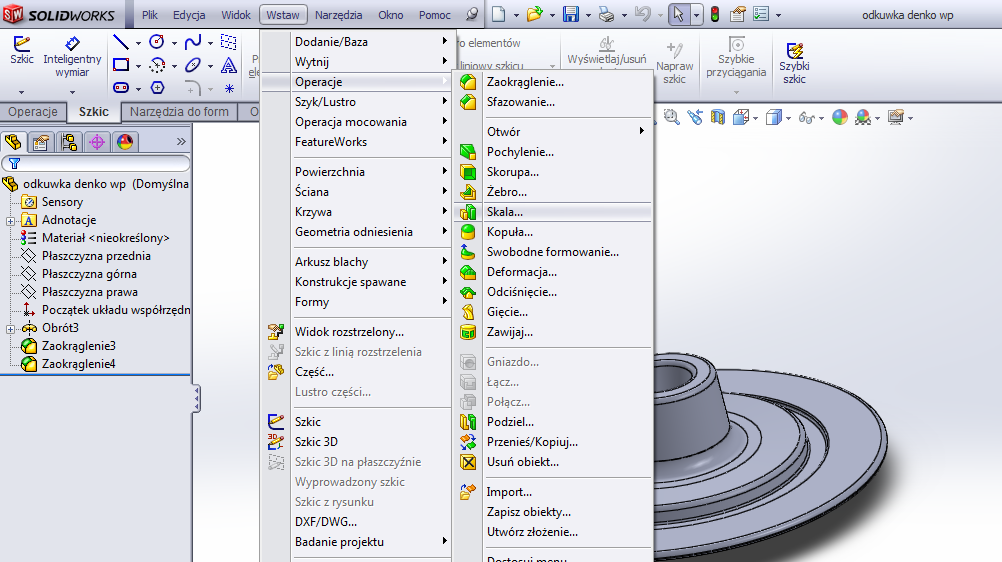
After final calculation:

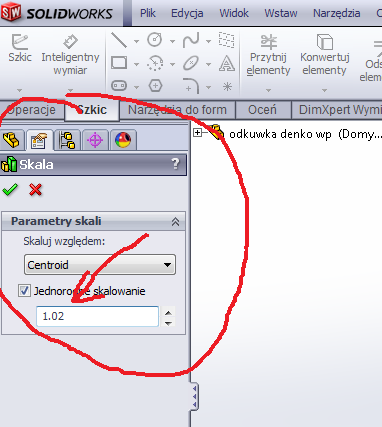
D = 54,82 (after rounding D = 55 mm)

H = 135mm.

A cylindrical shape of workpiece was assumed

Taking into account a thermal expansion because of forging in high temperature a **thermal expansion coefficient** was assumed equal to **2%** of the forged part volume. This phenomenon was considered at the stage of designing of tools (scale of the forged part geometry = **1.02**).





**4. Process simulation in QForm**

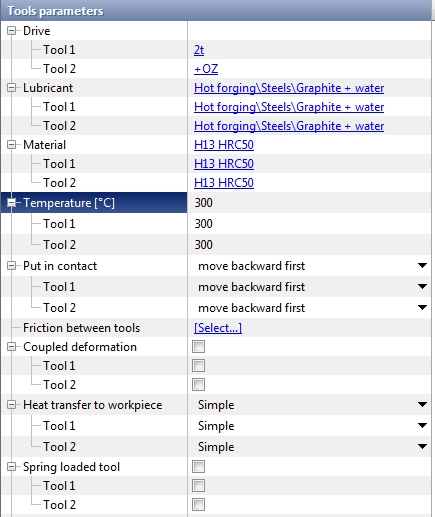
* Material: **Steel C45**
* Material temperature: **1100°C**

Forging process includes two operations: upsetting and final die forging

**1st operation: Upsetting**

The goal of this operation is to increase a deformation degree of the material and to change the preliminary shape of the workpiece.

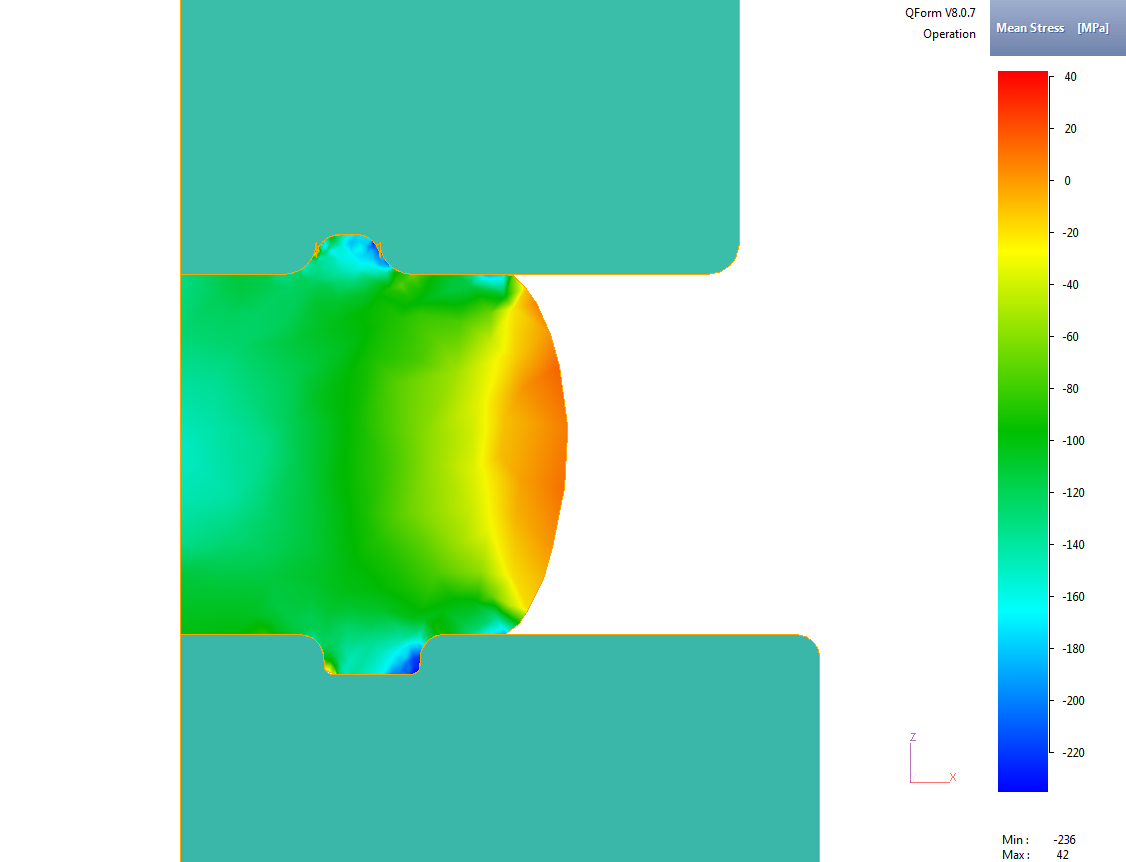
Boundary conditions assumed in both operations:

