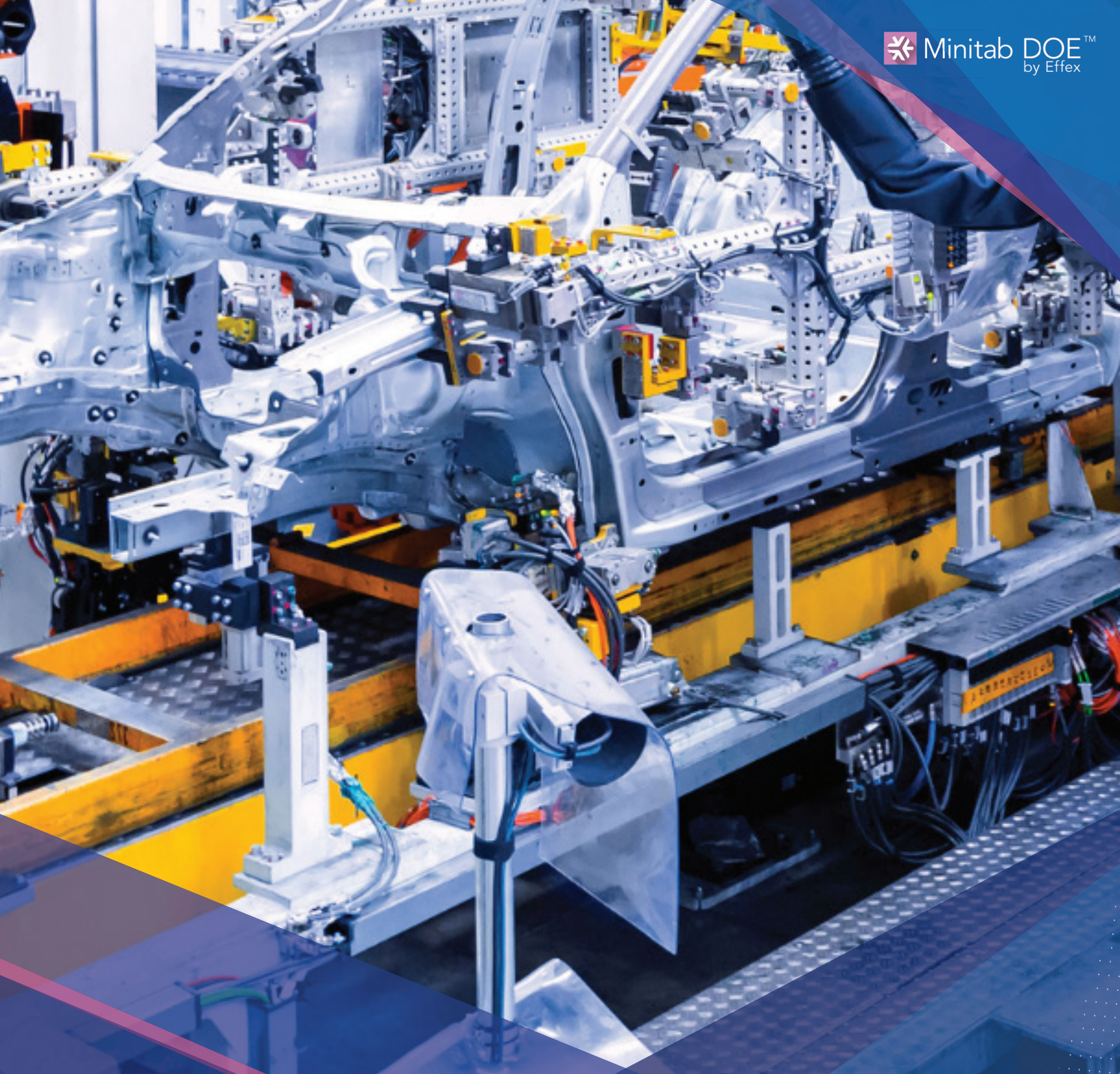

Minitab DOE™ by Effex

Minitab

Using DOE to Build a Predictive System for Automotive Polypropylene

SUMMARY

A couple of years ago, Domo PolyPropylene Compounds (a producer of thermoplastic materials), Europlasma (a developer of gas plasma systems), Structuplas (a company that specialized in the finishing of thermoplastic materials) and Techni-Coat International (a company that specialized in applying coatings) joined forces to conduct a large experiment to investigate the joint effect of several additives and a gas plasma surface treatment on the adhesive properties of polypropylene.

