New Manufacturing Concepts with Line-integrated Plating Process

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Today's customers and markets demand more flexibility, cost efficiency and shorter delivery times. On the other hand, metal surface layers gain more importance for technical abilities and qualities of products, so the trend to partially or fully integrated plating processes in manufacturing lines starts today. Basic concepts and ideas of line integration will be explained and technological challenges will be described. Several examples of existing integrated proceses and their advantages will be described in detail. Research goals and development trends will be explained that will pave the way to exploit the unused potential of plating processes through the use of line integration.

Introduction

Products have to get better and cheaper in these times more rapidly than we are accustomed to. The pressure to do so simultaneously and to get far better and much cheaper will grow in the time to come. So new ideas, concepts, methods and machines for smart, flexible, high quality and cheap production will be neccessary to meet the demands of todays customers. Surface technology is one powerful way to meet these demands. Smart applications and combinations with other techniques pave the way for intelligent manufacturing concepts that enable smart and multi-functional products.
To fully exploit the technological and functional potential of surface processes the concept of surface engineering has to be used. This means the planning of surface processes for manufacturing right from the beginning and the deliberate use of the additional functional possibilities of customized surface layers.
Today surface processes have influences in several fields like mechanical engineering, automotive engineering, electronics, communication technology, but also optics and plastics. Applications reach from tribological and wear resistant layers to corrosion resistance, shielding in electronic devices and micro system devices. Surface layers have a strong influence on functionality, lifetime, design possibilities, manufacturing costs and competitiveness of products. By that surface technology has a considerable influence and impact on the technological competitiveness in the mentioned fields and on the gross national product.
Innovations in surface technology enable new products and manufacturing processes. With this in mind it is getting more and more important to develop surface processes to an integratable, fully controllable manufacturing technology which can be used like drilling or laser processing without special process knowledge.

Concepts of production integration

Surface processes can be integrated in manufacturing systems in two ways. The first stage of integration places the coating equipment near the rest of the system but still in it's own area (figure 1). Interfaces between surface treatment and other processes will be analyzed to minimize needless process steps (such as storage, temporary corrosion protection, cleaning etc.) and logistics.

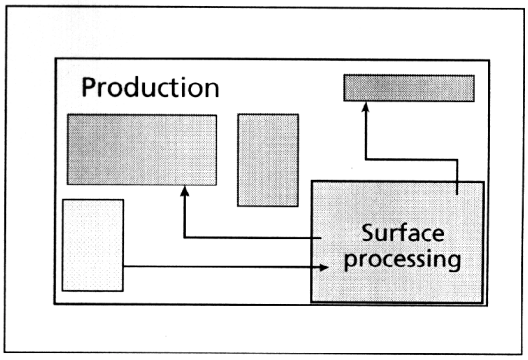

Figure 1: First stage process integration of plating processes.

Further advantages would be given if the processes were sealed within the equipment, keeping all emissions inside. High geometrical precision of the deposited layers would increase advantages even more. All this can be accomplished with a closed, modular plating equipment concept. It consists of specific plating chambers that are adapted to part geometry and deposition process and the neccessary peripheral components for storage, distribution, transport and conditioning of process media (figure 2).

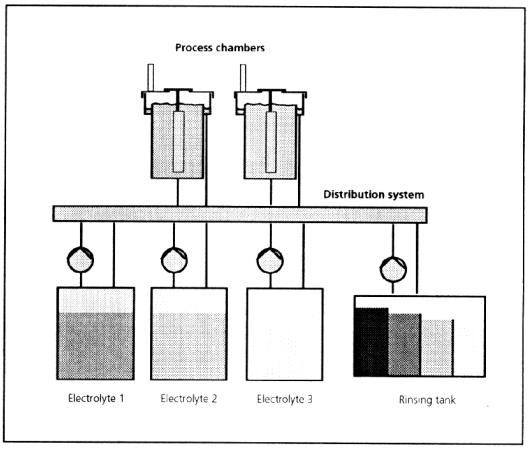

Figure 2: General equipment concept for process integratable plating processes

For plating processes the plating chambers can be designed to a maximum accuracy of layer thickness and layer thickness distribution. Control processes and user interfaces have to be adjusted so that workers without special knowledge can operate the equimp-

ment that could be seen as plating machines.
This concept takes advantage of short ways, high flexibility of the whole manufacturing system and the high precision that can be built into the plating machines. This precision can make subsequent processing steps such as grinding obsolete or minimize the need for processing.
Production integration of the second stage for surface processes means the integration of the process chambers directly in automated production lines (figure 3). Parts will be processed in the mechanical steps and will then go into the plating process. The process has to be as rapid as the other manufacturing steps and process times have to be minutes instead of hours as it is today in many cases.

