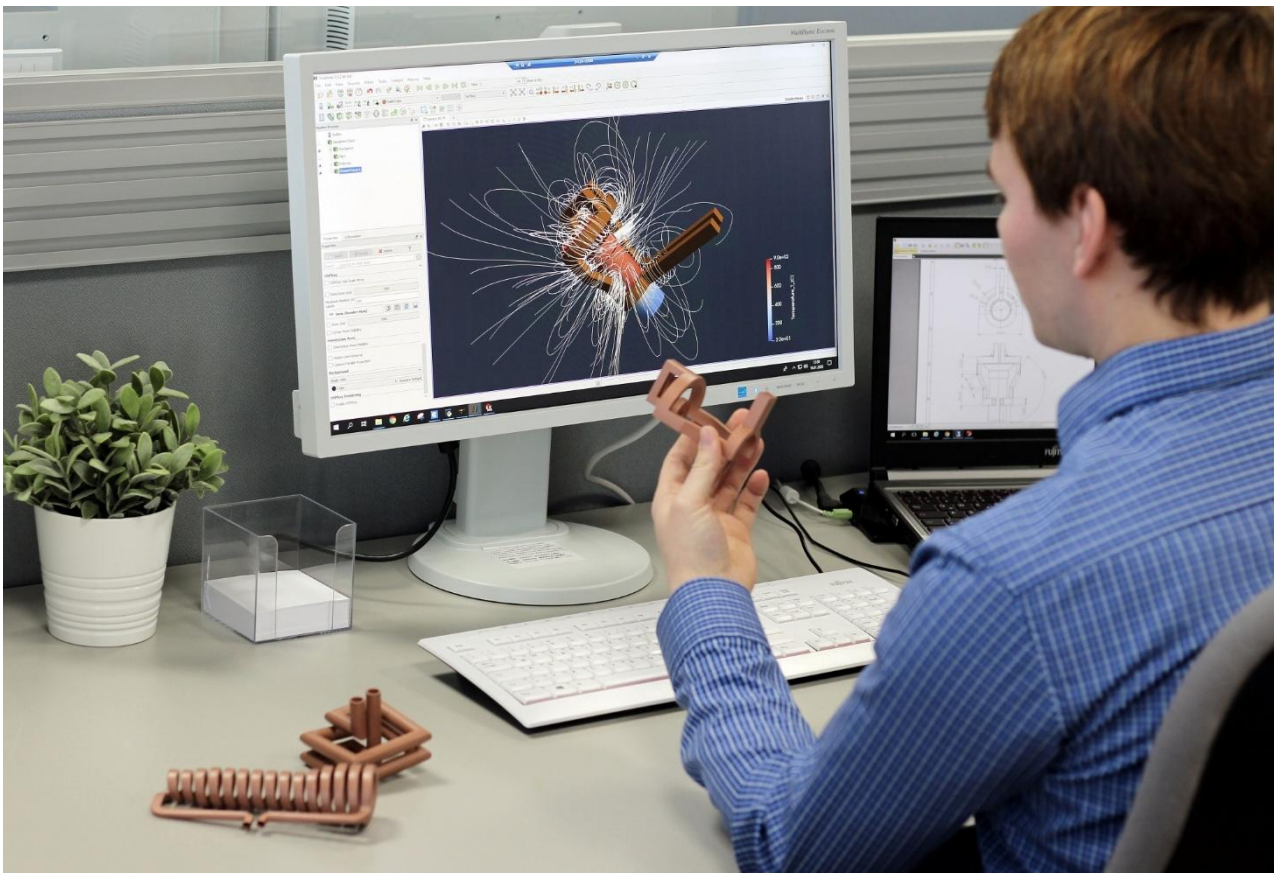
First use of pure copper in 3D printing

Tapping into the advantages of the manufacturing process for other industrial applications

(A technical article from 2020, author: Max Wissing, design and development engineer, Protiq GmbH, Blomberg)

The conventional development of complex inductors requires a lot of time and expensive testing. Protiq GmbH shows that things can be done differently. The behaviour of the coils in the process is visualized using numerical simulation methods and an optimized inductor geometry is determined.
The company then produces the intricate components quickly and cost-effectively using 3D printing - recently also from pure copper.



