Research Article

An Application of Self-Healing Clear Coat

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Abstract

The self-healing concept for an acrylic polymer was investigated. In the study, the self-healing performance of the developed varnish was examined. Varnish used; It is a two-component, solvent-based, hydroxylated acrylic resin-based varnish. An isocyanate-based hardener was used as the second component.

To demonstrate self-healing performance; Varnish mixed with hardener and thinner in appropriate mixing ratio was applied to the surface with a spray gun. Deformation was created on the varnish, which was cured at 80°C for 30 minutes, and the self-healing performance of this deformation was monitored by gloss measurements.

At the end of the study, it was determined that the varnish developed could self-heal at a rate of 90%.

Keywords: Self-healing, hydroxy acrylic resin, intrinsic self-healing, clear coat, gloss

1. Introduction

Exposure of polymeric materials to harsh environmental conditions causes various deteriorations in the structure of these materials. Additionally, depending on use, small scratches and cracks may occur in the materials. In other words, micro scratches and cracks may progress over time and cause the material to partially deteriorate or the material to expire. Additionally, as damage to the interior of the material progresses, it

becomes more difficult to repair, so it would be better if the materials have self-healing properties. In fact, it is known that self-healing mechanisms operate in nature, and there are many articles in this field [1-3].

Self-healing materials have the ability to repair and replace themselves using existing facilities. Whether the repair process is autonomous or with external assistance (e.g. heating, exposure to UV light), the healing process begins with the damage to the material. Self-healing materials offer new ways to prepare and develop our safer, longer-lasting products [2-4-5].

Self-healing materials can be divided into three groups: capsule-based, vascular, and intrinsic. As shown in Figure 1. Each approach varies from the current valid mechanism to the damage-induced healing process. The type of healing mechanism is determined by the volume of damage that can be healed, the repeatability of healing, and the rate of healing for each approach. These mechanisms are basic and can be depicted schematically in Figure 1 [2].

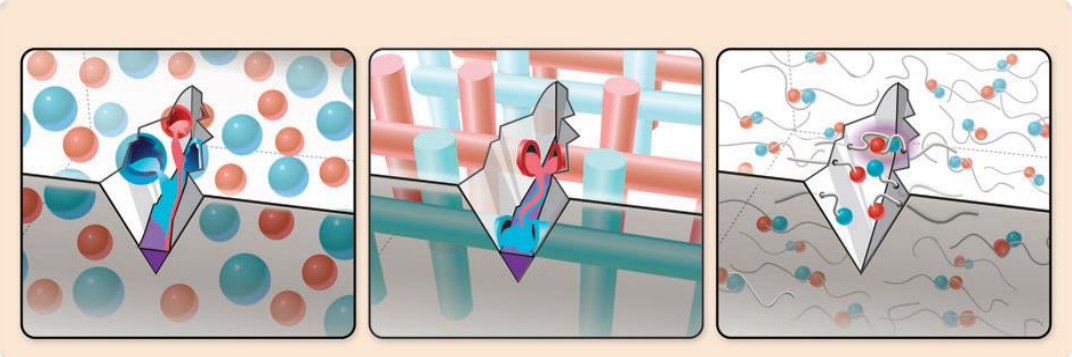

Figure 1: Approaches to self-healing include [2].

Intrinsic self-healing can be accomplished through thermally reversible reactions, hydrogen bonding, ionomeric coupling, a dispersed meltable thermoplastic phase, or molecular diffusion [6-7-8] . Self-healing occure utilizing a latent material ability that is triggered by damage an external stimulus such as heat, light, or pressure [2-9].

There are four types of materials with internal self-healing properties.These can be listed as follows [2]:
*Self-healing Polymers Based on Reversible Reactions
*Self-healing From Dispersed Thermoplastic Polymers
*Ionomeric Self-healing Materials

*Supramolecular Self-healing Materials

2. Materials and Methods

In the study, newly developed hydroxylated acrylic resin based clear coat (DCC) and standard acrylic resin based clear coat (SCC) were used. Both products are solvent-based and two-component. Isocyanate derivative hardener was used as the second component.

