RoDip – a new system for pretreating and electrocoating car bodies

The automotive industry places a high value on paint finishing for two main reasons: high-quality paintwork provides good protection against corrosion and mechanical damage, and it has a major impact on car sales. Since the paint finish can only ever be as good as the car body pretreatment, every stage in the process – cleaning, degreasing, activation, phosphating, passivation and electrocoating – is important. At each of these stages the car bodies are fully submerged in a process tank and rotated to ensure a uniform, homogeneous coating. The complex geometry of the car bodies has made it necessary to continually improve the pretreatment process. ABB Flexible Automation has developed a completely new method of pretreatment, called RoDip, with several important advantages over conventional processes.

A number of successful systems for the pretreatment and electrocoating of car bodies have been developed over the years, and today both continuous and discontinuous systems are in use in the automotive industry. The discontinuous, or stop and go, dipping systems have several important advantages over the continuous processes. For example, the lines are shorter, tank volumes are smaller, chemicals and paints are used in smaller quantities, and less water is wasted. These benefits apply especially to paint shops working at lower capacities.

The discontinuous systems employ vertical dipping, while horizontal dipping is used on the continuous lines. ABB Flexible Automation has developed a new rotational system, called Roll Over Dip, or RoDip, which combines these two techniques. Tests have been carried out in pilot installations and the system has been patented. The first RoDip systems are currently being installed in paint shops in the automotive industry. Tests carried out on actual car bodies as well as computer simulations have confirmed the performance and suitability of the new system, especially for lines designed for smaller capacities.

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RoDip is based on a skid-type floor conveyor. The car bodies are stopped over a dipping process tank, automatically fixed to a turntable and dipped in the tank by rotating them 180° from the horizontal axis perpendicular to the conveyor direction **1**.

Operating principle and advantages of the RoDip system

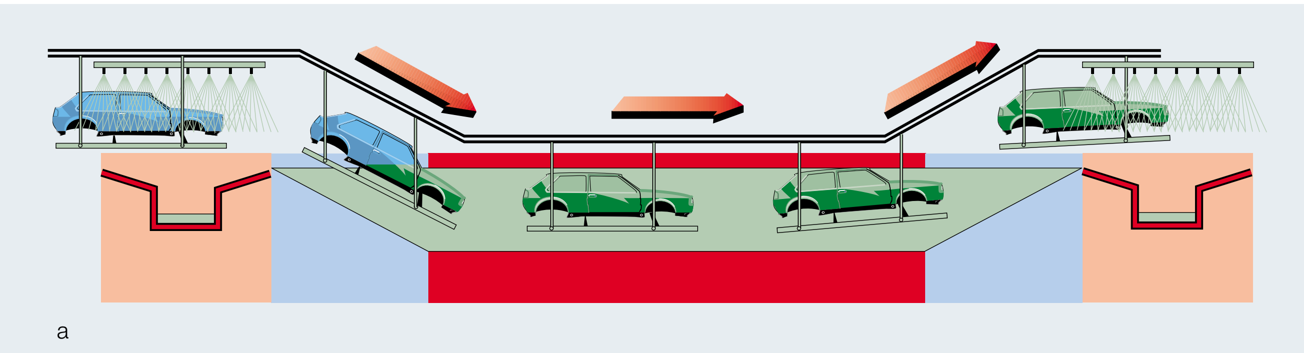
The RoDip line consists of a series of dipping tanks for the different process stages – cleaning, degreasing, activation, phosphating, passivation, electrocoating, and various intermediate rinsing stations. The car bodies are fixed to skid carriers which are transported by roller conveyors from tank to tank **2**. As soon as a car body reaches the correct position above the tank, it is secured to the RoDip tilting device. Afterwards, it is submerged in the tank by means of a forwards rotational motion about the axis of a horizontal motor-driven shaft situated below the skid. The car body remains in the tank for the residence time required for the respective process stage. The body is then rotated back to the upwards position with an intermediate stop to allow the liquid in the body interior to drip back into the process tank. This reduces carry-over of the liquid to subsequent tanks. In the horizontal position, the car body is released from the tilting device and moved to the next process stage.

