Lightweight Design – taken to the extreme with 3D-printing

Franke GmbH, based in Aalen, Germany, develops and manufactures wire-race bearings, a lighter alternative to the usual "solid bearings". In partnership with simulation experts from CADFEM and Rosswag as a solution provider for 3D printing in metal, Franke's bearing specialists pushed the technology to its limits.

Since the sixties, lightweight construction has been one of the drivers in the further development of wire-race bearings. For some years now, Franke has also been relying on 3D-printed aluminum bodies, as additive manufacturing makes it possible to save material without losing strength.

"Innovative, customer-specific solutions are our core competence."

Arne Jankowski, technical sales manager, Franke GmbH

Such bearings are used, for example, in the movement of satellite antennas for telephone and Internet in aircraft. These antenna dishes are often housed in the tail unit. They must remain constantly aligned with the satellite during flight to enable data transmission.

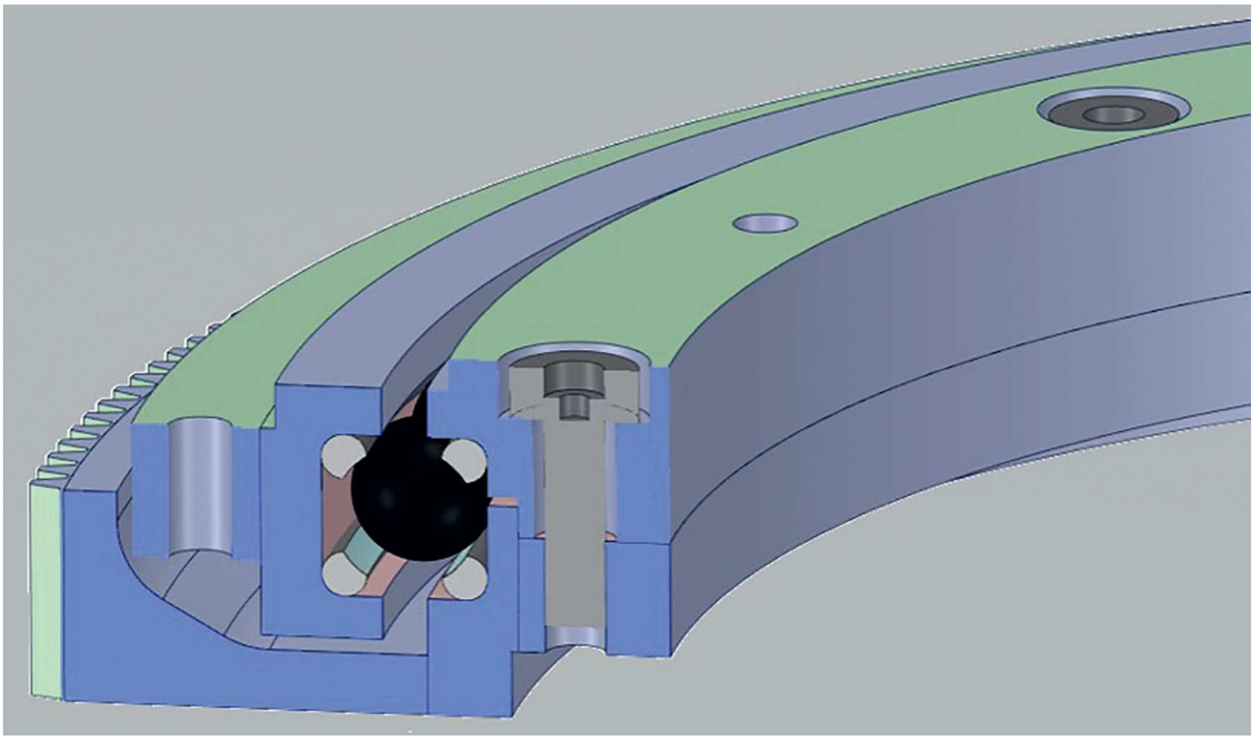
At the same time, of course, the bearings should be as light as possible in order to minimize the aircraft's kerosene consumption and, specifically, increase the payload. For example, one kilogram of weight saved on a commercial aircraft saves around $ 2,000 in fuel costs every year - and, by the way, a correspondingly large amount of CO2.