The additive manufacturing of induction coils made from highly conductive copper materials offers new possibilities for producing even more complex coil geometries; the optimized inductors are determined at Protiq using numerical simulation methods

3D printing - also known as additive manufacturing - has been driving innovation in numerous areas of industrial production for a number of years.
Thanks to the newly gained design freedom, components can now be produced economically where conventional manufacturing was previously not possible.
If computer-aided optimization is used as early as the development phase, the components can also be designed in the best possible way and their properties improved during operation. Protiq GmbH uses the resulting options to design and produce innovative coils for induction heating, among other things.

Since the invention of 3D printing in the 1980s, the technology has developed rapidly. There are now a large number of new 3D printing processes - such as selective laser melting or laser sintering - which also enable the production of series components.
Then as now, the components are built up layer by layer across all processes. These processes allow even complicated geometries - such as complex free-form surfaces or internal structures - to be manufactured efficiently. The wealth of 3D printing processes available also allows a wide bandwidth of materials to be processed. As a service provider for industrial 3D printing, Protiq uses many engineering plastics and metallic materials.
Founded in 2016 as part of the Phoenix Contact Group, the company has since been characterized by high production quality and short delivery times.

Unalloyed copper offers maximum electrical conductivity

The highly conductive copper materials developed by Protiq are a special feature. Copper is particularly valued in the electrical industry for its high electrical conductivity of up to 58 megasiemens per meter (MS/m) - or 100 percent IACS (International Annealed Copper Standard). In the additive manufacturing of metal components based on selective laser melting, a powerful laser creates complex components by melting fine metal powders layer by layer. For a long time, the processing of electrically highly conductive copper materials in this process was not considered feasible.

Due to the wavelength of the infrared laser used, a large proportion of the laser energy is reflected by the red copper material. This can damage the delicate production equipment from the inside and, in the worst case, destroy the expensive laser source.

The melting behavior of the material can be improved by adding alloying elements, among other things. However, this reduces the electrical conductivity of the material, which is why the components can no longer be used for current-carrying applications.

As a pioneer in this field, Protiq has overcome the challenges described above after many years of research and has been offering an electrically highly conductive copper alloy for several years now. The so-called RS copper achieves a value of up to 52 MS/m and has a copper content of 99 percent. Since November 2019, users have also been able to order their additively manufactured components made of pure copper on the Protiq platform. Thanks to its expertise, Protiq is the world's first 3D printing service provider to be able to additively process even pure copper with process reliability. The material contains no other alloy components and corresponds to the material Cu-ETP, the industrial standard with electrical conductivities of 58 MS/m or 100 percent IACS.

