Dr. Michael Twickler, Dr. Gerhard H. Arfmann CPM GmbH, Herzogenrath

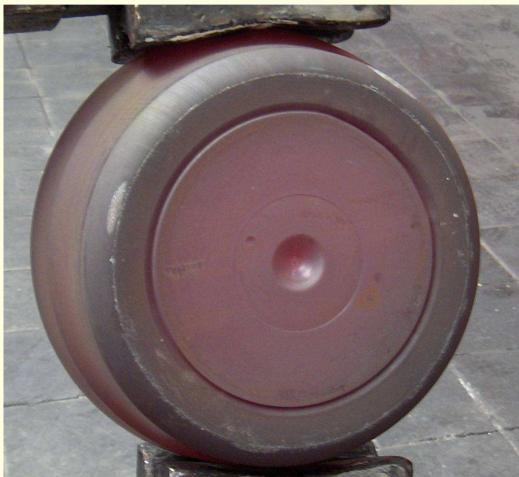
Validation: By whom? Why? How? A) Software developer - to check the correct implementation of the algorithms used - to check the internal data management - to check new approaches i.e. material modelling, friction, damage - etc. - by comparison with analytic solution (for simple applications) - by examining the internal data transfer - by using links to external data processing software to analyse local results - etc. **B)** Software user - Increase the acceptance of simulation as a reliable tool in process design - Increase the understanding of the local and global results of a simulation - In crease the technological understanding of the processes - etc. BY - comparison of global results with available measured process data - checking the volume constancy during simulation - comparison of the simulated geometry with measurements of real parts - comparison with local defects like folding or other marks - etc.

Example 1: Inconel 718 disc with a folding

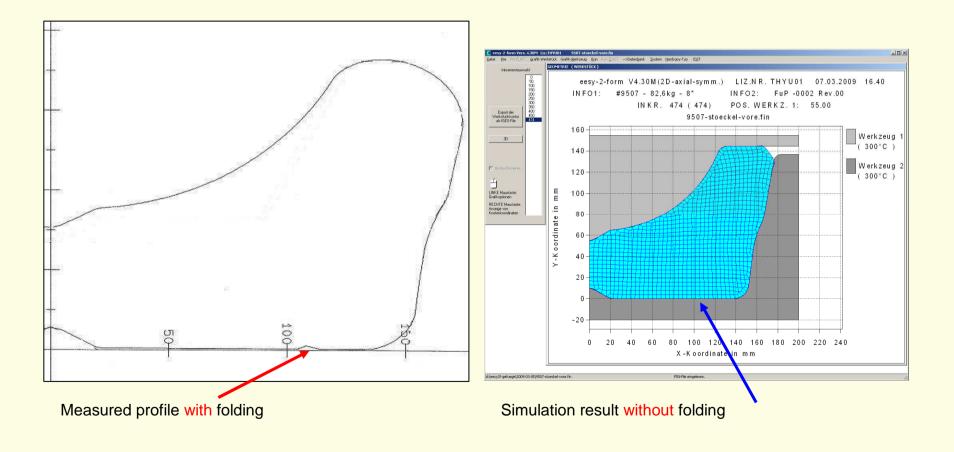
Problem:

folding on the bottom of the part after the second operation.

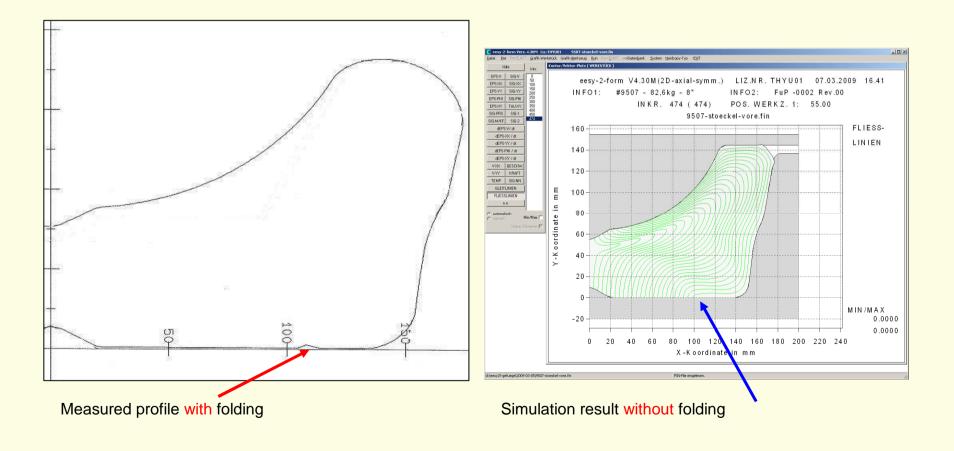
Question: Is the simulation able to show the same folding so that it can be used for optimizing the process?

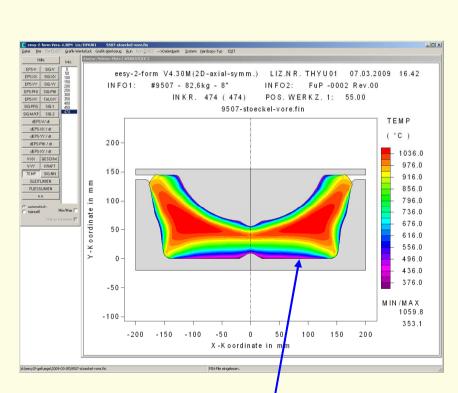


Example 1: Inconel 718 disc with a folding



Example 1: Inconel 718 disc with a folding





Example 1: Inconel 718 disc with a folding

Temperature gradient at the bottom (< 500°C)