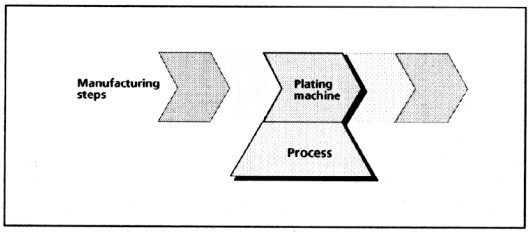

Figure 3: Integration of plating processes directly into the production line

Plating takes place only in plating chambers that are adapted to the processed parts and optimized to the used process.
In this setup many optimization potentials of the process can be used and plating accuracy and quality can be reached which is difficult to get with external plating services. If changes to a part occur, the according process chamber can be either adjusted or exchanged. Plating chambers are rather simple components considering their manufacturing and can therefore be exchanged easily. The most important feature is their geometry, which determines to a great extent the accuracy of the plating.
For this concept several new components for plating machines have to be developed. The main differences to the first stage of integration are automated handling, measurement and control components which are closely interwoven with the rest of the manufacturing system.
Not only must the plating processes themselves be speeded up a lot but also all handling and control operations for the parts. With high demands on precision for the single part and also over long production periods measurement of geometry, layer thickness distribution and also layer characteristics becomes more and more important. These functions have to be integrated in the plating equipment and have to work as fast as the plating process.

Advantages of process integration

To fully exploit the potentials of surface processes they have to be integrated in manufacturing systems or lines. This gives the user of these processes the following advantages:

- High quality of surface layers for the single part as well as over long production periods.
- High geometrical precision of the coatings that eliminates or minimizes the need for subsequent mechanical processing.
- Rapid and high throughput.
- High flexibility.
- Less logistics needed.
- Less handling needed, by that the danger of part damage is decreased.
- Part specific processes and equipment which exploits all possibilities of the process.
- Build-up and conservation of important, product specific know-how.

Today's manufacturing systems have to exhibit a wide variety of characteristics like flexibility, efficiency, controllability, environmental friendliness and so on. New concepts for plating technology like process integration will help to meet these requirements and the needs of today's customers.

Components of production integrated surface processes

Today several examples of first stage integration and few of second stage integration exist. Below some examples will be described for first stage integration. For second stage integration there is still some research neccessary, the main issues of which will be discussed later.
Because integrated equipment has to be special, adapted, optimized, it has to be modular and flexible to keep costs for configuration and reconfiguration low. Processes tend to high depostition rates and high geometrical precision in terms of layer thick-

ness and partially plated areas. So the process chamber will become a central component of plating equipment or, as we call it, plating machines.

Process chamber

In order to get excellent results in plating chamber design simulation based on finite elements or similar techniques has to be employed. It has to take into account electrical phenomena, heat and mass transfer and fluid dynamics. Today only few software programs are able to combine all of these and to produce integrated results. However, even if only mass transport and electrical phenomena are simulated the advantages for cell design are considerable. In some applications even today accurracies of cell geometry and shields have to be within a few tenths of a millimeter.

Peripheral components

Storage, control, conditioning or distribution of process media takes place in external or peripheral components such as storage tanks or heat exchangers. Basic concepts for peripheral equipment are already availiable including basic design rules, materials and component types.
Specific conditioning systems like filters, electrolysis cells or others must be integrated in the peripherals.

Control

Systems for process control are an important part of the overall plating system. They must guarantee a simple and save operation of the system without special knowledge about equiqment or process. They also have to monitor and control the process to ensure high and durable quality.

Examples of integrated plating processes

Below three examples of plating processes and the used equipment will be described that illustrate today's possibilities of process integration.