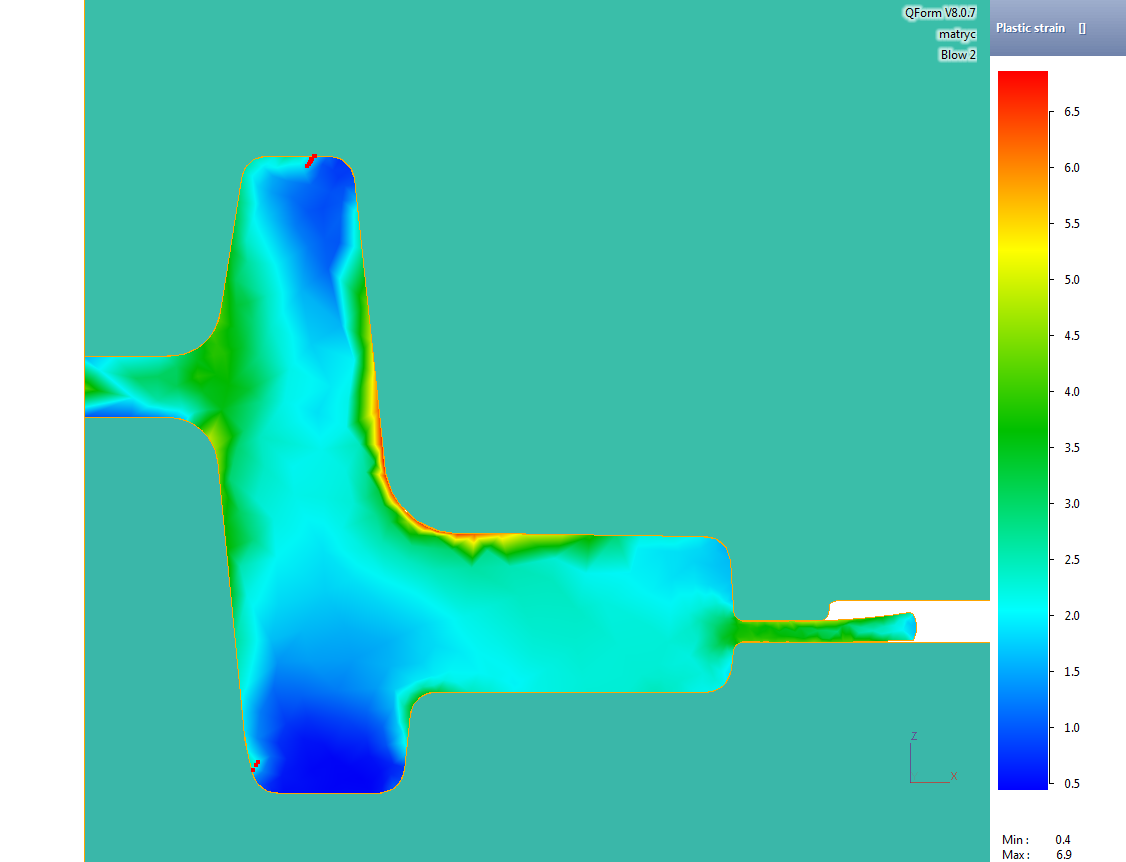


Besides in the 1st operation was assumed:

* Number of blows: **1**
* Final distance between tools: **45 mm**
* Cooling in air: **3 s,**
* Cooling in tools: **2 s**