	RIAL:	2.4000, 110011	01110, 00010	70 [°C], 0.1-10 [11000,00-10		(c) iax. 80 Char.)
о А(uswahl einer	Fließkurvenbe	schreibung	Hensel-Spitt	el		<u></u>
		0.00000 0.00000 0.00000 0.00000		0.00000 0.00000 0.00000 0.00000			
_ ото Г	abellarische I PHIPKT	Definition von l	PHI / KF	10.0	0.00	0.00	
		0.100		10.0	0.00	0.00	
	PHIPKT Anzahl	0.100	1.00				
	PHIPKT Anzahl emperaturen	0.100	1.00	4 🐳			_
	PHIPKT Anzahl emperaturen Temp. 1:	0.100 4 ÷	1.00 5 🛃 950.00	4 🔹			•
	PHIPKT Anzahl emperaturen Temp. 1: Temp. 2:	0.100 4 ÷ 950.00 980.00	1.00 5 -	4 ਦ 950.00 980.00			
	PHIPKT Anzahl emperaturen Temp. 1: Temp. 2: Temp. 3:	0.100 4 ÷ 950.00 980.00 1010.00	1.00 5 950.00 980.00 1810.00	4 ÷ 950.00 980.00			
	PHIPKT Anzahl emperaturen Temp. 1: Temp. 2: Temp. 3: Temp. 4:	0.100 4 ÷ 950.00 980.00 1010.00	1.00 5	4 ÷ 950.00 980.00			
	PHIPKT Anzahl emperaturen Temp. 1: Temp. 2: Temp. 3: Temp. 4: Temp. 5:	0.100 4 ÷ 950.00 980.00 1010.00	1.00 5	4 ÷ 950.00 980.00			

Applied YS – strain curve without data at low temperatures Lowest values are at 950°

Example 1: Inconel 718 disc with a folding

ATERIAL:	INCO 718 erweite	ert um tiefere "	Temperaturen				
					(max. 80 Char.)		
Auswahl eine	er Fließkurvenbesc	hreibung	Hensel-Spittel		7		
						Datei Bre Pre-ELAST Grafik-Werkstüt	uz.11111011 - 9307-tatoská vyměli kenecím lenádok: Garli Azenábas (par. 1571–1571 - – Sokrégerk: Sjoken: Berkoop-Tijo: ESIT (El Gorennie: (Weststülice)
						0 100 150	eesy-2-form V4.30M(2D-axial-symm.) LIZ.NR. THYU01 07.03.2009 1
	0.00000		0.00000			150 200 250	INFO1: #9507 - 82,6kg - 8" INFO2: FuP -0002 Rev.00
	0.00000		0.00000			Export der Verfetslickkontur ein IGES File 400	INKR. 474 (474) POS.WERKZ.1: 55.00 9507-stoeckel-vor-fk-erwe.fin
	0.00000		0.00000			dis IGES-File	160
						30	
	0.00000		0.00000				
						History Elemente	120
Tabellarische	e Definition von PH	II / KF				UNKE Maustaster	E 100
PHIPKT	0.100	1.00	10.0	0.00	0.00	Grafikoptionen RECHTE Maustaste:	
Anzahl							
Temperature	en 10 🕂	5 🕂	5 🕂	0 🗧	0 🕂		
Temp. 1:	316.00	900.00	900.00				
	472.00	950.00	950.00				
Temp. 2:	538.00	1000.00	1000.00				20
Temp. 2: Temp. 3:	330.00	1100.00	1100.00				
		1100.00					
Temp. 3:	650.00	1150.00	1150.00				
Temp. 3: Temp. 4:	650.00 760.00		1150.00				-20-
Temp. 3: Temp. 4: Temp. 5:	650.00 760.00		1150.00		_		
Temp. 3: Temp. 4: Temp. 5:	650.00 760.00		1150.00				

YS – Strain curves added at lower temperatures

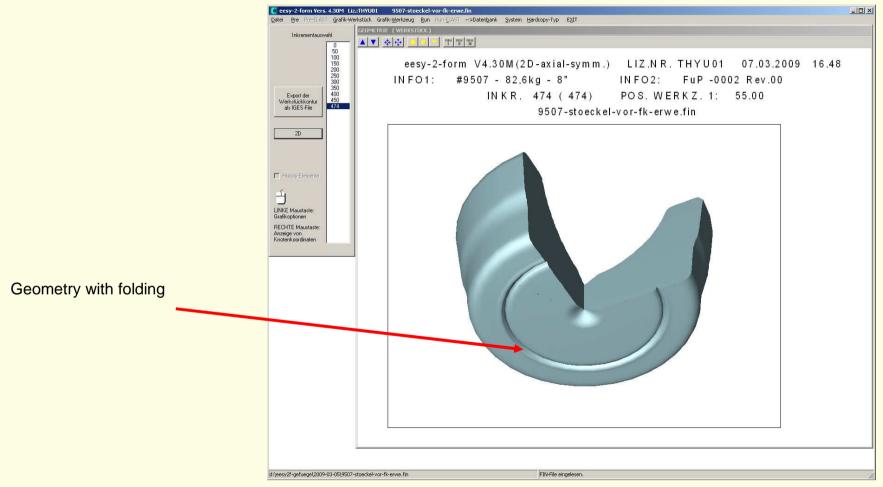
With the added data the simulation shows the folding

Example 1: Inconel 718 disc with a folding

,	(max. 80 Char.	
Auswahl einer Fließkurvenbeschreibung	Hensel-Spittel	
	,	C essy-2-form Vers-4-30M Liz-111/1001 9507-stoeckel van-fik-erwedin Detei die Pre-Extor gelitivereistuk, Galit-Werksaug Bun Enrop/ArtRotenberk, Soten Berkany-Tro Egit
		Hite Irizz Kantur/Vektor-Pols (WERSTRUC)
		eesy-2-form V4.30M(2D-axial-symm.) LIZ.NR.THYU01 07.03.2009 16
0.00000	0.00000	Тереми 300/и тереми 300/и 10 FO1: #9507 - 82,6kg - 8" INFO2: FuP -0002 Rev.00
		EPSKY TAUKY 30 IN K. 474 (474) POS. WERKZ. I: 55.00
0.00000	0.00000	SIGM/KF SIG2
0.00000	0.00000	dEPS-WX/d
0.00000	0.00000	алуула алуунда 140-
,		dEPSXY / a VXX GESCHW/
Tabellarische Definition von PHI / KF		VYY R84T TEMP SIGNAL
raboliansche Delinition von Fint / Kr		GLITIANEN E 100-
PHIPKT 0.100 1.00	10.0 0.00 0.00	
Anzahl 10 10		C monuel Min/Max E and Min/Max E
Temperaturen 10 + 5 +	5 🗧 0 🗧 0 🗧	
Temp. 1: 316.00 900.00	900.00	
Temp. 2: 472.00 950.00	950.00	
		20-
	1000.00	
Tomp. c.	1100.00	
Temp. 4: 650.00 1100.00		0-
Temp. 4: 650.00 1100.00 Temp. 5: 760.00 1150.00	1150.00	0 -20
Temp. 4: 650.00 1100.00		міл/м
Temp. 4: 650.00 1100.00 Temp. 5: 760.00 1150.00	1150.00	-20 -20 0 20 40 60 80 100 12 140 160 180 200 220 240
Temp. 4: 650.00 1100.00 Temp. 5: 760.00 1150.00	1150.00	-20 -20 -20 -20 -20 -20 -20 -20 -20 -20

