

Sensori di pressione nello stampo Ottimizzazione e controllo del ciclo con utilizzo del DOE

KISTLER
Michele Segato

Moldex3D

Kistler at a glance

Facts & Figures

10,000+

active customers
worldwide

60+

locations
worldwide

2,200+

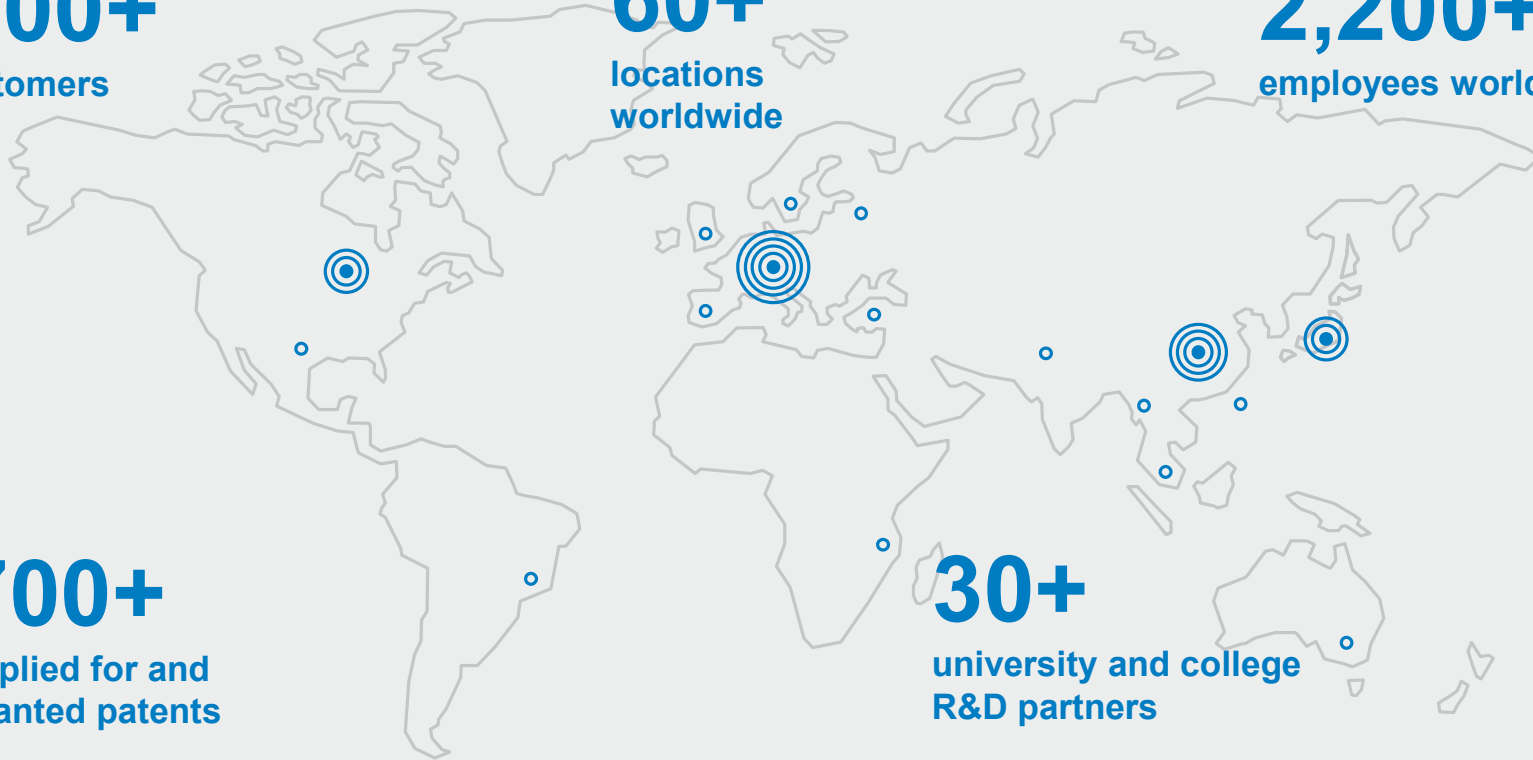
employees worldwide

700+

applied for and
granted patents

30+

university and college
R&D partners



Le nostre competenze

Dove trovare le nostre soluzioni?



Sensor Technology (ST)

Industrial Process Control (IPC)

Automotive Research & Test (ART)

Division Industrial Process Control



Plastics
Monitoring and control systems
for plastics processing



Joining System Business
Electromechanical joining systems
with integrated process control



Production Monitoring
Production monitoring with force-
displacement measuring systems



Test Automation
Automated test systems for
mass-produced and series parts



Fastening Technology
Analyse systems for separable fasteners



Test Stand Systems
Test stands for electric motors

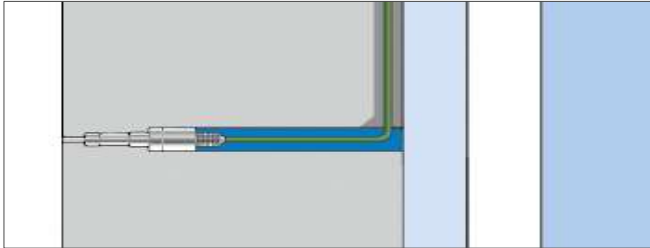


Assembly Systems
Automated production lines

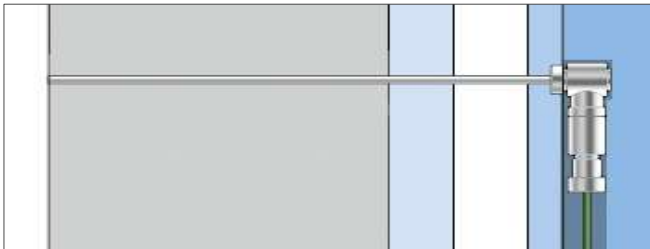
Sensori di Pressione + Centralina ComoNeo



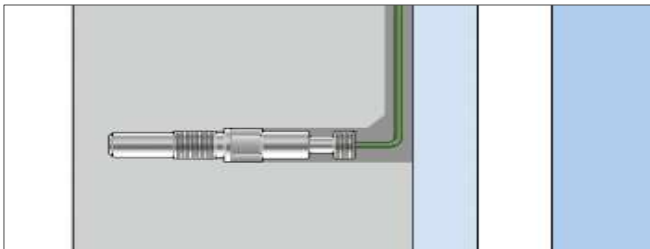
Sensori di pressione Diretti / Indiretti



