COMPARISON OF SIMULATION PROGRAMMES WITH EXPERIMENTAL TEST AT UPSETTING AND TENSILE TEST

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Abstract

This comprehensive paper deals on comparison of real material experiment, simulation via software Antares and simulation via software SuperForge. The goal of article was verification whether simulation results are authentic to comparison with an experimental results. For this comparison, upsetting and tensile test were selected as compressive and tensile forming mode. Blanks were made of commercialy pure titanium.

Key words

upsetting, tensile test, antares, MSC. SuperForge, forming simulation programme

Introduction

The process of a prediction for forming operation is one of the main work of right production preparation. Technology of forming simulation enables engineers and designers making formed pieces with higher precision of dimension, design die, forming characteristics etc. Therefore it is very important to select the appropriate simulation software. We performed an analyze for two forming simulation programmes to verify their capabilities. Results of this verification are shown in this paper and compared to material experiment.

Methods

Experimental results and simulation results of Antares were taken from [1]. The used workpieces for upsetting forming mode are shown in figure 1. In the figure 2 you can see four workpieces to test by tensile test. Material experiments were made by standard mode on tensile device (at the tensile test) and on hydraulic press (at upsetting).

There was a little confusion with giving input data for material, since for all three experiments were used other material. For material experiment, Poldi Titan 45 (Czechoslovakia titanium alloy) was used. However, as input material in Antares had to be selected Titanium 72 of Antares`s option of materials, because it does not involve more similar material to Poldi Titan 45. Titanium Type-2 was selected from material library of SuperForge as testing material for simulation on SuperForge, since SuperForge`s library does not posess Titanium Grade 1. Titanium. Poldi Titan 45, Titanium 72 and Titanium Type 2 have very similar properties due to their similar chemical compound and properties of all three alloys close to properties of Titanium Grade 1. We used 2D FEM method to simulate both cold forming modes on Antares as well as on SuperForge.

The process of work on Antares and SuperForge is possible to divide into three steps. In the step I, it is giving input data by operator, step II is running process and step III includes evaluation of simulation results. The most important issue is input data at the simulation, whereby depends precision and authenticity of simulation results.

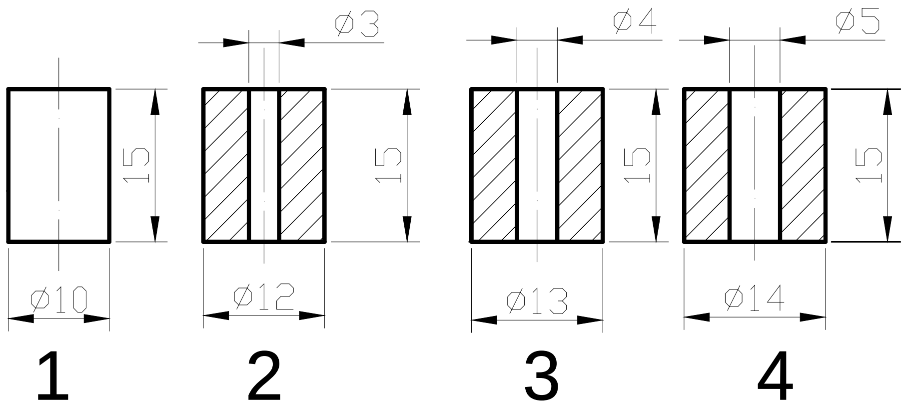

Fig. 1. *Specimens for upsetting*

Required mechanical and physical input data for starting simulation on Antares and SuperForge:

- velocity: 0.5 mm.s^{-1}

- specify heat and heat capacity: 0.56 J/g.K

- coefficient of thermal expansion: 8.6.10^{-6} K^{-1}

- thermal conductivity: 20.8 W/m.K

- Poisson´s Ratio: 0.34

- minimum yield stress: 1.5 GPa

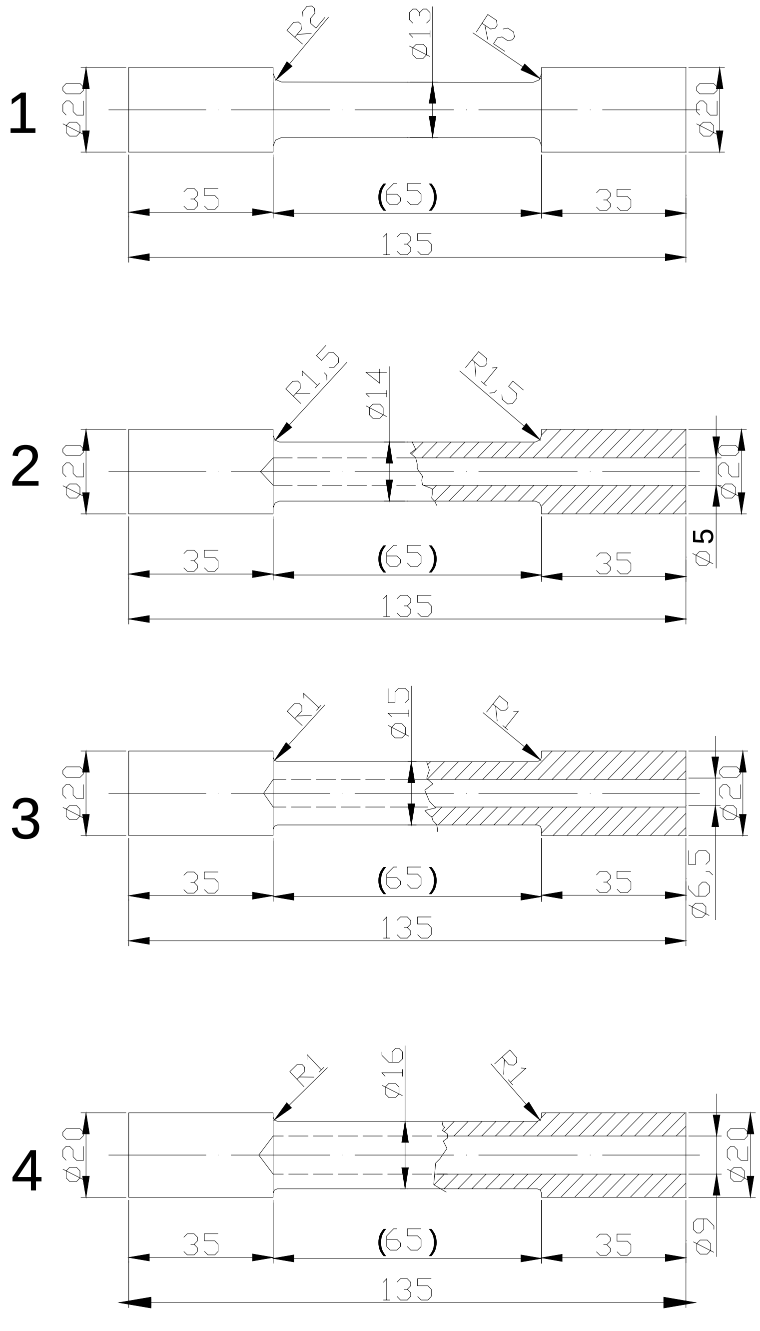

Fig.c2. *Specimens for tensile test*

Results

<u>UPSETTING TEST</u>

The results of upsetting are showed in the tables and depicted in the figures hereinafter.