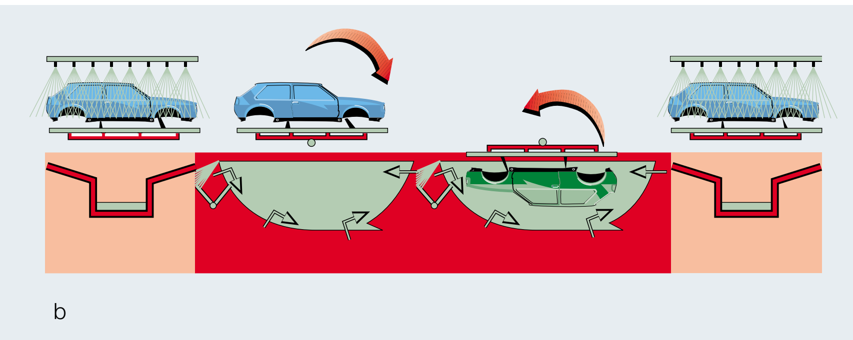
A special feature of the RoDip system is the conveyor. In the region of a process tank, the tilting station is equipped with sideways removable rollers which allow the body to be rotated and dipped into the tank. As soon as the body is submerged, the rollers are moved back to their normal position to allow the other car bodies to be carried to other baths without disturbing the process going on in the

Pilot installation for car body pretreatment with the ABB RoDip system. The car bodies are dipped in the tanks by rotating them 180°

tank. This feature is one of the main factors allowing an increase in line capacity. The maximum capacity is determined by the slowest process stages, normally the phosphating and electrocoating baths, each of which usually requires a residence time of 3 minutes. This corresponds to a cycle time of approximately 4 minutes and a maximum capacity of 15 car bodies per hour.

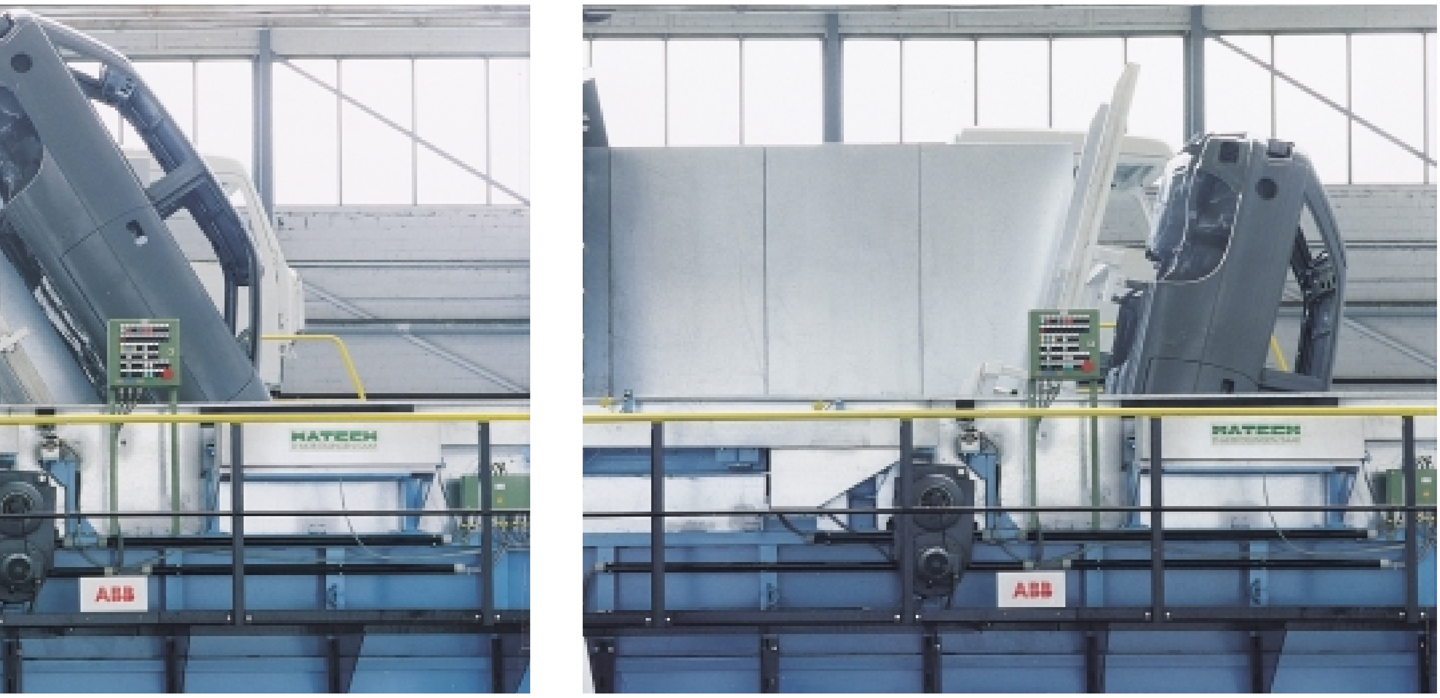
By connecting two tanks in series for the critical process stages (phosphating,