Sensore diretto
e.g. 6157B



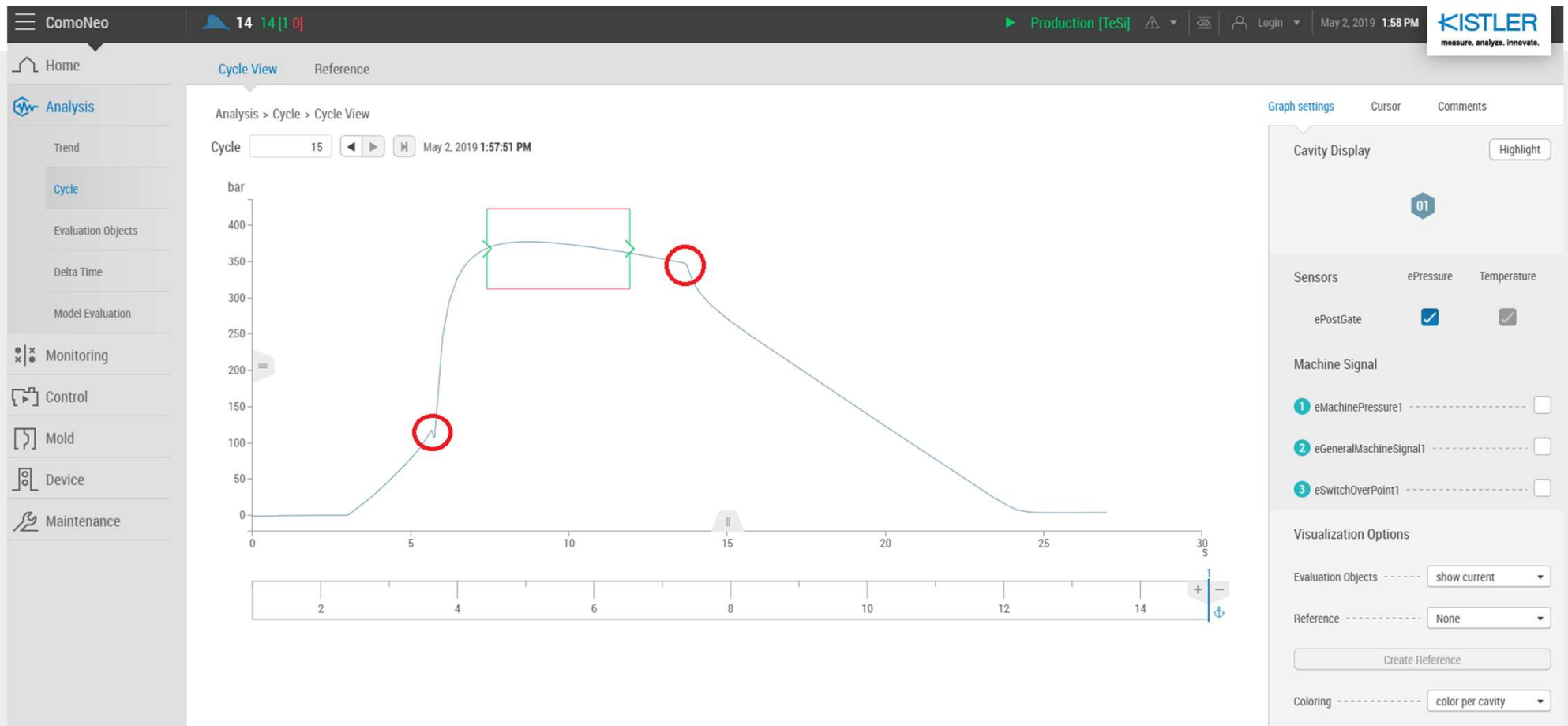
Sensore indiretto
e.g. 9211A



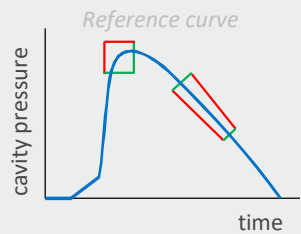
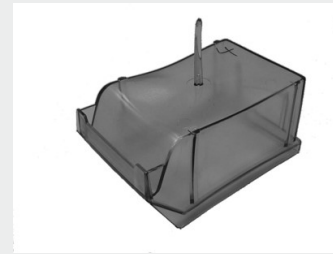
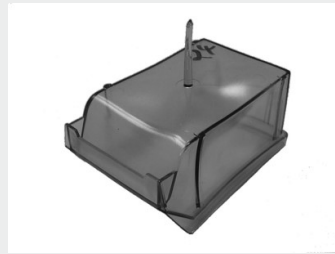
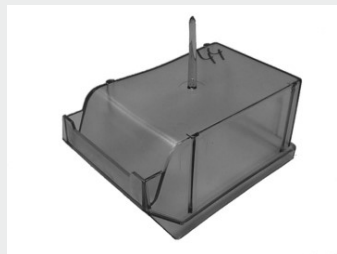
Sensore senza contatto
e.g. 9247A



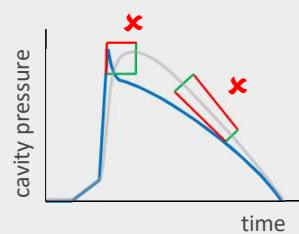
Curva di Pressione su ComoNeo



Monitoraggio del processo tradizionale con Finestre di Valutazione

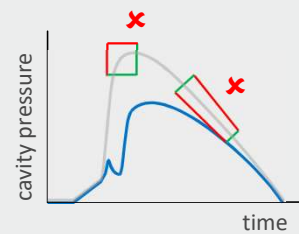


✓ Good part



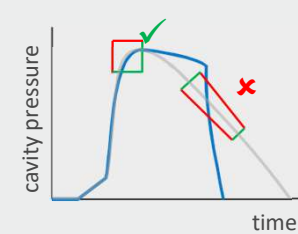
✗ Bad part

Both EOs violeted
Signal «Sort»



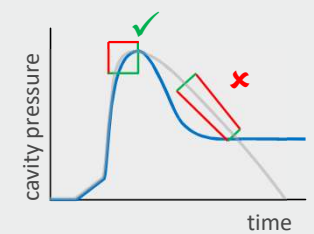
✗ Bad part

Entry box not activated
Holding pressure EO
violeted
Signal «Sort»



✗ Bad part

Holding pressure EO
violeted
Signal «Sort»

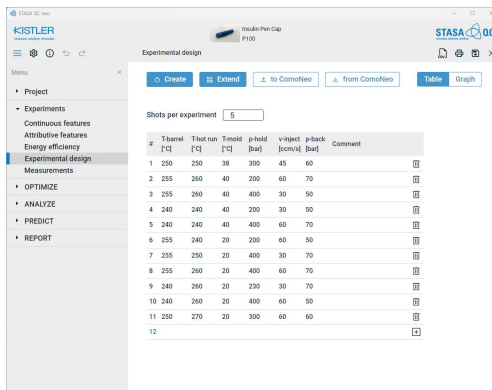


✗ Bad part

Holding pressure EO
violeted
Signal «Sort»