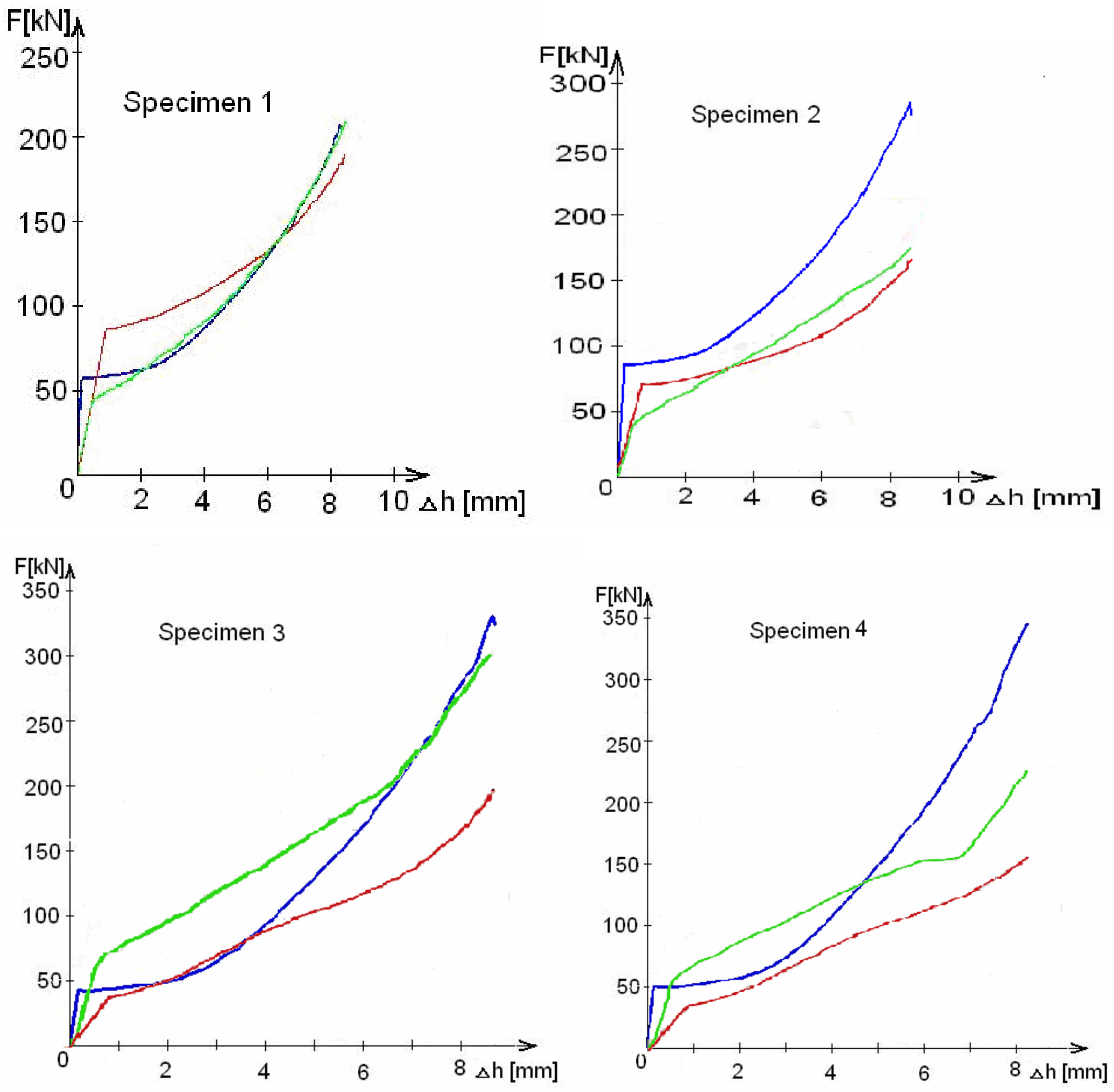

Fig. 3. *Graph of force and strain for all four upsetting specimens*

material experiment

Antares´s simulation

Superforge´s simulation

COMPARISON OF ENGINEERING FORCE FOR UPSETTING Table 1

	1	**2**	**3**	**4**
Δh [mm]	8.5	8.6	8.7	8.2
F [kN] - Experiment	208.0	185.6	260.8	198.4
F [kN] - Antares	190.0	160.0	170.0	150.0
F [kN] - SuperForge	209.0	291.6	333	346