Dressing roll hard chromium plating unit

Dressing rolls are used in steel sheet production to impress a certain required roughness on the sheet surface. In the case discussed here the rolls themselves in turn are structured by applying a special chromium coating with tiny hemispheres on the surface.

This coating has to be plated with a layer thickness deviation of a few micrometer over a surface of about 2 square meters. The rolls are about 4.5 meter long, have diameters between 500 and over 600 millimeter and a weight of about 5 to 6 metric tons.
The plating unit had to be installed in a steel mill to minimize transportation costs and increase flexibility over external plating services.
To accomplish the required accuracy an equipment concept according to figure 3 was chosen. Process chamber and storage tanks are standing on the same level and electrolytes are pumped through the chamber and removed actively from it after end of the plating process.
Figure 4 shows a schematic draw of the plating chambers. They contain only anodes and the roll to be plated. Pumps are placed on the bottom level of the plant near the process chambers.

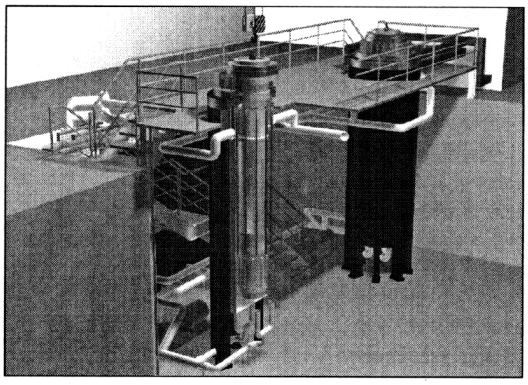

Figure 4: Schematic view of the two process chambers ot the dressing roll hard chroming plant

The overall setup of the plating plant can be seen in figure 5 which shows a model of the whole unit. Beside the process chambers the storage tanks are situated in the hole. The rectifiers are placed on the rim of the hole together with the cooling unit. The plant is operated in two or three shifts for some years now without major technical problems. It is operated by workers from the mill without any particular process knowledge. Operation is save and process control on the basis of proven process programs ensures a high reproducibility of plating results.

Flexible plating for assembled rolls

Sometimes the problem evolves in big or difficult to assemble machines to plate an assembled roll because it is too expensive to

disassemble it. Plating within a machine is a special case of integrated plating processes. It can save a lot of money and bring back or enhance the function of the roll.

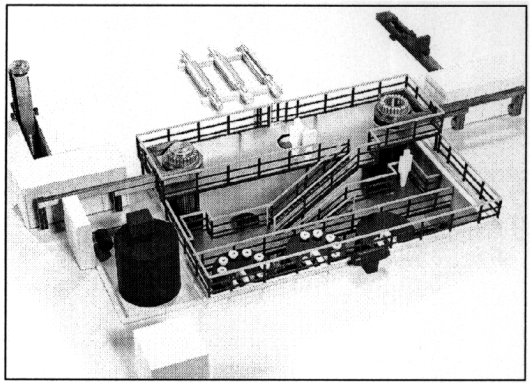

Figure 5: Overview of the whole plating unit with process chambers, storage tanks (below), recifiers (left and right) and cooling unit (lower left hand corner)

We have developed a process and the equipment to plate assembled steel rolls within a complex and sensitive machine environment. The rolls are pretreated and afterwards zinc plated. Rolls can be derusted and stripped with the plating unit as well.

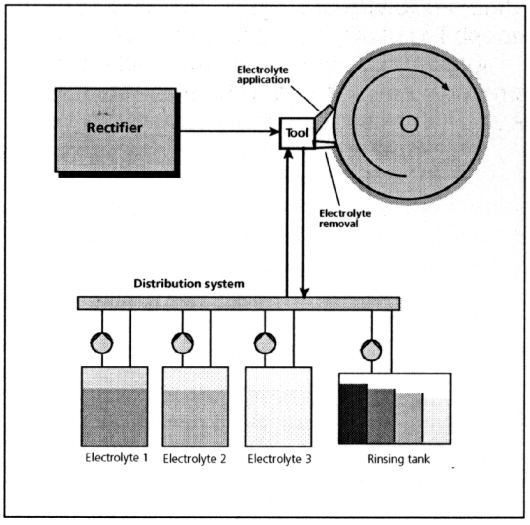

Figure 6: Schema of assembled roll integrated plating unit

Plating takes place on the surface of the roll. The electrolyte is applied to the surface of the rotating roll with a special tool and remove after one round again. The tool supplies also the current neccessary for the plating to take place. The whole setup is shown schematically in figure 6.