Monitoraggio al 100% con Modello predittivo generato dal DOE

Data via experiments



	Tbarrel	Tbarrel [°C]	Tsmall	p-hold	v-ject	p-back	Comment
1	250	250	38	300	45	60	
2	255	260	40	200	60	70	
3	255	260	40	400	30	50	
4	240	240	40	200	30	50	
5	240	240	40	400	60	70	
6	255	240	20	200	60	50	
7	255	250	20	400	30	70	
8	255	260	20	400	60	70	
9	240	260	20	230	30	70	
10	240	260	20	400	60	50	
11	250	270	20	300	60	60	
12							

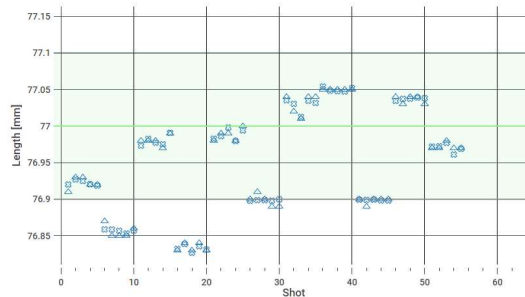
Running the DoE with Kistler ComoNeo



Measuring the parts



Automatic generation of prediction model



Transfer of the prediction model to Kistler ComoNeo



Definizione numero di Cavità e Sensori in StasaQC

The screenshot displays the 'Cavity assignment' interface in the STASA QC neo software. The interface is divided into a left-hand menu, a top header, and a central table.

Menu:

- Project
- Project info
- Cavity assignment**
- Machine parameters
- Settings
- Experiments
- OPTIMIZE
- ANALYZE
- PREDICT
- REPORT

Header:

Insulin Pen Cap P100

Table:

Article name	Article number	Cavities
Insulin Pen Cap	InsulinPenCap	01 02 03 04 05 06 07 08
Insulin Pen		01 02 03 04 05 06 07 08
new part		01 02 03 04 05 06 07 08 +

The table shows three rows of cavity assignments. The first row is for 'Insulin Pen Cap' with article number 'InsulinPenCap', showing 8 active cavities (01-08) in blue. The second row is for 'Insulin Pen', showing 8 active cavities (01-08) in blue. The third row is for 'new part', showing 8 inactive cavities (01-08) in grey and a plus sign (+) to add more.

Definizione Variabili di Processo da modificare

STASA QC neo

KISTLER
measure. analyze. innovate.

Insulin Pen Cap
P100

STASA QC
measure. analyze. predict.

Machine parameters

The machine parameters defined first are varied least frequently in the experimental design. Usually these are temperatures. The order can be changed by dragging the ☰ symbol.

Name	Abbreviation	Unit	Smallest value	Largest value	Step size	
☰ barrel temperature	T-barrel	°C	240	255	1	🗑️
☰ hot runner temperature	T-hot run	°C	240	270	1	🗑️
☰ mold temperature	T-mold	°C	20	40	1	🗑️
☰ holding pressure	p-hold	bar	200	400	10	🗑️
☰ injection speed	v-inject	ccm/s	30	60	1	🗑️
☰ back pressure	p-back	bar	50	70	1	🗑️
new machine parameter						+

Menu

- Project
 - Project info
 - Machine parameters**
 - Settings
- Experiments
- OPTIMIZE
- ANALYZE
- PREDICT
- REPORT

Definizione Criteri di Qualità da misurare

STASA QC neo

KISTLER
measure. analyze. innovate.

Insulin Pen Cap
P100

STASA QC

Attributive features

Active	Name	Abbreviation	Attributes
	new quality feature		2 steps not ok ok +

new quality feature

- Flash formation
- Surface finish
- Void
- Underfilling

Menu

- Project
- Experiments
 - Continuous features
 - Attributive features
 - Energy efficiency
 - Experimental design
 - Measurements
- OPTIMIZE
- ANALYZE
- PREDICT
- REPORT

STASA QC neo

KISTLER
measure. analyze. innovate.

Insulin Pen Cap
P100

STASA QC

Continuous features

Active	Name	Abbreviation	Unit	Lower tolerance	Nominal value	Upper tolerance
☰	Length	Length	mm	76.9	77	77.1
☰	Weight	Weight	g	3.02	3.05	3.08
	new quality feature					+

Menu

- Project
- Experiments
 - Continuous features
 - Attributive features
 - Energy efficiency
 - Experimental design
 - Measurements
- OPTIMIZE
- ANALYZE
- PREDICT
- REPORT

Definizione parametri di Efficienza energetica

The screenshot shows the STASA QC neo software interface. The main window title is 'Insulin Pen Cap P100'. The 'Energy efficiency' configuration window is open, displaying a table of parameters. The table has columns for 'Active', 'Name', 'Abbreviation', and 'Unit'. There are three rows: 'Cycle time' (Active: checked, Unit: s), 'Energy consumption' (Active: checked, Unit: Wh), and 'new quality feature' (Active: unchecked, Unit: blank). A '+' icon is visible at the end of the third row. On the left, a 'Menu' sidebar is open, showing options like 'Project', 'Experiments', 'Energy efficiency', 'OPTIMIZE', 'ANALYZE', 'PREDICT', and 'REPORT'. The 'Energy efficiency' option is currently selected.

Active	Name	Abbreviation	Unit
<input checked="" type="checkbox"/>	Cycle time	CT	s
<input checked="" type="checkbox"/>	Energy consumption	EC	Wh
<input type="checkbox"/>	new quality feature		

Creazione del piano sperimentale (Design Of Experiment)

STASA QC neo

Insulin Pen Cap P100

Experimental design

Buttons: Create, Extend, to ComoNeo, from ComoNeo

Table/Graph view

Shots per experiment: 5

#	T-barrel [°C]	T-hot run [°C]	T-mold [°C]	p-hold [bar]	v-inject [ccm/s]	p-back [bar]	Comment
1	250	250	38	300	45	60	🗑️
2	255	260	40	200	60	70	🗑️
3	255	260	40	400	30	50	🗑️
4	240	240	40	200	30	50	🗑️
5	240	240	40	400	60	70	🗑️
6	255	240	20	200	60	50	🗑️
7	255	250	20	400	30	70	🗑️
8	255	260	20	400	60	70	🗑️
9	240	260	20	230	30	70	🗑️
10	240	260	20	400	60	50	🗑️
11	250	270	20	300	60	60	🗑️
12							+

Visualizzazione del piano sperimentale (Design Of Experiment)



Inserimento risultati delle misurazioni dei criteri di qualità

STASA QC neo

KISTLER
measure. analyze. innovate.