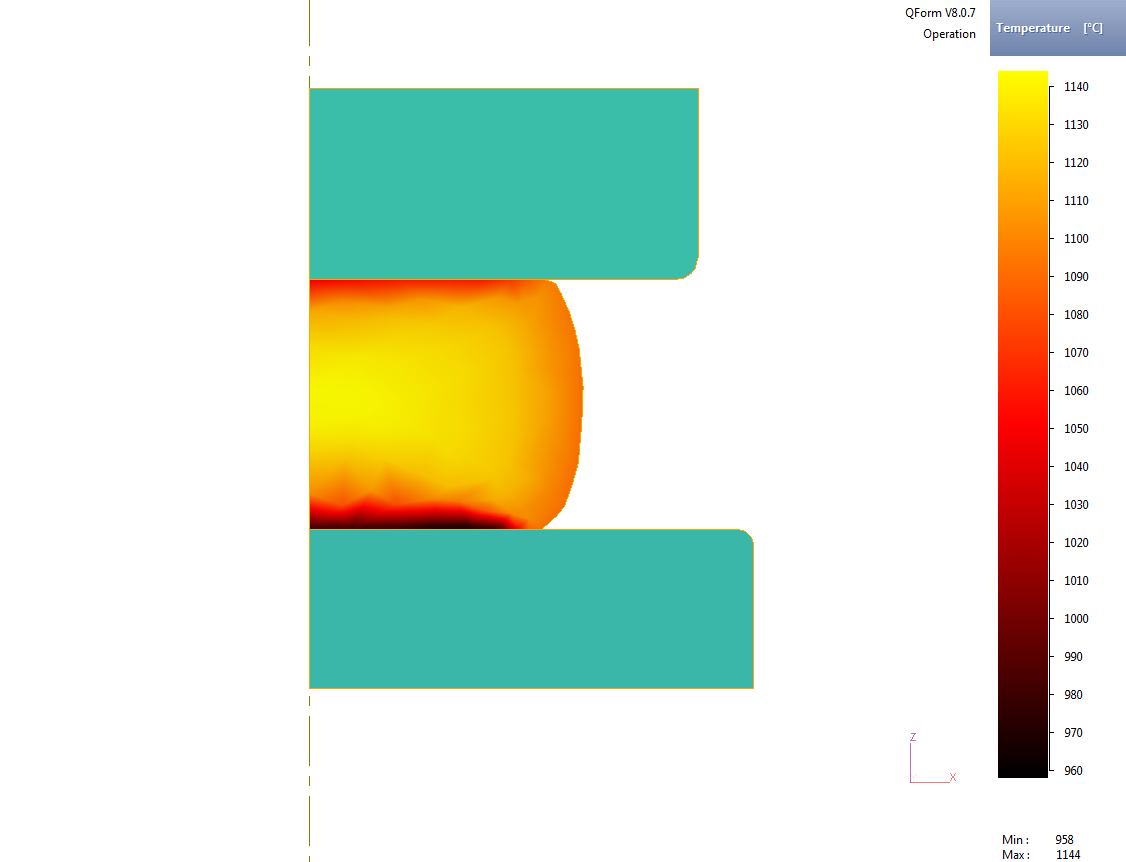
First results of the simulation were not satisfying because of **two laps** appeared in the area of final part.





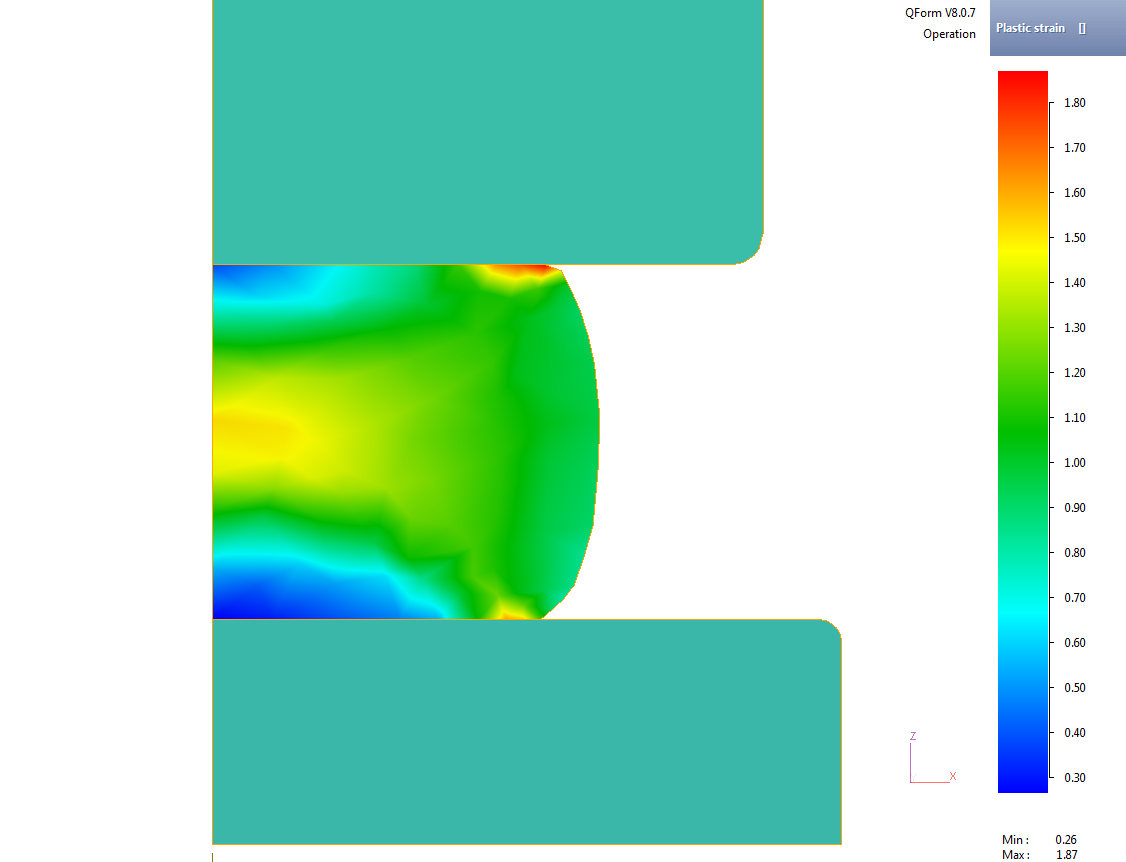
Because of defects inside the product structure after forging, some changes in manufacturing process were necessary.

Approach 2



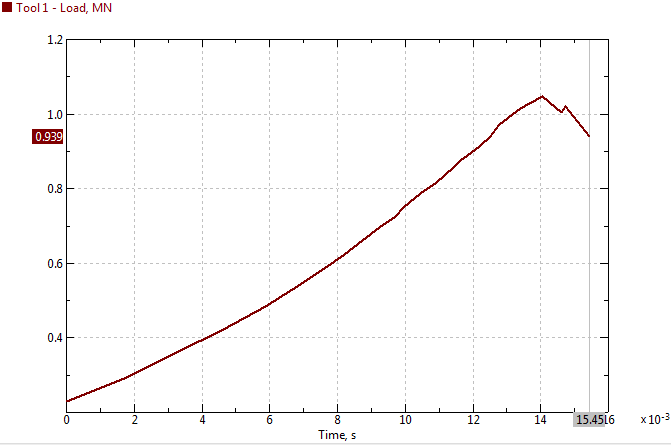
Temperature distribution after upsetting.