Electrolytes together with rectifier and process control unit are mounted on an external platform that can be moved to different operating places. The whole unit requires only electric current and purified water from time to time to replace parts of the rinsing water.
The electrolyte had to be modified compared to conventional recipes to account for the special process environment. This was developed concurrently with the equipment and is now operated at a customer regularly by service technicians without special plating or process knowledge.

Fast pretreatment of bore walls

A project currently under development in our labs is the fast and precise pretreatment of aluminium surfaces. Parts made of aluminium with bores in them have to be plated inside the bore. Therefore they have to be pretreated fast and precise. High geometrical precision together with very good layer adhesion are critical for this product that comes in high quantities.
We are developing multi unit single bore treatment cells which will enalble a very good process control within the single bores together with a high capacity of the unit. To accomplish this an appropriate cell design together with an assembly concept for mount and part that enables easy automation. Considering the design of the cells and the connection with the peripheral components one of the main issues is the rapid flooding and emptying of the parts with the various process media and the even distribution of the media over a large number of parts simultaneously.

Future of process integration and further developments

The new concept for plating machines will broaden the application potential for plating processes. Equipment that will keep any process emissions within and has smart control devices built in enables companies to use high-end plating technologies in house. So technologically important process know-how remains in the companies and processes can be optimized for certain products. There are several issues on which further research has

to be carried out to bring surface processes into a wide variety of manufacturing systems:

- Processes
  Deposition rates as high as several micrometer per minute have to be developed. These processes should have a good reproducibility of layer characteristics and should be precisely controllable by physical parameters only.

- Process chambers
  Tools for design of plating chambers are already available. They will be improved to integrate not only electrochemistry and thermodynamics but also fluid dynamics and two-phase flows as in chromium plating.

  Simulation has to be improved to cover not only heat and mass transfer and electrical fields but also fluid dynamics of one and two phase flows. Integrated automation concepts are neccessary to integrate process chambers into production lines. The whole design has to be very reliable to ensure high availability.

- Peripheral components
  Standards for suppliers of peripheral components will make it easier to flexibly configure plating units. Peripheral components should be easy combinable with standard interfaces for plumbing, electricity and pneumatics. Usability for different processes will broaden the basis for application.

- Process and product measurement
  High-speed deposition processes require on-line process analysis. Fast, precise and reliable measurement methods and components are neccessary to control integrated surface processes. Additionally the processes part have to be controlled for quality and defects. This has to take place also in-line, fully automated with measurement times in the order of plating times.

- Pretreatment processes
  All kinds of pre- and posttreatment also have to be speeded up a lot. Especially cleaning processes will get crucial to reach the required quality. Here also new and fast measurement techniques have to be used to fully control these processes.

- Automation
  One of the most important issues is the development of automated handling systems to integrate modern plating machines seamlessly into todays automated production lines. Because plating often has very different requirements with respect to handling we are now beginning to develop concepts which will integrate transport, handling, electrical contacting of parts, sealing of plating chambers and neccessary measuring operations without interruption.

- Control systems
  New control and user interface concepts will have to be developed to enable operators who know virtualy nothing about the process and intricacies of the equipment to safely operate processes on high quality levels over long periods.

- Media conditioning
  New cleaning and conditioning technologies for fast processes will have to be developed which are not only as fast as the deposition processes themselves but can also serve to control these processes to a certain extent.

- Troubleshooting / field service
  New and quick troubleshooting methodologies for plating processes and the equipment have to be developed. The tools for development and implementation are currently developed at our institute. Smart help systems have to be integrated in the control systems to enable virtually any user without prior knowledge to control the process efficiently and also to do some maintenance and repair safely. Multimedia tools will show context sensitive help texts or figures or even films. For more delicate problems augmented reality can help a lot.