Insulin Pen Cap
P100

STASA QC
measure. analyze. innovate.

Menu

- Project
- Experiments
 - Continuous features
 - Attributive features
 - Energy efficiency
 - Experimental design
 - Measurements**
- OPTIMIZE
- ANALYZE
- PREDICT
- REPORT

Measurements

Please select quality features... ^

01 02 03 04 05 06 07 08

Outlier view

1 - 10 of 19

Active	Experiment Shot	Length Cav. 1 [mm]	Length Cav. 2 [mm]	Length Cav. 3 [mm]	Length Cav. 4 [mm]	Length Cav. 5 [mm]	Length Cav. 6 [mm]	Length Cav. 7 [mm]	Length Cav. 8 [mm]	Weight Cav. 1 [g]
✓	1.1	76.91	76.92	76.95	76.95	76.92	76.93	76.87	76.9	3.051
✓	1.2	76.93	76.99	76.95	76.95	76.91	76.96	76.88	76.92	3.052
✓	1.3	76.93	76.92	76.95	76.96	76.92	76.94	76.88	76.91	3.051
✓	1.4	76.92	76.92	76.95	76.97	76.91	76.94	76.88	76.9	3.051
✓	1.5	76.92	76.91	76.96	76.95	76.91	76.94	76.87	76.9	3.05
✓	2.1	76.87	76.86	76.9	76.91	76.89	76.88	76.85	76.86	3.037
✓	2.2	76.85	76.86	76.89	76.91	76.88	76.88	76.85	76.85	3.036
✓	2.3	76.85	76.87	76.91	76.9	76.89	76.88	76.85	76.85	3.036
✓	2.4	76.85	76.86	76.89	76.91	76.88	76.88	76.84	76.86	3.035
✓	2.5	76.86	76.85	76.91	76.9	76.87	76.87	76.84	76.86	3.035
✓	3.1	76.98	76.96	77.01	77.01	76.98	77	76.94	76.97	3.071
✓	3.2	76.98	76.97	77.01	77.02	76.99	77.02	76.94	76.96	3.069
✓	3.3	76.98	76.96	77.01	77.01	76.97	76.99	76.94	76.96	3.069
✓	3.4	76.97	76.96	77	77	76.97	76.99	76.93	76.96	3.069
✓	3.5	76.99	76.96	77	77	76.98	76.99	76.93	76.97	3.067
✓	4.1	76.83	76.82	76.88	76.88	76.86	76.86	76.8	76.86	3.042
✓	4.2	76.84	76.88	76.85	76.83	76.89	76.85	76.79	76.84	3.042
✓	4.3	76.83	76.81	76.86	76.88	76.83	76.86	76.79	76.83	3.044
✓	4.4	76.84	76.82	76.83	76.86	76.83	76.86	76.77	76.83	3.042