Very intensive decreasing of the temperature at the material-tools contact surface could be observed. The highest values of the temperature were achieved in the area inside of the forged part.



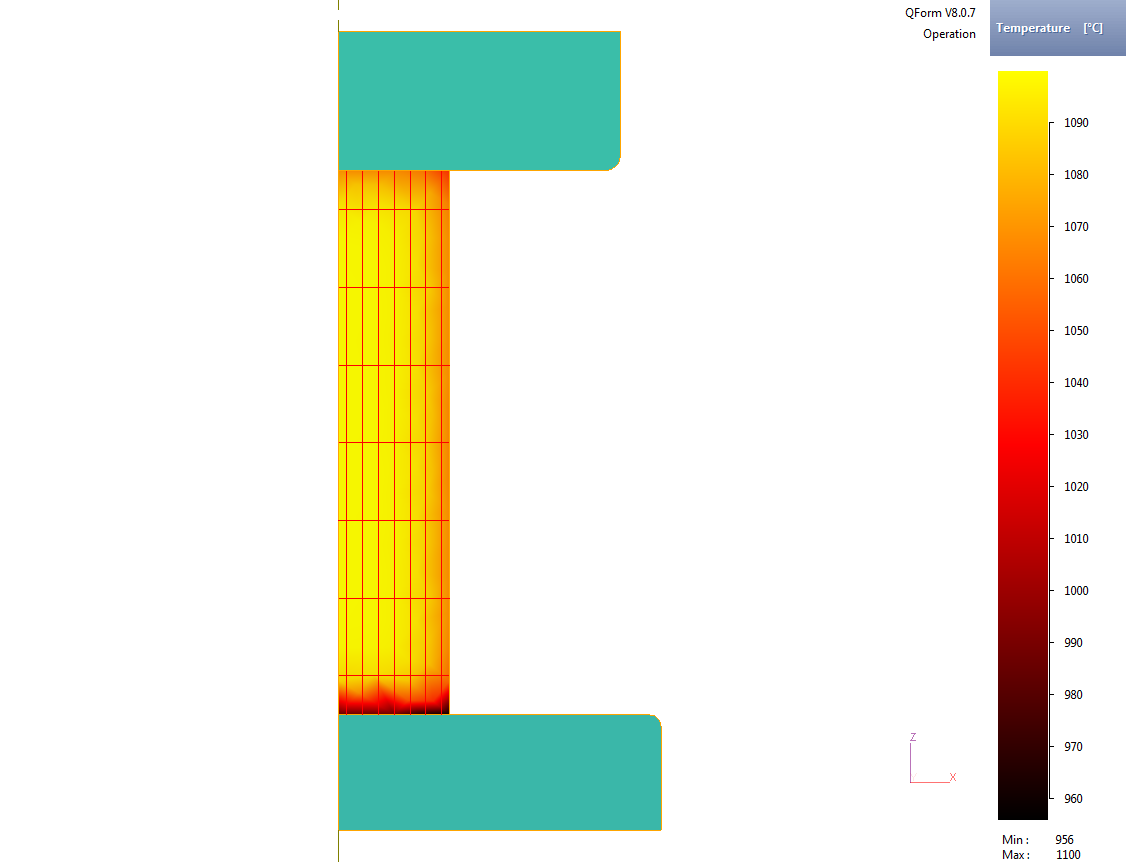
Plastic strain distribution after upsetting.

This figure shows that the lowest values of plastic strain are localized in the lower and upper parts of the forged product. Highest values are observed in the middle of the part and on the side surface near the tools.

