

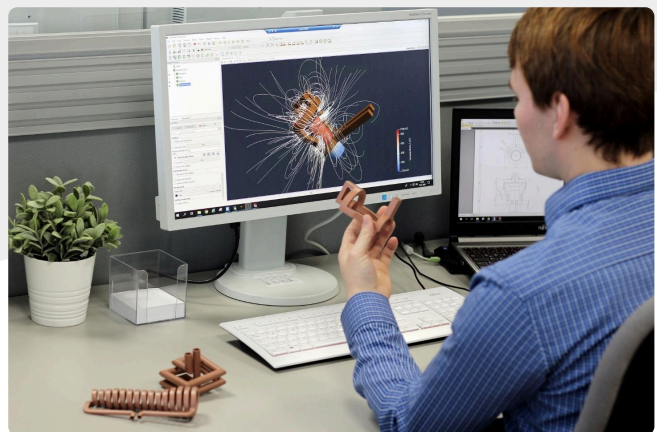
First use of pure copper in 3D printing

(A technical article from 2020, author: Max Wissing, Design and Development Engineer, Protiq GmbH, Blomberg)

The conventional manufacturing of complex inductors requires a great deal of time as well as expensive trials. Protiq GmbH shows that there is another way. The company produces these intricate components quickly and cost-effectively by 3D printing – and now also from pure copper. The behavior of the coils in the process can be visualized using numerical simulation methods, and an optimized inductor geometry can be determined.

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

Since 3D printing was invented in the 1980s, the technology has advanced rapidly. Today there is a wide variety of new 3D printing processes – for example selective laser melting or laser sintering – that also allow the production of series components. Then as now, the components are built up layer by layer, regardless of the process. These processes make it possible to efficiently manufacture even complicated geometries – such as elaborate freeform surfaces or internal structures. The large number of available 3D printing processes also allows a broad range of materials to be processed. As a service provider for industrial 3D printing, Protiq uses many engineering plastics and metallic materials.



▼ Additive manufacturing of induction coils from highly conductive copper materials opens up new possibilities for producing even more complex coil geometries; the optimized inductors can be determined using numerical simulation methods

Founded in 2016 as part of the Phoenix Contact Group, the company has since been distinguished by high production quality and short delivery times.

Unalloyed copper offers the highest electrical conductivity

The highly conductive copper materials developed by Protiq are a special feature. Copper is valued, particularly 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 fusing fine metal powder layer by layer. For a long time, processing highly electrically conductive copper materials in this process was considered unfeasible.

Because of the wavelength of the infrared laser used, a large part of the laser energy is reflected by the red copper material. This can damage the sensitive production systems from the inside and, in the worst case, destroy the expensive laser source. The melting behav-



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

ior of the material can be improved, among other things, by adding alloying elements. However, this lowers the electrical conductivity of the material, which means the components can no longer be used for current-carrying applications.

As a pioneer in this field, ProtIQ has overcome these challenges after many years of research and has been offering a highly electrically conductive copper alloy for several years. 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 can now also 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 succeed in reliably processing even pure copper additively. The material contains no other alloying constituents and corresponds to the material Cu-ETP, the industrial standard with electrical conductivities of 58 MS/m or 100 percent IACS.

Bending and brazing limit design freedom

In this context, 3D printing of complicated inductors made of highly conductive copper, which are used for induction heating, offers particularly 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 highly reproducible process has become the industrial standard above all for the surface

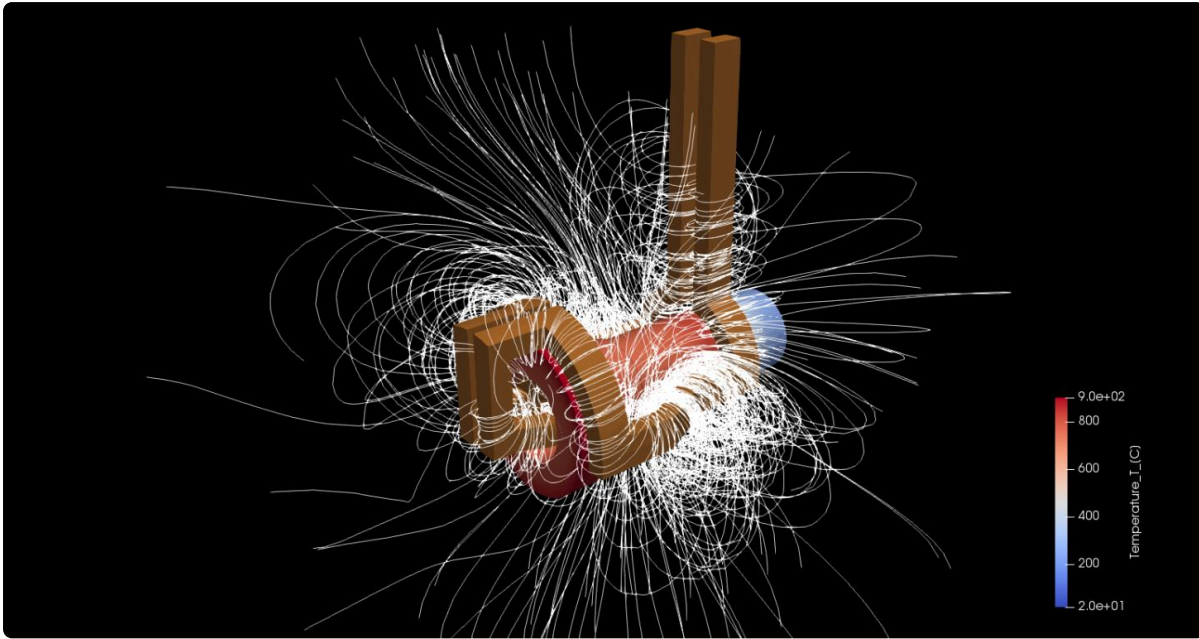
hardening of mechanically highly stressed components – such as gears or transmission components. The quality of the resulting hardening pattern depends directly on the magnetic field generated and thus on the shape of the inductor.