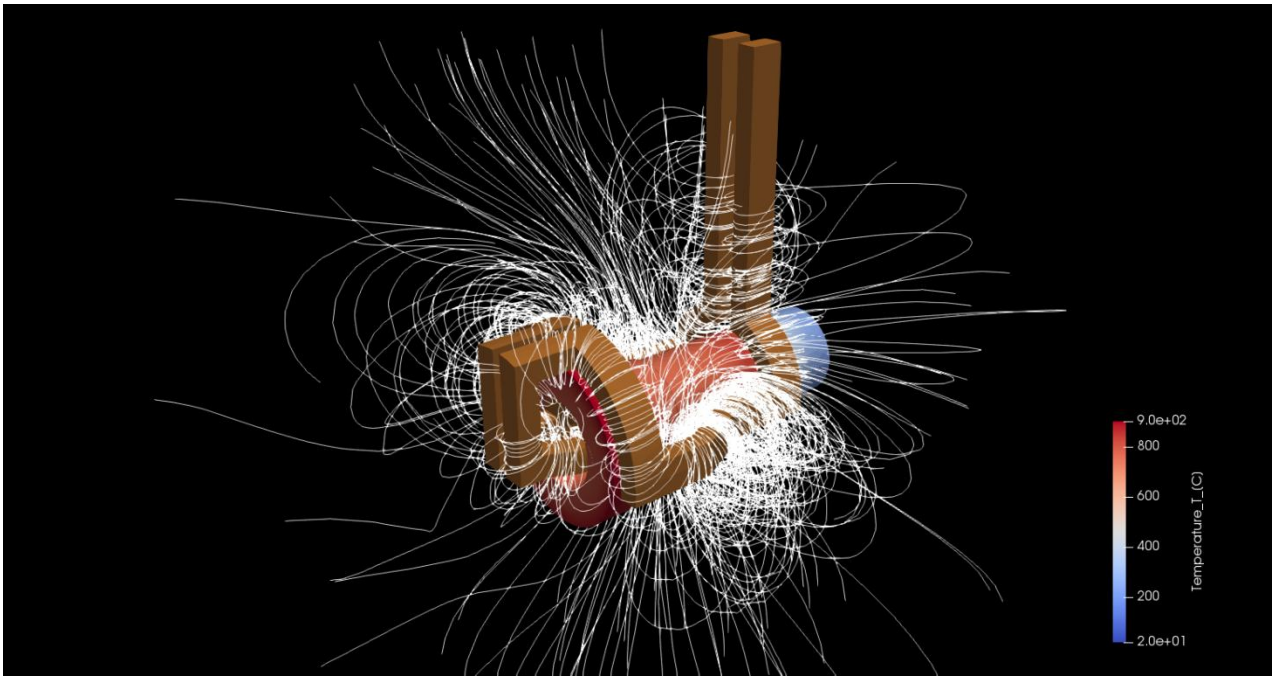
The process developed by Protiq for processing highly conductive pure copper in a selective laser melting process enables the production of innovative components for the electrical industry

Bending and soldering restricts design freedom

In this context, the 3D printing of complicated inductors made of highly conductive copper, which are used for inductive heating, offers great potential.

In induction heating, the inductor generates an alternating magnetic field, which induces an electric current in the component and heats the material through Joule heating. This effective and easily reproducible process has become the industrial standard, particularly for the surface hardening of components subject to high mechanical stress, such as gear wheels or gear components. The quality of the set hardening pattern depends directly on the magnetic field generated and therefore on the shape of the inductor.

Inductors are conventionally manufactured by bending and soldering copper profiles. Round or rectangular hollow profiles are used to implement the water cooling required for operation. The often manual and therefore time-consuming process results in high production costs and long delivery times. In addition, minimal bending radii and the selected profile shape limit the design freedom. As a result, the full potential of the inductor can often not be exploited.



The numerical simulation of the inductive heating process can avoid expensive tests; the simulation results enable a detailed analysis of the electromagnetic behavior

Additive manufacturing of inductors made from highly conductive copper overcomes the disadvantages of manual production. The automated production process is characterized by better repeatability and higher accuracy compared to the manual bending process. In addition, Protiq provides the user with 3D printed inductors that are not only more cost-effective, but also significantly faster. The previous delivery time of several weeks for a coil geometry is reduced to just a few days.