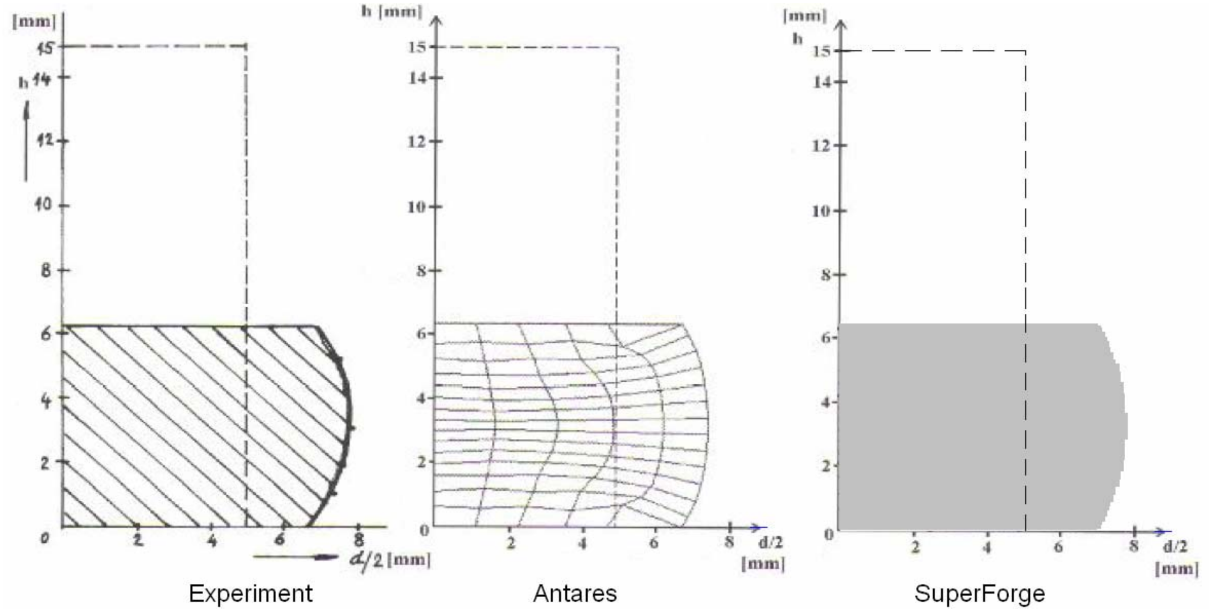

Fig. 4. *Shapes of specimen 1 after upsetting*

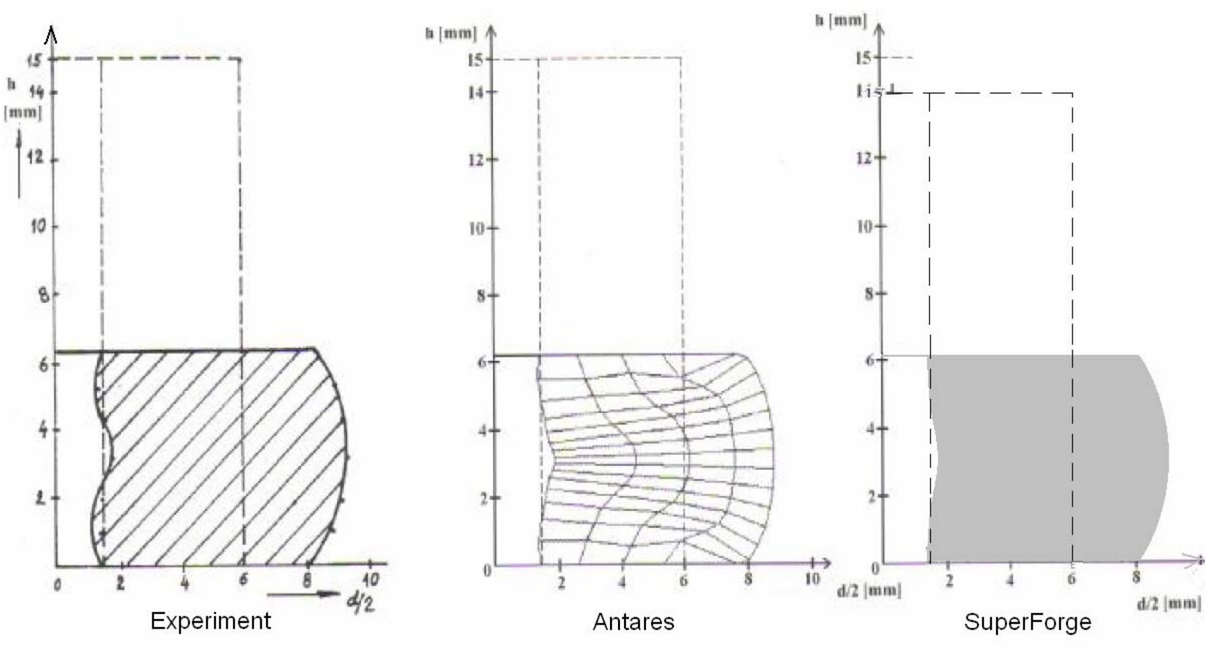

Fig. 5. *Shapes of specimen 2 after upsetting*

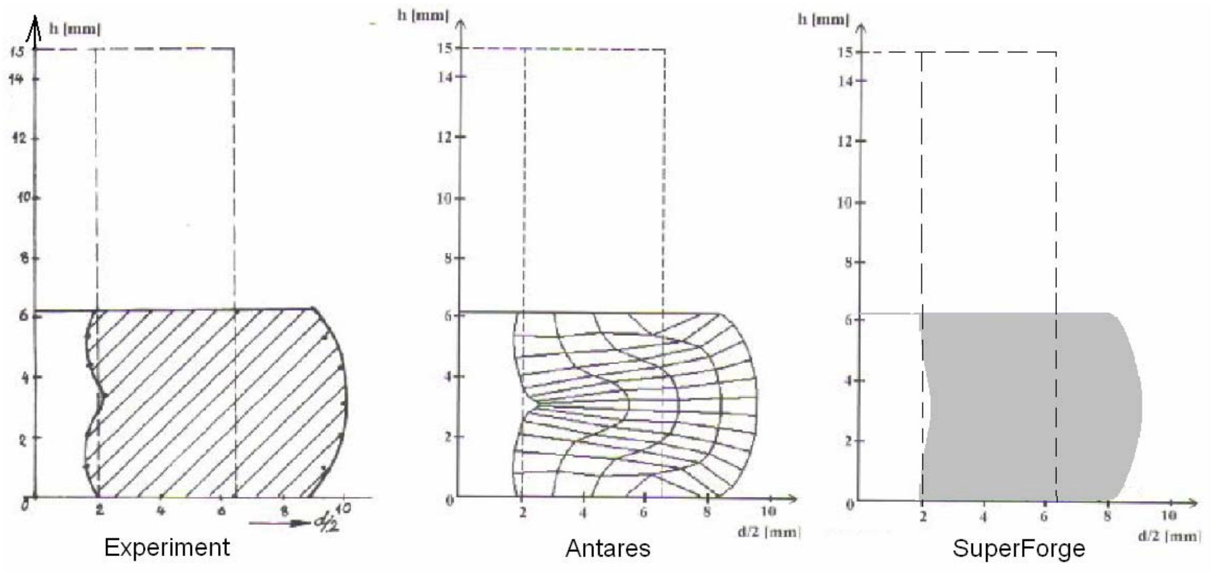

Fig. 6. *Shapes of specimen 3 after upsetting*

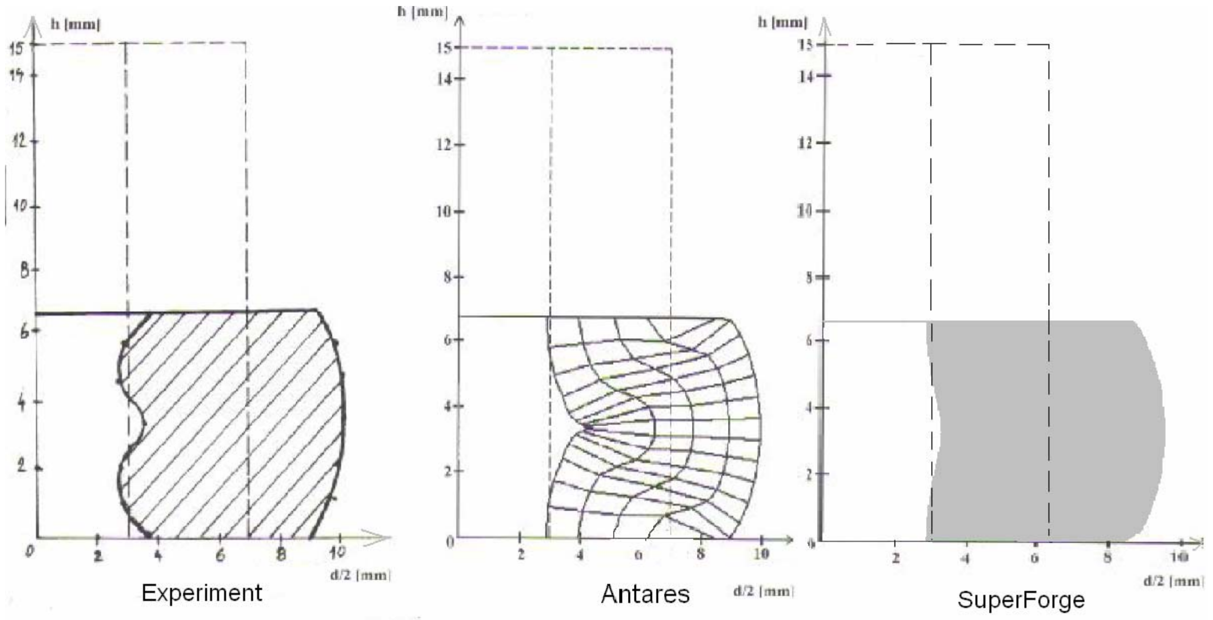

Fig. 7. *Shapes of specimen 4 after upsetting*

The shapes of all specimens for the upsetting in the final stage after upsetting are shown in the figure 4, fig.5, 6 and 7. The results of upsetting were sufficiently precision, at the simulation of shapes. Simulation with Antares provided faithful reproduction of material behavior taking into consideration the shape and strain results and also the size of formed parts at upsetting. The only difference was following: after the upsetting, small discrepancy among inside diameters of all three specimens.