Comparison of RoDip with another conveyor technology for pretreatment and electrocoating processes **2**

a *Pendulum conveyor*
b *RoDip system*



from the horizontal axis perpendicular to the conveyor direction. **1**

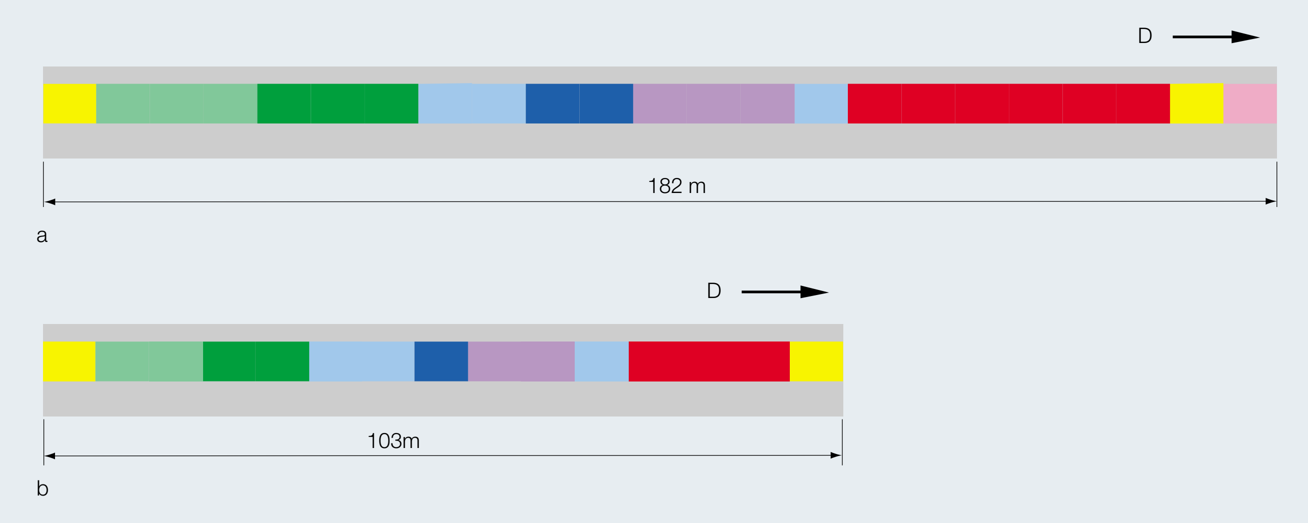
electrocoating and degreasing), the removable rollers in the RoDip tank area will allow an increase in maximum capacity to 30 bodies per hour. A further increase in the number of tanks in series per process stage does not significantly increase the capacity, since time is lost in conveying the bodies over the baths that are being used. For plants handling more than 30 car bodies per hour, ABB recommends the use of a continuous overhead or pendulum conveyor system.

The main advantages of the RoDip pretreatment and electrocoating system are summarized below:

- High-quality, homogeneous coating at every process stage, especially in the car body cavities due to the excellent flow conditions and the virtual exclusion of trapped air bubbles.
- Reduced dirt inclusions on the horizontal surfaces due to the body being rotated in the process tank.
- Exactly defined dipping times for each type and size of car body.
- Car bodies can be tilted in the tanks to increase the agitation of the process liquid.
- Reduced boundary layer thickness of the liquid flow over the body surface, increased process intensity, removal of bubbles trapped during the process.
- Simple, proven roller conveyor technique for easy and minimal maintenance.
- Clean conveyor system with all drives and movable parts outside the tank area; minimum contamination of process liquids.
- Optimum drainage, since the car body can be stopped in any required position during rotation; minimized transfer of bath liquids to the next tank.
- Round dip tanks for optimum bath liquid circulation and minimum sludge deposits.
- Automatic contacting in the ED (electrophoretic dip) tank; additional dry anodes can be introduced to reduce coating time and maximize the coating uniformity.
- Smallest possible bath volumes minimize energy required for pumping and heating as well as amounts of wastewater and sludge.
- Tanks, roller conveyors, piping and process equipment are of modular design. Site installation and commissioning time are minimized by manufacturing, preassembly and pretesting in the workshop prior to shipment.
- Very short line lengths and minimum total space requirements.
- Investment, operating and total costs are lower than for any other dip system.
- High level of production flexibility with possibility of increased capacity, if required; ideal system for production transplants.

RoDip development steps

The RoDip system was developed in close cooperation with the automotive industry and paint and chemical suppliers. To optimize the process parameters, full-scale dipping tests were



Comparison of RoDip with another conveyor technology for pretreatment and electrocoating processes 3

a *Pendulum conveyor*
b *RoDip system*

Production	*480 bodies per day*
Actual working time	*1,120 minutes*
Average production	*25.7 bodies per hour*
Tank volume for continuous process	*580 m³*
Tank volume for RoDip process	*360 m³*

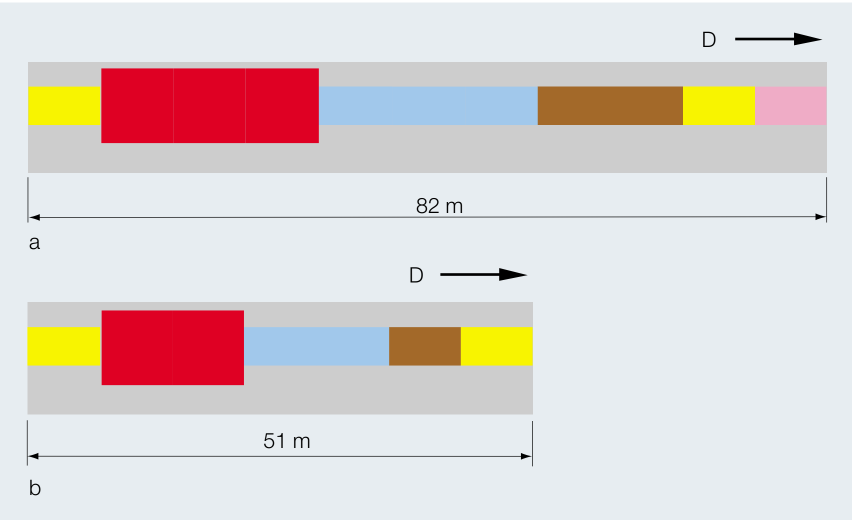
Yellow	*In/out zones*
Light-green	*Degreasing spray*
Green	*Degreasing tank*
Light-blue	*Rinsing spray*
Dark-blue	*Activation tank*
Purple	*Phosphating tank*
Red	*Rinsing tank*
Light-red	*Transfer zone*
D	*Process direction*

Comparison of electrocoating plant layouts 4

a *Pendulum conveyor* b *RoDip system*

Production	*480 bodies per day*
Actual working time	*1,120 minutes*
Average production	*25.7 bodies per hour*
Tank volume for continuous process	*312 m³*
Tank volume for RoDip process	*152 m³*

Yellow	*In/out zones*
Red	*Electrocoating*
Light-blue	*Rinsing spray*
Brown	*Rinsing tank*
Light-red	*Transfer zone*
D	*Process direction*



carried out on various car bodies, vans and truck cabs. The development activities further included the design of the conveyors, tanks, skid fixing devices, contacting devices for the electrocoating, control systems and other equipment. Process flowsheets were also developed and the plant layout was optimized. A material flow simulation and a three-dimensional motion simulation of the RoDip plant helped with the optimization of the conveyor system and provided the basis for a video demonstration of the plant's operation as a whole.

A feasibility study was also carried out. It compared the RoDip system with other systems for plant capacities of up to 30 car bodies per hour and confirmed the advantages of the RoDip system in terms of both investment and operating costs.