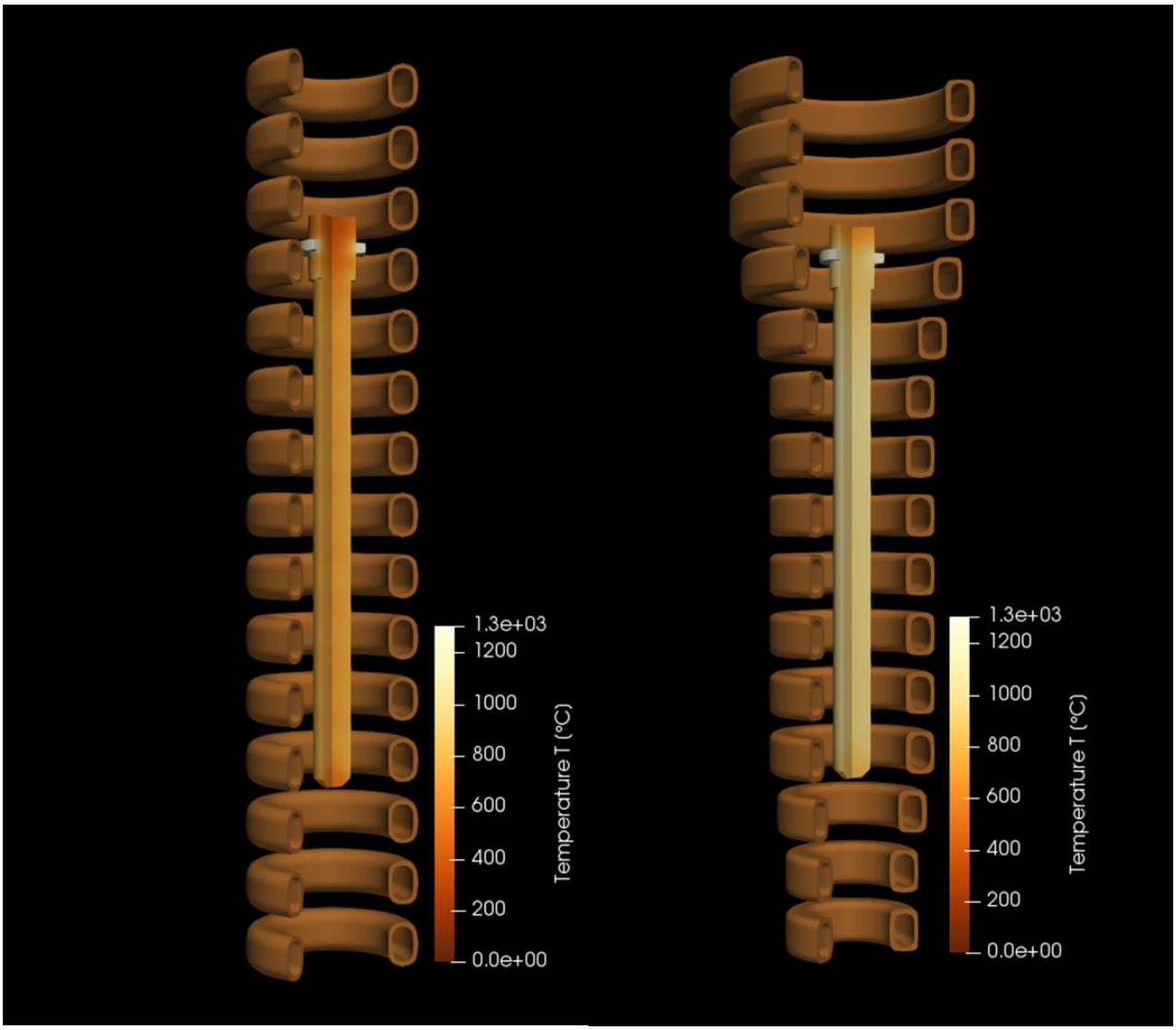
Simulations reduce the scope of testing and development time

The development of new inductors usually involves expensive and time-consuming tests. Various test geometries have to be produced and checked in real heating tests before the final inductor can be developed. By using computer-aided numerical simulations, the number of expensive tests and valuable development time can be reduced. Thanks to Protiq's expertise, the induction heating process is mapped in a simulation model that includes both the geometry of the inductor and the component to be heated as well as information about the existing boundary conditions and process parameters. On this basis, the thermal heating behavior of the component and the electromagnetic properties of the coil can be investigated.

The simulation results obtained by Protiq enable a much deeper analysis of the process behavior than real heating tests can offer. For example, the heating can also be observed inside the component or the magnetic field that builds up can be visualized. In this way, new and existing inductors can be evaluated and improved or the parameters for new heating tasks can be designed. Furthermore, 3D printing allows much greater design freedom, as there are no minimum bending radii or specified cross-sections to consider. This allows new, innovative inductor geometries to be developed with optimized magnetic field guidance and improved process properties.