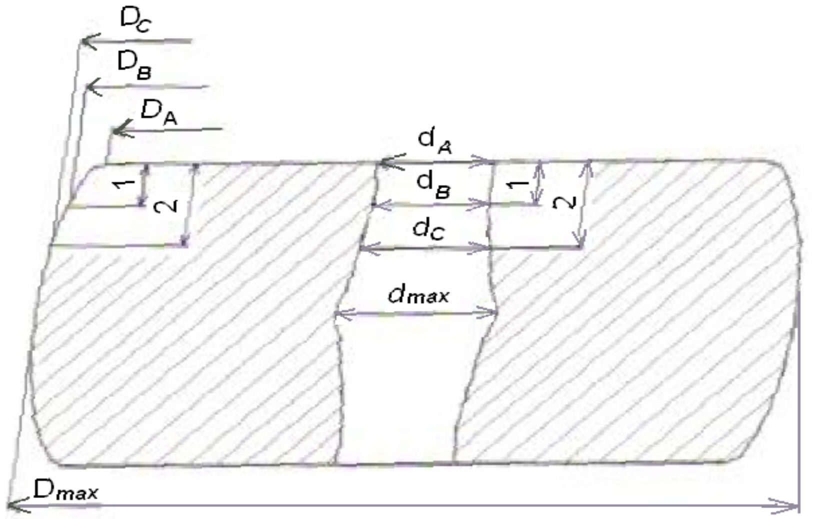

Fig. 8. *Sizes of specimen after upsetting*

This Antares and Superforge simulation helps determine correct mold of blanks after upsetting and we could rely on this programme without the need of real material experiment. The computer experiment (simulation) of upsetting was similar to material experiment. The comparison of material experiment and computer simulation of material flow in upsetting die proved that the results of physical experiment in real conditions are equal to theoretical – mathematical model of forming simulation. However it does not offer a proper achieved values of upsetting forces for all specimens, what to obviously see in the table 1 or in the figure 3, where each color curve means other forming kind.

After comparison of results we could verify usage of simulation programmes Antares and SuperForge. Simulation of upsetting run without problems. There was no serious problem with shapes, sizes, graphs and values of force were approximately precision at Antares`s and SuperForge`s simulation. Evaluation of the results showed that the highest achieved forces are on the places where SuperForge was used to simulate and the lowest achieved values of forces occurred at Antares simulation.

COMPARISON OF DIAMETERS FOR UPSETTING SPECIMEN 1 Table 2

	D_A	D_B	D_C	D_{max}
Experiment	13.800	14.893	15.500	15.815
Antares	14.080	14.780	15.350	15.490
SuperForge	13.984	14.800	15.288	15.635

COMPARISON OF DIAMETERS FOR UPSETTING SPECIMEN 2 Table 3

	D_A	D_B	D_C	D_{max}
Experiment	16.600	17.800	18.460	18.610
Antares	16.320	17.590	18.440	18.520
SuperForge	16.833	17.98	18.450	18.531

	d_A	d_B	d_C	d_{max}
Experiment	2.530	2.705	2.825	3.700
Antares	2.940	2.880	3.470	3.900
SuperForge	3.580	3.300	3.988	4.550

COMPARISON OF DIAMETERS FOR UPSETTING SPECIMEN 3 Table 4

	D_A	D_B	D_C	D_{max}
Experiment	17.900	18.900	19.820	19.925
Antares	17.510	19.140	19.970	20.160
SuperForge	18.040	18.850	19.730	19.540

	d_A	d_B	d_C	d_{max}
Experiment	3.790	3.400	3.360	4.470
Antares	3.750	3.410	3.830	5.140
SuperForge	4.75	4.950	5.380	5.600

COMPARISON OF DIAMETERS FOR UPSETTING SPECIMEN 4 Table 5

	D_A	D_B	D_C	D_{max}
Experiment	18.600	19.890	20.110	30.360
Antares	18.330	19.530	20.150	20.720
SuperForge	18.680	19.500	20.100	20.220

	d_A	d_B	d_C	d_{max}
Experiment	6.140	5.770	5.655	7.060
Antares	5.900	5.930	6.850	8.340
SuperForge	5.450	5.760	6.500	6.400

TENSILE TEST

Uniaxial tensile tests were performed on a hydraulic test machine. The stress and strain measurement and the resultant mechanical properties of strength (yield strength and ultimate tensile strength), failure or fracture stress and ductility (quantified as strain to failure) was provided as a computer output by the control unit of the test machine.The room temperature tensile properties of titanium specimens are sumarized in the table 6. Dependance of a force and strain for tensile test is depicted in the figure 3.

COMPARISON OF ENGINEERING FORCE AT EXPERIMENT AND BOTH SIMULATIONS
Table 6

Specimen No.	1	2	3	4
Experiment				
R [%]	40.99	38.29	36.87	33.88
Δl [mm]	17.00	14.80	15.82	19.50
F_{YS} [kN]	43.6	49.2	52.0	40.0
F_{US} [kN]	57.8	62.2	66.6	61.2
F_R [kN]	37.6	44.0	46.4	45.6
Antares				
R [%]	48.33	40.64	35	40.81
Δl [mm]	20	20	68	68
F_{YS} [kN]	31	63	36	34
F_{US} [kN]	55	67	41	40
F_R [kN]	18	46	27	20
SuperForge				
R [%]	72.58	59	66.93	48.75
Δl [mm]	30.00	13.00	19.72	14.87
F_{YS} [kN]	NM	NM	NM	NM
F_{US} [kN]	118	118	126	121
F_R [kN]	0	0	9	0

NM* - not measurable

Δl - elongation

R – reduction in area

F_{YS} – force of yield strength

F_{US} – force of ultimate strength

F_R – force of rupture

Unlike upsetting, uniaxial tensile test was very uncovincing. At least, the values of elongation between real material experiment and SuperForge was somewhat similar and we a little succed also in determination of shape between real material experiment and Antares. A careful study of the tensile properties reveals that the Antares simulation specimen has marginally higher values of elongation when compared to the real test specimen. SuperForge had again enhanced values of forces when compared to the real material experiment.