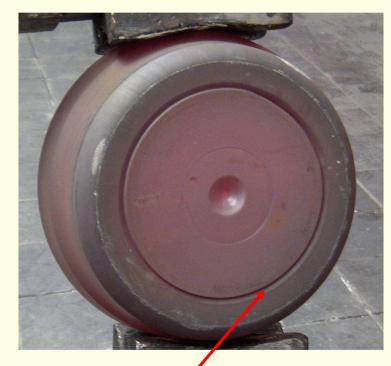
YS – Strain curves added at lower temperatures

With the added data the simulation shows the folding

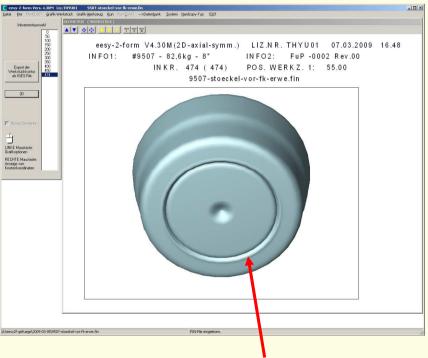


Example 1: Inconel 718 disc with a folding

Example 1: Inconel 718 disc with a folding



Forged disc with folding



Simulation result showing the folding

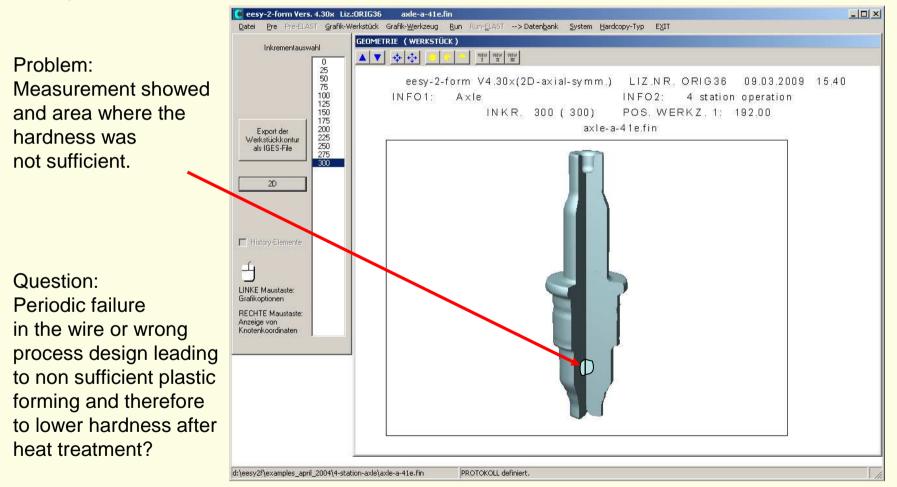
Example 1: Inconel 718 disc with a folding

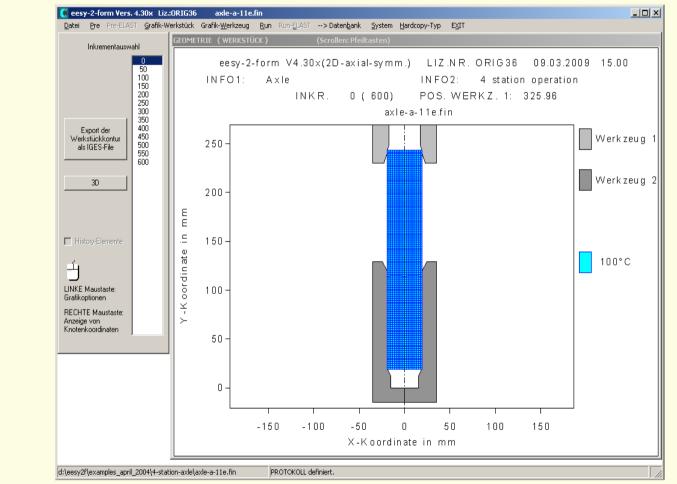
Fazit:

The simulation is sensitive enough to react to differences in the material data.

With correct material data the position and the size of the folding will be predicted correctly.

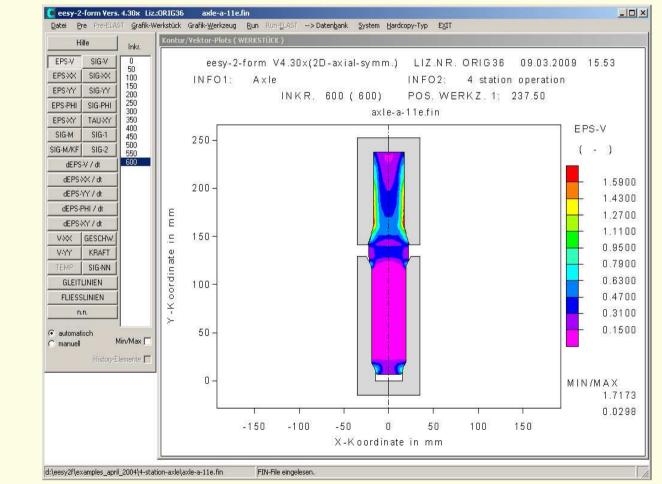
Example 2: Shaft with non sufficient hardness





