Case Study

CO_2 Cleaning Demonstration on Kenworth T680 Hood

Abstract

Testing of the RSTG Cleanmaster PPM CO_2 cleaning system with two CE10 cleaning heads on a FANUC P-350iA Painting Robot, cleaning a Kenworth fiberglass hood. This study will demonstrate how both dust and oil contaminants can be removed from the Kenworth part with CO_2 cleaning. DeWalt Orange Chalk is representative of the toughest dry contaminants from a factory floor and prep operations such as sanding, from a scale of 1-1000 microns. Coconut oil represents the bonding energy of several common wet contaminants, such as fingerprints, oils, cosmetic products and mold release. The technology will be tested, and techniques like Infrared Spectrometry and Wavelength Particle Count will be used to validate cleaning using FTIR and PartSens respectively.

Parameters

Air Input -------------------- 90 scfm (required 160 scfm)

CO2 Input Pressure--------- 300 psi (required 350 psi)

CO2 Input Flow Rate-------- 50 lb/hr (required 90lb/hr)

Speed ----------------------- 350 mm/s (dependent on input variables)

Cleaning speed is dependent on air and CO_2 inputs. Required air is 160 SCFM, because the supply at FANUC is limited to 90 SCFM, CleanMaster PPM was therefore set to clean at a maximum speed of 350 mm/s. Speed and cleaning efficiency of CleanMaster PPM can be improved if provided with the required input parameters of Air and CO_2.

Materials

Following materials were used for this case study

- CleanMaster PPM CO_2 Processing Module (RSTG, Reliabotics)
- CE10 Cleaning Heads (RSTG, Reliabotics)
- FANUC p-350iA Painting Robot (FANUC)
- Orange Chalk as a dry contaminant (DeWalt, MFR #: DWHT47076L)
- Liquid Coconut Oil as a wet contaminant (Walmart # 554869379)
- Paint Roller for applying the chalk
- Duster for spreading the chalk
- Airbrush (atomizer) for applying coconut oil
- PartSens particle counter instrument (for detecting dry particles)
- Agilent 4300 FTIR (for identifying liquid contaminants)

Procedure

Following procedure was followed to demonstrate the cleaning using different nozzles (CE10 & CE20) for different contaminants,

CE20 Test with Dry Contaminant

1) Apply orange chalk (dry contaminant) on painted hood using a paint roller.
2) Use the duster to spread that chalk and get rid of loose particles.
3) Use PartSens to take 20 samples of this dirty surface (area of surface covered in each sample is 31.96 mm^2).
4) Turn the machine on and press start button. Once the machine is ready and the air start coming out of the nozzles, run the program and show the cleaning with just the air.
5) Use PartSens to take 20 samples of the surface treated by just the air.
6) Once done, press the start button again and observe the CO_2 jets and wait for them to stabilize.
7) Run the program again and observe the cleaning with CO_2.
8) Use PartSens to take 20 samples of the clean surface treated by CO_2.
9) After each cleaning pass, take 20 samples with PartSens.

CE10 Test with Liquid Contaminant

1) Start by marking a 2x2 inches patch on the painted hood.
2) Take a background sample of that clean 2”x2” patch using FTIR.
3) Apply coconut oil (liquid contaminant) on painted hood using the atomizer inside that 2”x2” patch.
4) Take a sample of this contaminated surface using FTIR.
5) Save the produced IR spectrum of this contaminated surface.