To observe the self-healing feature, deformation was first created on the surfaces. The surface was deformed by an apparatus glued to the end of a 1 kg load with scotch brite. The apparatus (Figure 2) was moved back and forth for 10 turns on the varnished surfaces. Gloss values were measured to determine the self-healing performance of the clear coat. The gloss values of the clear coat were measured before, after the damage and during the healing process. BYK Gardener GMBH brand, MICRO TRI type gloss measuring device was used. The gloss meter gives results by measuring the reflection levels of the light sent at different angles. In the measurements, the measurement results at a 20° angle were examined.
In measurements of shiny surfaces, 20° measurements are evaluated.

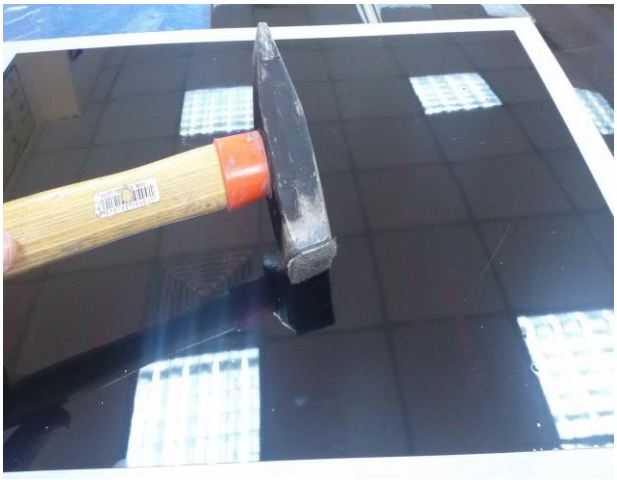

Figure 2: scratch apparatus.

2.1. Preparation of Paint Mixture

As given in Table 1, clear coat were mixed homogeneously with 50% hardener by weight. 50% acrylic thinner was added to the mixture to bring it to application viscosity (Table 1). Applications were made with a 1.4 nozzle diameter spray gun.

Table 1: Mixing Ratio

Clear Coat Type	**Hardener**	**Thinner**	**Mixing Ratio (by volume) Clear Coat / Hardener / Thinner**	**Application Viscosity (at 25°C)**
DCC	İsosynate type Hardener	Buthyl asetate based thinner	100:50:50	20 seconds
SCC	İsosynate type Hardener	Buthyl asetate based thinner	100:50:50	20 seconds

Application process; First, acrylic primer was applied to the metal surface and it was allowed to cure in the oven at 80°C / 30 minutes. Subsequently, a light sanding process was performed and the surface was cleaned with cleaning thinner. Then, acrylic basecoat was applied with a spray gun and 10 minutes later, acrylic varnish was applied on it. The contamination process of the varnishes was again carried out in the oven at 80°C/30 minutes.

3. Result

According to the results given in Table 2, the gloss of the varnished surfaces is DCC: 87 gloss, SCC: 85 gloss. After the surfaces were deformed, the gloss values decreased to DCC: 27 gloss, SCC: 7 gloss.

In order to evaluate the healing performance, the gloss values of the deformed surfaces of the panels kept under laboratory conditions were measured at certain time intervals.

Table 2: Gloss Value

Gloss Value (at 20° angle)	**DCC Developed Clear Coat**	**SCC Standat Clear Coat**
Before Deformation	87 gloss	85 gloss
After Deformation	27 gloss	7 gloss

1 min.	70 gloss	7 gloss
10 min.	70 gloss	7 gloss
20 min.	72 gloss	7 gloss
30 min.	72 gloss	7 gloss
1 hour	76 gloss	7 gloss
2 hours	77 gloss	14 gloss
3 hours	78 gloss	14 gloss
4 hours	78 gloss	16 gloss
5 hours	78 gloss	17 gloss
6 hours	78 gloss	17 gloss
24 hours	78 gloss	20 gloss
48 hours	78 gloss	20 gloss

Deformed and healed pictures of SCC are shown in Figure 3. Deformed and healed pictures of DCC are shown in Figure 4.