10

Verifica Ok/NOK dei criteri di qualità

STASA QC neo

Insulin Pen Cap P100

STASA QC

Measurements

Please select quality features... 01 02 03 04 05 06 07 08 Outlier view

Length × Weight × Outliers ×

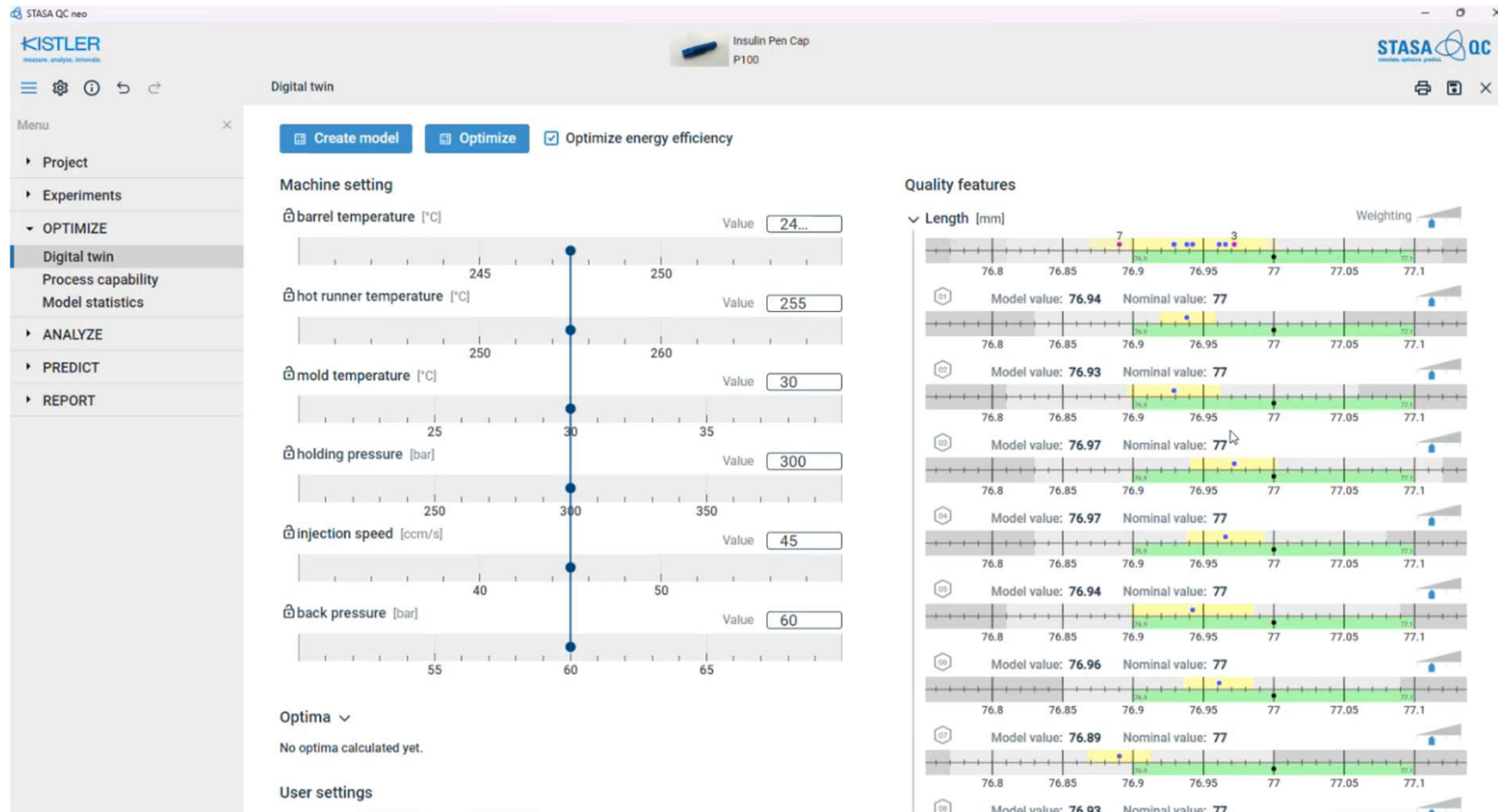
1 - 5 of 5

Active	Experiment Shot	Length Cav. 1 [mm]	Length Cav. 4 [mm]	Weight Cav. 1 [g]	Weight Cav. 4 [g]
✓	1.1	76.91	76.95	3.051	3.04
✓	1.2	76.93	76.95	3.052	3.043
✓	1.3	76.93	76.96	3.051	3.042
✓	1.4	76.92	76.97	3.051	3.042
✓	1.5	76.92	76.95	3.05	3.04
✓	2.1	76.87	76.91	3.037	3.025
✓	2.2	76.85	76.91	3.036	3.025
✓	2.3	76.85	76.9	3.036	3.027
✓	2.4	76.85	76.91	3.035	3.026
✓	2.5	76.86	76.9	3.035	3.025
✓	3.1	76.98	77.01	3.071	3.053
✓	3.2	76.98	77.02	3.069	3.056
✓	3.3	76.98	77.01	3.069	3.054
✓	3.4	76.97	77	3.069	3.055
✓	3.5	76.99	77	3.067	3.058
✓	4.1	76.83	76.88	3.042	3.03
✓	4.2	76.84	76.83	3.042	3.008
✓	4.3	76.83	76.88	3.044	3.029

Generazione del modello predittivo Digital Twin

The screenshot displays the STASA QC neo software interface. At the top, the window title is "STASA QC neo" and the product name "Insulin Pen Cap P100" is visible. The main area shows "Training OPTIMIZE model..." with a progress bar at 94%. A blue circular logo is centered below the progress bar. On the left, a menu is open, listing options: Project, Experiments, OPTIMIZE (expanded), Digital twin (selected), Process capability, Model statistics, ANALYZE, PREDICT, and REPORT. The STASA QC logo is in the top right corner.

Visualizzazione del modello predittivo



Ottimizzazione del Digital Twin

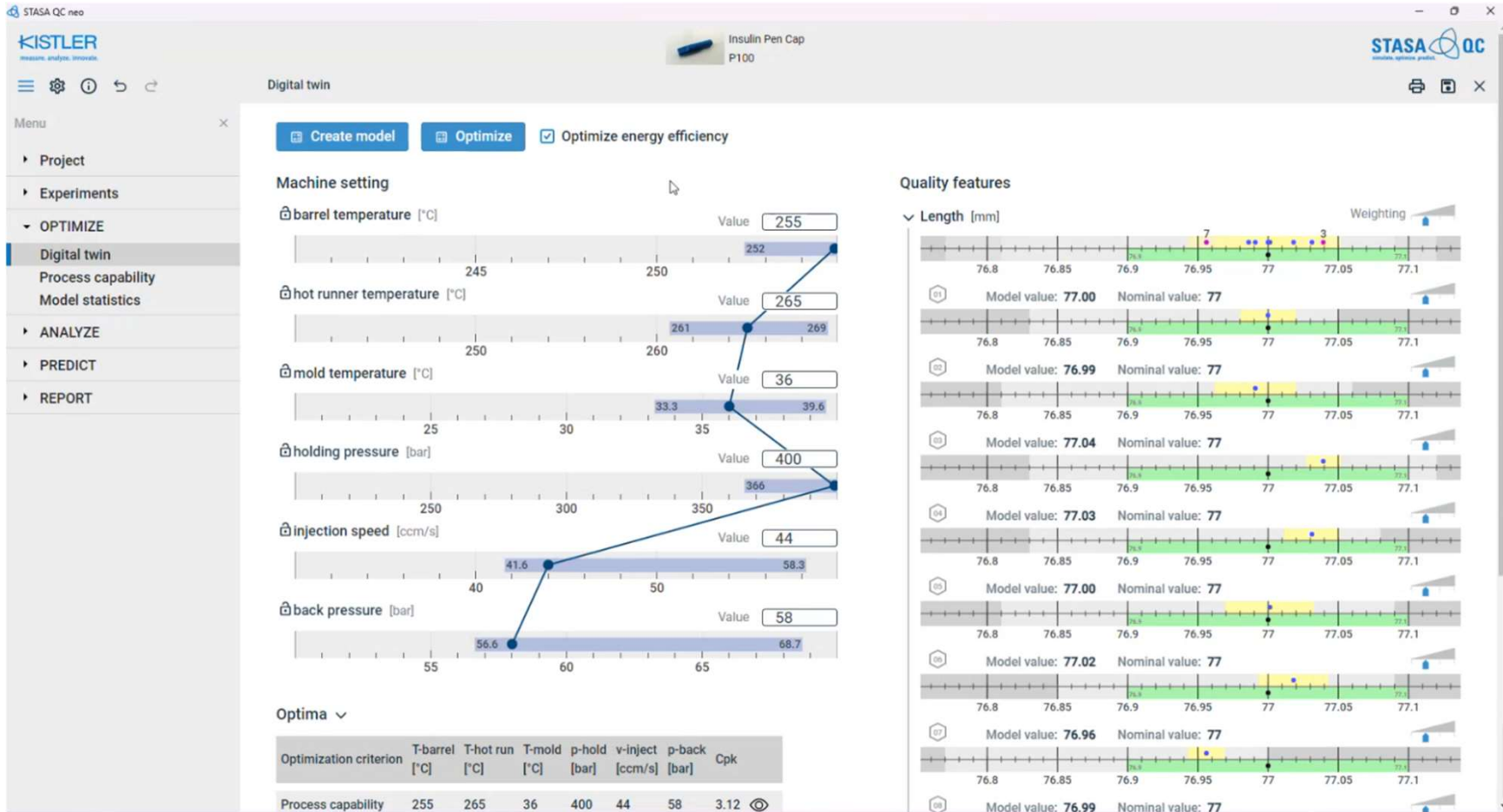
The screenshot displays the STASA QC neo software interface. The window title is "STASA QC neo". The top bar includes the KISTLER logo, a navigation menu with icons for settings, help, and refresh, and the project name "Insulin Pen Cap P100". On the right side of the top bar, there is a "STASA QC" logo with the tagline "simulate. optimize. predict." and icons for print, save, and close.

The main workspace is titled "Digital twin" and shows the text "Optimizing process..." above a blue progress bar. The progress bar is currently at 56%. A blue circular icon with three overlapping loops is positioned below the text.

