Perceptron (formerly Autospect, Inc.)

Laser Ultrasonics to Improve Automotive Painting Process

Whether the hue is sports-car red, school-bus yellow, or sleek black, the automotive painting process has frustrated manufacturers for years. Of all automotive manufacturing processes, painting has historically been the most costly ($345 per vehicle in 1995) and arguably the most painstaking, involving 13 discrete steps. Moreover, the slightest inaccuracy can cause corrosion, adhesion, and poor finish, requiring that the auto body undergo a costly repair process. Existing paint-thickness-measurement systems could only measure dry paint, so by the time controllers detected errors and made proper adjustments, paint-booth operators had often coated up to 100 more units. To remain competitive, U.S. automotive manufacturers needed an accurate and reliable non-contact method for online paint-thickness measurement, and in 1995, Autospect proposed to develop a new wet-paint-thickness measurement system using its existing laser ultrasonics (LU) method.

Autospect suggested that three significant benefits would accrue to the industry: savings of $683 million annually for the Big 3 auto manufacturers (Ford, General Motors, and DaimlerChrysler), improved vehicle quality, and lower volatile organic chemical emissions. Due to the technical risk, direct funding from the Big 3 was unavailable; they did, however, commit to participating in the project's process integration stage. In 1995, Autospect was awarded $1.8 million in cost-shared funding from the Advanced Technology Program (ATP) to develop a wet-film-measurement (WFM) system. By the end of the ATP project in 1998, Perceptron had successfully produced a prototype LU WFM system for a DaimlerChrysler test site. Though the prototype WFM system has proven its value and technical viability, Autospect (now Perceptron, which acquired Autospect in 1997) encountered severe financial difficulties in 1998 that have forestalled its ability to commercialize the technology.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 95-02-0005 were collected during October - December 2001.

Measurement Techniques Fail to Simplify Painstaking Painting Process

In the early 1990s, the painting process represented a disproportionate amount of the total automobile manufacturing costs and labor requirements, requiring several expensive materials and 13 discrete steps to coat a bare-metal auto body with a high-quality finish. Additionally, painting errors were frequent and costly, and the paints and solvents used posed a threat to the environment. Consequently, there was increased pressure from both consumers and environmentalists to produce high-quality finishes through efficient methods.

For example, a 1994 Delphi study indicated that 50 percent of consumer appeal and satisfaction derives from factors directly or indirectly related to the automobile's paint job, such as appearance, durability, and resistance to scratching. Further, amendments to the 1989 Clean Air Act limited the discharge of volatile organic chemicals (VOCs), thereby requiring automotive manufacturers to consider the environment by more efficiently using paints and solvents.

Before the ATP project, existing paint-thickness-measurement methods failed to help automotive manufacturers address these concerns or to reduce the

high cost of painting each vehicle. At the time, non-contact-measurement techniques were not reliable outside the laboratory, so magnetic-inductance methods, including the Elcometer and the Fischer Scope, were the only available paint-measurement technologies. Both of these methods were extremely time-consuming. After each coat (i.e., the electrocoat, primer, base coat, and clear coat), manufacturers had to wait for the coat to dry and then had to remove the test vehicle from the assembly line for inspection of the coat at 60 to 80 points on the car's surface.

Fifty percent of consumer appeal and satisfaction derives from factors related to the automobile's paint job.

With these costs, manufacturers could only afford sampled quality control, measuring approximately 1 to 3 cars per day, or about 1 out of every 500 vehicles. Moreover, the slowness of the quality control contributed to poor feedback response time. By the time quality control detected a problem and made proper adjustments, up to 100 vehicles had passed through the defective painting production line. Manufacturers had to repair all vehicles with defective paint coatings by using one or both of the low bake repair (LBR) and high bake repair (HBR) processes, at a cost of $600 to $1,200 per vehicle in 1995. In some extreme cases, the manufacturer had to completely scrap the vehicle. At the time of the ATP project, 15 percent of all vehicles required HBR, putting a massive strain on overall automotive production budgets.