They used design of experiments (DoE) to define the polypropylene formulations and gas plasma treatments to be tested. After the experiment, they used a statistical analysis technique called regression analysis to build an expert system that was able to predict the best gas plasma treatment for any polypropylene formulation. Before the expert system was in place, excessive testing was necessary to find a suitable gas plasma treatment for every polypropylene formulation. Now, the expert system predicts the best gas plasma treatments, after which only a couple of confirmatory tests have to be done. Needless to say that this saved much time and costs.

THE PROBLEM

One of the materials that is heavily used in automotive is polypropylene. This is because it is inexpensive and light, and because it can be recycled easily. Polypropylene is used , for instance, for dashboards, door panels and bumpers.

An undesirable property of polypropylene is that glues and coatings do not adhere well to its surface unless it undergoes a surface treatment. One treatment that is capable of improving polypropylene's adhesive properties is a gas plasma treatment.

The challenge is to find the best possible settings for the gas plasma treatment. One choice that has to be made is the type of gas used. Another choice is the duration of the treatment. Finally, also a flow rate has to be selected for the gas, as well as the power. So, optimal settings have to be identified for four inputs: gas type, duration, gas flow rate and power. Here, the word optimalmeans a low cost gas plasma treatment that has a short duration.

DOE TO THE RESCUE

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The final DoE created was therefore intended to study four gas plasma treatment inputs as well as seven additives in a single experiment. The DoE satisfied several practical and logistical constraints:

- The researchers wanted to study at most 20 different polypropylene formulations.
- The total number of combinations of polypropylene formulation and gas plasma treatments that could be tested was 100.
- The additives talc and mica could not be used at the same time, as they are substitutes.

The following table shows the 11 inputs that were studied in the experiment, as well as their ranges:

Additives (%)	
EPDM	0 - 15%
Ethylene	0 - 10%
Talc	0 - 20%
Mica	0 - 20%
Lubricant	0 - 1.5%
UV Stabilizer	0 - 0.8%
Ethylene Vinyl Acetate	0 - 1.5%

Plasma Treatment Inputs	
Flow Rate	1000 - 2000 sccm
Power	500 - 2000 w
Duration	2 - 15 min

Gas Type

- Etching
- Activation 1
- Activation 2

The ranges for the flow rate, the power and the duration to be be explored during the experiment were determined by means of a few pilot tests, to confirm the subject matter expertise present.

After each test defined by the DoE, the adhesive properties of the resulting material were measured. One key property was the total surface tension. Other properties were the ASTM scores for the adhesion of various water-based, solvent-based and UV-dried coatings (where ASTM stands for American Society for Testing and Materials).

FROM STATISTICAL MODELS TO EXPERT SYSTEM

After all tests had been performed, statistical models were built to link the input settings to the outputs (i.e., the adhesive properties of the polypropylene). These models belonged to the family of regression models. They indicated which of the inputs had a large impact on the adhesive properties, and which didn't. They also indicated which inputs had a positive impact and which had a negative impact.

Another benefit of the models was that the could predict the adhesive properties for a broad variety of polypropylene formulations subject to a broad range of gas plasma treatments, which any need for additional testing. Last but not least, the models allowed the experimenters to identify the most economical gas plasma treatment for any given polypropylene formulation.

This feature of the model inspired the experimenters to build a user-friendly expert system in which the desired polypropylene formulation could be inputted, and a simple push on a button predicted the most cost or time efficient plasma treatment.

The expert system offered the tremendous benefit that excessive testing to find a suitable gas plasma treatment for every polypropylene formulation a new client desired became unnecessary.

Needless to say that this saved substantial time and costs.