Full-scale electrocoating and degreasing tests with different types of car body demonstrated the superiority of the pretreatment processes with RoDip.

RoDip feasibility study

The feasibility study was undertaken for a pretreatment and an electrocoating process with a production rate of 480 car bodies per day in two shifts. A comparison was made of various economic aspects of the RoDip system and a continuous pendulum conveyor system. The feasibility study assumed the following process sequence:

Pretreatment

- Spray and dip degreasing, spray rinsing
- Dip activation, dip phosphating
- Spray and dip rinsing, dip passivation
- Dip rinsing and transfer zone

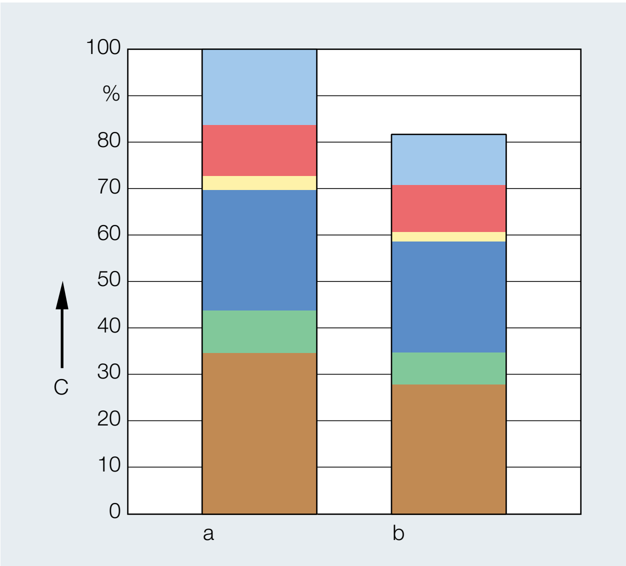
Electrocoating

- Electrocoat tank
- Spray and dip rinsing

The comparison of the two conveyor technologies showed that the pendulum conveyor requires a considerably longer line than the RoDip system **2**, **3**, **4**.

Sizing and costing of the two pretreatment and electrocoating systems produced the results shown graphically in **3**, **4**, **5**, **6**. It is seen that with the RoDip system the line length can be reduced by more than 40 percent for the pretreatment plant and by slightly less than 40 percent for the electrocoating plant. The tank volumes with the RoDip system are also smaller by roughly 40 percent.

The comparison of the total cost of the two systems **5**, **6** shows the investment costs for the RoDip plant to be roughly 20 percent lower than for the pendulum conveyor system. A considerable saving results in the case of certain operating costs; the electrical energy consumption, for example, is much lower due to the smaller tank volumes. The cost of the chemicals and paints, which represents a large portion of the total costs, is similar for each.



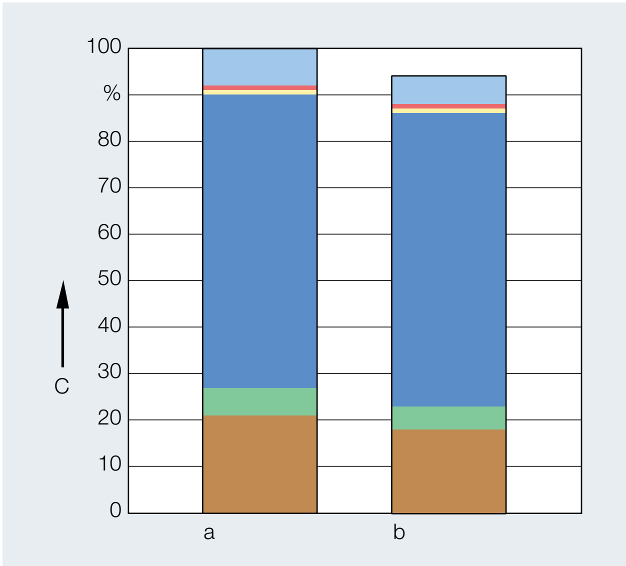
Comparison of total costs for pretreatment plant **5**

a *Pendulum conveyor*
b *RoDip system*

Production *480 bodies per day*
Actual working time *1,120 minutes*
Average production *25.7 bodies per hour*

Tank volume for continuous process *580 m³*
Tank volume for RoDip process *360 m³*

