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A comparison of plasma and gas nitriding processes from an environmental point of view

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Plasma and gas nitriding are already essential processes in business sectors such as aerospace, mechanical engineering, automotive, safety technology, and many more. In order to keep up with steadily increasing requirements for the surface treatment of steel materials and to continuously upgrade their leadership in technology, RUBIG relies on intensive research and development in the field of equipment as well as in process technology. As a nitriding specialist, RUBIG builds appliances for gas as well as for plasma nitriding in order to make optimum use of specific process benefits and to be able to offer tailor-made solutions for customers' applications. Optimization of equipment and processes to suit customer requirements results in a wide range of technological features such as vertical bells or pit furnace systems, horizontal chamber equipment, etc. and specially developed process variations.

New challenges

"Besides the increase in the filling rate, i.e. the maximum number of parts which could be nitrided at the same time in a single charge and the related reduction of cost per part and the equipment's direct control of temperature of the parts, the improvement in energy efficiency is proving to be ever more important", states Thomas Müller, Managing Director of RUBIG Industrial Furnaces. The trend is swaying to more economic plasma nitriding.

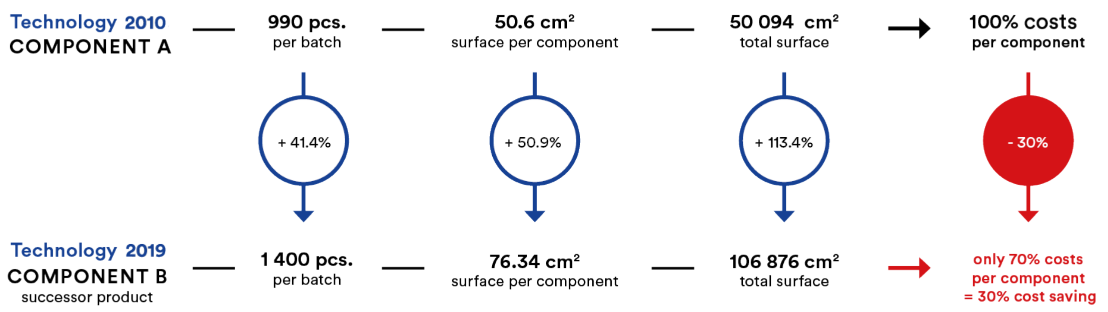

Figure 1: Efficiency development in industrial plasma nitriding technology

Hence the main reasons for further development of plasma technology are efficiency and environmental friendliness. The Austrian family-owned company has already succeeded in considerably reducing the energy demand in plasma nitriding, which brings along a significant relief on environmental burden. Nevertheless, utilization of gas nitriding technology still plays and will play a role in the future for many applications. Therefore,

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RUBIG is already working to find solutions on how to reduce the environmental impact and emission levels.

Economic advantage – a real-life example of environmental impact assessment

The main goal of this environmental impact assessment is to perform a comparison between traditional gas nitriding and newer plasma nitriding technology in order to analyze and assess the whole production process of the part. The selected study investigates the environmental effect of the procedures and thus reviews competitive ability from the environmental point of view.

Considering the objective, which is to perform a complex review of the processes, the underlying processes of each method (such as raw material and energy supply) were also included in the analysis. At the same time, the cleaning of the part was not taken into account as it was not taken into account in the study by Bell(1) and it is necessary to clean the parts prior to both of these processes. Equally, the investigated part itself is not a subject of the study, as it is identical for both methods, as well as the transport and the infrastructure of the nitriding equipment and the preceding processes.

Nitriding of the investigated reference part, a coupling device made of material grade 42CrMo4, is considered as a function. As a functional unit, the “nitrided volume” is defined (nitrided volume [kg] = part density x nitrided depth x nitrided surface). The plasma nitriding equipment used has a volumetric capacity of 1.4 m^3 and may accommodate approx. 500 pieces of vehicle coupling devices with a utilization factor of about 80 %. In comparison, the investigated gas nitriding equipment has a volumetric capacity of 1.1 m^3 and may only contain about 340 pieces per charge with a utilization factor of approx. 70 % for nitriding.
In order to verify the results, a study by Prof. Tom Bell(1) was used for comparison. This is the study that also deals with an environmental assessment of carbonitriding processes. This study has already shown that gas consumption, as well as the emission levels of the plasma carbonitriding process, are far lower compared to the gas carbonitriding process.
We may see in Figure 2 that when comparing the gas consumption of plasma nitriding and the gas nitriding process per functional unit [m3/fE], as well as gas consumption per hour [m3/h] standardized for a standard charge capacity (500 vehicle coupling devices), we reach a 4 to 6-fold reduction. The values (gas consumption per hour and NOx emissions) by Bell are used for comparison. The emissions of polluting gases such as NOx, CO and CO2, are reduced by about a factor of between 250 to 2,200. By means of this comparison we may instantly recognize that in the case of plasma nitriding the mass flows on both input and output sides are considerably lower and, in this way, this is the combination which limits the negative environmental impact.