Autospect Proposes a More Efficient Coating Process

To address the problems that riddled the automotive painting process, Autospect proposed to develop a wet-film-measurement (WFM) system that would provide non-contact inspection and online measurement. This process would eliminate the need for an operator and would allow manufacturers to measure every vehicle, thus reducing the time it took them to detect and respond to problems in the coating process. Thickness and distribution information would feed back immediately to logic controllers that controlled paint flow

to sprayers, reducing the number of vehicles that passed through the process after error detection from up to 100 units to just 1 to 2 units. With accumulated feedback data, manufacturers could correlate wet-film-build measurements with flow-control methods so they could predict future behavior and develop more precise systems.

Reduced paint use and reduced defects would save $683 million annually for the Big 3 manufacturers and would lower costs and improve quality for consumers.

Autospect envisioned a non-contact WFM system that included a precise and reliable instrument for the online measurement of paint thickness and that provided closed-loop feedback in real time for the painting process. The proposed system would function in the hostile environment of the factory paint booth, withstanding paint splatter, temperature and humidity fluctuations, and exposure to evaporated solvents, without performance degradation.

Broad-Based Benefits Extend to the Environment and Consumers

The proposed WFM system also promised broad-based economic benefits. The automotive industry would reap significant advantages, as demonstrated in Autospect's cost-benefit analysis. Before the ATP project, 106 of the 168 paint production lines in North America used Autospect's existing QMS-I and QMS-BP products. Thus, the company's equipment assisted in the production of nine million vehicles annually. The average cost of paint required to coat a vehicle was $345. Unfortunately, up to 60 percent of the paint was wasted due to inefficient production processes. Therefore, a measurement system that reduced excess paint could lead to savings of up to $200 per vehicle. Conservatively estimating that its WFM system would save $50 in paint per vehicle, Autospect projected an annual savings of $360 million for its existing customer base. Because figures indicated that 15 percent of all vehicles required HBR at a cost of at least $600 per vehicle, a system that prevented painting defects could save Autospect's customers another $323 million

annually. Thus, reduced paint use and reduced defects resulting from the company's WFM system would save $683 million annually for the Big 3 manufacturers and would lower costs and improve quality for consumers.

Autospect also expected that consumers would benefit from improved vehicle appearance as well as from reduced repair costs related to low-quality paint coats that easily scratch and corrode. Autospect identified the environment as another beneficiary, since a more efficient painting process would lead to lower VOC emissions. Further development of a WFM system could provide advantages to other industries in which the painting of large surfaces is expensive and environmentally hazardous, such as the aerospace and coil-coating industries. Finally, Autospect itself would benefit by tapping into a potential market of $500 to $750 million, increasing its engineering leadership by 5 to 10 employees, and strengthening its position to provide best-in-class measurement and control for the U.S. automotive industry.

WFM Technology Supported by Industry But Lacks Funding

Despite the many potential benefits, Autospect recognized the high risk involved in developing a breakthrough product. Measurement systems that appear promising from a theoretical standpoint often fail to realize the flexibility and ruggedness required for the factory floor. Thus, as a small company with about 10 employees and limited internal research funds, Autospect could not single-handedly undertake such a project. Without additional funding, Autospect would need to scale back its goals and focus on small, incremental development.

Although unable to find private funding, Autospect secured the support of the entire industry for cooperative development and feedback. The Big 3 auto companies committed to participating in the project's process integration stage. Painting-robot manufacturer Fanuc, paint shop manufacturer Haden, and automotive paint suppliers PPG and BASF agreed to help, and PPG also offered the use of its Flint Applications Facility for product testing. Confident of the importance of WFM technology to the automotive industry, Autospect applied for and was selected to receive $1.8

million in cost-shared funding from ATP's 1995 motor vehicle manufacturing technology-focused program competition.