Example 2: Shaft with non sufficient hardness

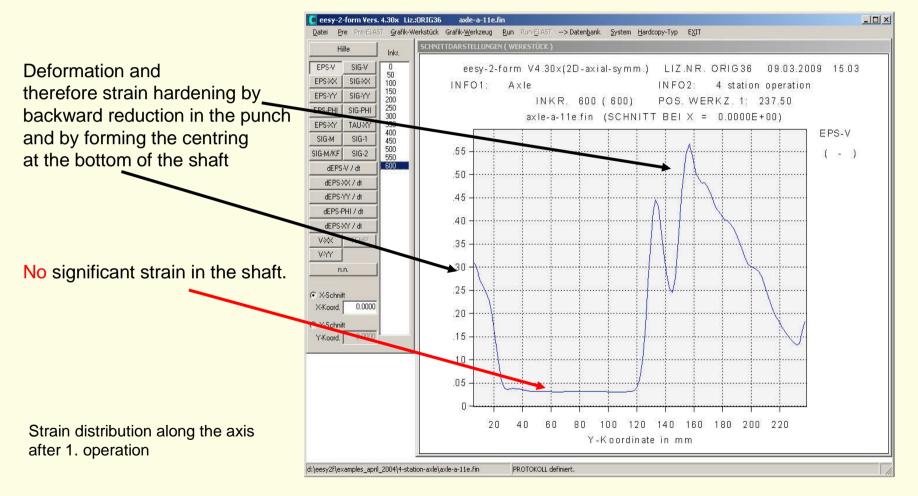


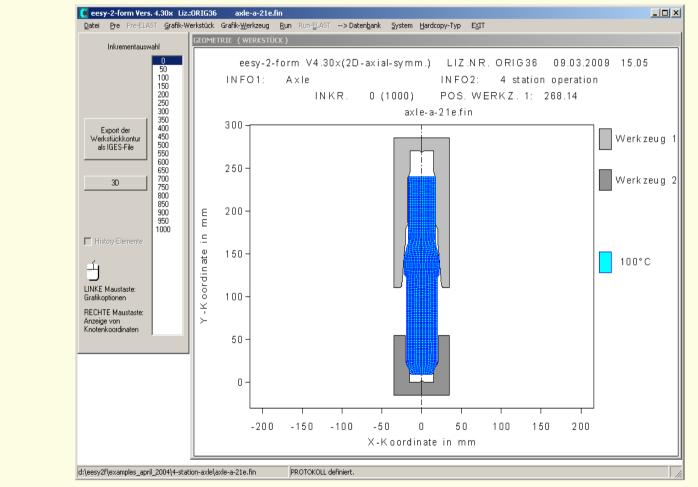


Example 2: Shaft with non sufficient hardness

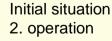
Strain distribution after 1. operation

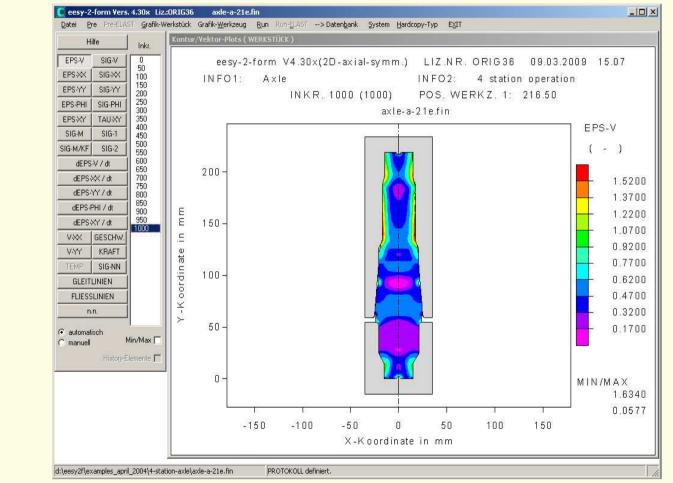
Example 2: Shaft with non sufficient hardness



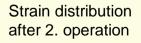


Example 2: Shaft with non sufficient hardness





Example 2: Shaft with non sufficient hardness

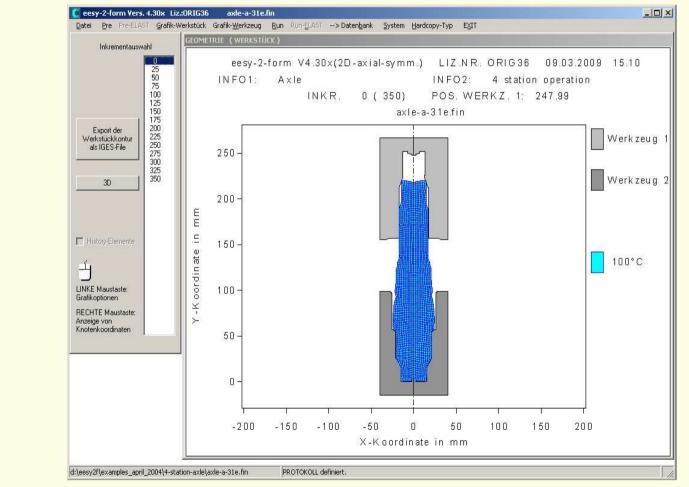


- 0 × 🚺 eesy-2-form Vers. 4.30x Liz.:ORIG36 axle-a-21e.fin Datei Pre Pre-ELAST Grafik-Werkstück Grafik-Werkzeug Run Run-ELAST --->Datenbank System Hardcopy-Typ EXIT SCHNITTDARSTELLUNGEN (WERKSTÜCK) Hilfe Inkr. EPS-V SIG-V 0 50 eesy-2-form V4.30x(2D-axial-symm.) LIZ.NR. ORIG36 09.03.2009 15.09 SIG-XX EPS-XX 100 INFO1: Axle INFO2: 4 station operation 150 EPS-YY SIG-YY 200 INKR. 1000 (1000) POS. WERKZ. 1: 216.50 250 300 EPS-PHI SIG-PHI axle-a-21e.fin (SCHNITT BELX = 0.0000E+00) TAU-XY EPS-XY 350 400 EPS-V SIG-M SIG-1 450 500 550 600 650 SIG-2 SIG-M/KF (-) .70 dEPS-V / dt dEPS-XX / dt 700 750 800 .60 dEPS-YY/dt 850 900 dEPS-PHI / dt 950 dEPS-XY/dt .50 1000 V-XX V-YY .40 n.n. X-Schnitt .30 0.0000 X-Koord. C Y-Schnitt .20 Y-Koord. 0.0000 .10 20 40 60 80 100 120 140 160 180 200 Y-Koordinate in mm d:\eesy2f\examples_april_2004\4-station-axle\axle-a-21e.fin PROTOKOLL definiert.

