Press information from Sensor Instruments

October 2023

Test report on the inline color measurement of recyclates

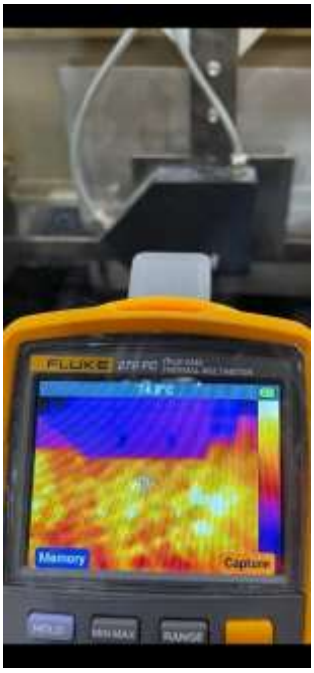
11/10/2023. Sensor Instruments GmbH:

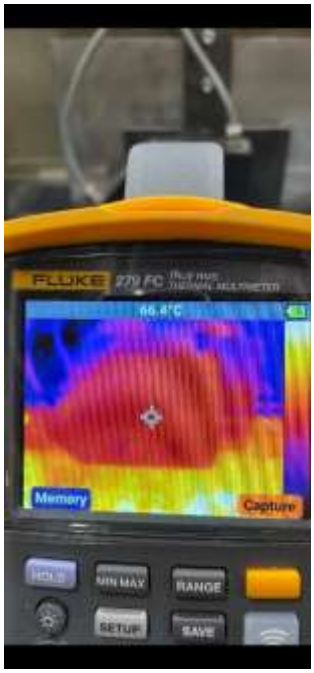
The increasing use of recyclates in the plastics industry means that efficient product control is assuming ever-greater importance. Whilst laboratory-based random quality control was sufficient in the past, the industry is increasingly considering the deployment of 100% control, especially in terms of the color gradient. Sensor Instruments has launched a number of inline systems to perform this function. Providing production staff with information about recyclate production at a very early stage, this covers not only the trend in the color of the recyclates, but the color of the recyclates in combination with their temperature, whilst monitoring the product flow level. The product flow level is important for exact determination of the recyclate color, whilst also providing timely information about a possible blockage of the sieve immediately after the vibrating feeder. The data is also made available for quality assurance via a digital-serial interface (Ethernet).

1. Preparatory measures

First, the current Windows® software SPECTRO3 MSM DOCAL Scope V1.4 was installed on the panel PC. The SI-PPC-500-15” panel PC was positioned immediately after the extrusion system for inline color measurement at the vibrating feeder. Then, the SPECTRO-3-FIO-MSM-ANA-DL (SI inline system) color sensor array was calibrated using a white reference surface (a RAL 9003-P plastic card served as the white reference surface) and to the relevant recyclate. Calibration was performed inline, i.e. the sensor array did not have to be removed from the system for this purpose and calibration was performed on the moving recyclate flow. This meant that the random position of the individual granules could be averaged out. The optimal working distance to the KL-D-0°/45°-85-1200-D-S-A3.0 color sensor front end of 85mm was ensured using a deflector plate. A light spot diameter of type 20mm already performed optical averaging of the random position of the plastic pellets. Averaging over a settable time window of between 5 and 60s can be set using the SPECTRO3 MSM DOCAL Scope V1.4 software. A period of 15s has already emerged as the ideal time window during the first tests. With a recyclate flow speed of 50mm/s to 100mm/s, this results in a measuring length of 750mm to 1500mm. Before

performing the actual color measurement of the various recyclates, the temperature of the recyclate flow at the measuring position and the housing temperature of the color sensor front end were measured.





The surface temperature of the recyclate flow was measured as c. 75°C at the measuring point, whilst the housing temperature of the color sensor front end was c. 66°C.
As there are no optoelectronic or electronic components at the front end of the KL-D-0°/45°-85-1200-D-S-A3.0 color sensor, the temperature of the housing did not constitute a problem. A black, a white and a blue masterbatch were prepared for the upcoming test measurements. The idea was to start with black colored recyclate. Then, the feed of black masterbatch should be stopped and a white masterbatch be added with a time delay. After stopping the addition of white masterbatch, a blue masterbatch should be added after a certain time. In addition, the black masterbatch should be added after a certain time, and the supply of blue masterbatch should be reduced.

2. Inline color measurement on the vibrating feeder

The inline color measurement could begin:
Start of recording: 10:21.
End of recording: 11:12.
In addition to the date, time and the actual L*a*b* color values of the recyclate, the deviations dL*da*db* were recorded in relation to the black recyclate using the SPECTRO3 MSM DOCAL Scope V1.4 software on the SI-PPC-500-15” panel PC:

Record results of: SPECTRO3 MSM DOCAL Scope V1.4

DATE	TIME	X	Y	Z	L*	a*	b*	delta E	delta L*	delta a*	delta b*	COLOR	TEMPs
09-20-2023	10:20:56	184	195	224	27.417	-0.477	-1.293	2.006	-1.923	-0.437	0.367	0	50
09-20-2023	10:21:11	190	202	232	27.884	-0.5	-1.346	1.559	-1.456	-0.46	0.314	0	50
09-20-2023	10:21:26	193	205	236	28.089	-0.357	-1.426	1.311	-1.251	-0.317	0.234	0	50
09-20-2023	10:21:41	189	200	231	27.777	-0.365	-1.406	1.617	-1.563	-0.325	0.254	0	50
09-20-2023	10:21:56	195	206	239	28.221	-0.226	-1.595	1.137	-1.119	-0.186	0.065	0	50
09-20-2023	10:22:12	216	228	266	29.709	-0.347	-1.809	0.503	0.369	-0.307	-0.149	0	50
09-20-2023	10:22:27	249	263	309	31.853	-0.09	-2.165	2.563	2.513	-0.05	-0.505	0	50
09-20-2023	10:22:42	315	329	386	35.624	0.435	-2.269	6.331	6.284	0.475	-0.609	0	50
09-20-2023	10:22:57	357	375	430	37.918	-0.077	-1.595	8.578	8.578	-0.037	0.065	0	50
09-20-2023	10:23:12	323	347	392	36.5	-1.527	-1.133	7.332	7.16	-1.487	0.527	0	50
09-20-2023	10:23:27	338	366	411	37.471	-2.05	-0.985	8.403	8.131	-2.01	0.675	0	50
09-20-2023	10:23:43	360	388	435	38.58	-1.927	-0.864	9.465	9.24	-1.887	0.796	255	49
09-20-2023	10:23:58	380	409	458	39.526	-1.887	-0.897	10.381	10.187	-1.847	0.763	255	50
09-20-2023	10:24:13	385	416	464	39.82	-1.935	-0.802	10.684	10.48	-1.895	0.858	255	50
09-20-2023	10:24:28	396	427	476	40.311	-1.89	-0.759	11.162	10.971	-1.85	0.901	255	50
09-20-2023	10:24:43	405	436	484	40.721	-1.864	-0.647	11.57	11.381	-1.824	1.013	255	50
09-20-2023	10:24:58	408	439	487	40.854	-1.781	-0.629	11.691	11.514	-1.741	1.031	255	50
09-20-2023	10:25:14	410	441	489	40.951	-1.877	-0.592	11.804	11.611	-1.837	1.068	255	50
09-20-2023	10:25:29	406	437	485	40.777	-1.929	-0.593	11.641	11.437	-1.889	1.067	255	50
09-20-2023	10:25:44	400	432	480	40.529	-2.06	-0.679	11.412	11.189	-2.02	0.981	255	50
09-20-2023	10:25:59	402	433	481	40.576	-1.904	-0.69	11.431	11.236	-1.864	0.97	255	50
09-20-2023	10:26:14	408	440	488	40.884	-1.902	-0.612	11.74	11.544	-1.862	1.048	255	50
09-20-2023	10:26:29	420	453	502	41.443	-1.959	-0.585	12.301	12.103	-1.919	1.075	255	50
09-20-2023	10:26:44	423	455	505	41.517	-1.83	-0.642	12.35	12.177	-1.79	1.018	255	50
09-20-2023	10:27:00	416	448	497	41.236	-1.899	-0.594	12.087	11.896	-1.859	1.066	255	50
09-20-2023	10:27:15	408	440	488	40.867	-1.937	-0.647	11.725	11.527	-1.897	1.013	255	50
09-20-2023	10:27:30	407	439	486	40.844	-1.977	-0.578	11.716	11.504	-1.937	1.082	255	50
09-20-2023	10:27:45	405	437	484	40.744	-1.955	-0.62	11.611	11.404	-1.915	1.04	255	50
09-20-2023	10:28:00	403	434	482	40.637	-1.942	-0.625	11.502	11.297	-1.902	1.035	255	50
09-20-2023	10:28:15	404	436	483	40.706	-2.002	-0.589	11.584	11.366	-1.962	1.071	255	50
09-20-2023	10:28:31	396	427	474	40.343	-2.005	-0.631	11.224	11.003	-1.965	1.029	255	50
09-20-2023	10:28:46	390	422	469	40.093	-2.16	-0.657	11.006	10.753	-2.12	1.003	255	50
09-20-2023	10:29:01	438	473	524	42.23	-2.098	-0.606	13.096	12.89	-2.058	1.054	255	50
09-20-2023	10:29:16	516	557	618	45.508	-2.117	-0.712	16.329	16.168	-2.077	0.948	255	50
09-20-2023	10:29:31	606	653	722	48.874	-2.173	-0.586	19.68	19.534	-2.133	1.074	255	50
09-20-2023	10:29:46	664	715	793	50.861	-2.166	-0.709	21.647	21.521	-2.126	0.951	255	50
09-20-2023	10:30:01	717	772	855	52.598	-2.265	-0.692	23.384	23.258	-2.225	0.968	255	50
09-20-2023	10:30:17	758	814	899	53.829	-2.115	-0.543	24.603	24.489	-2.075	1.117	255	50
09-20-2023	10:30:32	763	820	904	53.991	-2.13	-0.523	24.765	24.651	-2.09	1.137	255	50
09-20-2023	10:30:47	752	808	892	53.665	-2.136	-0.513	24.443	24.325	-2.096	1.147	255	50
09-20-2023	10:31:02	769	826	910	54.18	-2.164	-0.466	24.959	24.84	-2.124	1.194	255	50
09-20-2023	10:31:17	810	870	956	55.398	-2.108	-0.385	26.171	26.058	-2.068	1.275	255	50
09-20-2023	10:31:32	827	888	974	55.88	-2.075	-0.321	26.652	26.54	-2.035	1.339	255	50

Extract of the data saved by SPECTRO3 MSM DOCAL Scope V1.4 and evaluated using Excel®.

A diagram was generated showing the L*a*b* color values as a function of time and a diagram showing the course of dL*da*db* in relation to the black recyclate sample (L* = 29.34 a* = -0.04 b* = -1.66).