A sidebar menu is visible on the left side, titled "Menu". It contains the following items:

- Project
- Experiments
- OPTIMIZE
 - Digital twin
 - Process capability
 - Model statistics
- ANALYZE
- PREDICT
- REPORT

Visualizzazione del Processo Ottimizzato



Eventuali modifiche dimensionali dello stampo

STASA QC neo

KISTLER
measure. analyze. innovate.

Insulin Pen Cap
P100

STASA QC
measure. optimize. predict.

Process capability

Menu

- Project
- Experiments
- OPTIMIZE
 - Digital twin
 - Process capability**
 - Model statistics
- ANALYZE
- PREDICT
- REPORT

Please select quality features... ^

01 02 03 04 05 06 07 08

Process capability given for selected quality features? **yes**

Prediction of overall process capability **1.48**

Threshold **Cpk values >1.33**

Quality feature	Lower tolerance	Nominal value	Upper tolerance	Model value	Cpk	Process capability?	Mold correction	Part dimension correction
Length Cav. 1	76.9 mm	77.0 mm	77.1 mm	76.98 mm	4.65	yes	not necessary	0.0187 mm
Length Cav. 2	76.9 mm	77.0 mm	77.1 mm	76.97 mm	2.73	yes	not necessary	0.0279 mm
Length Cav. 3	76.9 mm	77.0 mm	77.1 mm	77.02 mm	6.62	yes	not necessary	-0.0191 mm
Length Cav. 4	76.9 mm	77.0 mm	77.1 mm	77.01 mm	5.03	yes	not necessary	-0.0112 mm
Length Cav. 5	76.9 mm	77.0 mm	77.1 mm	76.98 mm	2.24	yes	not necessary	0.016 mm
Length Cav. 6	76.9 mm	77.0 mm	77.1 mm	77.0 mm	4.22	yes	not necessary	0.0007 mm
Length Cav. 7	76.9 mm	77.0 mm	77.1 mm	76.94 mm	2.78	yes	not necessary	0.0627 mm
Length Cav. 8	76.9 mm	77.0 mm	77.1 mm	76.97 mm	3.05	yes	not necessary	0.032 mm
Weight Cav. 1	3.02 g	3.05 g	3.08 g	3.06 g	4.88	yes		-0.0123 g
Weight Cav. 2	3.02 g	3.05 g	3.08 g	3.04 g	4.04	yes		0.0102 g
Weight Cav. 3	3.02 g	3.05 g	3.08 g	3.05 g	5.81	yes		0.0021 g
Weight Cav. 4	3.02 g	3.05 g	3.08 g	3.05 g	4.72	yes		0.0002 g
Weight Cav. 5	3.02 g	3.05 g	3.08 g	3.02 g	1.48	yes		0.0259 g
Weight Cav. 6	3.02 g	3.05 g	3.08 g	3.04 g	3.49	yes		0.0149 g
Weight Cav. 7	3.02 g	3.05 g	3.08 g	3.03 g	2.12	yes		0.0172 g

Analisi Statistica dei criteri di qualità

STASA QC neo

KISTLER
measure. analyze. innovate.

Insulin Pen Cap
P100

STASA QC
measure. optimize. predict.