Brown *Investment*
Green *Electrical energy*
Dark-blue *Chemicals*
Yellow *Wastewater*
Red *Thermal energy*
Light-blue *Maintenance*
C *Costs per year*



Comparison of total costs for electrocoating plant **6**

a *Pendulum conveyor*
b *RoDip system*

Production *480 bodies per day*
Actual working time *1,120 minutes*
Average production *25.7 bodies per hour*

Tank volume for continuous process *312 m³*
Tank volume for RoDip process *152 m³*

Brown *Investment*
Green *Electrical energy*
Dark-blue *Chemicals, paint*
Yellow *Wastewater*
Red *Thermal energy*
Light-blue *Maintenance*
C *Costs per year*

Removing a car body from the tank in a RoDip electrocoating installation **7**

This reduces the difference in the total cost to something below 20 percent for the pretreatment plant and to less than 10 percent for the electrocoating plant.

The results show clearly that the RoDip technology has economical advantages for hourly plant capacities of 30 car bodies and fewer.

Full-scale tests

Acceptance of any new paint finishing technology in the automotive industry usually takes a long time. To minimize problems and production risks it is necessary to address a long list of issues. The RoDip testing sequence was therefore defined in a way that provides answers to the questions likely to be asked by the automotive industry. The result was the logical sequence of RoDip full-scale tests described in the following.

Dip tests with different car bodies

The first question always concerns the potential risk of mechanical damage to the body due to the fixing, rotating and dipping processes. To confirm that every type of car body can be dipped without any damage being caused to it the first prototype had to be full size and optimized through tests and studies. Different bodies were tested – small to large passenger cars, vans, heavy truck cabs and even one small bus. All the dip tests, which lasted from 10 to 30 seconds, were successful.

Full-scale electrocoating tests

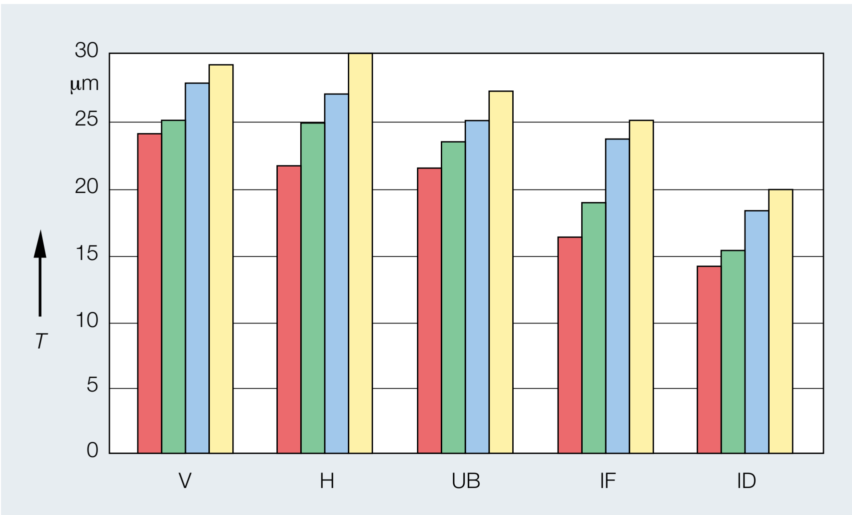
The second issue is usually the quality of the RoDip processes, especially degreasing, phosphating and electrocoating. Interest is centered mainly on the trapped bubbles and dirt inclusions, since they are expected to be lower than in the other dipping systems.

Two series of RoDip electrocoating tests were performed with three passenger car models of different sizes

RoDip electrocoating tests – comparison of coating thicknesses under different operating conditions **8**

Red *Conventional dip*
Green *RoDip*
Blue *RoDip with internal anode*
Yellow *RoDip with anode, increased solvent content*

V *Vertical surfaces*
H *Horizontal surfaces*
UB *Underbody*
IF *Scuff panel*
ID *Interior*
T *Coating thickness*



supplied by two well-known German carmakers. The tests were carried out in the electrocoat test installation of a major German paint supplier. The transportable RoDip system was designed, manufactured and installed on the existing crane mechanism for the conventional dipping tests. A total of 20 pretreated car bodies were coated 7 and the quality of the finish evaluated. Several parameters were varied:

- Car body type and size
- Process conditions: time, temperature, voltage, dipping under voltage and without voltage
- Tilting of the body during the process
- Additional dry anodes positioned under the body
- Additional dry anodes positioned inside the body
- Paint solvent content, which was increased slightly

The test results that were evaluated were:

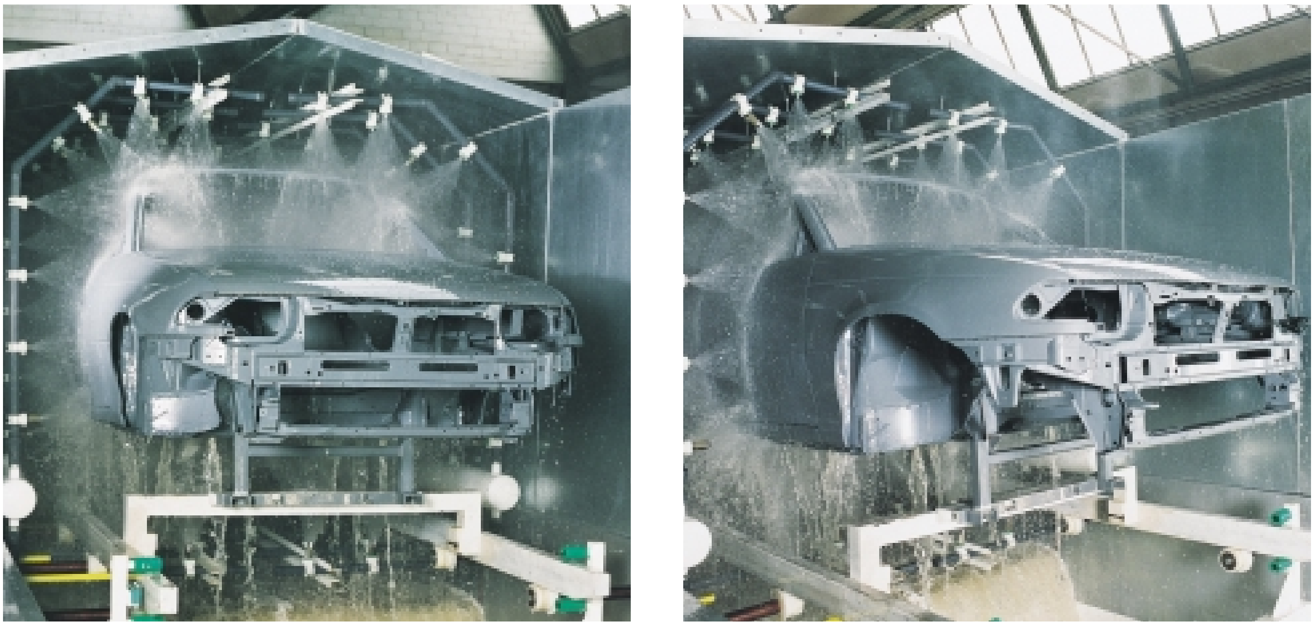
- Current-voltage curves
- Coating process parameters
- Dry paint layer weight
- Paint layer thickness at 60 to 70 points on the surface of the body
- Paint layer uniformity and appearance

The comparison of the average layer thickness in the second series of tests with a medium-size car body shows that the RoDip system considerably enhances the coating process compared with conventional electrocoating 8. The statistical evaluation of the measured layer thickness shows a superior uniformity, ie, lower standard deviation in the paint layer thickness of the RoDipped bodies. Installing extra dry anodes inside the car body accelerates the coating of the internal surfaces and cavities.

The paint material properties have a decisive influence on the coating. For example, an increase in the solvent content of the water-borne paint from 1 to 1.3 percent increases the process rate considerably 8. In addition to the paint layer thickness distribution, some other electrocoating problems were tested and analyzed. They included trapped air bubbles, foam or hydrolysis bubbles and dirt inclusions. It has been proved that all these potential problems can be solved by the RoDip technology. The quality of the coating in cavities was checked after the critical areas of selected car bodies had been cut open.