10:22 Stop black masterbatch feed

10:29 Add white masterbatch

10:33 Stop feeding white masterbatch and add black masterbatch

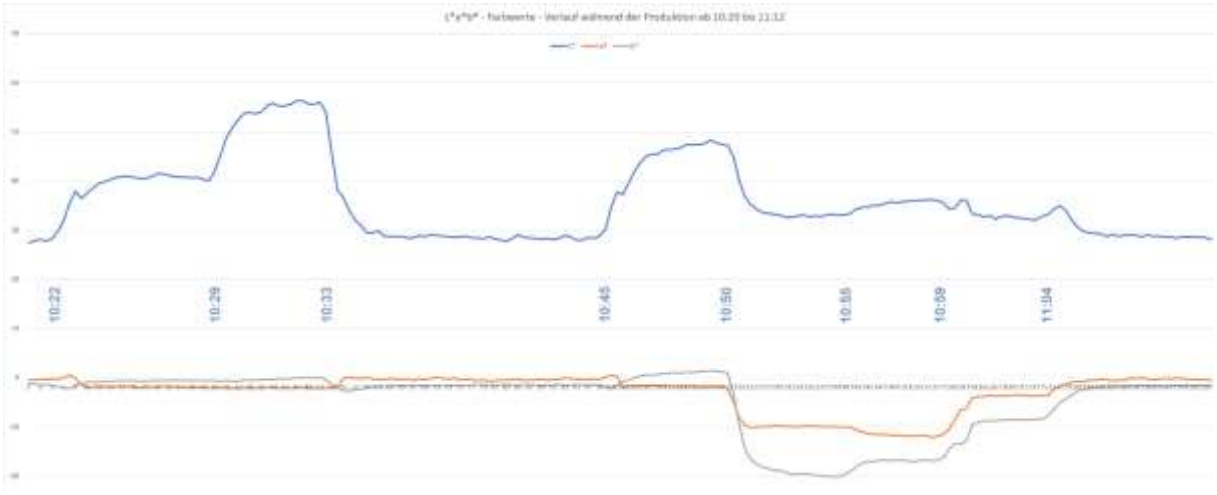
10:45 Stop feeding black masterbatch

10:50 Add blue masterbatch

10:55 Add white masterbatch

10:59 Stop feeding white masterbatch and add black masterbatch

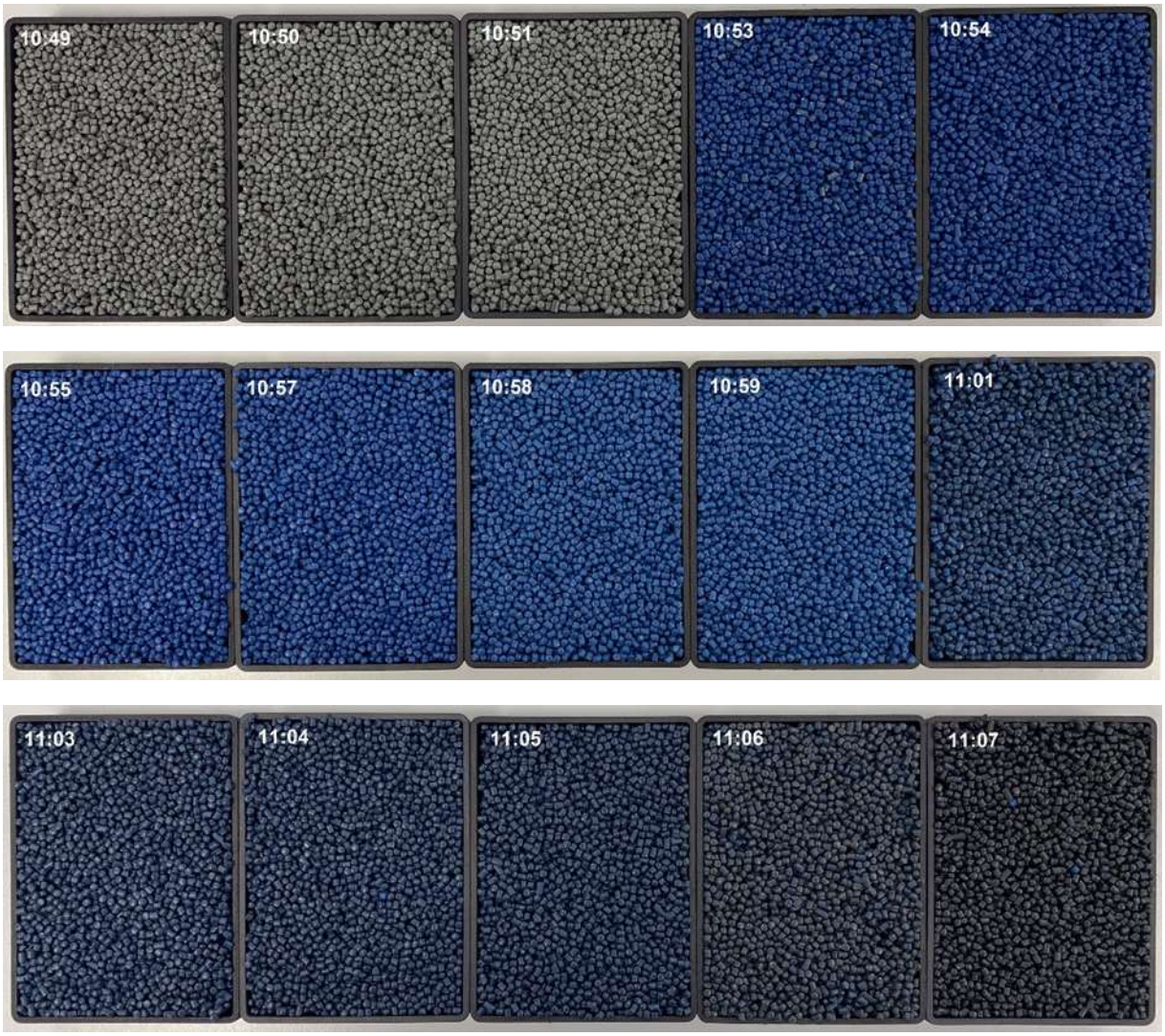
11:04 Stop feeding blue masterbatch


10:22
10:29
10:33
10:45
10:50
10:58
10:59
11:04

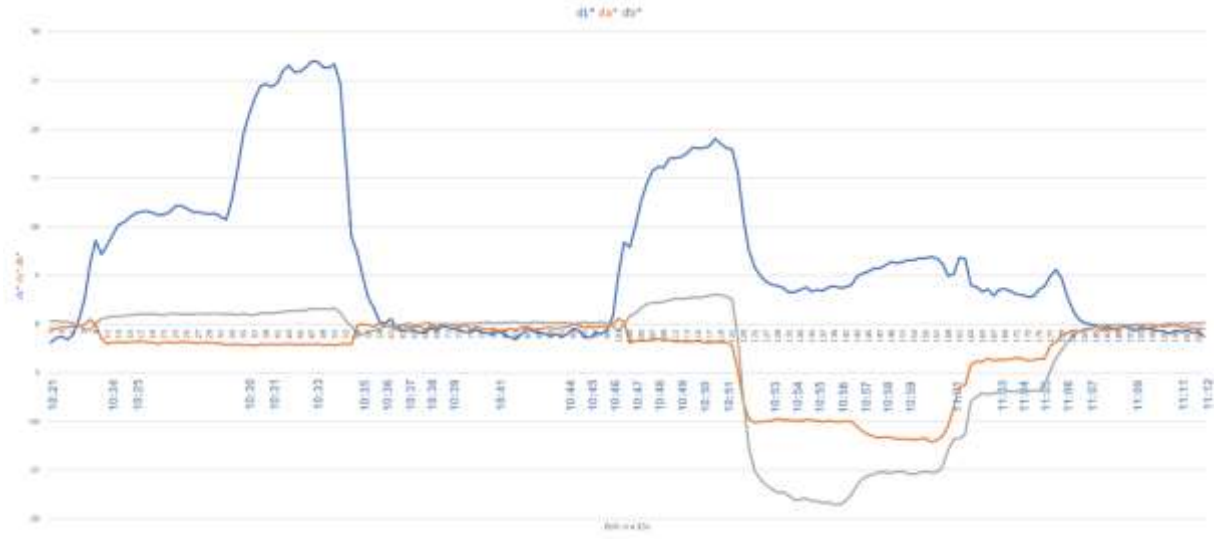

10:23
10:24
10:25
10:30
10:31


10:33
10:35
10:36
10:37
10:38

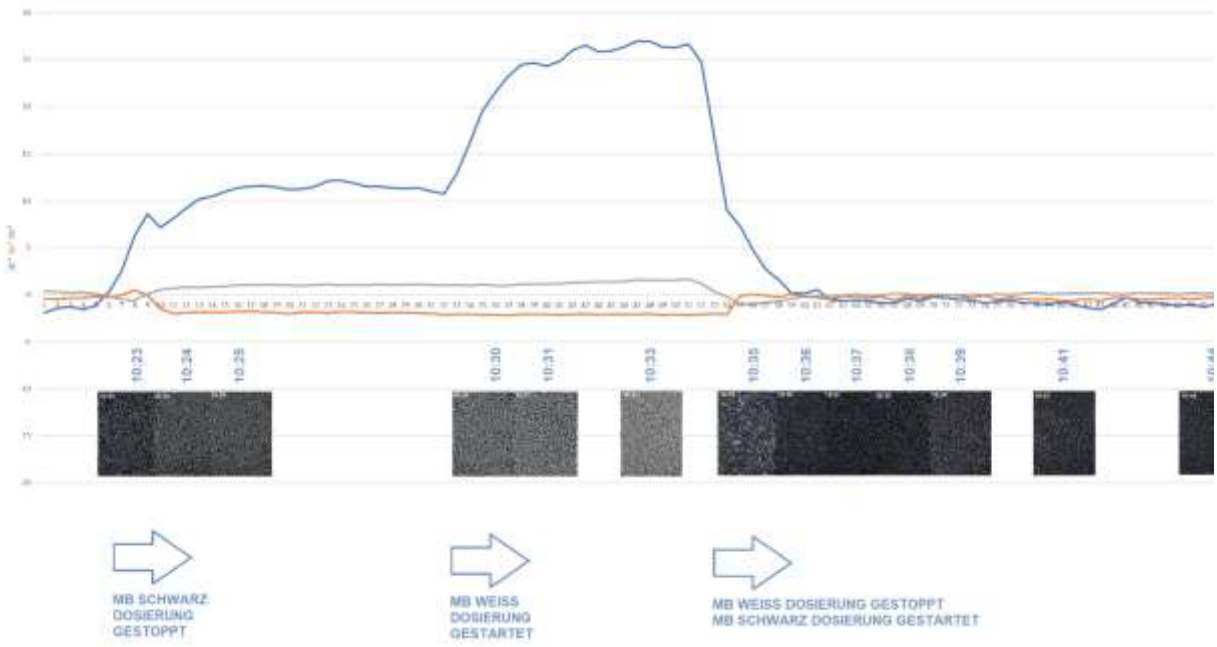