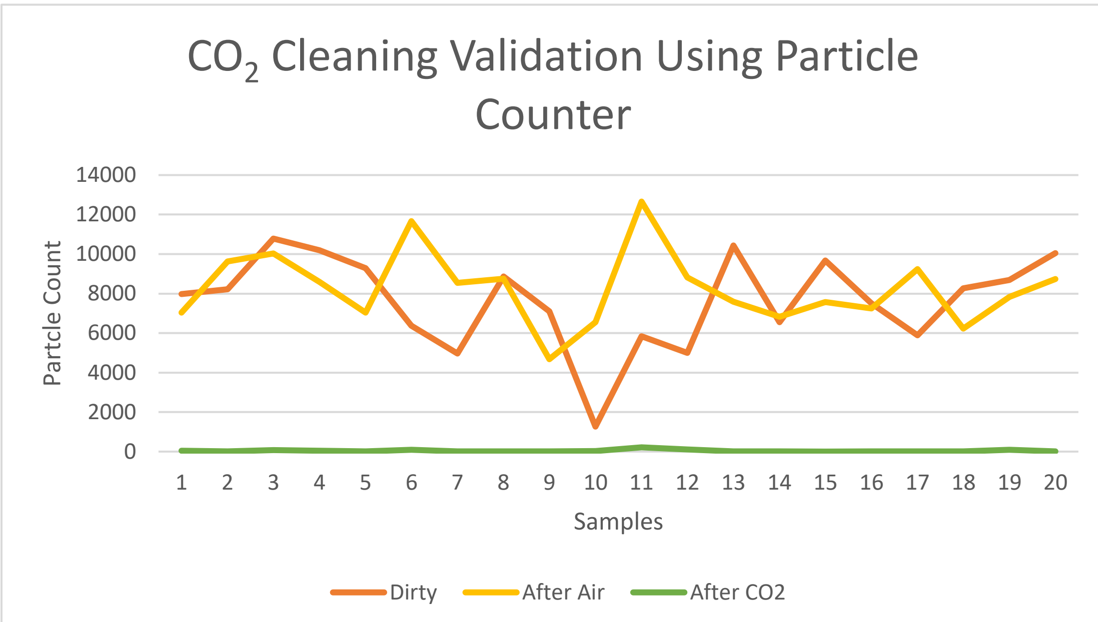
6) Use CleanMaster PPM system with a modular CE10 (handheld) to clean the 2x2 patch contaminated with coconut oil.
7) Take an FTIR sample of the surface cleaned with CO_2.
8) Compare both IR spectrums of before and after the cleaning.
9) Repeat the test if necessary.

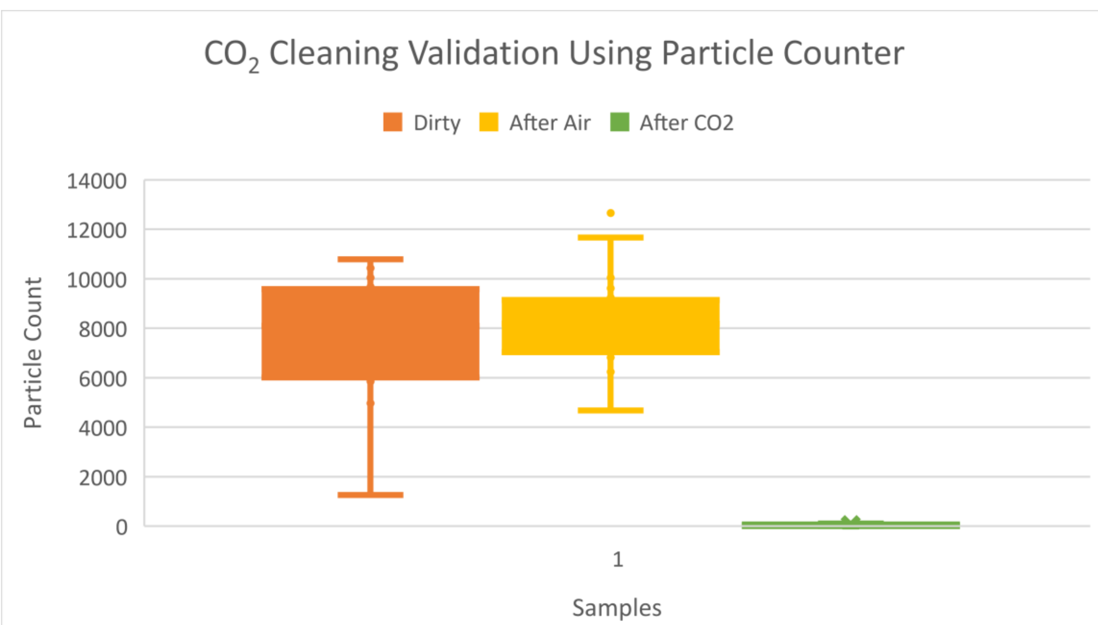
Results

To properly demonstrate the cleaning validation, twenty different samples were taken showing the particle count of dirty surface, twenty samples analyzing the surface after air treatment and twenty samples analyzing the surface after CO_2 treatment. Following are the results demonstrating the efficiency of CO_2 cleaning, (see appendix for extensive data with particle size range),