Full-scale flow optimization and degreasing tests

The optimization tests performed with the first prototype and experience gained from a large number of electro-



RoDip spray degreasing in the full-scale prototype installation. This process ensures optimum cleaning of the outside body surface. 9

coating tests with the second showed that the liquid circulation in the tank is a very important factor in the quality of the pretreatment and electrocoating. To test the flow conditions and the degreasing process in the RoDip tank, a third full-scale prototype was built. It featured the latest conveyor design, tanks with an optimum rounded shape and all of the process equipment, including the heaters, pumps and circulation nozzles for the degreasing tests. The prototype has one spray zone, one dip zone and one transfer zone to allow it to be used for automatic long-time testing of the critical parts.

The first phase of the tests was devoted to investigating and optimizing the flow in the tank, the second to degreasing the car body. Tests were carried out with three bodies and with the standard chemicals and temperatures. The best results were achieved with the combination of spray and dip degreasing. The mechanical cleaning effect of the spraying process **9** is necessary to ensure optimum degreasing of the outside body surface. Subsequent dip degreasing **10** is required to clean the interior surfaces and cavities. The motion of the body during tilting in the tank – to increase the shear between the liquid and the body surface – makes an important contribution to the good degreasing result.

Car body being tilted during RoDip degreasing in the prototype installation. The purpose of this process is to ensure optimum cleaning

RoDip simulation

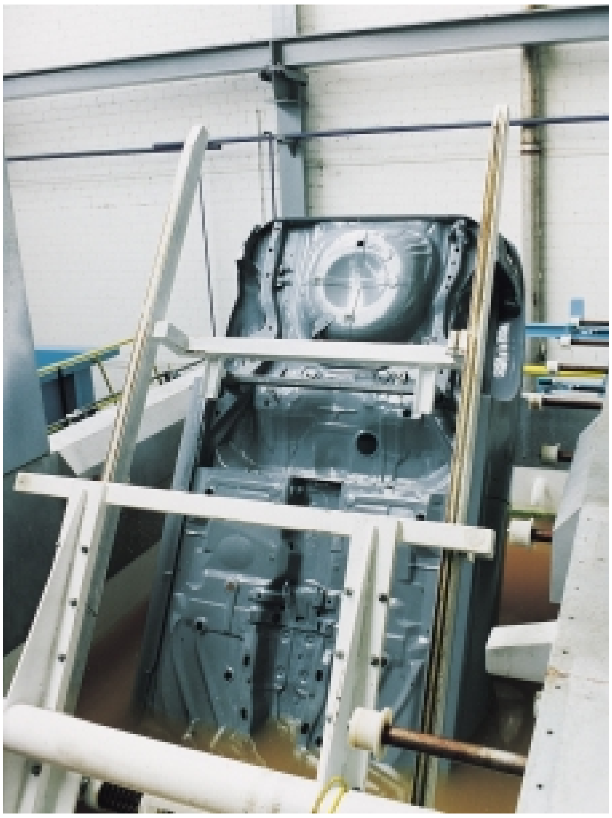
To test the material handling and conveyor logic of the RoDip system, a full three-dimensional material flow simulation was performed with the software package QUEST during the early development phases. The three-dimensional RoDip workcells were simulated with the help of the robot simulation software IGRIP.

The aim of the simulation was to reduce the RoDip development and process optimization time through computer testing of the following process parameters:

- Maximum capacities for different process configurations and system optimization
- Influence of different times for dipping and removing car bodies from the tanks
- Variation in body transfer speed between the process stages

- Interaction between continuous and stop-and-go processes and collision tests
- Optimization of arrangements for different dip and spray zones and process sequences
- Influence of downtimes of the individual process stages on total system availability

The detailed feasibility study shows the RoDip system to be superior to all other systems. Its advantages of compact equipment, which takes up less space, smaller process tank volumes and reduced chemical and paint consumption, add up to lower investment and operating costs.




of the interior surfaces and cavities. **10**

Proven superiority of the RoDip system

The three-dimensional computer simulation of the RoDip system has confirmed the maximum achievable RoDip line capacity of 15 bodies per hour in the case of single tanks for all dip process stages, and 30 bodies per hour when double tanks are installed for the process stages with the longest residence times.

RoDip is an environmentally friendly process producing only small quantities of wastewater and sludge. These features of RoDip have already led to a remarkably high level of acceptance of the system by the industry. ABB anticipates extensive use of RoDip in automotive paintshops in the future, with first orders for installations already received from the USA and Colombia.

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