Example 2: Shaft with non sufficient hardness

Slight increase of the strain level in general by further reduction in the punch and upsetting in the shaft

Strain distribution along the axis after 2. operation



Example 2: Shaft with non sufficient hardness

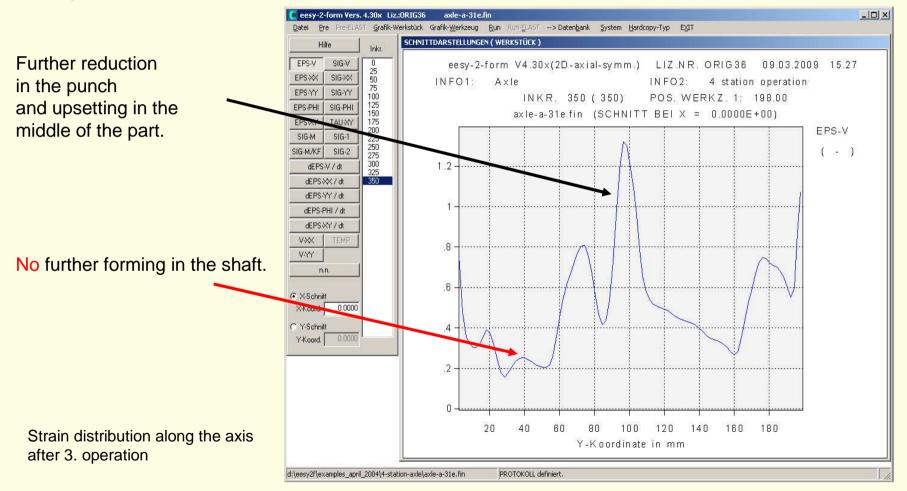
Initial situation

3. operation

Cesy-2-form Vers. 4.30x Liz.:ORIG36 axle-a-31e.fin _ 🗆 × Datei Pre Pre-ELAST Grafik-Werkstück Grafik-Werkzeug Run Run-ELAST --->Datenbank System Hardcopy-Typ EXIT Kontur/Vektor-Plots (WERKSTÜCK) Hilfe Inkr. EPS-V SIG-V 0 25 50 75 eesy-2-form V4.30x(2D-axial-symm.) LIZ.NR. ORIG36 09.03.2009 15.10 SIG-XX EPS-XX INFO1: Axle INFO2: 4 station operation EPS-YY SIG-YY 100 INKR. 350 (350) POS. WERKZ. 1: 198.00 125 150 SIG-PHI EPS-PHI axle-a-31e.fin TAU-XY EPS-XY 175 200 225 250 275 EPS-V SIG-1 220-SIG-M SIG-2 SIG-M/KF (-)200 300 dEPS-V / dt dEPS-XX / dt 350 180-2.3600 dEPS-YY/dt 2.1300 160 dEPS-PHI / dt Έ 1.9000 dEPS-XY/dt ε 140-1.6700 V-XX GESCHW Ξ 120-1.4400 V-YY KRAFT oordin ate 1.2100 SIG-NN 100-0.9800 GLEITLINIEN 80. 0.7500 FLIESSLINIEN ¥ 60 0.5200 n.n. 0.2900 e automatisch 40 Min/Max [C manuel 20 History-Elemente 0 MIN/MAX 2.5068 -20 0.1579 -50 100 150 -150 -100 П 50 X-Koordinate in mm d:\eesy2f\examples_april_2004\4-station-axle\axle-a-31e.fin PROTOKOLL definiert.

Example 2: Shaft with non sufficient hardness

Strain distribution after 3. operation



Example 2: Shaft with non sufficient hardness

- 0 × Cesy-2-form Vers. 4.30x Liz.:ORIG36 axle-a-41e.fin Datei Pre Pre-ELAST Grafik-Werkstück Grafik-Werkzeug Run Run-ELAST -->Datenbank System Hardcopy-Typ EXIT GEOMETRIE (WERKSTÜCK) Inkrementauswahl eesy-2-form V4.30×(2D-axial-symm.) LIZ.NR. ORIG36 09.03.2009 15.28 25 50 75 100 125 150 175 200 225 250 275 300 INFO1: Axle INFO2: 4 station operation INKR. 0 (300) POS. WERKZ. 1: 214.08 axle-a-41e.fin Export der Werkzeug Werkstückkontur als IGES-File Π 200 Werkzeug 2 3D ε 150 Ξ F History-Elemente oordin ate 100°C Ţ 100 LINKE Maustaste: Grafikoptionen ¥ **RECHTE Maustaste:** Anzeige von 5 Knotenkoordinaten 50 0 -50 50 100 150 -150 -100 0 X-Koordinate in mm d:\eesy2f\examples_april_2004\4-station-axle\axle-a-41e.fin PROTOKOLL definiert.

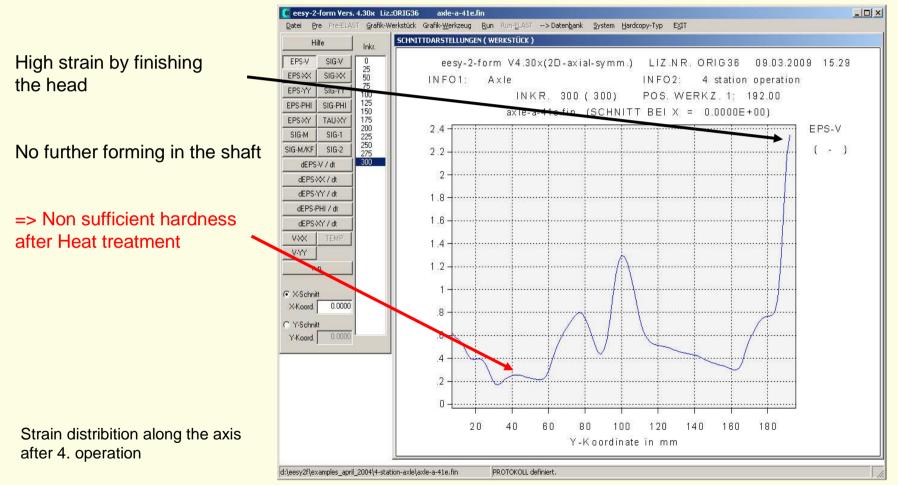
Example 2: Shaft with non sufficient hardness