Series production works with shorter cycle times

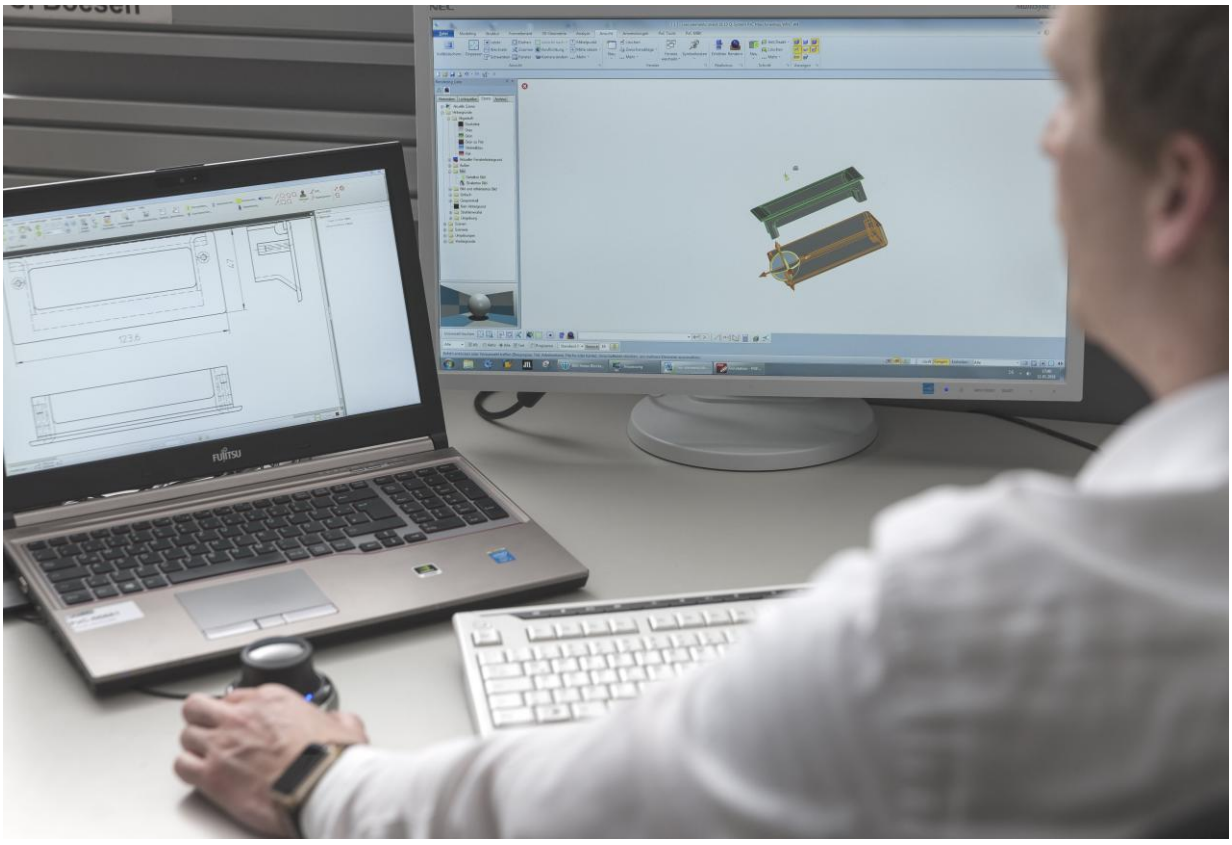
The inductors designed by Protiq in the manner described and additively manufactured from copper are impressive in operation thanks to their faster and more precise heating behavior. As a result, more precise hardening patterns can be set on the component and cycle times in series production can be reduced.



The coils optimized by simulation allow for more precise heating and reduced cycle times
(left a conventional coil geometry, right the optimized coil with improved heating behavior)

Competent support in the creation of 3D data

To ensure that the speed of the additive manufacturing process is not delayed by the conventional ordering process, Protiq provides its customers with an end-to-end digital online platform. Customers upload their individual component to the platform as a three-dimensional model and immediately receive information on manufacturing costs and delivery times. An official quotation can then be created and the order placed with Protiq within a few minutes. A quality check of the supplied data takes place automatically during the upload. Minor errors are automatically corrected by a repair algorithm.



Protiq offers competent support in the implementation of new 3D projects

If the customer does not have 3D data for the components, Protiq offers to create them as an engineering service. The 3D file can either be designed in the CAD program - in accordance with a 2D technical drawing - or created by means of reverse engineering using a CT scan.

Protiq also offers its customers expert support for complex engineering projects. Both the adaptation of a component with regard to production-ready design in 3D printing and computer-aided optimization projects can be offered on request.

Further information:

www.protiq.com