Laser Ultrasonics Can Improve Efficiency and Reduce Costs

In accordance with its plan, Autospect explored three potential measurement techniques. After eliminating other non-contact methods, such as an alternating current impedance method and a method using micro-strip microwave resonators, Autospect turned to laser technology to develop the ideal technique for wet-film measurement. Extensive research indicated that laser ultrasonics (LU), a non-contact ultrasound technique, was most promising in terms of repeatability, measurement sensitivity, practicality, and cost.

Autospect valued the LU method for its simplicity. It requires only three square feet of paint booth space and three main components: two lasers and an interferometer. To measure wet-paint thickness, the first laser produces a very short pulse to generate ultrasound on the painted surface. The absorption of this light causes a temperature rise in the paint film, inducing a density gradient in the material and thereby producing an ultrasonic acoustic signal. Thus, the short laser pulse is analogous to a quick hammer strike to a bell. The second laser detects the minute ultrasonically induced motions (about 0.1 nanometers) on the paint surface. This detecting laser light is reflected off the surface and coupled into the interferometer, which strips away and measures the surface vibrations. The resulting spectra provide raw data for analysis, as film thickness has an inverse relationship to resonant frequency.

In addition to saving paint booth space, which costs about $100,000 per square foot, the LU method has many other advantages. The system can measure all automotive body coatings, both wet and dry. Its measurement is extremely fast and does not require calibration, even for new paint materials. Since laser light can be fiber-optically coupled to the paint booth, a manufacturer can place sensitive equipment far away from the spray area, thereby eliminating splatter disturbance and vibration problems. The LU method also provides advantages on the factory floor because the measured parametric frequency of the ultrasound is

not affected by changes in intensity of the signal, which is a parameter susceptible to many environmental conditions. Finally, and perhaps most importantly, the LU system can be multiplexed; that is, 250 or more sensors in multiple locations can make measurements that feed to one set of equipment, allowing for the measurement of every vehicle in a plant by a single system.

Successful Prototype Proves System's Technical Feasibility

By the end of the ATP project in 1998, Autospect (hereafter referred to as Perceptron, which acquired Autospect in 1997) had successfully developed a WFM system and had achieved positive results from in-plant testing at PPG's Flint facility. Perceptron engineers Jeffrey White, Frederick LaPlant, and John Dixon coauthored a paper with PPG engineers Donald Emch and Vince Datillo that discussed the LU WFM technology. The paper, titled "Non-Contact Real Time Film Thickness Gauge," won the Best Paper Award at the 1998 International Body Engineering Conference.

Shortly after the close of the project, Perceptron sold a prototype system to DaimlerChrysler and installed it at the company's Windsor Assembly Plant, creating an alpha test site. Tests at the Windsor facility continued to prove the system's technical feasibility. Perceptron initiated its eight-stage product development process and planned its next step to pursue sales of the WFM system to each of DaimlerChrysler's eight plants. In 1998, Perceptron set target sales at 4 systems by 2000 and another 8 in 2001, with the hope of ramping up sales to 12 annually by 2002.

Financial Difficulty Halts Perceptron's Commercialization Effort

Equipped with a clear-cut business plan, Perceptron aimed to move forward to commercialize the LU WFM technology. However, the company began to experience the effects of the automotive industry's 1991 to 1993 slump and its stagnant sales from 1994 to 1997. The company's stock, which had peaked at just under $40 a share and had held steady there during 1996 and 1997, dropped to about $20 per share in the second half of 1998. Since then, Perceptron has not

been able to recover, with its stock continuing to fall to around $5 per share between 1999 and 2000. In 2001, its shares decreased further and as of fall 2001 were valued at $.03.