10:39
10:41
10:44
10:47
10:48



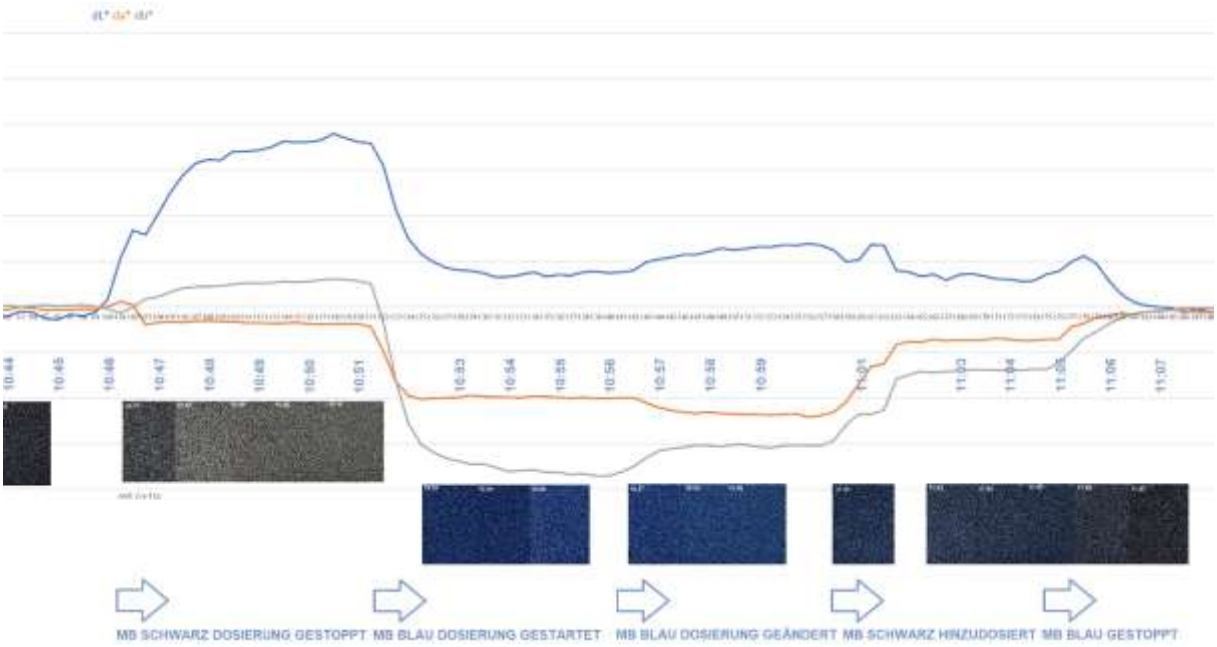
The following graph shows the dL*da*db* course in reference to the black recyclate (L* = 29.34 a* = -0.04 and b* = -1.66):



The following two graphs show the course in approximately double resolution. The pictures of the individual recyclates have been integrated into the diagrams:



Part one: from black to grey and back to black again

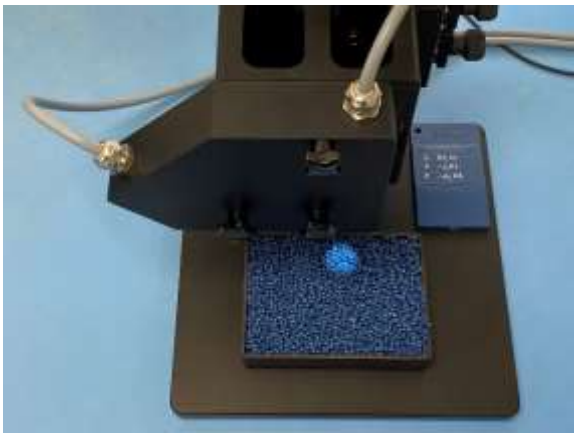


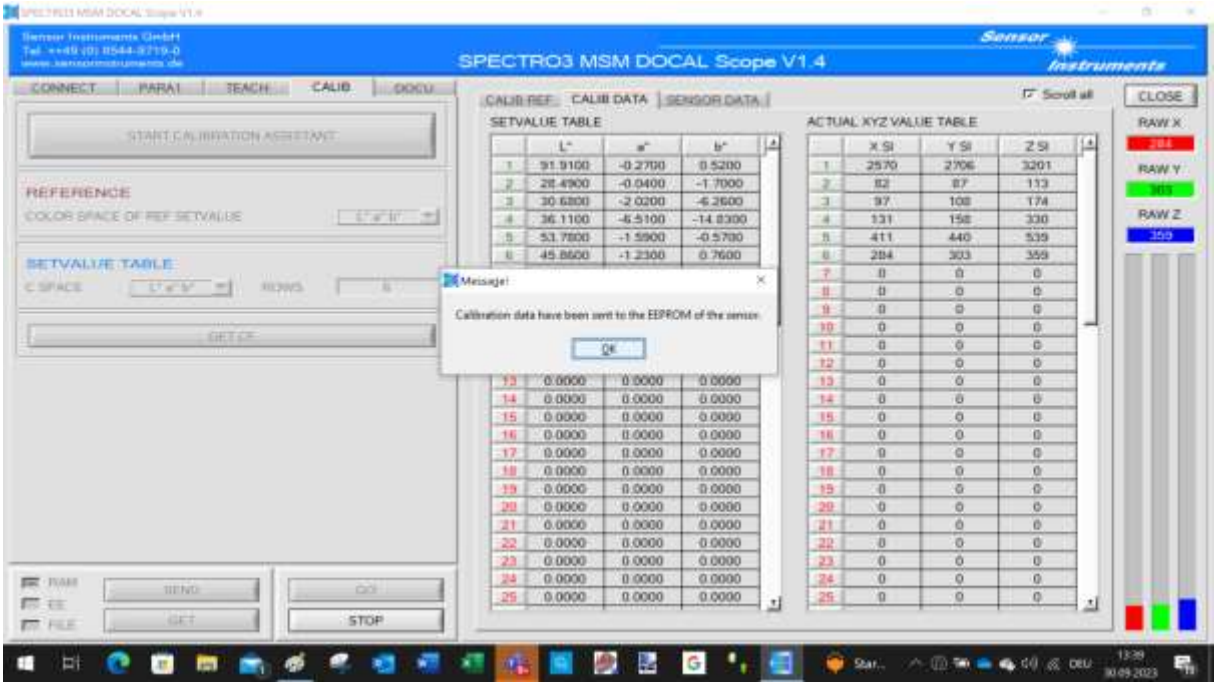
Part two: from black to blue via grey and back to black again