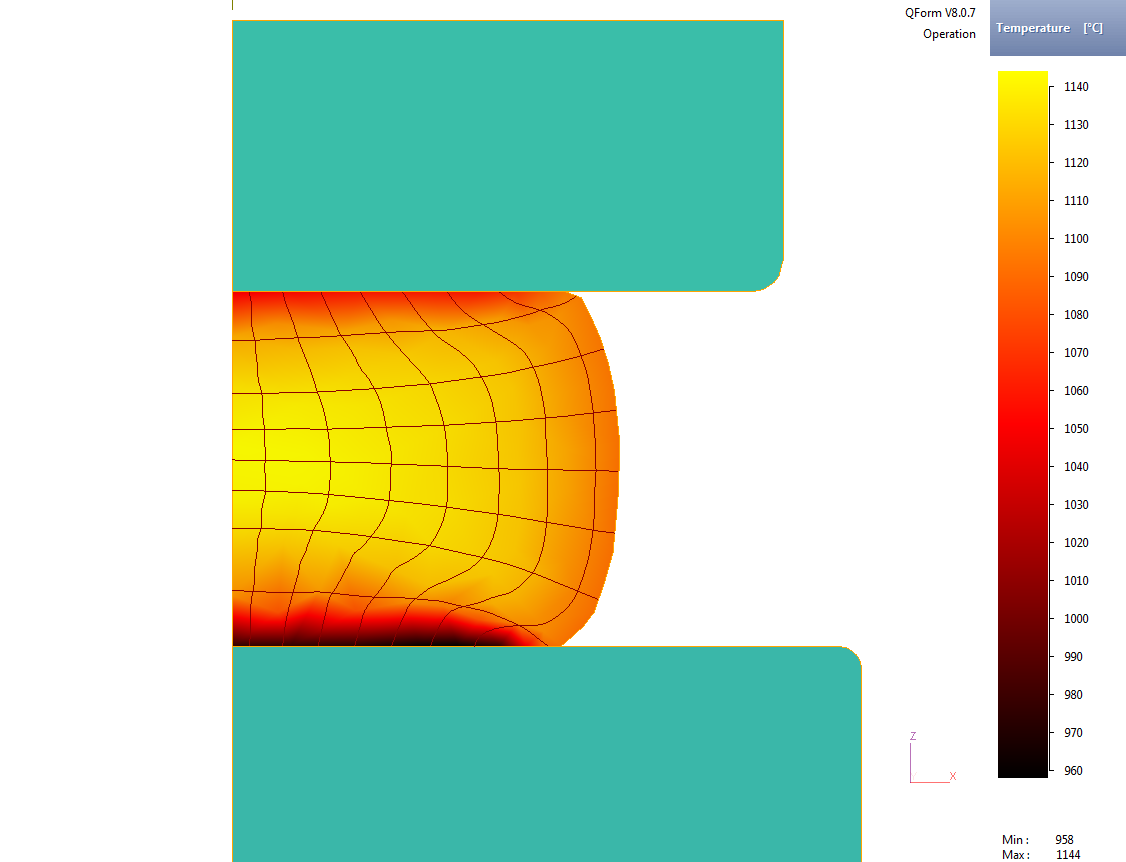


Forging load evolution during 1st operation. Maximum achieved value is equal to about **1 MN**.

Figures below show the material flow lines before and after upsetting:



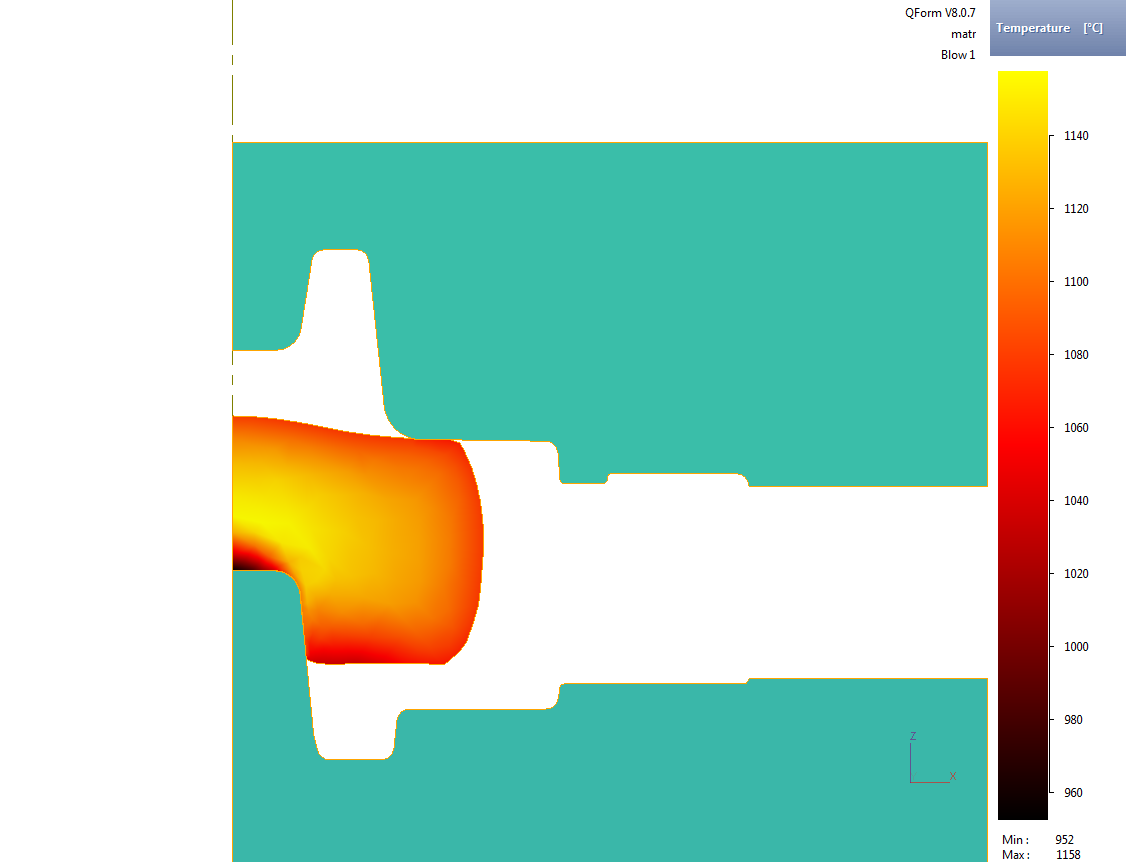
Material flow lines at the beginning of the process

  
Material flow lines after upsetting (1st operation)