Because of these severe financial difficulties, Perceptron has focused on survival strategies, and product development of the new WFM technology has become a low priority. Perceptron has managed to invest more than $1 million of its internal funds since the close of the ATP project, working with DaimlerChrysler to fine-tune the prototype and to convert raw thickness and distribution data into useful feedback information. Perceptron estimates that the system will require three years of product development before full-scale commercial release becomes feasible. At this time, the company is unable to pursue that development due to its financial position. Perceptron engineer Mr. White confirmed that the company is open to the possibility of a transfer of the technology to another company, but expressed doubt that any other automotive suppliers are in a position to take on the risk or the investment.

The WFM system has also sparked interest from the aerospace industry and coil-coating manufacturers, who are currently considering investments in the development of the WFM technology for their applications.

Industry Resistance Presents Another Barrier to Commercialization

In addition to the lack of available funds to commercialize the WFM system, industry resistance has presented another unforeseen challenge. Mr. White explained that because automotive painting is such a fragile and expensive process, manufacturers worry that constant adjustments to spray flow and other parameters will only compound the problems. Even though the existing process is error-laden, manufacturers hesitate to alter it until a new system demonstrates proven quality control elsewhere. While the DaimlerChrysler prototype exhibits superior measurement, researchers need to perform further testing and complete research to convert raw data into useful feedback before proving the WFM system's capability for total closed-loop feedback control.

Conclusion

As a result of the ATP project, Perceptron successfully developed a WFM (wet-film-measurement) system based on its LU (laser ultrasonics) technology. The company affirms that this advance would not have occurred without ATP's support. Despite the system's excellent technical outlook, however, Perceptron has not been able to fund commercial development because of severe financial difficulties and industry resistance. If Perceptron regains financial strength, it plans to resume commercialization efforts. In consideration of its present situation, the company expresses its willingness to negotiate a technology transfer to another company.

PROJECT HIGHLIGHTS
Perceptron (formerly Autospect, Inc.)

Project Title: Laser Ultrasonics To Improve Automotive Painting Process (Wet Paint Thickness Measurement System)

Project: To develop a non-contact method for online measurement of wet-paint thickness to enable a high-quality, time-efficient, and cost-effective painting process for the automotive industry.

Duration: 9/15/1995-9/14/1998
ATP Number: 95-02-0005

Funding (in thousands):

ATP Final Cost	$1,800	81%
Participant Final Cost	421	19%
Total	$2,221	

Accomplishments: Perceptron successfully developed the technology for a wet-film-measurement (WFM) system using its laser ultrasonics (LU) technology; tested the system at PPG's facility in Flint, Michigan; and installed a prototype for further development at DaimlerChrysler's Windsor, Ontario plant.

Company engineers received the Best Paper Award at the 1998 International Body Engineering Conference for a paper discussing the ATP technology titled, "Non-Contact Real Time Film Thickness Gauge."

Perceptron received the following patents for technologies developed during the ATP project:

- o "Method and system for processing measurement signals to obtain a value for a physical parameter" (No. 6,092,419: filed November 21, 1997; granted July 25, 2000)

- o "Method and system for measuring a physical parameter of at least one layer of a multi layer article without damaging the article and sensor head for use therein" (No. 6,128,081: filed November 27, 1997; granted October 3, 2000)

Commercialization Status: Although Perceptron sold a prototype WFM system to DaimlerChrysler after the close of the project, the company has ended its commercial development efforts due to severe financial difficulties caused by the auto industry's weakness in the early and mid 1990s.

Outlook: Currently, Perceptron's weak financial status and the industry's resistance to the new technology prevent the commercial development of the WFM system. However, the prototype system has demonstrated technical success and holds promise for future commercial development and improvement of the automotive painting process. The WFM system has also sparked interest from the aerospace industry and coil-coating manufacturers. These industries are currently considering investments in the development of the WFM technology for their applications.

Composite Performance Score: *

Number of Employees: (figures are for the Autospect division only) 10 employees at project start, 15 as of December 2001

Focused Program: Motor Vehicle Manufacturing Technology, 1995

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