3. Examining the recyclate samples with the SPECTRO-3-0°/45°-MST SI laboratory device

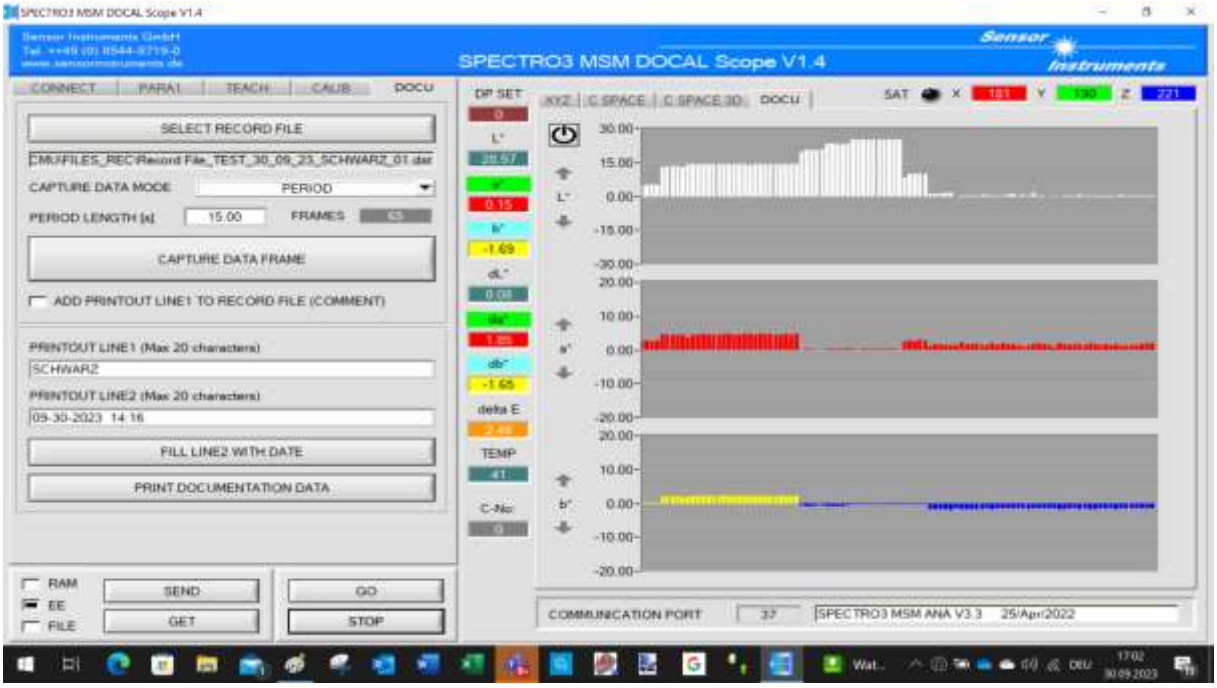
In order to establish a reference to the color measurement systems already available in the laboratory, it was first necessary to make injection moulding plates from selected recyclate samples (a measurement with the laboratory color measurement system requires the production of injection moulding plates). After ascertaining the L*a*b* color values from the injection moulding plates using a laboratory color measurement system, the recyclates matching the injection moulding plates were presented to the SPECTRO-3-0°/45°-MST SI laboratory device (a color sensor array identical to the inline system) for user calibration; the L*a*b* values determined using the laboratory color measurement system were assigned using the SPECTRO3 MSM DOCAL Scope V1.4 software. The calibration wizard made the user calibration very easy.

Calibration of the SPECTRO-3-0°/45°-MST, SI laboratory device was performed using the recyclate samples shown in the picture. These were placed one after the other at the correct distance under the color sensor front end of the SI laboratory device and guided by the calibration assistant. To avoid being dependent on the random position of the pellets in the light spot during calibration, the respective calibration sample was continuously moved under the sensor head within the intended and settable time window. Once calibration had been completed, the calibration factors were stored in the color control electronics.

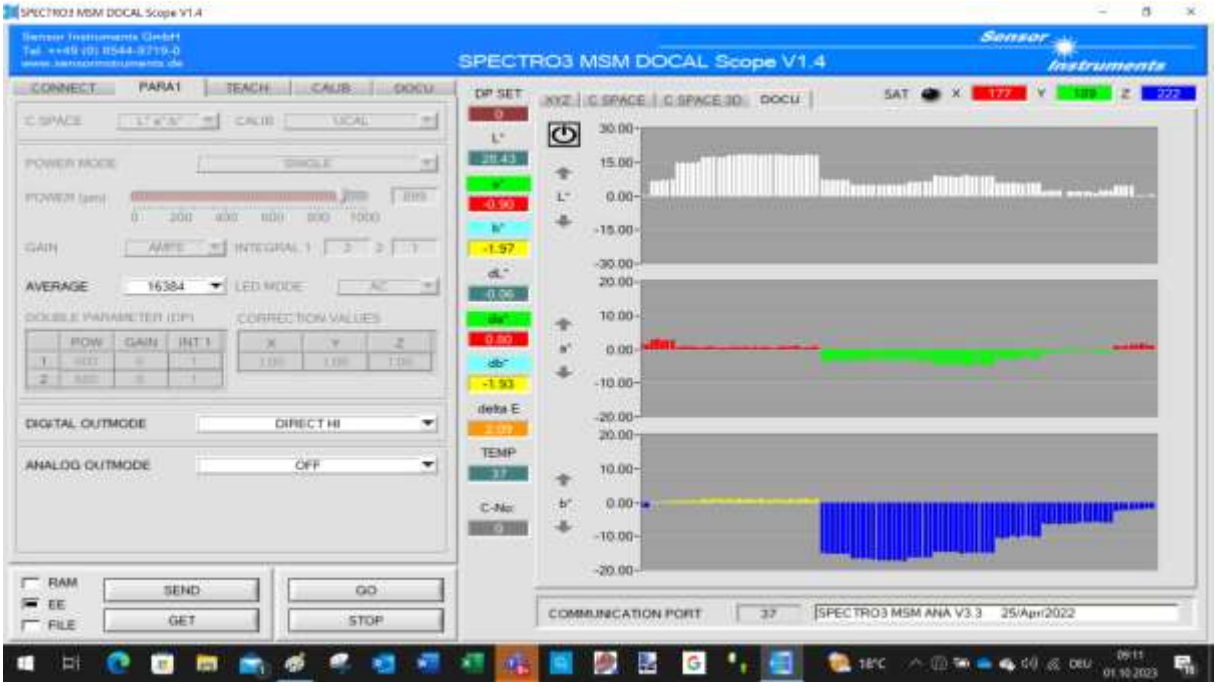




This was followed by color measurement of the 30 different recyclate samples using the SPECTRO-3-0°/45°-MST SI laboratory device. Here, too, the measurements were carried out using SPECTRO3 MSM DOCAL Scope V1.4.