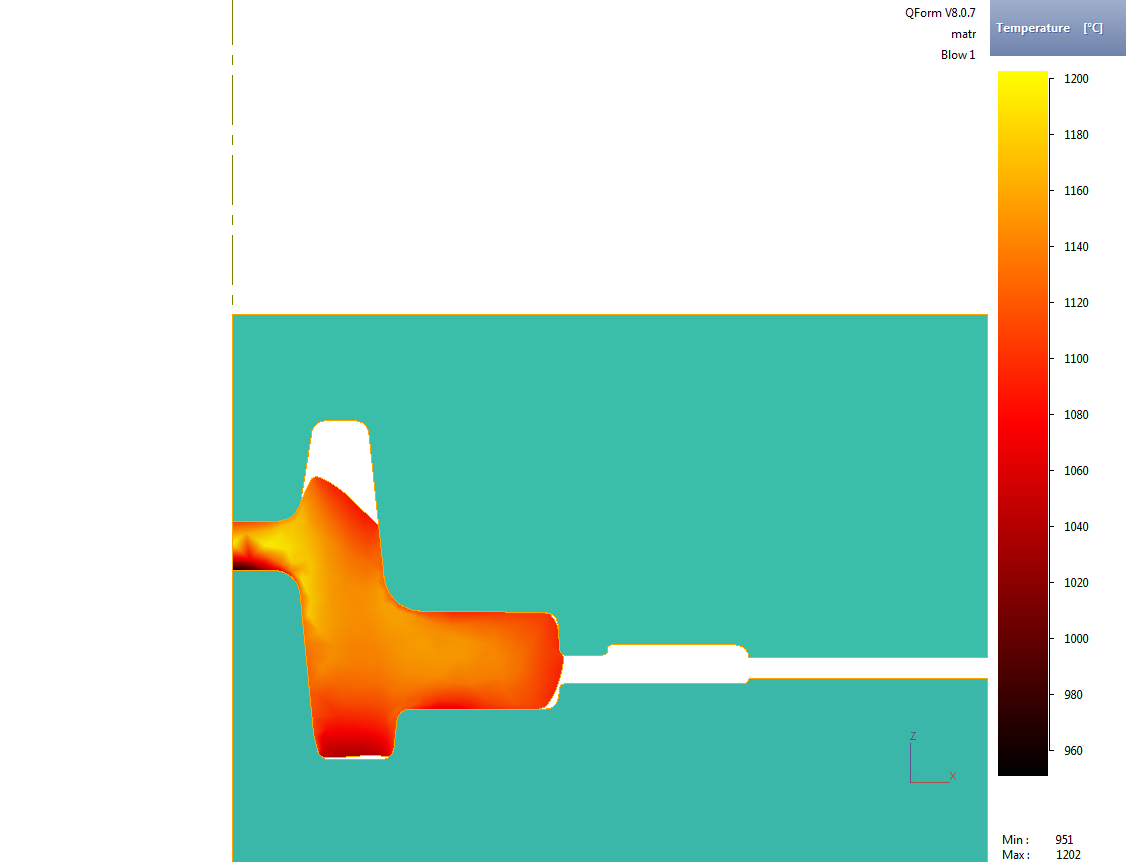
**2nd operation: final die forging**

Assumption taken into consideration:

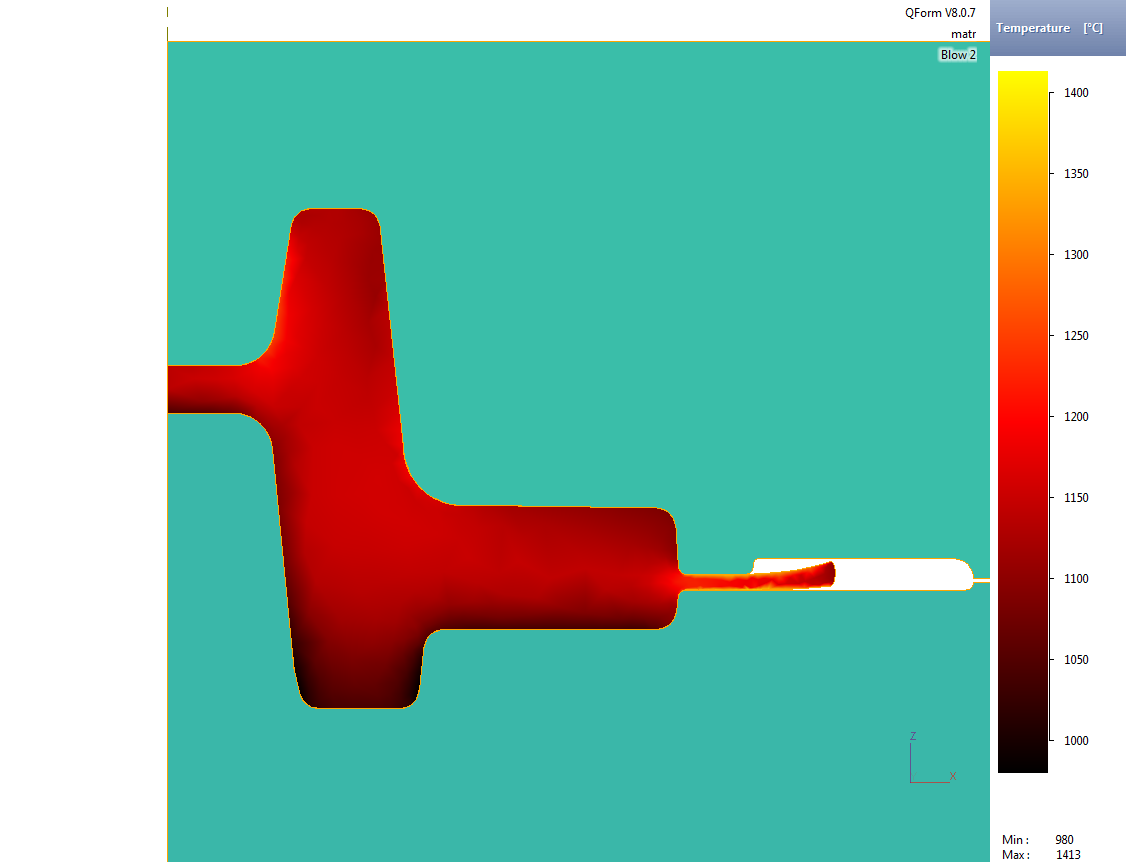
* Different geometry of tools
* Number of blows: **3**
* Final distance between tools: **0.5 mm**