Initial situation 4. operation

Cesy-2-form Vers. 4.30x Liz.:ORIG36 axle-a-41e.fin _ 🗆 × Datei Pre Pre-ELAST Grafik-Werkstück Grafik-Werkzeug Run Run-ELAST --->Datenbank System Hardcopy-Typ EXIT Kontur/Vektor-Plots (WERKSTÜCK) Hilfe Inkr. EPS-V SIG-V 0 25 50 75 eesy-2-form V4.30x(2D-axial-symm.) LIZ.NR. ORIG36 09.03.2009 15.29 SIG-XX EPS-XX INFO1: Axle INFO2: 4 station operation EPS-YY SIG-YY 100 INKR. 300 (300) POS. WERKZ. 1: 192.00 125 150 SIG-PHI EPS-PHI axle-a-41e.fin TAU-XY EPS-XY 175 200 225 250 275 220 EPS-V SIG-1 SIG-M SIG-2 SIG-M/KF 200-(-)dEPS-V / dt 300 180dEPS-XX / dt 2.5400 dEPS-YY / dt 2.2900 160 dEPS-PHI / dt Έ 2.0400 Ξ dEPS-XY / dt 140-1.7900 V-XX GESCHW Ξ 120 1.5400 V-YY KRAFT oordin ate 1.2900 SIG-NN 100 1.0400 GLEITLINIEN 80. 0.7900 FLIESSLINIEN ¥ n.n. 0.5400 60 0.2900 automatisch Min/Max [40-C manuel History-Elemente 20 MIN/MAX Π 2.6731 0.1675 -100 -50 100 150 -150 П 50 X-Koordinate in mm d:\eesy2f\examples_april_2004\4-station-axle\axle-a-41e.fin PROTOKOLL definiert.

Example 2: Shaft with non sufficient hardness

Strain distribution after 4. operation



Example 2: Shaft with non sufficient hardness

Example 2: Shaft with non sufficient hardness

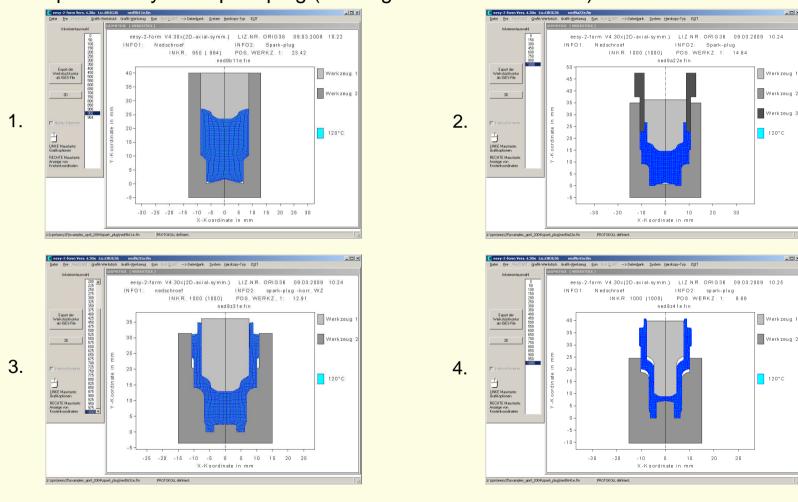
The simulation explains the non sufficient hardness found in measurements.

The strain distribution along the axis can be used as criterion to optimize the process design.

Example 3: body of a spark plug (investigation in material flow)

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFOR - Porto Alegre, RS, Brazil

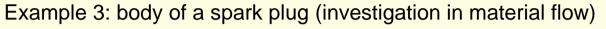
4 forming operations with final additional piercing

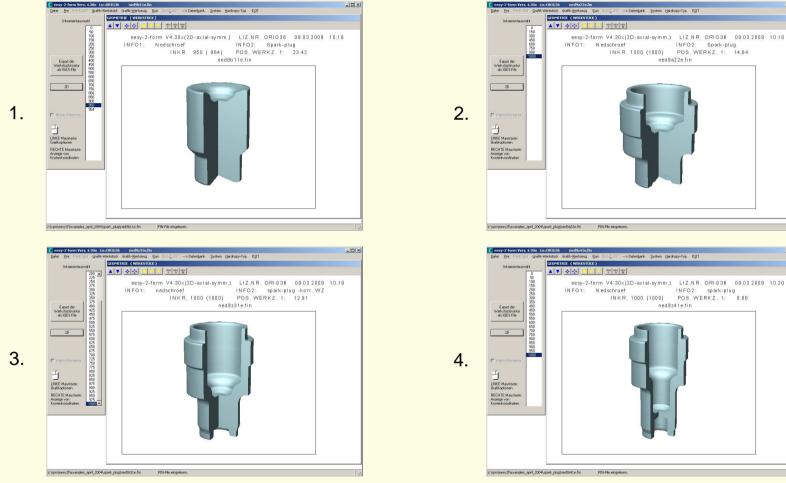


(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFOR -

Example 3: body of a spark plug (investigation in material flow)