Conventionally, inductors are produced by bending and brazing copper profiles. Round or rectangular hollow profiles are used to provide the water cooling required for operation. This often manual and therefore laborious process results in high production costs and long delivery times. In addition, minimum bending radii and the chosen profile shape limit design freedom. As a result, the full potential of the inductor often cannot be exploited.

Additive manufacturing of inductors from highly conductive copper overcomes the disadvantages of manual production. Compared with the manual bending process, the automated production process offers better repeatability and higher accuracy. Moreover, ProtIQ provides users with the 3D-printed inductors not only more cost-effectively but also much faster. The previous delivery time of several weeks for a coil geometry is reduced to a few days.

Simulations reduce testing effort and development time

The development of new inductors usually relies on expensive and lengthy trials. Before the final inductor is reached, various test geometries have to be manufactured and verified in real heating trials. Using computer-aided numerical simulations reduces the number of



▼ Numerical simulation of the inductive heating process makes it possible to avoid expensive trials; the simulation results enable a detailed analysis of the electromagnetic behavior

expensive tests and the amount of valuable development time. The inductive heating process can be represented in a simulation model that includes the geometry of the inductor and of the component to be heated as well as information on the prevailing 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.

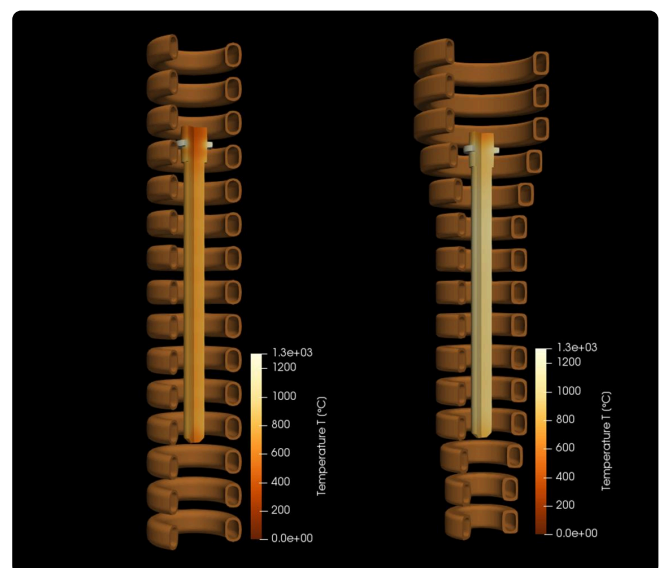
The simulation results obtained allow a considerably deeper analysis of the process behavior than real heating trials can offer. For example, the heating can also be observed inside the component, or the magnetic field as it builds up can be visualized. In this way, new and existing inductors can be evaluated and improved, or the parameters can be designed for new heating tasks. Furthermore, 3D printing allows considerably greater design freedom, as no minimum bending radii or predefined cross-sections have to be taken into account. This makes it possible to develop new, innovative inductor geometries with optimized magnetic field guidance and improved process properties.

Series production with shorter cycle times

The inductors designed in the manner described and additively manufactured from copper impress in operation with faster and more precise heating behavior. As a result, more accurate hardening patterns can be achieved on the component and cycle times in series production can be reduced.

Further information:

www.protiq.com



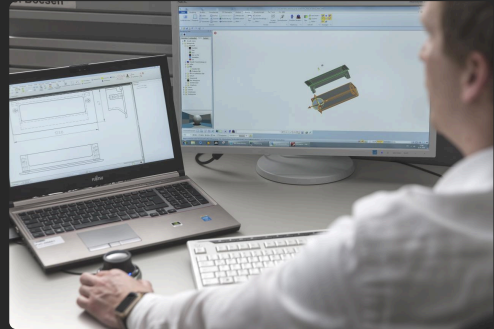
▼ The coils optimized by simulation enable more precise heating and reduced cycle times (left: a conventional coil geometry, right: the optimized coil with improved heating behavior)

Expert support in creating 3D data

So that the speed of the additive manufacturing process is not slowed down by the conventional ordering process, ProtIQ provides its customers with a fully digital online platform. Customers upload their individual component as a three-dimensional model to the platform and immediately receive information on manufacturing costs and delivery times. Within a few minutes, an official quotation can then be generated and the order placed with ProtIQ.

If the customer does not have 3D data for the components, ProtIQ offers to create it as an engineering service. The 3D file can either be designed in a CAD program – based on a technical 2D drawing – or created by reverse engineering using a CT scan.

ProtIQ also offers its customers expert support for complex engineering projects. The adaptation of a component for a design suited to 3D printing can be offered on request.



ProtIQ offers expert support in implementing new 3D projects