Seeing the Light:
3-D Radiometers

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Abstract

A novel industrial UV Coating transforms actual production parts into "3-Dimensional Radiometers" (3DRs) enabling UV line operators to ‘see’ variations in UV irradiation on production parts. A non-technical discussion of 3DR operation and applications is presented.

Introduction

Ultimately, the most critical factor in curing industrial UV coatings relies on proper positioning of UV lights to achieve optimal irradiation of parts. In addition to facilitating set-up of lights, 3DR's provide a means for on-line confirmation of irradiance integrity. Coating a representative part with a proprietary coating that changes color with exposure to UV light makes a ‘3-D Radiometer’. This transforms the part into a reusable, 3-dimensional, visual indicator of UV irradiation.

For the first time, UV ‘shadows’ and ‘hot spots’ can be immediately identified and corrected. Dubbed the ‘UV litmus test’, 3DRs revert to their original color allowing for years of reusability.

3-D Lines

Ultimately, UV cure is contingent on proper lamp positioning to irradiate coated parts[1]. There is little the coating formulator or the equipment integrator can do if production parts are not properly irradiated with UV light. Proper lamp set-up is critical for 2-dimensional and especially 3-dimensional UV lines.

In the case of 3-dimensional UV processing, lamp set-up is performed with the UV sources turned off. (The UV wavelengths required for cure are invisible to human eyes, and damaging to unprotected eyes and skin. Industrial UV lights produce large amounts of visible light that should not be used as an 'indicator' of UV light.) First, a 'target part' is positioned in the cure zone, as it would normally be found in production. Then, UV sources are positioned and directed at the 'target' part with the line operators using their best guess in directing the lights onto the part. When the UV curing chamber is safe, the lamps are powered up, and test parts are coated and run to test cure. If an area on the part feels under-cured, the line operator must power down the UV lights, allow

Fig. 1. An automotive thermoplastic part prior to UV irradiation.

Fig. 2. The same automotive part from Fig. 1. after UV exposure. Note the effect of UV blocking film laid on the part had on the 3DR indicator underneath.

the chamber to cool, renter and re-adjust the UV lamps to correct for the perceived under-cured area. Then another test part is run. This cycle is repeated until satisfactory cure is perceived. This process is time and labor intensive with significant, attendant generation of scrap parts and material.

2-D Lines

In the case of 2-dimensional UV processing, or flat-lines, the flat surface nearest the lamp(s) usually does not experience cure problems. However, sides, lead and trailing edges/contours are often presumed to acquire adequate irradiation for cure. Line operators presume that if there is enough UV to cure the top surface, there should be enough UV to cure the adjacent contours, sides and edges. This presumption is incorrect and may lead to falsely concluding that the coating is at fault. If 2-D line operators had access to a 3DR, they would quickly be able to differentiate between cure problems due to under irradiated areas versus coating fault

The State of the Art

Conventional radiometers provide information on UV energy at a single sensor point on the radiometer. This is typically a circular sensor less than 0.5 In. in diameter. Beyond the sensor's detection area, no further information is available on the UV irradiation on the balance of the part's surface.
Such systems are excellent in quantifying UV energy - at a single point at a time.

An Ideal Indicator

An ideal UV radiometer would be identical in size and shape to the actual production part. Such a UV radiometer would allow the operator to 'see' UV distribution over the entire part providing immediate visual identification and location of UV "shadows" or "hot spots". Further, such a tool will allow on-line confirmation, diagnostic and quality assurance of part irradiation integrity. 3DRs allow for immediate indication that any lamp(s) may have moved out of position, or some other unattended factor is effecting part irradiation.

Theory

Combined advances in chemistry[2] and industrial UV curing equipment have eliminated the line-of-sight curing limitation of three-dimensional parts for both pigmented and clear UV coatings[3].