Porto Alegre, RS, Brazil





(c) CPM GmbH, Herzogenrath, Germany

- 29th SENAFOR -Porto Alegre, RS, Brazil

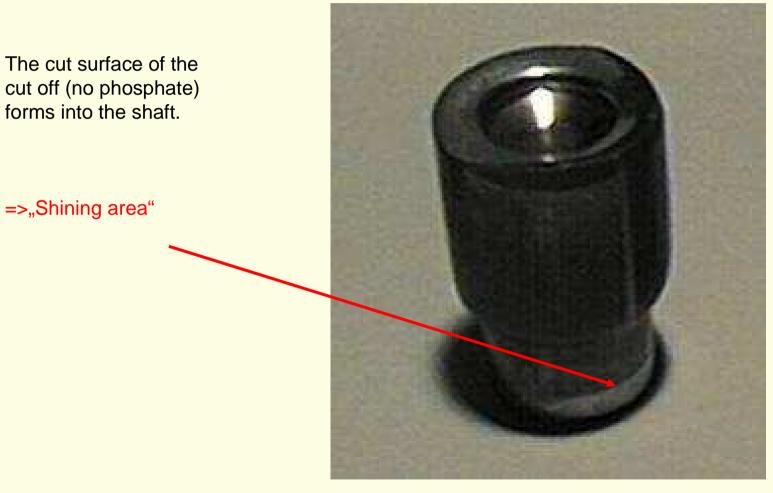
System Hardcopy-Typ ES

ned9a22e fin

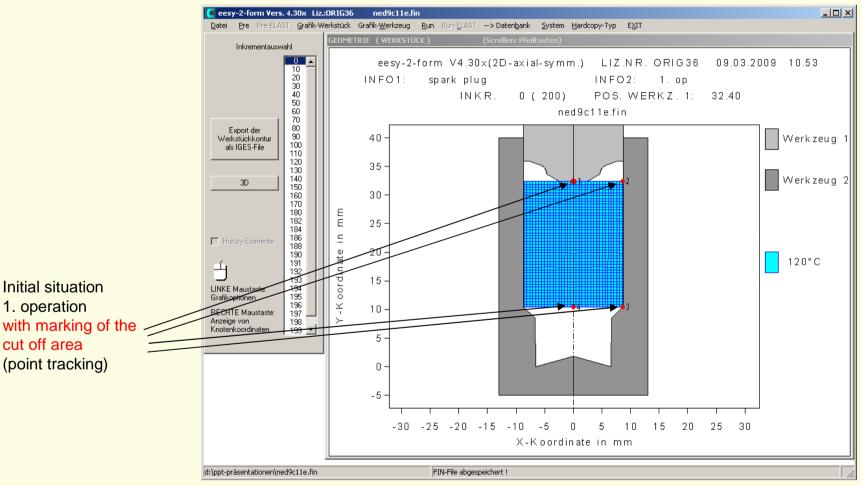
INFO2: spark-plug

ned9z41e.fin

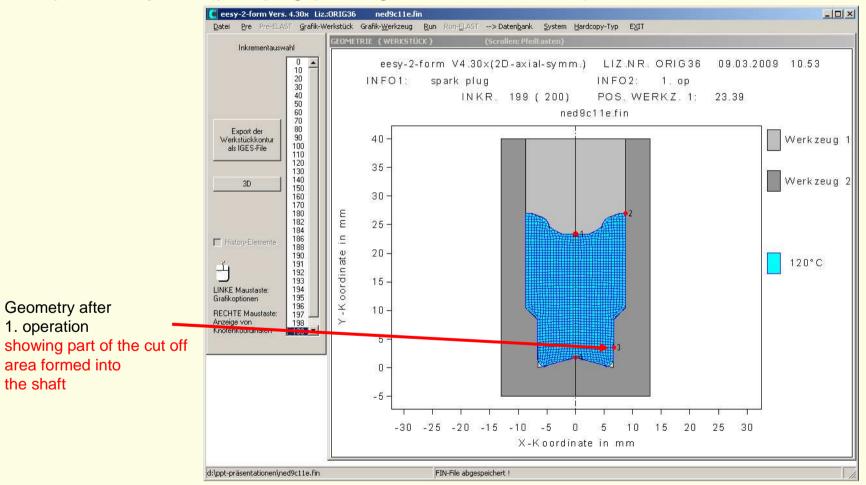
Example 3: body of a spark plug (investigation in material flow)

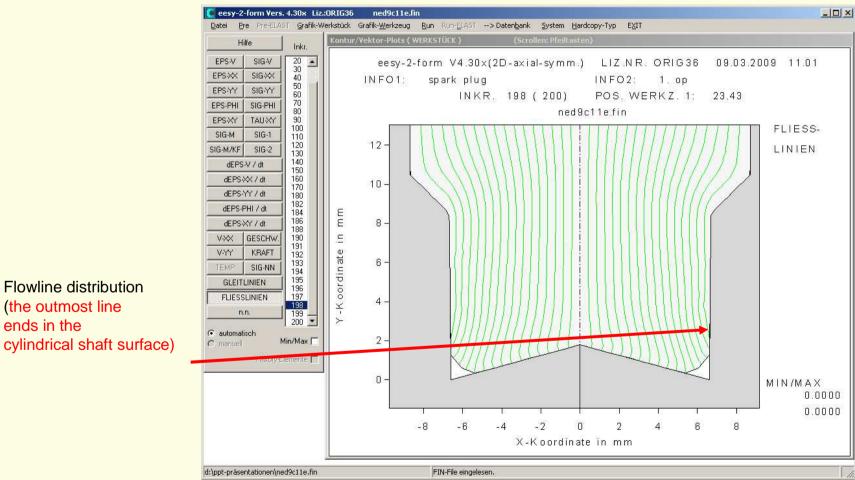


Example 3: body of a spark plug (investigation in material flow)

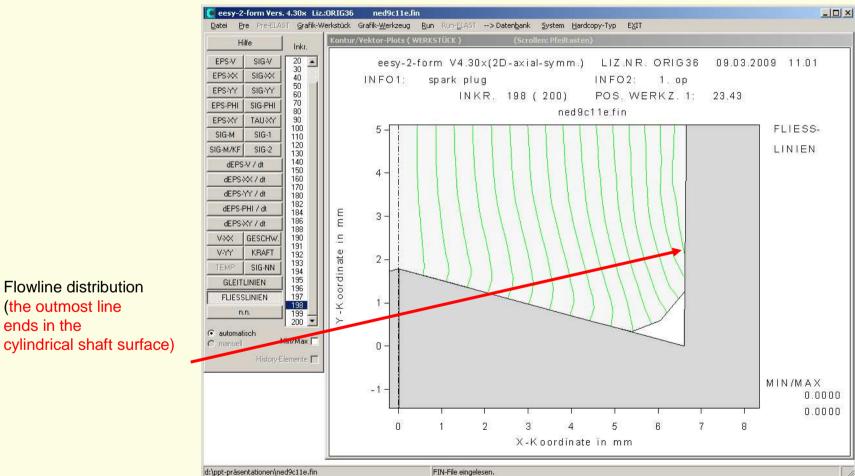


Example 3: body of a spark plug (investigation in material flow)





Example 3: body of a spark plug (investigation in material flow)



Example 3: body of a spark plug (investigation in material flow)

Example 3: body of a spark plug (investigation in material flow)

Fazit:

The simulation is precise enough to show the local material flow leading to the forming of the cut surface in to the cylindrical shaft surface.

Therefore for other effects resulting from the material flow similar precision can be expected.

Example 4: "Inner Race" (with typical under filling)

Problem: After operation 1 and after operation 2 as well the "Inner Race" shows under filling in the lower area.