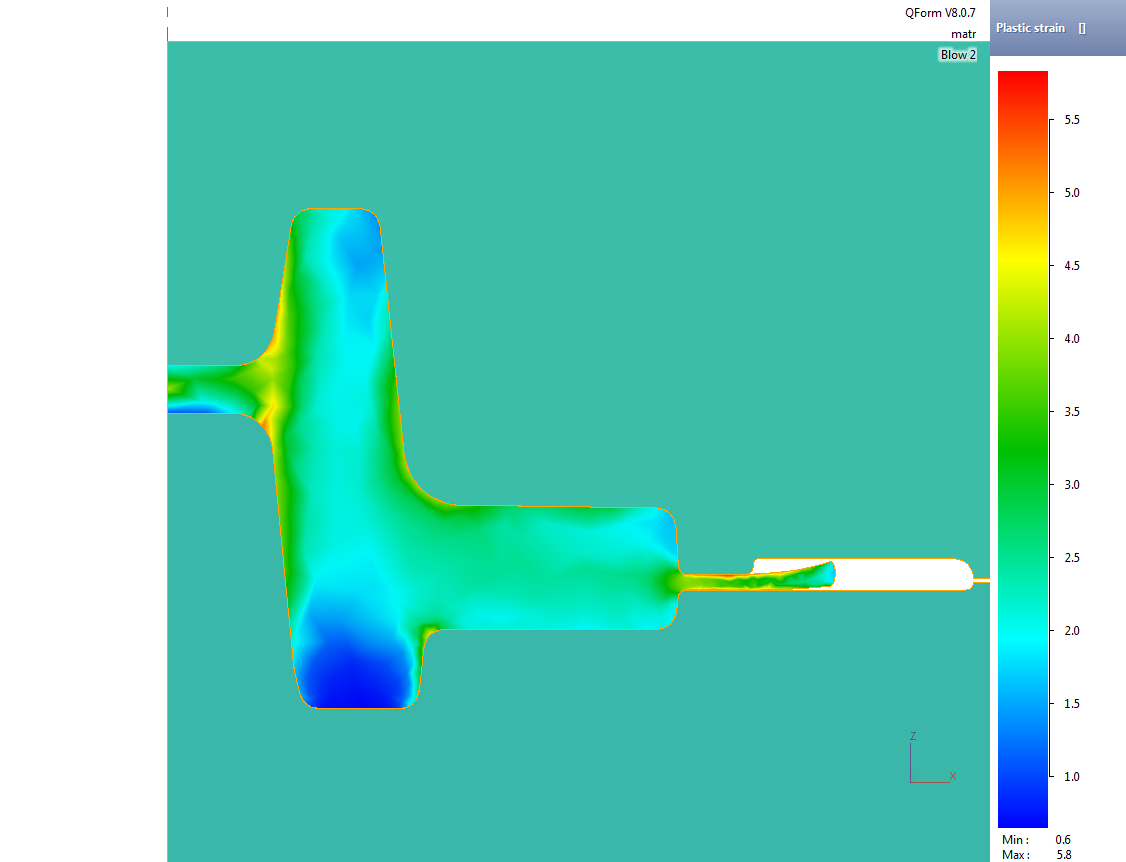
Temperature distribution during 1st blow



Temperature distribution after 1st blow

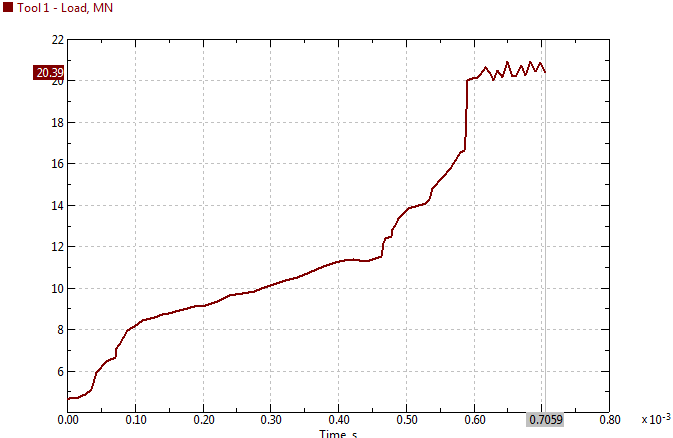


Temperature distribution at the end of the process. Final range of temperature is between 1000 and 1200°C.



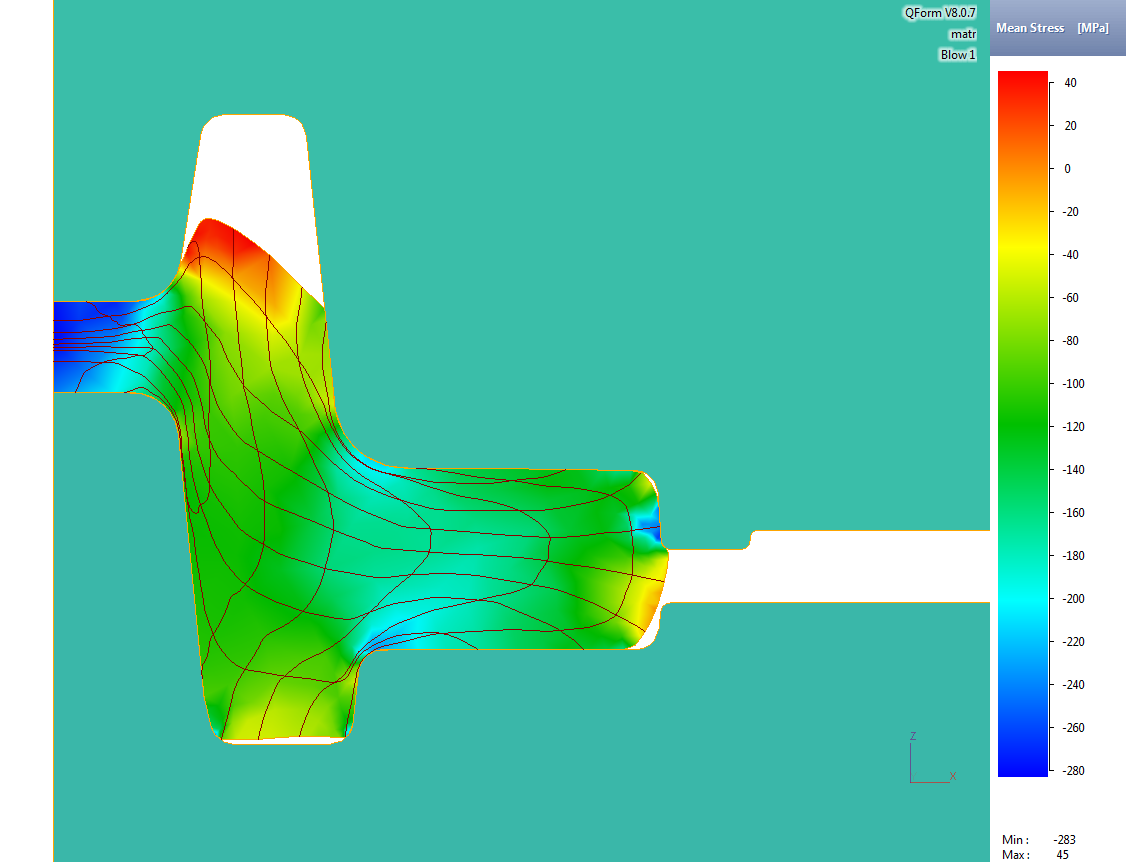
Plastic strain distribution after the forging process.