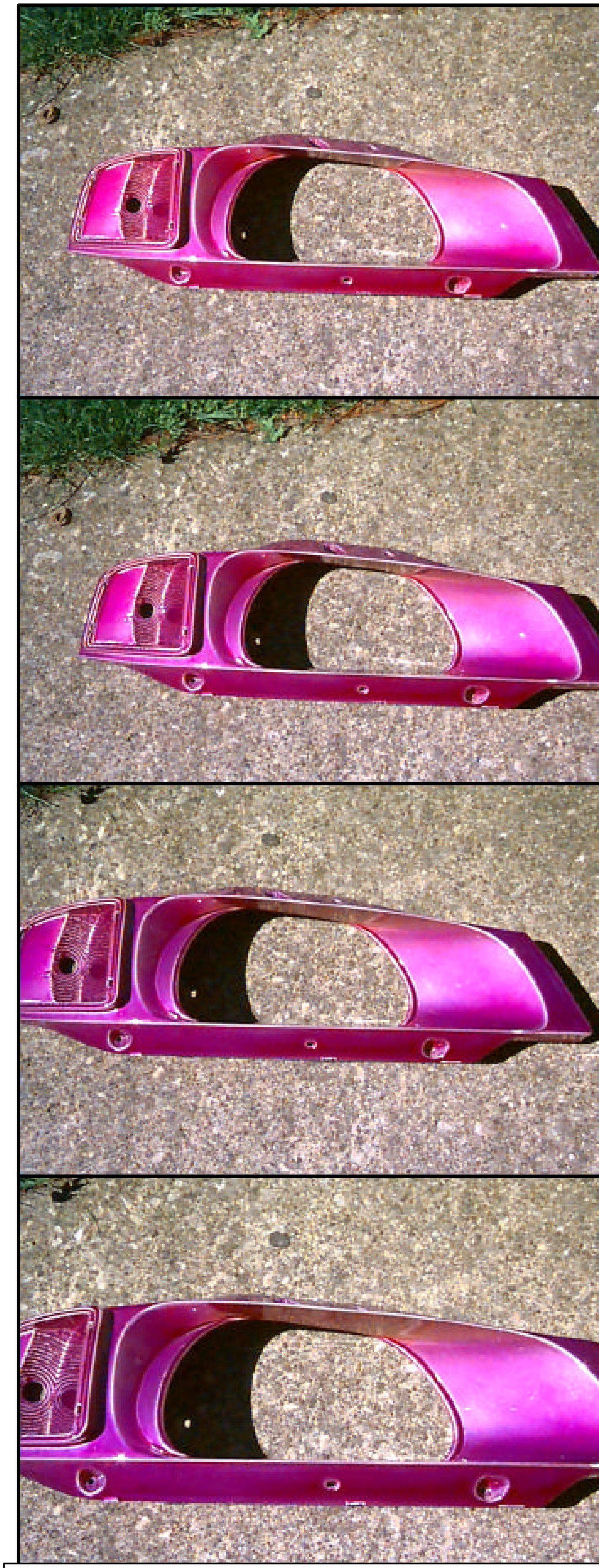

Fig. 3. As the 3DR begins to respond to UV (Top) the part changes color revealing surface variations in UV exposure.

The chemical mechanism by which the chromophoric structure is created by exposure to UV light and the reverting mechanism to ground state are beyond the scope of this paper. A less follows to explain the operation of 3DR's.

In the absence of UV light, 3DRs possess a pale coloration the intensity of, which is dependent on the concentration of the photochromic component. 3DRs change color in reaction to exposure to UV light. The rate of change, color and return to ground state color are controlled by the photochromic component. The ophthalmic application of this application is familiar to most readers in the form of corrective lenses (glasses) that change color on exposure to sunlight. The greater the UV exposure the darker the color transition.