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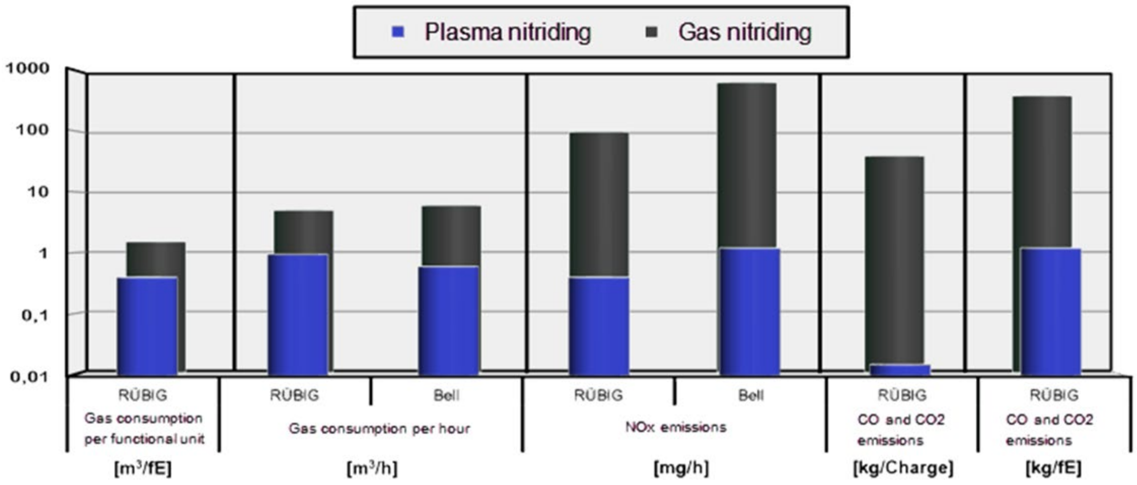

Figure 2: A comparison of gas demand and emissions of gas vs. plasma nitriding

As the electric power consumption plays a vital role, especially in the plasma process, it is divided into three areas as we may see in Figure 3. These are electric power consumption for plasma production, power for heating elements, and residual electric power consumption. The largest proportion of electric power is required for the heating stage. Less energy is required during the nitriding process itself – which lasts much longer - as the heating energy is provided mainly by plasma. The increased residual electric power consumption at the end of the process may be explained by the air cooling fan. The total electric power consumption for this plasma nitriding process thus amounts to 707 kWh. Compared to this, the electric power consumption of the gas nitriding process at 1007 kWh is significantly higher.

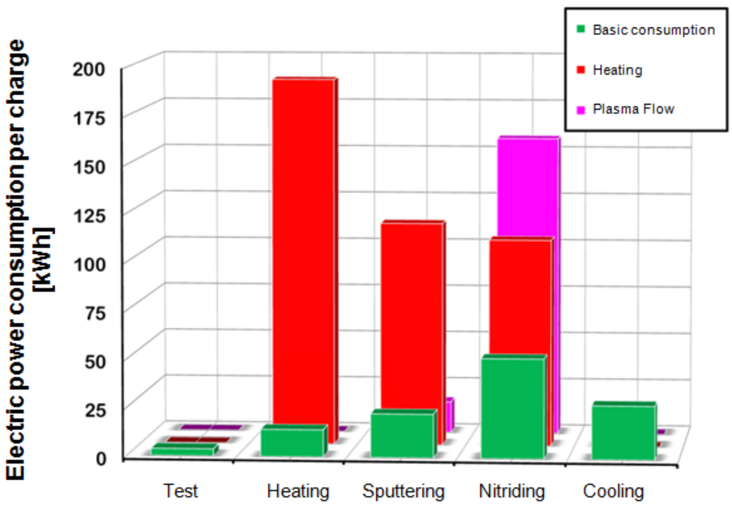

Figure 3: Electric power demand for the plasma nitriding process

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In order to present the result in a more straightforward manner and to provide a benchmark value to Bell's study[(1)], this study also compared the value of yearly emissions using a fleet of passenger cars as a reference value. The car fleet consists of 100 vehicles with an average annual driving performance of 15,000 km. Operating time throughout the period of one year is considered.