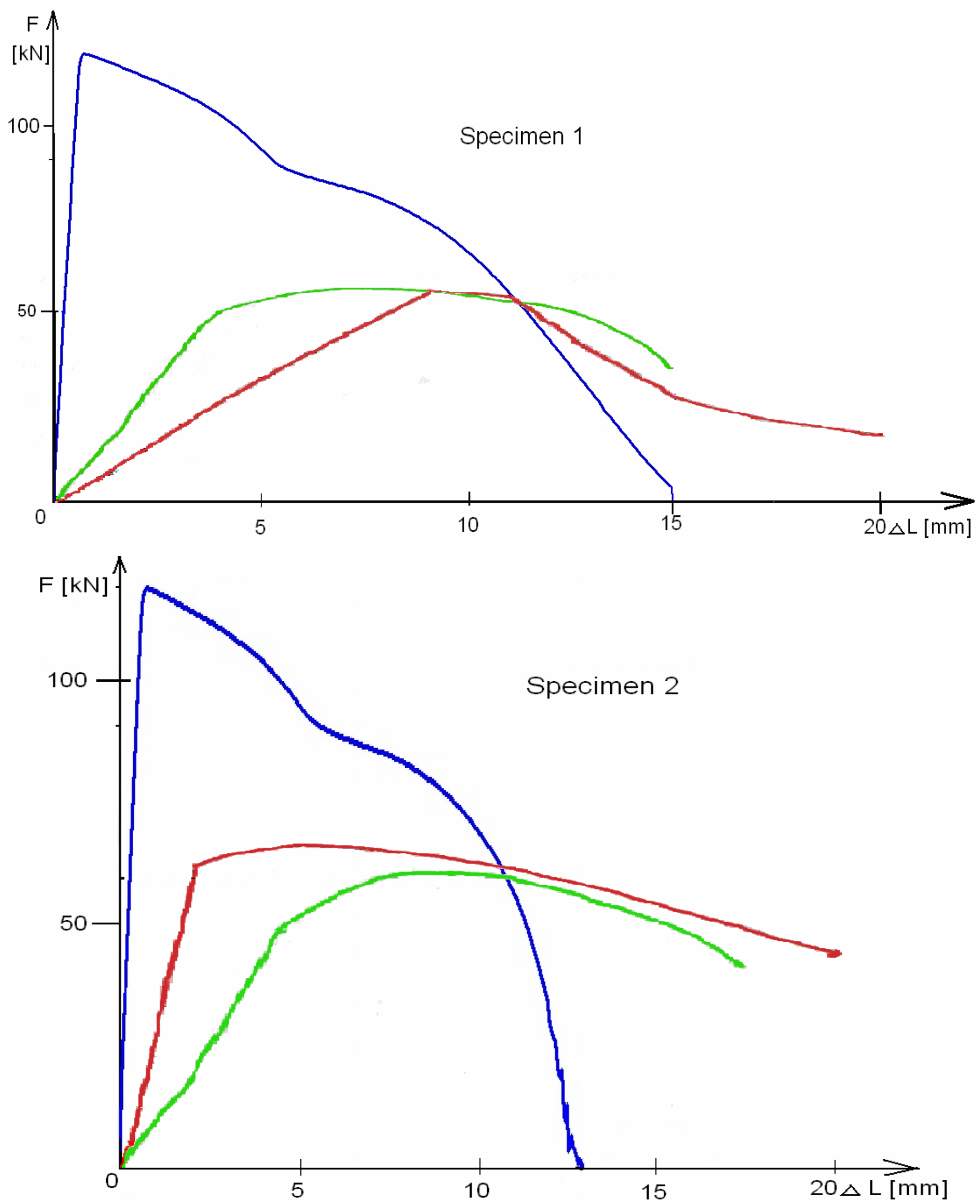

Fig. 9 Graphs of force and strain for tensile specimens

material experiment

Antares´s simulation

Superforge´s simulation

Using Antares and SuperForge softwares we cannot be satisfied with simulation results at tensile tests. Specifically: tensile specimens never tore, but they were only tensed to the moment when it had to arise a failure. The failure did not occur, beside it, computer wrote error. Simply, we can state these simulation programmes are not made to perform formability tests. Simulation experiment based on the real material tests of tensile specimens in die with fixed ends showed that the process of material behavior at the tensile test to determine fundamental formability can be precisely found only thank's to real material experiment.