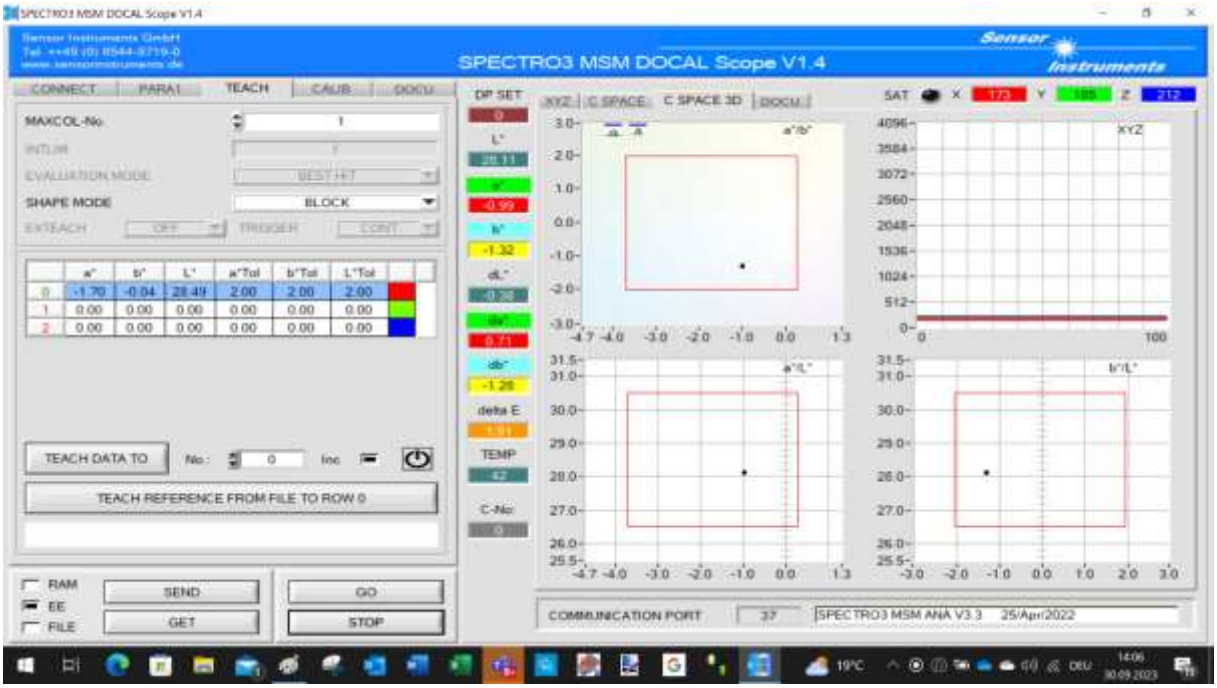


Part one: from black to grey and back to black again

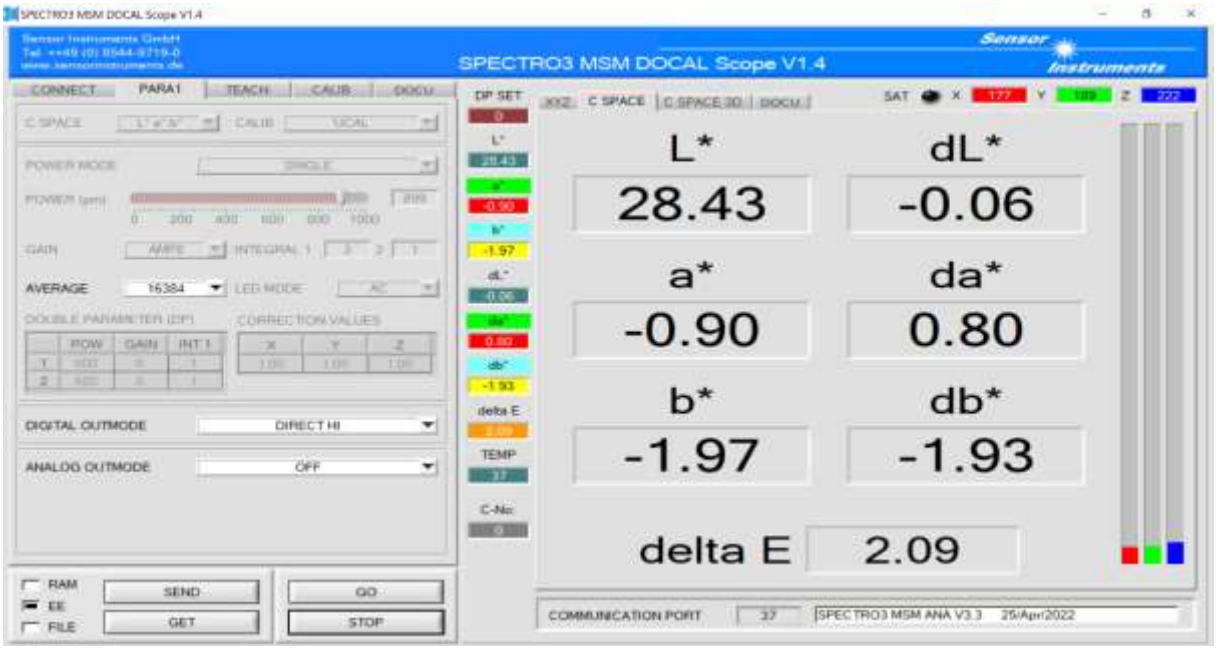


Part two: from black to blue via grey and back to black again

In addition to displaying the dL*da*db* values in relation to an entered reference, the color values L*a*b* incl. the color deviations dL*da*db* were saved in a file which is editable using Word® and Excel®. It was also possible to choose between different representations during color measurement recording: trend display (DOCU); numerical color value and color value deviation display (C SPACE); display of the current color value in the color space inc. the color tolerance windows (C SPACE 3D) and display of the raw data (XYZ).

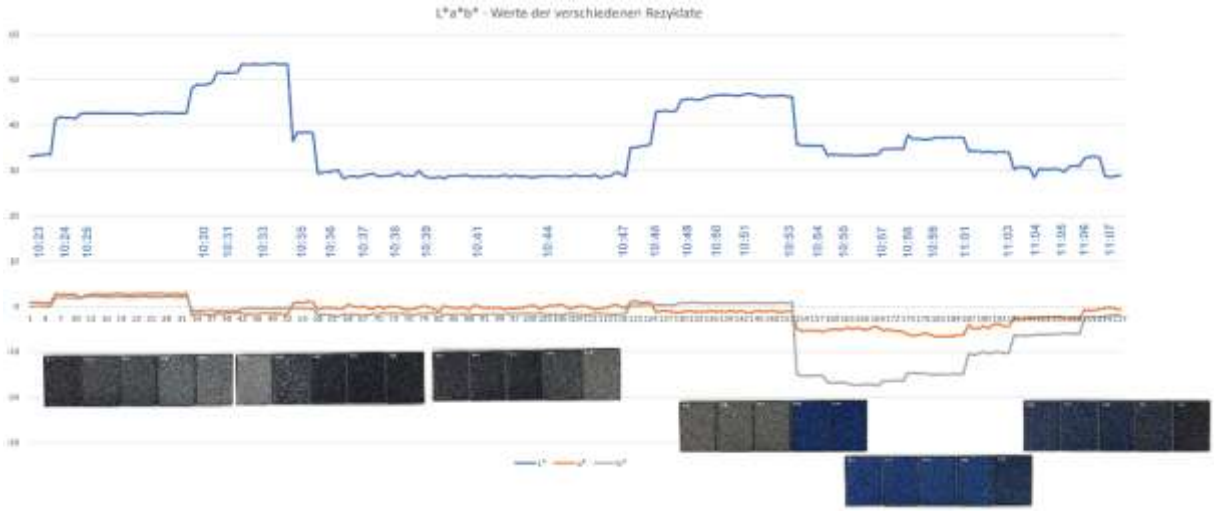


C SPACE 3D: Display of the current color value in various diagrams inc. the tolerance windows