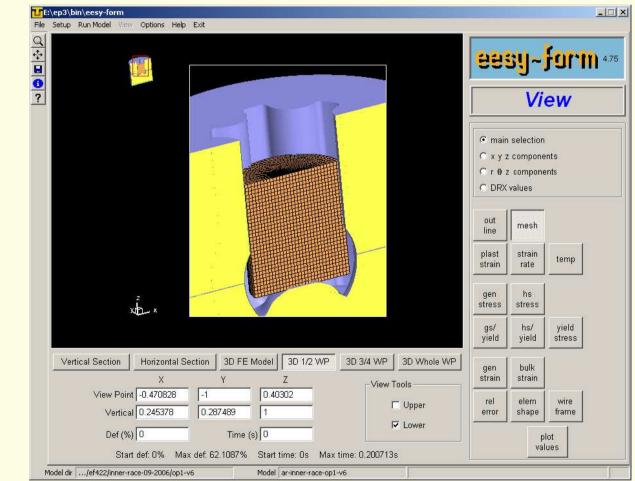
Question: Can the simulation predict these under fillings?

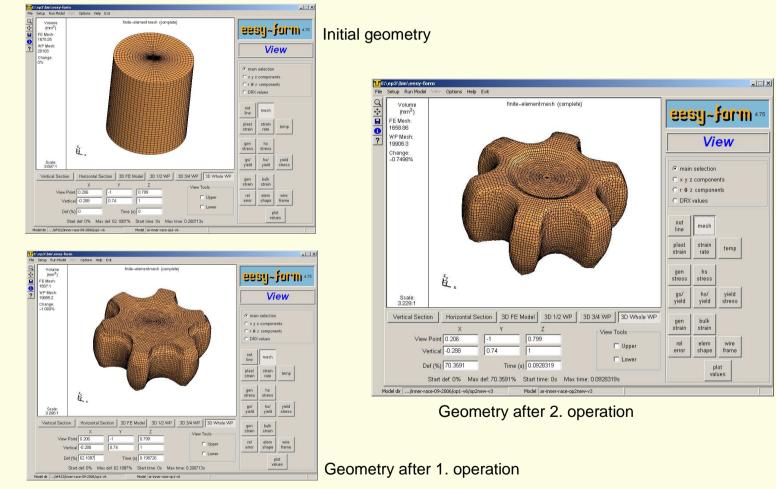


Example 4: "Inner Race" (with typical under filling)

Part in the die

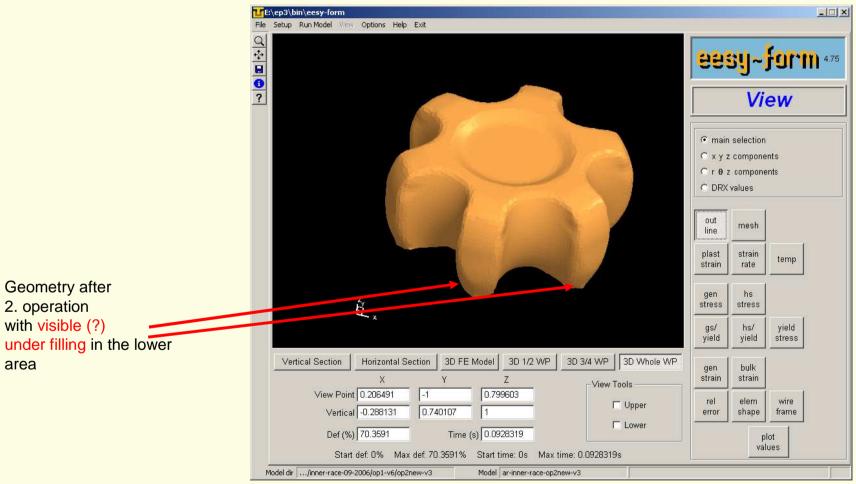
(initial situation)



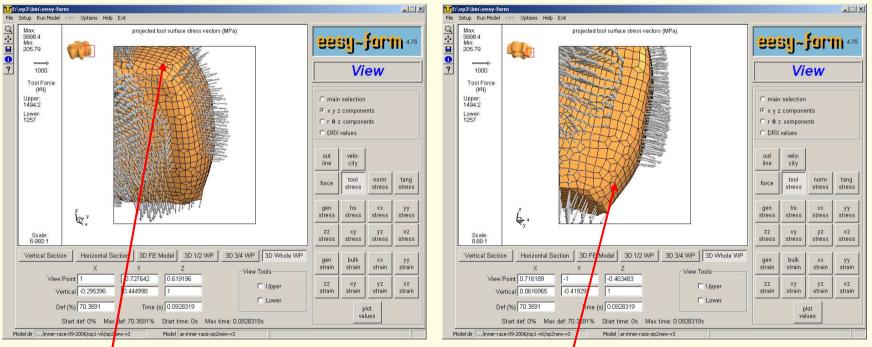


Example 4: "Inner Race" (with typical under filling)

Example 4: "Inner Race" (with typical under filling)



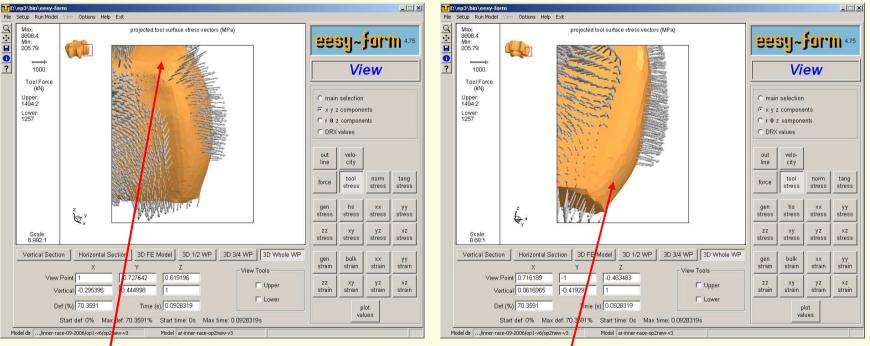
Example 4: "Inner Race" (with typical under filling)



Contact stresses on the tool surface showing the under filling (with mesh)

Contact stresses on the tool surface showing the under filling (with mesh)

Example 4: "Inner Race" (with typical under filling)



Contact stresses on the tool surface showing the under filling

Contact stresses on the tool surface showing the under filling

Example 4: "Inner Race" (with typical under filling)

Fazit:

The simulation is precise enough to show the under fillings.

The contact stresses on the tool surface can be used to analyse the contact situation and to optimize the filling.