The results are already providing interesting insights. Thus, it is possible to recognize that the consumption of the gas nitriding equipment is approx. 87 % of that of the reference process, and, in the case of plasma nitriding equipment, it is approx. 36 %. In this way, it is possible to reduce a really stunning 56 % of primary energy consumption by using the plasma nitriding process compared to gas nitriding.

Climate change has also been examined in more detail. In mutual comparison we may recognize very well that, on the one hand by means of a higher gas flowrate, and on the other hand by the subsequent post-combustion of the process gases used in the gas nitriding procedure, this entails a much higher rate of gas supply and consumption in the core process, which results in a significantly larger impact than in the case of the corresponding plasma nitriding.

Figure 4 shows the comparison of the global warming potential of a car fleet to that of the nitriding processes. Here it is possible to recognize once more that the environmental impact of a fleet of 100 passenger cars with an annual driving performance of 15,000 km each is considerably higher than that of the investigated gas nitriding equipment, and about 4-times higher than that of plasma nitriding equipment.

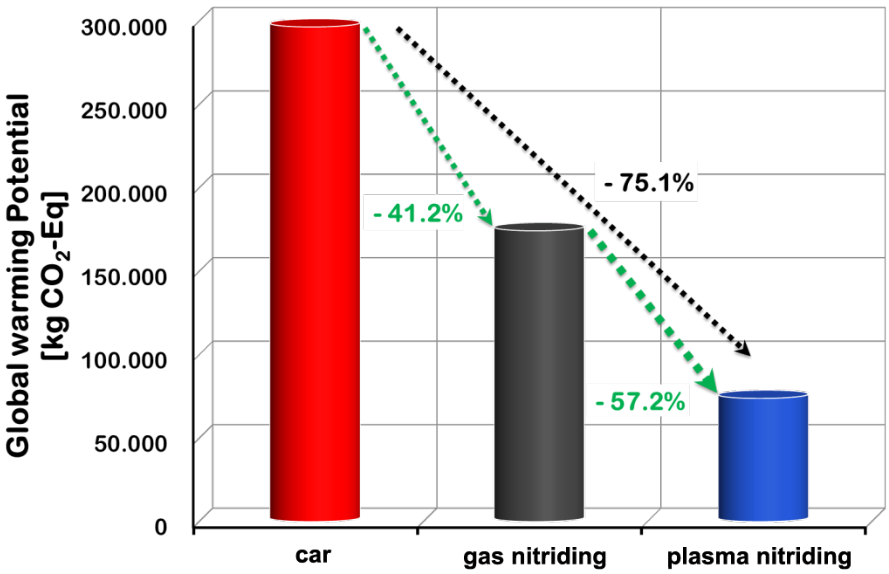

Figure 4: The comparison of environmental burden expressed as an effect on the climate change

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The instrument of environmental assessment is an excellent method for such investigations to gain more results on environmental aspects in a systematic manner and within an acceptable time period and, in most cases, it provides opportunities for optimizing and improvement measures. The study could provide a very clear explanation of the difference in environmental impacts between plasma and gas nitriding. The choice of the best fitting nitriding technology for diverse applications depends on many factors. Nevertheless, it must be emphasized that the examination of environmental impacts will play an ever increasing role in the field of heat treatment in the future.

About RUBIG Group
Since its establishment in 1946, RUBIG has developed from a small drop forger to a successful center of excellence in metals. With sites in Austria, Germany, Slovakia, the USA and China, the group of companies forms an internationally effective technology network. About 490 employees play the role of the main driver encouraging the development of technology and innovations. RUBIG Industrial Furnaces produces plasma and gas nitriding equipment as its premium segment, which has proved its worth in many applications – from providing paid heat treatment services, through the automotive industry up to aviation and wind energy.

Sources:

(1) Bell, Tom, Sun, Y. and Suhadi: A. Environmental and technical aspects of plasma nitrocarburising, Vacuum Surface Engineering, Surface Instrumentation & Vacuum Technologies, Vacuum 59, pp. 14 – 23. 2000