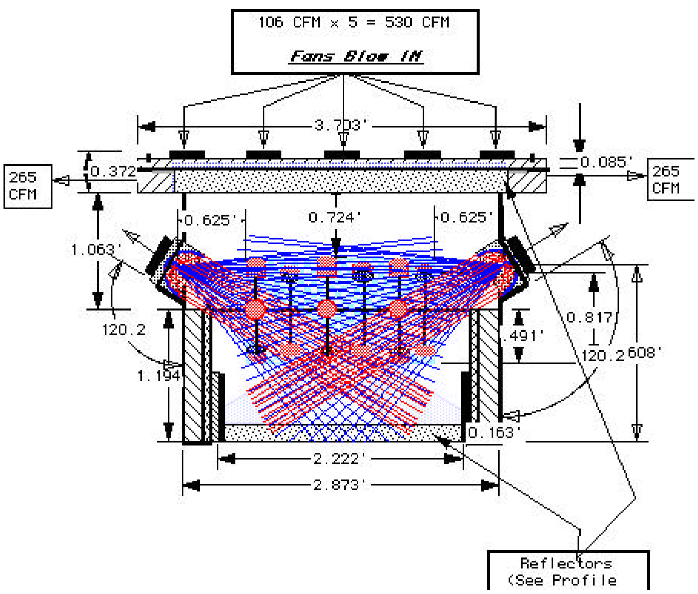

Fig. 4. In addition to divergent irradiation, both UV and IR hot spots are depicted as reflected shafts of irradiation in this vector ray tracing[1] of non-focussed UV light sources.

Infrared (IR) hot spots, coinciding with UV hot spots (Fig. 4.), cause the center of the hot spot to revert to the original ground state color. While the surrounding fringe area of the hot spot is demarked with very dark blue. 3DR's revert to their original color in minutes making them a highly reusable and cost effective production and quality assurance tool for UV processing lines.

Application: Where's the UV?

Line-of-sight cure afforded a straightforward diagnostic approach to determining cure problems. The elimination of line-of-sight cure introduces a complexity to resolving cure issues, which requires correspondingly more sophisticated tools such as 3DR's. Prior to 3DRs, vector ray tracings provided the closest means by which to visualize reflection patterns within the cure chamber in determining surface irradiation with UV.

3DR's are used by simply passing the 3DR part through the UV cure chamber. (Care should be taken not to coat the 3DR with the production UV coating first.) As the 3DR is a production part, it provides a non-invasive measurement that preserves all factors influencing cure normally found in production. The 3DR provides a ***qualitative*** indication of UV irradiation (conventional radiometers provide ***quantitative*** UV information). This allows evaluation of irradiation without the need for UV lights operating at full intensity. This then further eliminates cool down time and speeds the set-up.

Use of 3DRs regardless of the UV equipment's manufacturer, further extends their versatility. "Instant on" systems, microwave type as well as electrode-arc systems are suitable for 3DR use.

Typically, electrode-arc systems are not turned off during breaks or shift changes; rather they are idled at low power to extend lamp life. This allows UV line operators to confirm the integrity of part irradiation not only at the initial lamp configuration but even prior to start of the shift and during production breaks.

For the first time, the 3DR[4]:

- Allowed 'visualization' of UV distribution on parts
- Indicated location of UV shadows on parts
- Indicated 'hot spots' on parts
- Identified contour based cure issues
- Eliminated 'trial-and-error' lamp set-up time
- Differentiated between cure and chemistry issues
- Eliminated scrap test parts and materials
- Allowed online verification of irradiance integrity

Conclusion

The UV/EB industry continues to mature and develop sophistication in both equipment and chemical aspects. Correspondingly, sophisticated new methods for monitoring and understanding the UV/EB process are emerging as demand for such supportive technologies grows. The 3-Dimensional Radiometer (3DR) is the first UV curing diagnostic tool that allows UV line operators to visualize UV irradiation on complex parts.

References

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About the Author

Andrew A. Sokol has been involved in the UV/EB industry for over 12 years. His experience base in both UV equipment and chemistry spans both the public and governmental sectors. Mr. Sokol has been awarded two US letters patent in the area of UV technology. He has additional patents, both domestic and foreign, pending in the area of UV/EB Technology.

Mr. Sokol is highly active in the US EPA's ETV-CCEP program. Mr. Sokol is a founding partner and Director of R&D for UV Coatings, Ltd., Cleveland, Ohio.