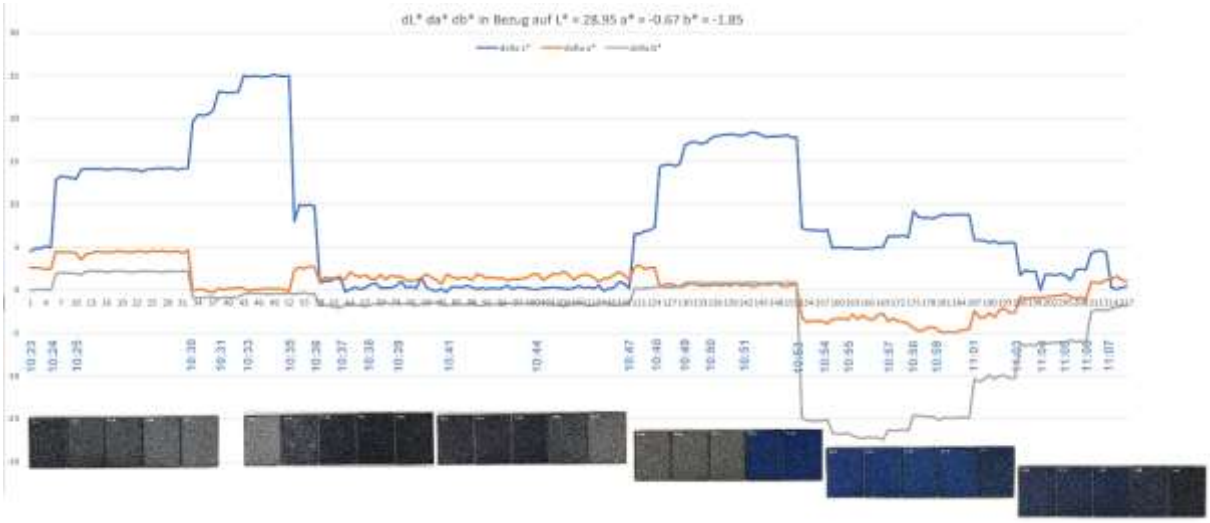


C SPACE: Numerical representation of the L*a*b* color values and the dL*da*db* color tolerance values

While the displays on the monitor provided the operator with valuable information regarding the trends of the color values of the respective recyclates, the evaluation of the stored data is of very great importance for quality assurance, since not only the dL*da*db* color deviations from an L*a*b* reference saved in the TEACH table are stored, but also the L*a*b* color values together with the date and time and information as to whether the color of the recyclate is still within the respective color tolerance range (color number). Below are the diagrams created using the Excel® file. The samples taken during production were marked with the time at which the respective recyclate sample was taken.

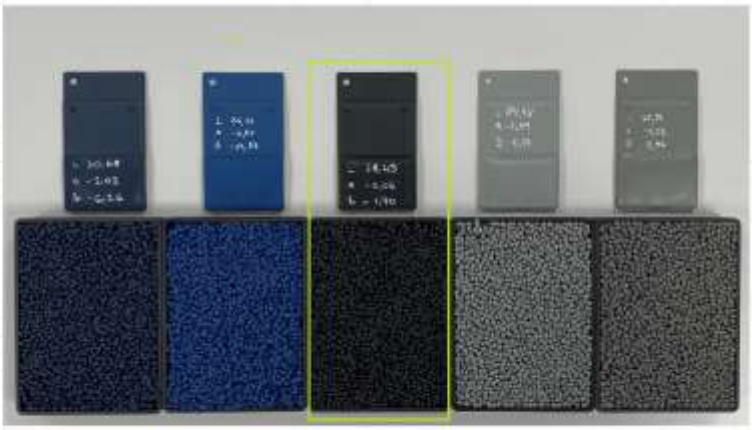


L*a*b*- values of the various recyclate samples, marked with the time of sampling during production



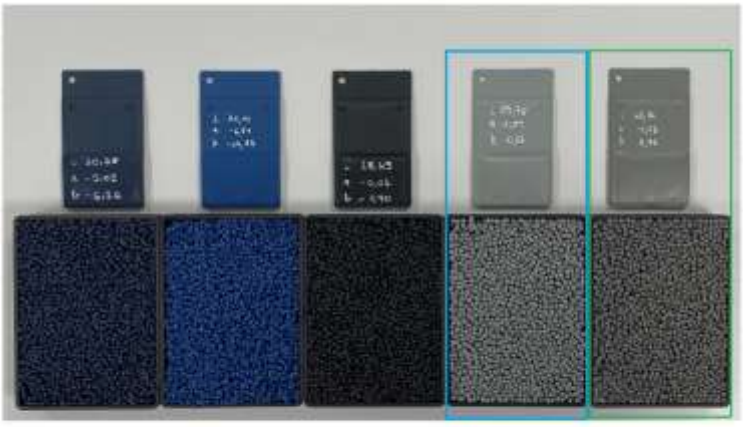
dL*da*db* values of the different recyclate samples, marked with the time of sampling during production

L*	a*	b*
28,092	0.089	-1,817
28,785	-0.852	-1,581
27,790	0.129	-1,721
27,521	-0.29	-1,671
27,551	0.547	-1,622
27,703	-0.622	-1,563
27,918	-0.674	-1,685
27,684	-0.489	-1,700
27,604	0.546	-1,580
27,601	-0.559	-1,708
27,598	-0.19	-1,711
27,368	-0.492	-1,772
27,224	-0.292	-1,694
28,181	-0.208	-1,584
28,559	0.498	-1,623
28,574	-0.209	-1,700
28,976	-0.683	-1,396
28,673	-0.73	-1,798
27,493	-0.155	-1,794
27,486	-0.077	-1,794
27,887	-1,076	-1,397
27,721	-0.057	-1,624
27,672	0.156	-1,764
46,332	-1,067	0.826
46,343	-1,232	0.876
46,445	-1,158	0.843
46,250	-1,209	0.796
46,332	-1,291	0.789
45,884	-1,065	0.727
45,890	-1,217	0.811



L*a*b* color values of the black recyclate sample

27,887	-1,076	-1,397
27,721	-0.057	-1,624
27,672	0.156	-1,764
46,332	-1,067	0.826
46,343	-1,232	0.876
46,445	-1,158	0.843
46,250	-1,209	0.796
46,332	-1,291	0.789
45,884	-1,065	0.727
45,890	-1,217	0.811
45,872	-1,069	0.808
45,885	-1,222	0.765
45,757	-1,249	0.822
45,790	-1,208	0.783
45,729	-1,152	0.755
45,661	-1,287	0.769
54,003	-1,545	-0.59
53,866	-1,616	-0.573
53,518	-1,683	-0.512
53,391	-1,531	-0.601
53,564	-1,493	-0.548
53,562	-1,513	-0.605
53,627	-1,782	-0.518
53,554	-1,506	-0.574
53,497	-1,634	-0.52
53,511	-1,710	-0.466
53,560	-1,458	-0.572
53,637	-1,682	-0.559
53,600	-1,718	-0.504
53,513	-1,605	-0.509
35,561	-6,415	-14,637
35,704	-6,630	-14,780