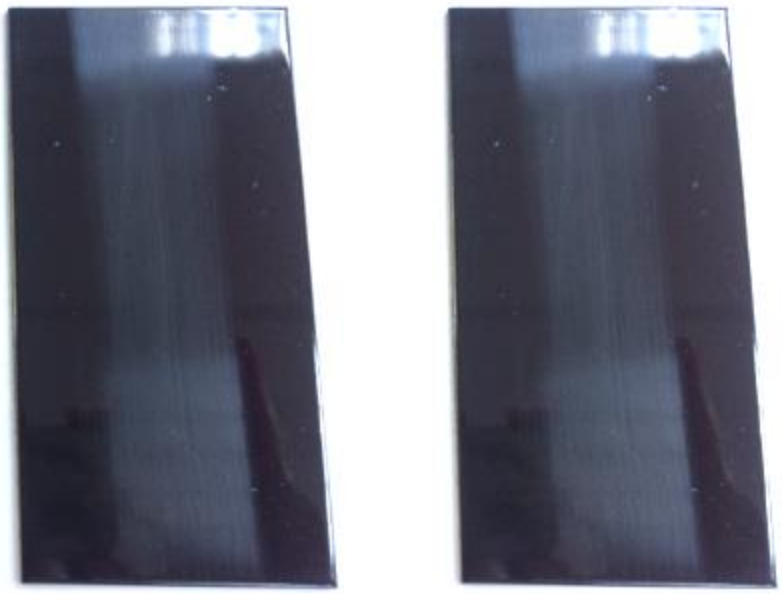

Figure 3: Self healing performans of SCC.

Figure 4: Self healing performans of DCC.

4. Discussion and Conclusion

There are many studies in the literature that work with the intrinsic self-healing mechanism. When studies on the supramolecular self-healing mechanism are examined, the effect of hydrogen bonds on healing has been shown. [2-10-11].

In this study; We aimed to show that the Supramolecular Self-healing mechanism can also be applied to products in the paint industry and that scratched surfaces can be healed thanks to this mechanism.

When the gloss measurements of the surfaces waiting under atmospheric conditions were examined, it was determined that DCC reached its old gloss value by 90%, that is, it healed on its own, but the recovery rate of SCC could reach up to 23%. It is observed that DCC shows 80% of its self-healing performance at the 10th minute after deformation. In SCC, it was determined that the first improvement occurred at a rate of 16% in the 2nd hour after deformation.

As can be seen in Figure 3. and Figure 4., scotch brite traces have disappeared due to the self-healing performance of the surface painted with DCC. However, a similar situation is not observed on the surface painted with SCC.

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References

[1] Trask, R. S., Williams H. R., & Bond, I. P. (2007). Self-healing polymer composites: mimicking nature to enhance performance. Bioinspiration and Biomimetics, 2, 1-9.
[2] Blaiszik, B. J., Kramer, S. L.B., Olugebefola, S. C., Moore, J. S., Sottos, N.R., & White, S.R. (2010). Self-healing polymers and composites. Annual Review of Materials Research, 40, 179-211.
[3] Murphy, E. B., & Wudl F. (2010). The world of smart healable materials. Progress in Polymer Science, 35, 223-251.
[4] Bergman, S. D., & Wudl, F. (2008). Meandable polymers. Journal of Materials Chemistry, 18, 41-62.
[5] Chen, X. X., Dan, M. A., Ono, K., Mal, A., Shen, H. B., Nutt, S. R., Sheran, K., & Wuld, F. (2002). A thermally remendable cross-linked polymeric material. Science, 295(5560), 1698-1702.
[6] Kalista, S., & Ward, T. (2007). Thermal characteristics of the self-healing response in poly(ethylenecomethacrylic acid) copolymers. Journal of Royal Society Interface, 4, 405–411.
[7] Liu, Y.-L., & Hesieh, C.-Y. (2006). Crosslinked epoxy materials exhibiting thermal remendablility and removability from multifunctional maleimide and furan compounds. Journal of Polymer Science 44, 905-913.
[8] Hayes, S. A., Jones, F. R., Marshiya, K., & Zhang, W. (2007). A self-healing thermosetting composite material. Composites A 38(4), 1116–1120.
[9] Ghosh, B., & Urban, M. W. (2009). Self-Repairing Oxetane-Substituted Chitosan Polyurethane Networks. Science, 323, 1458-1460.
[10] Cordier, P., Tournilhac, F., Soulie-Ziakovic, C., & Leibler, L. (2008). Self-healing and thermoreversible rubber from supramolecular assembly. Nature 451, 977-980.
[11] Montarnal, D., Tournilhac, F., Hidalgo, M., Couturier, J., & Leibler, L. (2009). Versatile one-pot synthesis of supramolecular plastics and self-healing rubbers. Journal of American Chemical Society, 131, 7966–7967.