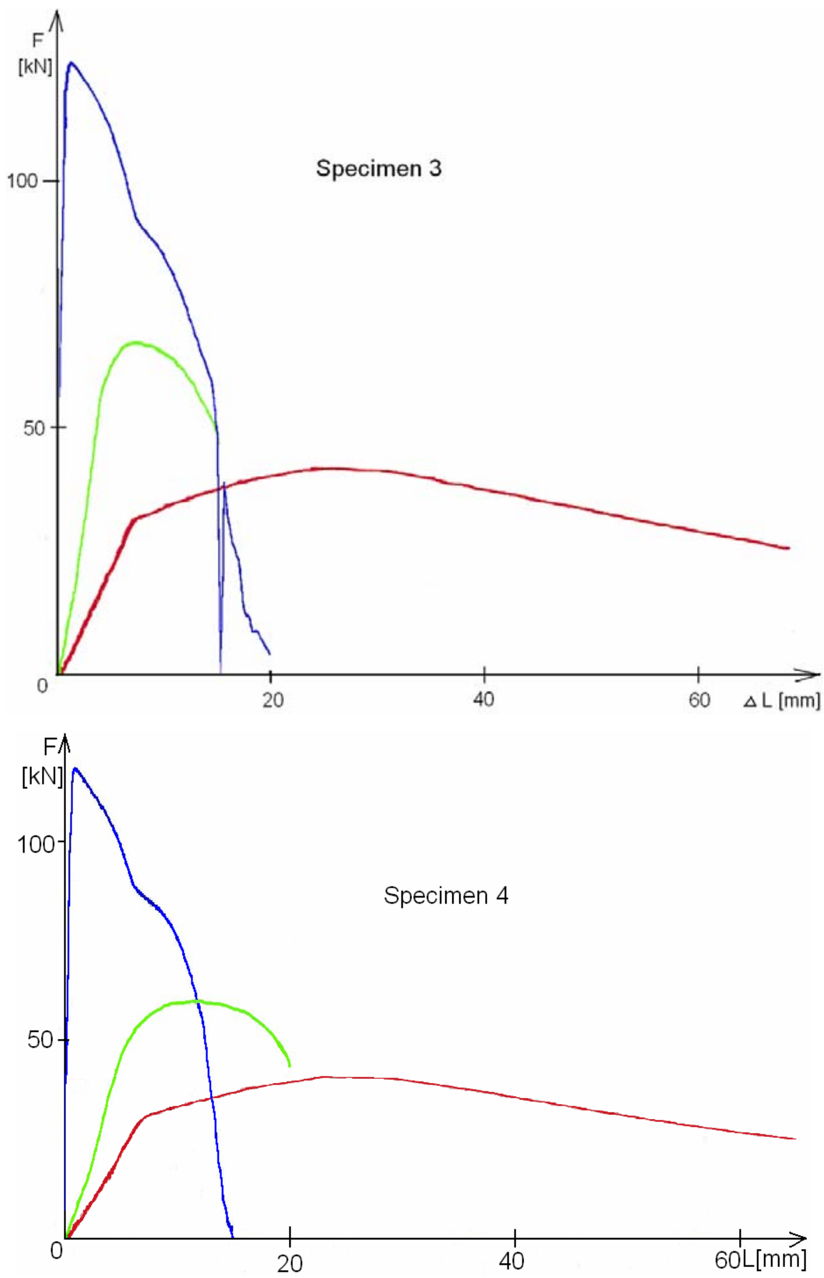

Fig. 10. *Graphs of force and strain for tensile specimens*

material experiment

Antares´s simulation

Superforge´s simulation

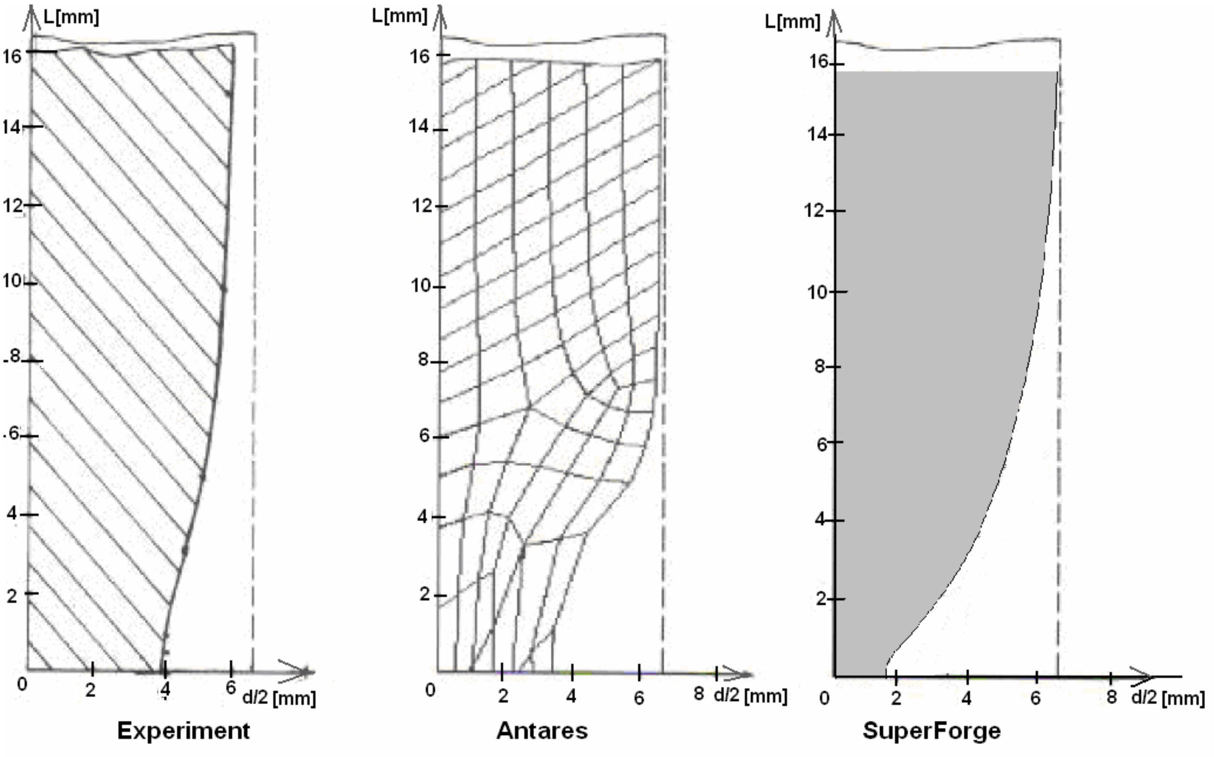

Fig. 11. Shape of specimen 1 after tensile test

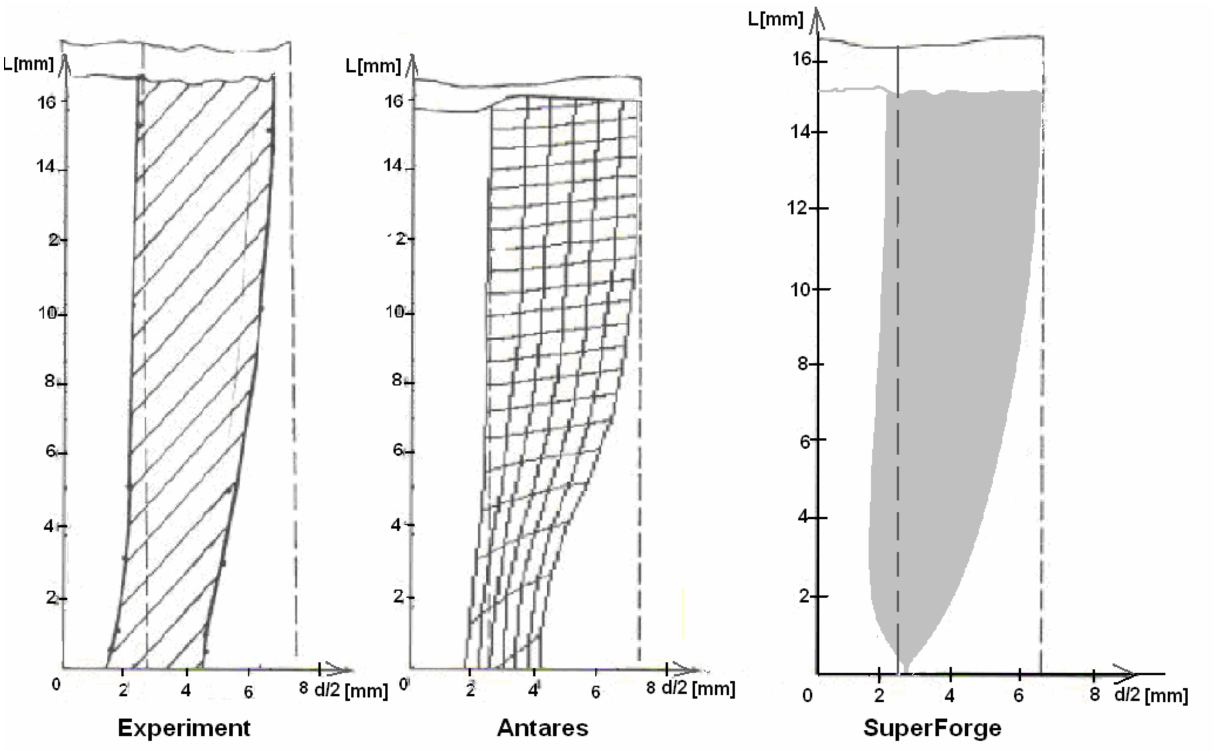

Fig. 12. Shape of specimen 2 after tensile test

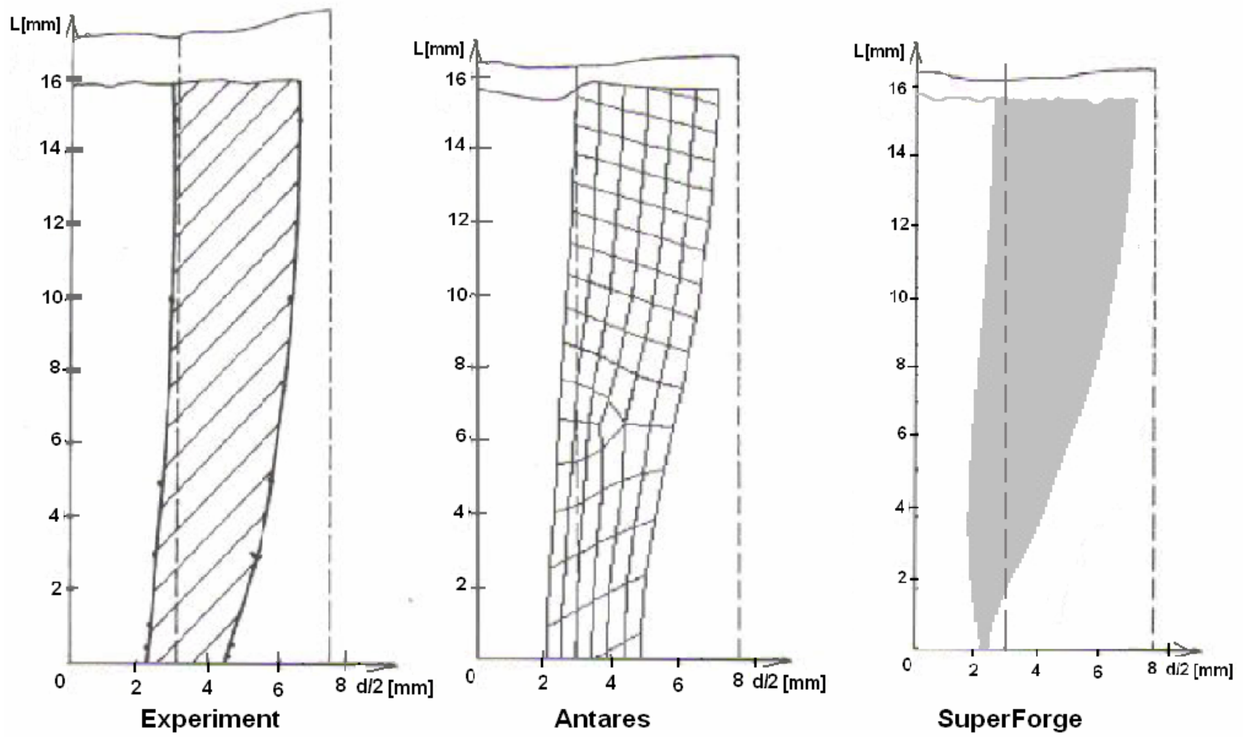

Fig. 13. *Shape of specimen 3 after tensile test*

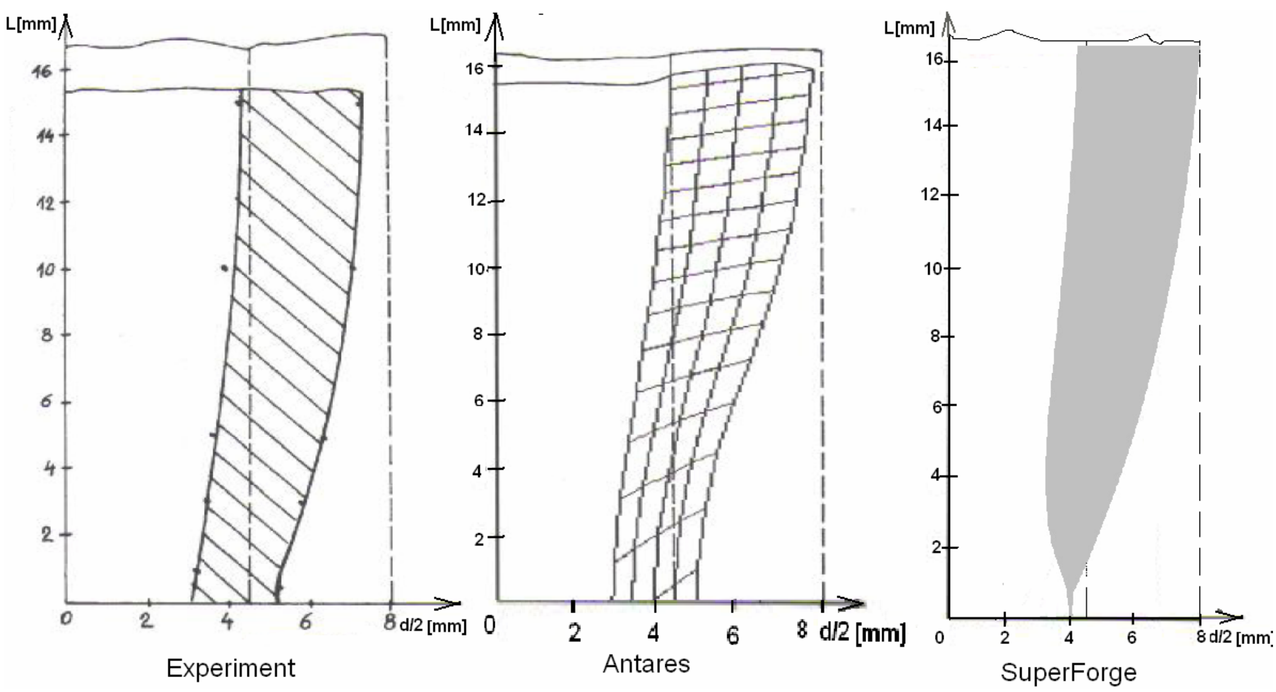

Fig. 14. *Shape of specimen 4 after tensile test*

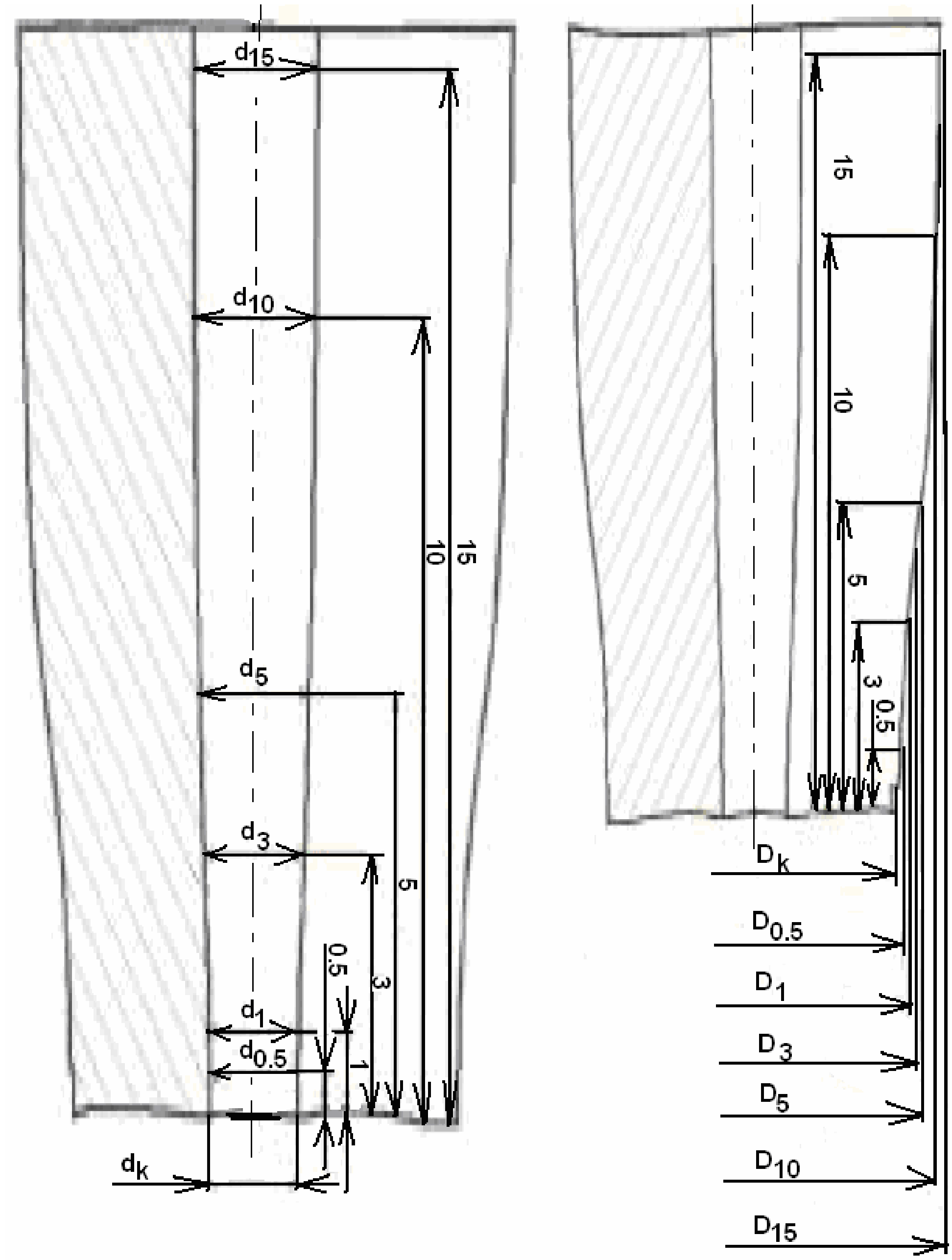

Fig. 15. *Sizes of tensile specimen after tensile test*

COMPARISON OF DIAMETERS FOR TENSILE SPECIMEN 1 — Table 7

	D_K[mm]	**$D_{0.5}$[mm]**	**D_1 [mm]**	**D_3 [mm]**	**D_5 [mm]**	**D_{10} [mm]**	**D_{15} [mm]**
Experiment	7.671	7.715	7.920	8.900	9.810	11.100	11.600
Antares	6.720	6.720	7.570	8.520	10.310	12.230	12.530
SuperForge	3.564	3.980	4.200	8.410	9.790	11.050	12.600

COMPARISON OF DIAMETERS FOR TENSILE SPECIMEN 2 Table 8

	d_K[mm]	$d_{0.5}$[mm]	d_1 [mm]	d_3 [mm]	d_5 [mm]	d_{10} [mm]	d_{15} [mm]
Experiment	3.60	3.66	3.70	3.85	4.20	4.50	4.70
Antares	3.00	3.15	3.54	3.82	3.91	4.20	4.50
SuperForge	5.30	5.03	4.10	3.80	4.07	4.70	4.89

	D_K[mm]	$D_{0.5}$[mm]	D_1 [mm]	D_3 [mm]	D_5 [mm]	D_{10} [mm]	D_{15} [mm]
Experiment	8.64	8.68	8.88	9.73	10.60	12.10	12.80
Antares	8.31	8.3	8.57	8.98	9.79	11.55	12.24