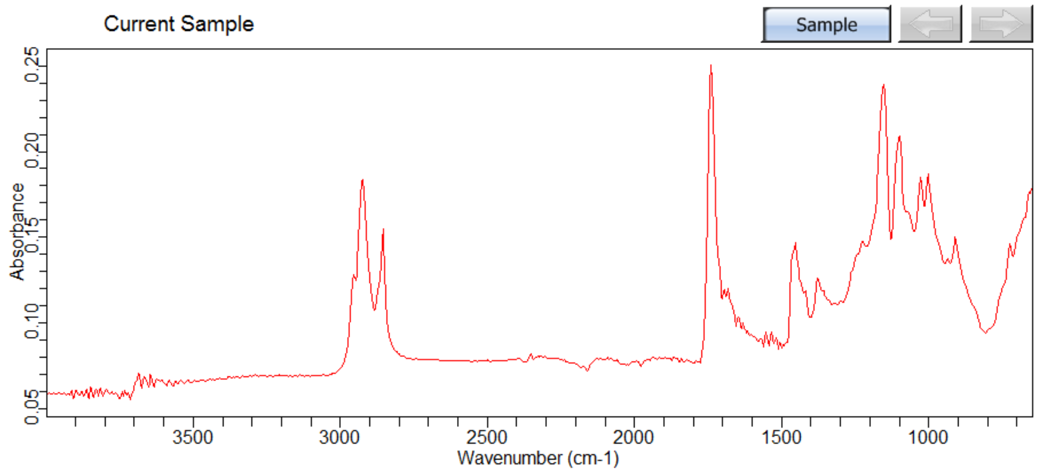
Sample	Before	After Air	After CO2
1	7975	7034	40
2	8218	9620	9
3	10785	10040	72
4	10201	8589	41
5	9292	7035	3
6	6379	11664	93
7	4965	8538	4
8	8862	8752	3
9	7095	4677	4
10	1264	6550	20
11	5843	12659	216
12	4990	8822	110
13	10430	7582	8
14	6549	6825	10
15	9678	7579	0
16	7508	7244	8
17	5895	9243	7
18	8275	6235	18
19	8687	7824	84
20	10049	8731	13

After analyzing the result, it was found that after the CO_2 treatment, the surface was 99.99% cleaner than before. Figure 1 & 2 graphically demonstrate the cleaning using the PartSens particle counter where the region represented by green shows the number of particles left behind after the CO_2 treatment. It is important to understand that these results only show 60-70% of the efficiency of the machine as the input requirements haven't been met due to the facility restrictions. These results can be improved further if given the parameters meet the requirements.

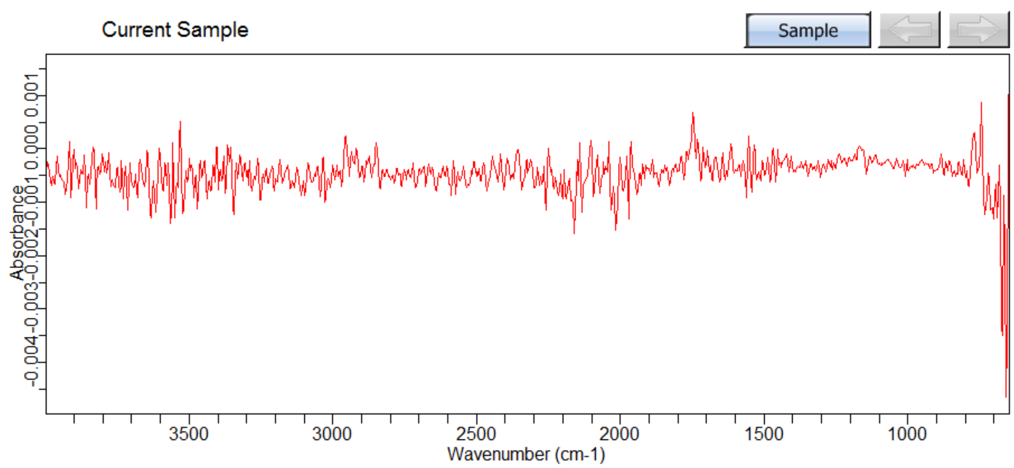




For liquid contaminants, a Fourier Transform Infrared Spectrometer (Agilent 4300 Handheld FTIR) was used. A background sample was taken on the clean surface and then some coconut oil was applied on the surface using an atomizer. An IR spectrum was taken and coconut oil was detected by its peaks shown underneath.



After cleaning, another IR spectrum was taken and this time no coconut oil was detected showing that the surface was perfectly clean.



Conclusion

CleanMaster PPM cleaned the Kenworth T680 hood contaminated with chalk and coconut oil with the efficiency of 99.99% validated by PartSens Particle Counter and FTIR respectively.

Appendix

Following is the extensive data showing the particle count in different size ranges before and after cleaning. This data was collected by PartSens Particle Counter.