L*a*b* color values of the dark grey and the light grey recyclate sample

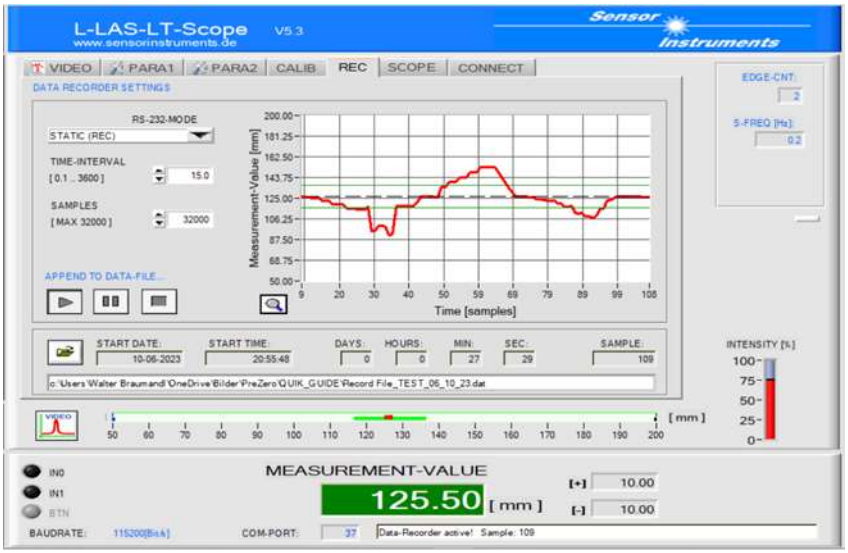
53,513	-1,605	-0,509
35,561	-6,415	-14,637
35,704	-6,630	-14,780
35,610	-6,674	-14,832
35,470	-6,621	-14,822
35,491	-6,940	-14,813
35,460	-7,161	-14,755
35,523	-6,419	-14,918
35,520	-6,773	-14,785
35,589	-6,526	-14,859
35,519	-6,678	-14,846
35,568	-6,502	-14,883
35,394	-6,700	-14,828
35,519	-6,336	-14,943
35,836	-6,223	-14,911
30,496	-2,386	-6,214
30,444	-2,118	-6,162
30,475	-2,138	-6,142
30,584	-2,702	-6,035
30,342	-1,764	-6,245
30,365	-1,909	-6,250
30,402	-2,369	-6,128
30,449	-1,968	-6,128
30,609	-2,382	-6,202
30,828	-1,384	-6,258
30,602	-2,340	-6,155
30,488	-2,379	-6,095
30,602	-2,696	-6,127
30,927	-2,176	-5,976
30,607	-2,032	-6,271
30,598	-2,012	-6,197
30,466	-1,724	-6,347
30,648	-2,472	-6,173

L*a*b* color values of the dark blue and the blue recyclate sample

4. Optimization measures

In principle, the color measurement works very well at the current measuring point, but some changes should still be made. For example, a greater volume of dust is generated whilst changing the big bag, whilst the lighter plastic flakes settled on the surface of the sensor array. It would certainly be advantageous to cover the sensor array. A very rough pellet flow surface was observed at the measuring point. In contrast, the plastic granulate flow near the sieve had a flat surface even without the use of a deflector plate. However, it was also found that the height of the pellet flow increased when the sieve was blocked or partially moved. In order to be able to make a correct statement about the color value of a recyclate, the distance of the recyclate surface to the front end of the sensor should be kept approximately constant. The level of the recyclate flow can be determined by attaching an additional laser distance sensor. For example, a warning lamp can be activated if an adjustable height tolerance window is exceeded or not

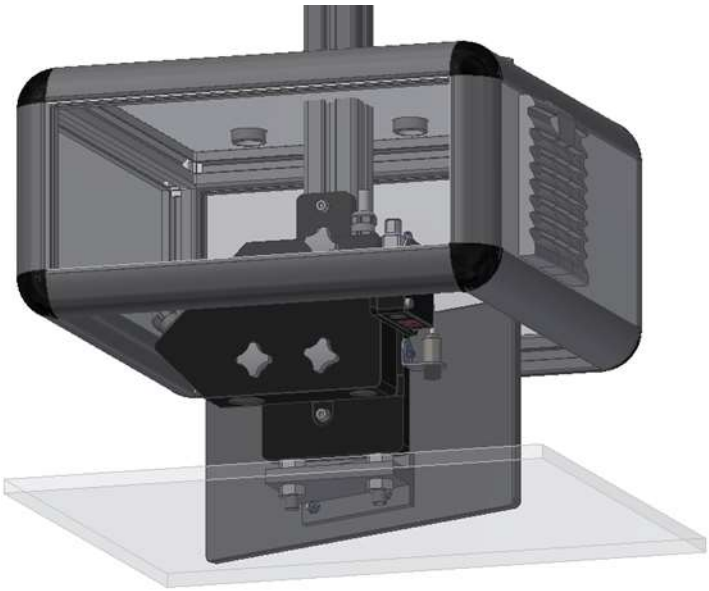
reached; in parallel, the height of the recyclate flow is also displayed by the evaluation unit (panel PC: SI-PPC-500-15“) and saved in a file. Preliminary tests with a type L-LAS-LT-130-SL-P laser distance sensor have delivered very good results on different coloured recyclate surfaces. The laser sensor also has a serial interface and provides digital outputs (0V/+24V) that inform whether the height of the recyclate flow lies within or outside an adjustable tolerance



window. Another important parameter is certainly the temperature of the recyclate flow, as this also influences the color of the recyclate. An infrared camera was used to take temperature

measurements on the recyclate flow; the surface temperature of the pellet stream was measured as c. 75°C. It is now planned to position a pyrometer together with the laser distance sensor near to the color sensor. The temperature is displayed on the control unit integrated in the SI-PPC-500-15” and the temperature is recorded by a panel PC. Exceeding an adjustable temperature limit can be indicated by a warning lamp.

The following section shows the individual sensors integrated in a protective housing. The laser distance sensor and pyrometer are located in the immediate vicinity of the color sensor head. The deflector plate has been replaced by a heat and abrasion-resistant plastic plate, which enables containment of the heat transfer from the recyclate flow to the sensor head. A fan is provided to ensure sufficient air circulation to prevent heat build-up inside the cover housing.



The sensor head can be positioned at different positions across the vibrating feeder with the help of the aluminium profile frame. The sensor array can be calibrated whilst installed, during operation, so it is not necessary to remove the sensor array. A mechanical bracket is provided with which to insert the white reference (for example RAL 9003-P), which can be mounted during operation. The calibration card bracket can be removed again once the white balance has been performed. Calibration is then performed on the recyclate currently under production; a sample taken from the current recyclate is used to produce an injection moulding plate for measurement of the color values (L*a*b*) using the laboratory color measurement system. After entering the color values into the software of the panel PC, the calibration process can be completed and the COLTEM-85 inline color measurement system can be used to determine the color and temperature of the recyclate.

Contact:

Sensor Instruments
Entwicklungs- und Vertriebs GmbH
Schlinding 15
D-94169 Thurmansbang
Telephone +49 8544 9719-0
Fax +49 8544 9719-13
info@sensorinstruments.de