Model statistics

Please select quality features... ^

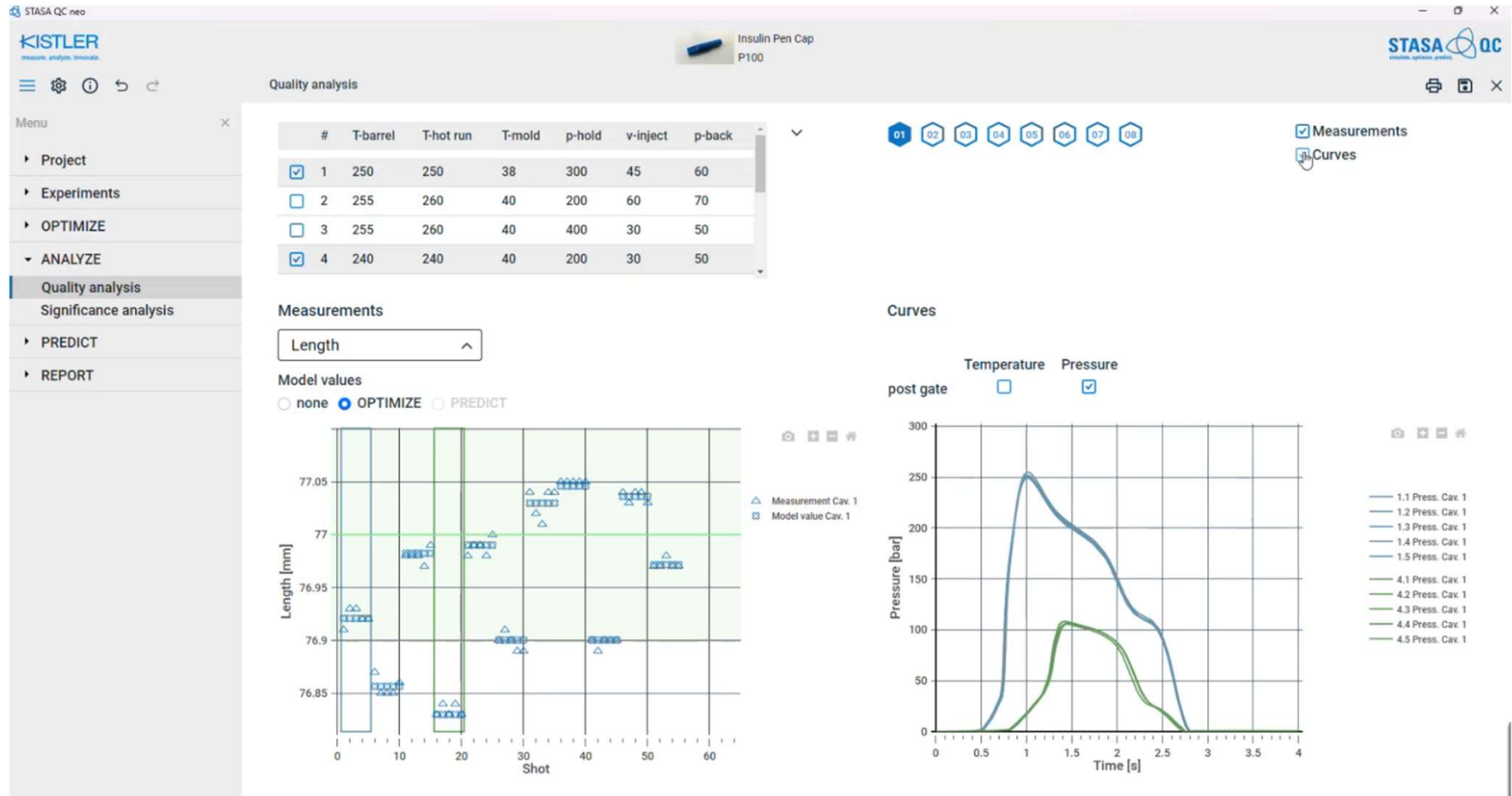
01 02 03 04 05 06 07 08

Name	Model type	R ²	Adj. R ²	Mean absolute error	Max absolute error	RMSE
Cycle time	linear	94.7%	94.1%	0.0746 s	0.184 s	0.6494 s
Length Cav. 1	linear	99.0%	98.9%	0.0056 mm	0.0198 mm	0.0533 mm
Length Cav. 2	linear	95.4%	95.0%	0.0085 mm	0.0711 mm	0.1099 mm
Length Cav. 3	linear	97.6%	97.3%	0.0096 mm	0.0409 mm	0.0934 mm
Length Cav. 4	linear	97.9%	97.6%	0.0075 mm	0.0336 mm	0.0748 mm
Length Cav. 5	linear	94.3%	93.7%	0.0113 mm	0.0674 mm	0.1245 mm
Length Cav. 6	linear	98.3%	98.2%	0.0073 mm	0.0288 mm	0.0705 mm
Length Cav. 7	linear	98.4%	98.2%	0.0066 mm	0.0186 mm	0.0601 mm
Length Cav. 8	linear	97.8%	97.6%	0.0081 mm	0.0358 mm	0.0751 mm
Weight Cav. 1	linear	98.4%	98.2%	0.0016 g	0.0046 g	0.0142 g
Weight Cav. 2	linear	97.7%	97.5%	0.0017 g	0.0102 g	0.0174 g
Weight Cav. 3	linear	96.0%	95.6%	0.0023 g	0.0076 g	0.0212 g
Weight Cav. 4	linear	85.8%	84.3%	0.0038 g	0.0166 g	0.0388 g
Weight Cav. 5	linear	92.4%	91.6%	0.0028 g	0.0213 g	0.0338 g
Weight Cav. 6	linear	98.5%	98.4%	0.0013 g	0.0048 g	0.0124 g
Weight Cav. 7	linear	98.2%	98.0%	0.0017 g	0.0055 g	0.0163 g
Weight Cav. 8	linear	98.3%	98.1%	0.0015 g	0.0052 g	0.0138 g

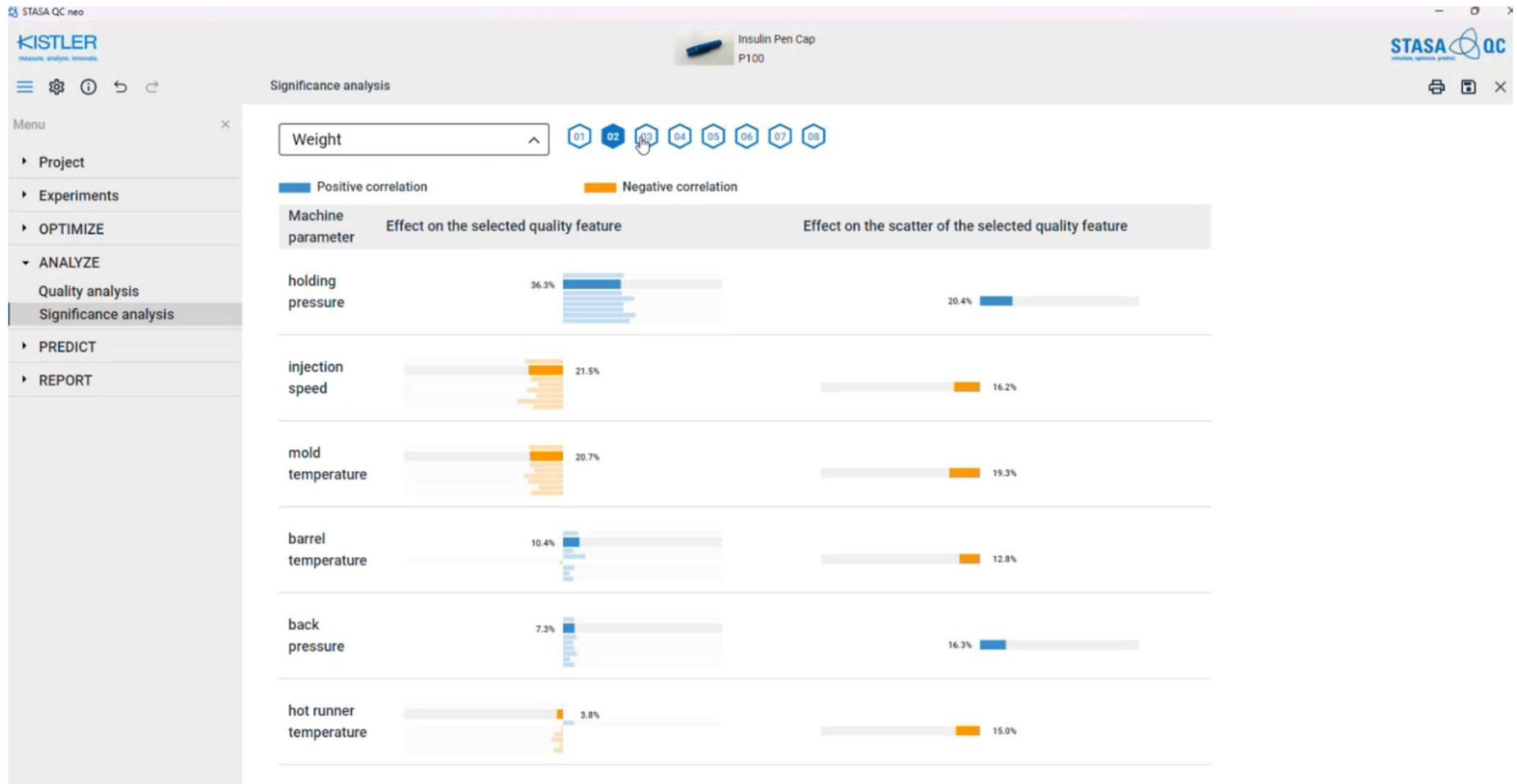
Menu

- Project
- Experiments
- OPTIMIZE
- ANALYZE
 - Quality analysis
 - Significance analysis
- PREDICT
- REPORT