Before											
Particle Size (µm)	5- 15	15- 25	25- 50	50-100	100-150	150-200	200-400	400-600	600-1000	> 1000	Total
1	285	271	4774	1793	387	179	178	45	38	25	7975
2	424	447	4990	1541	389	124	173	54	51	25	8218
3	66	61	7581	2444	389	132	88	17	6	1	10785
4	102	83	6415	2558	557	230	208	28	17	3	10201
5	33	27	6818	2012	279	61	56	5	0	1	9292
6	624	665	3016	1268	301	156	211	54	43	41	6379
7	297	350	2879	959	231	94	100	25	18	12	4965
8	28	24	6803	1658	235	70	35	6	2	1	8862
9	209	232	4443	1527	325	130	145	34	22	28	7095
10	85	63	323	392	143	73	102	33	22	28	1264
11	619	708	2797	1084	267	113	148	45	31	31	5843
12	500	709	2312	915	212	103	142	37	20	40	4990
13	147	119	6960	2365	429	173	167	42	13	15	10430
14	331	398	3934	1259	281	109	143	42	22	30	6549
15	77	78	7398	1630	253	106	101	15	12	8	9678
16	9	10	6208	1155	87	24	14	0	0	1	7508
17	423	517	3143	1105	270	133	179	47	39	39	5895
18	13	9	6643	1385	153	42	29	0	0	1	8275
19	200	196	5295	2003	455	220	228	50	25	15	8687
20	327	213	6981	1762	366	201	112	31	17	39	10049

After Air											
Particle Size (µm)	**5- 15**	**15- 25**	**25- 50**	**50- 100**	**100- 150**	**150- 200**	**200- 400**	**400- 600**	**600- 1000**	**> 1000**	**Total**
1	885	875	3042	1388	361	143	208	49	43	40	7034
2	89	97	6206	2340	491	192	153	33	17	2	9620
3	129	147	6596	2320	465	160	164	32	17	10	10040
4	1844	1416	3172	1238	361	158	255	68	40	37	8589
5	835	851	3292	1327	305	123	179	49	33	41	7035
6	32	33	8831	2331	288	84	57	6	0	2	11664
7	350	377	5312	1789	360	139	135	35	20	21	8538
8	1766	2240	3370	1043	182	71	49	11	11	9	8752
9	332	388	2265	1121	260	105	135	26	26	19	4677
10	897	1061	2385	1369	388	175	193	44	25	13	6550
11	36	29	9854	2247	322	103	58	8	1	1	12659
12	1246	1673	3545	1574	379	164	165	40	25	11	8822
13	1120	1391	3249	1170	297	129	134	45	25	22	7582
14	488	607	3476	1475	362	146	164	48	32	27	6825
15	510	554	4045	1552	406	164	217	62	35	34	7579
16	524	524	3754	1526	386	172	231	53	34	40	7244
17	136	117	5852	2244	485	185	174	33	9	8	9243
18	456	459	3361	1222	289	137	177	56	40	38	6235
19	901	1072	3428	1531	389	159	225	48	36	35	7824
20	876	991	4782	1228	399	161	190	51	32	21	8731

After CO_2											
Particle Size (µm)	**5- 15**	**15- 25**	**25- 50**	**50-100**	**100-150**	**150-200**	**200-400**	**400-600**	**600-1000**	**> 1000**	**Total**
1	21	10	8	1	0	0	0	0	0	0	40
2	1	2	6	0	0	0	0	0	0	0	9
3	20	22	28	2	0	0	0	0	0	0	72
4	8	7	22	3	1	0	0	0	0	0	41
5	1	0	2	0	0	0	0	0	0	0	3
6	27	38	28	0	0	0	0	0	0	0	93
7	1	0	2	1	0	0	0	0	0	0	4
8	0	2	0	1	0	0	0	0	0	0	3
9	1	0	2	1	0	0	0	0	0	0	4
10	2	4	9	3	2	0	0	0	0	0	20
11	108	77	30	1	0	0	0	0	0	0	216
12	46	38	25	1	0	0	0	0	0	0	110
13	2	2	3	1	0	0	0	0	0	0	8
14	2	3	5	0	0	0	0	0	0	0	10
15	0	0	0	0	0	0	0	0	0	0	0
16	6	1	1	0	0	0	0	0	0	0	8
17	3	3	1	0	0	0	0	0	0	0	7
18	11	4	3	0	0	0	0	0	0	0	18
19	29	32	20	3	0	0	0	0	0	0	84
20	7	3	3	0	0	0	0	0	0	0	13

The above data shows that CleanMaster PPM cleaned the particles in the range of 100-1000 µm with 100% efficiency and from 5-100 µm it cleans with the efficiency of 99.998%. An important thing to understand is that the machine was running at around 60% efficiency as the inputs were far below the required parameters. In other studies, and experiments where the input parameters were met the requirement, the results observed at smaller scale of 5-100 µm were also at 100%.