During the process defects in the structure of final product did not appear. Material flow was correct. The complete filling of the dies could be observed.

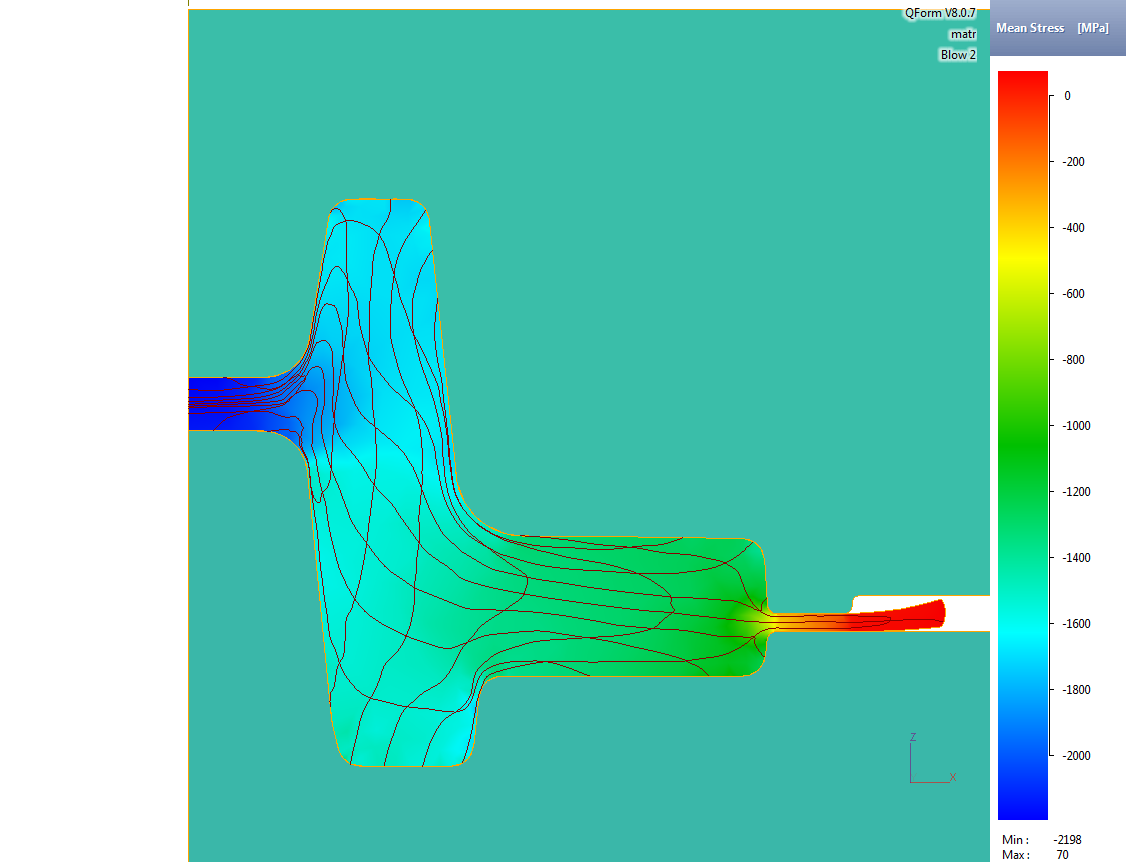


Load evolution during final blow

Maximum value of the load, necessary to achieve the final distance between tools, is equal to about 20,5 MN.



Material flow lines and mean stress distribution during final operation of forging.



Material flow lines and mean stress distribution at the end of the process.

The above analysis showed the correct flow of the material between the dies. The lowest values of mean stress are observed in the area of the bottom of forged part. The highest values of this parameter were in the gutter.

**5. Conclusions**

Forging temperature value has a huge influence on the material flow during closed die forging process. Disadvantage of high temperature of the material is a heating of tools in the time of forging, which could be adverse to their structure.

As a forging equipment a stream-air hammer was chosen, because of higher velocity of the ram in comparison to the press. The number of parts in one is a reason to use a dynamic manufacturing process from an economical point of view.

An operation of primary forging (before final die forging) could decrease a forging load in final operation and change a geometrical details e.g. edge radius, draft angles in final forged part.

*References:*

1. http://multistal.pl/upload/KARTY\_KATALOGOWE/Gatunek\_Stali\_C45\_\_\_1.0503.pdf
2. http://www.simr.pw.edu.pl/var/wwwglowna/storage/original/application/9a2e578128a59cef3dd35c02ea2aa374.pdf
3. http://www.zkp.pl/upload/pdf/matrycowe.pdf