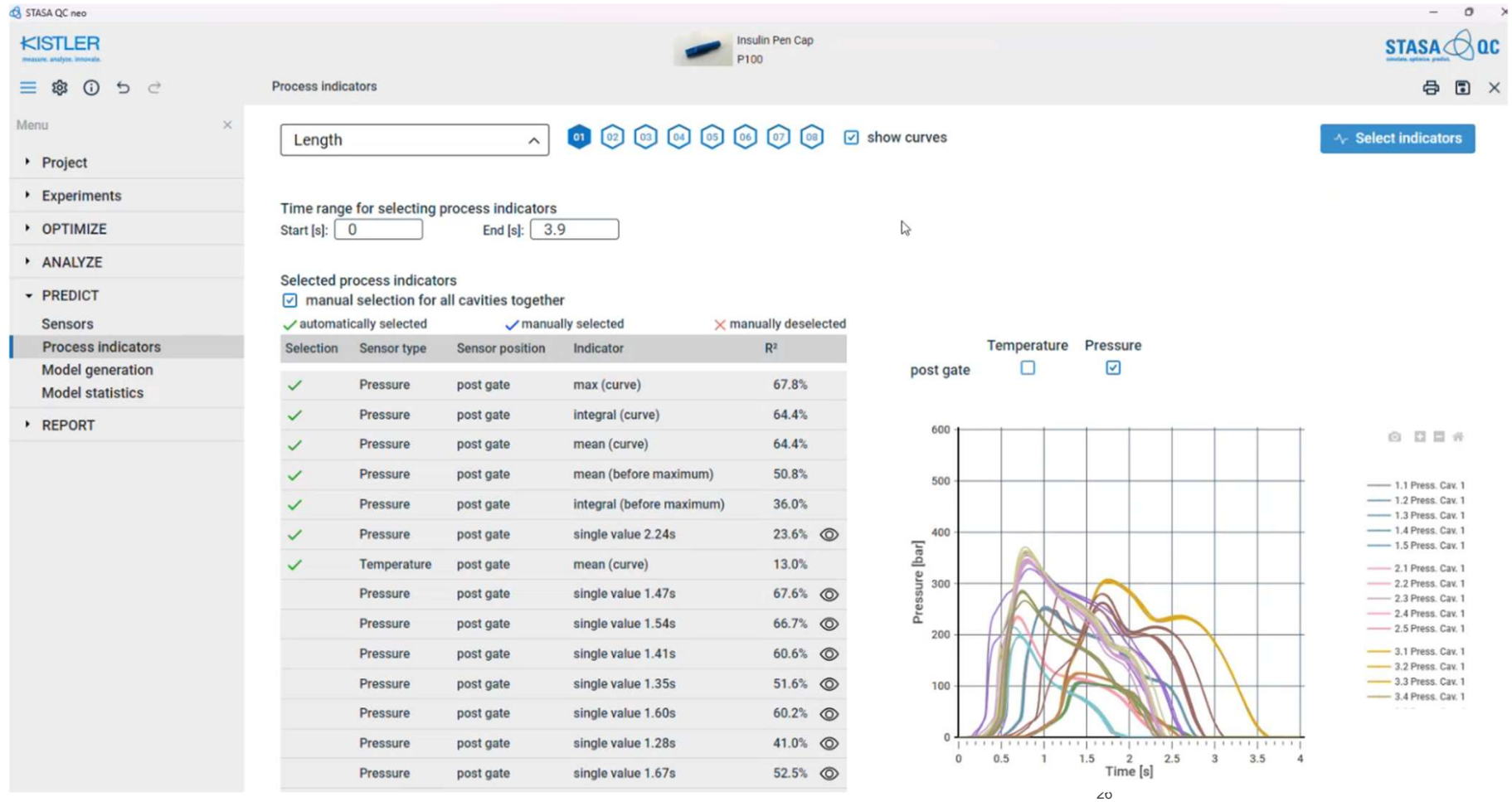
Visualizzazione Curve di Pressione per i vari esperimenti



Valutazione Impatto delle Variabili X sui Criteri Y



Definizione Automatica dei punti notevoli della Curva di Pressione per correlazione con criteri di qualità



Generazione modello di Previsione per Monitoraggio in ComoNeo

The screenshot displays the STASA QC neo software interface. At the top, the window title is 'STASA QC neo'. The main header area includes the KISTLER logo on the left, a central product image of an 'Insulin Pen Cap P100', and the STASA QC logo on the right. Below the header, the 'Model generation' section is active, showing the text 'Training PREDICT model...' and a blue progress bar at 69%. A navigation menu on the left side lists various options: Project, Experiments, OPTIMIZE, ANALYZE, PREDICT (with sub-items: Sensors, Process indicators, Model generation, Model statistics), and REPORT. The 'Model generation' item is currently selected.

Definizione limiti di accettabilità del Modello

STASA QC neo

KISTLER
measure. analyze. innovate.

Insulin Pen Cap
P100

STASA QC
control. optimize. predict.

Menu

- Project
- Experiments
- OPTIMIZE
- ANALYZE
- PREDICT
 - Sensors
 - Process indicators
 - Model generation**
 - Model statistics
- REPORT

Model generation

Create model

Model error type for ComoNeo: RMSE

Tolerance model validity limits (Y): 15 %

Tolerance model validity limits (X): 10 x 10ms

Model quality (R²): 97.97%

check data ok good

A prediction with the PREDICT model is only possible if the current sensor curve lies completely between the upper and lower validity limits for the respective sensor. This is a precondition and safeguard for the prediction, but not the prediction itself. The prediction is calculated with the PREDICT model.

to ComoNeo

Model validity limits

Temperature Pressure

post gate

Valutazione Statistica del Modello

STASA QC neo

KISTLER
measure. analyze. innovate.

Insulin Pen Cap
P100

STASA QC
simulate. optimize. predict.

Model statistics

Please select quality features... ^

Length x

Name	Model type	R ²	Adj. R ²	Mean absolute error	Max absolute error	RMSE
Length Cav. 2	non-linear	96.2%	95.6%	0.0082 mm	0.0631 mm	0.1009 mm
Length Cav. 3	non-linear	97.9%	97.6%	0.0084 mm	0.0424 mm	0.086 mm
Length Cav. 5	non-linear	95.8%	95.0%	0.0106 mm	0.0491 mm	0.1075 mm

Menu

- Project
- Experiments
- OPTIMIZE
- ANALYZE
- PREDICT
 - Sensors
 - Process indicators
 - Model generation
 - Model statistics
- REPORT

Monitoraggio della previsione dimensionale a fine ciclo durante la produzione con ComoNeo



The background features a series of flowing, wavy lines in shades of blue and orange, creating a sense of motion and depth against a dark background.

Thank you

Michele.Segato@kistler.com