SuperForge	5.74	5.98	7.05	8.80	11.03	11.08	12.50

COMPARISON OF DIAMETERS FOR TENSILE SPECIMEN 3 Table 9

	d_K[mm]	$d_{0.5}$[mm]	d_1 [mm]	d_3 [mm]	d_5 [mm]	d_{10} [mm]	d_{15} [mm]
Experiment	4.69	4.85	4.89	5.06	5.30	5.70	6.10
Antares	4.45	4.68	4.75	4.82	4.82	5.25	5.49
SuperForge	4.73	4.42	4.16	4.05	4.15	4.42	5.80

	D_K[mm]	$D_{0.5}$[mm]	D_1 [mm]	D_3 [mm]	D_5 [mm]	D_{10} [mm]	D_{15} [mm]
Experiment	9.47	9.67	9.85	10.70	11.50	12.70	13.20
Antares	9.75	9.95	10.12	10.12	10.27	11.41	12.84
SuperForge	4.96	5.20	5.43	7.76	8.34	12.12	13.6

COMPARISON OF DIAMETERS FOR TENSILE SPECIMEN 4 Table10

	d_K[mm]	$d_{0.5}$[mm]	d_1 [mm]	d_3 [mm]	d_5 [mm]	d_{10} [mm]	d_{15} [mm]
Experiment	6.53	6.56	6.60	6.70	7.10	7.70	8.30
Antares	5.47	5.50	5.71	5.86	6.05	6.87	7.58
SuperForge	7.70	7.55	7.80	7.04	7.78	8.20	8.64

	D_K[mm]	$D_{0.5}$[mm]	D_1 [mm]	D_3 [mm]	D_5 [mm]	D_{10} [mm]	D_{15} [mm]
Experiment	10.58	10.60	10.80	11.50	12.30	13.70	14.30
Antares	9.47	9.52	10.11	10.35	11.3	12.95	14.46
SuperForge	8.20	8.36	8.58	10.28	11.10	13.95	15.70

Conclusion

The verification of the function of design forming process for two different forming modes in the experiments showed that Antares simulation programme can be used for simulation of upsetting. It can replace material experiments, however not for tensile test, where it is better use real material experiment to determine formability. MSC. SuperForge simulation programme can be used for forming simulation under reservations. This software is more suitable for tradesmen, small and perhaps also for mid sized companies, where they do not claim precision scientific output. This programme is not sufficiently precise for scientists, universities, research or other demanding usage. Tensile test with SuperForge as well as with Antares was not successful and simulation cannot replace material experiments.

On the basis of experience with these simulation programmes, we can state that results of simulation depend on various factors as are for instance forming mode, input data as forming press, its velocity, coefficient of friction, used material, used element size or whether we use 2D or 3D simulation and Finite Element Method (FEM) or Finite Volume Method (FVM) to obtain simulation results. Analyze of these factors is not easy therefore they are researched nowadays for every new product. The accuracy and parameters of each forming operation has main influence on accuracy of formed parts. Nowadays these characteristics can be researched with the help of computers (numerical simulation) where technological parameters can be changed and optimal conditions of forming and shape of formed pieces can be achieved.

Acknowledgements

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