Franke has been supplying such weight-optimized bearings to the aerospace industry for a number of years, but so far with conventionally manufactured bearing bodies. In order to explore what further savings are possible with the latest technologies - such as topology optimization and additive manufacturing - Franke brought two partners on board for an industrial project: The first of which, Rosswag Engineering, a specialist for metal 3D printing that emerged from open-die forging, has long been Franke's supplier for additively manufactured lightweight bearings. The second, CADFEM from Grafing near Munich, is a specialist for numerical simulation, which, among other things, sells high-end simulation tools from ANSYS, and also offers its own engineering services.

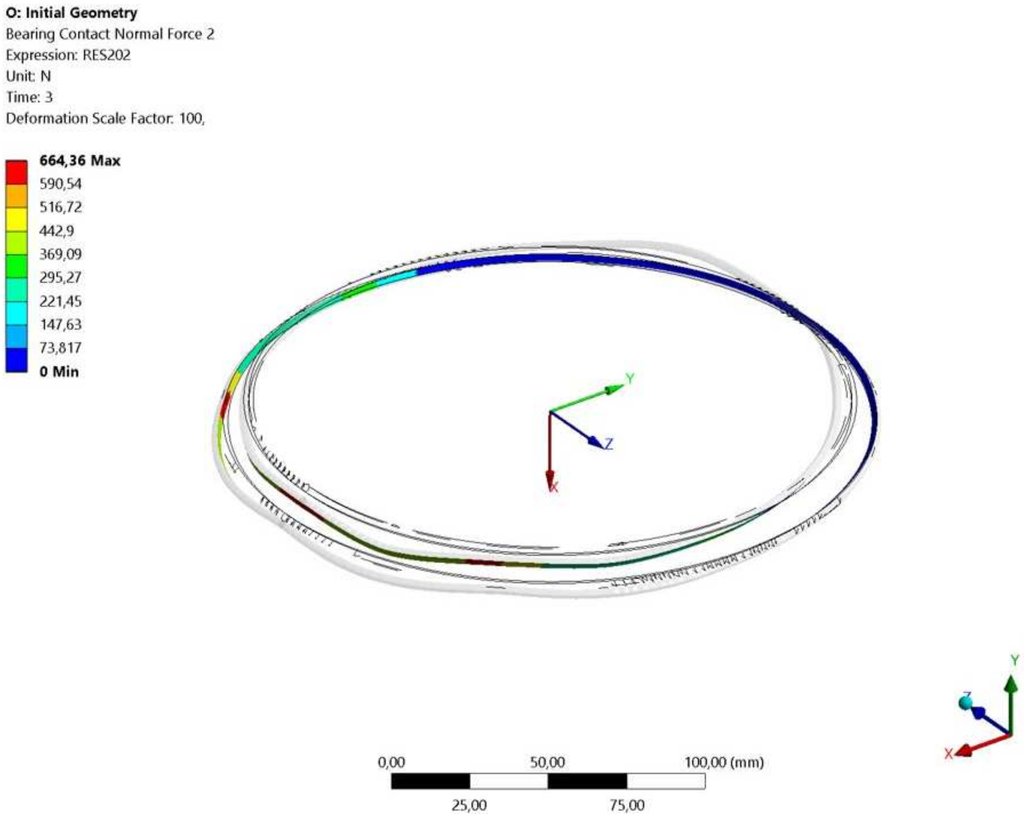
From CADFEM's side, Florian Hollaus of CADFEM Austria has took part in the project. Hollaus was able to bring to the bearing optimization project his many years of experience in numerous customer projects in which he performed topology optimization and other simulations as an external service provider. Many of these engineering projects, in which he often works directly with the customer and integrates into their team, also involve additive manufacturing, so Hollaus was able to draw on his wealth of experience here as well.

The starting point was a geometry supplied by Franke of the bearing used so far, which is constructed with a conventionally manufactured base body made of aluminum. Hollaus recalls, "the bearing with a diameter of about 25 centimeters consists of an outer ring and a two-part inner ring. The three aluminum parts were manufactured by the CNC method and optimized as far as possible in terms of weight for this process. With additive manufacturing, we are much freer in terms of shape design, so further material savings are possible, for example by replacing solid material with grid structures known as lattices."

Hollaus imported the geometry supplied by Franke into Ansys Workbench to prepare it for simulation. Defining ball bearings in FEM simulations is fundamentally difficult, but Hollaus was able to rely on an extension recently developed by CADFEM itself called CADFEM Rolling Bearing inside Ansys: "Each ball can theoretically have contact with the wire rings at four individual points, which is difficult to represent in the FEM mesh. Our extension automatically modifies the model so that the calculation can deliver optimal results."

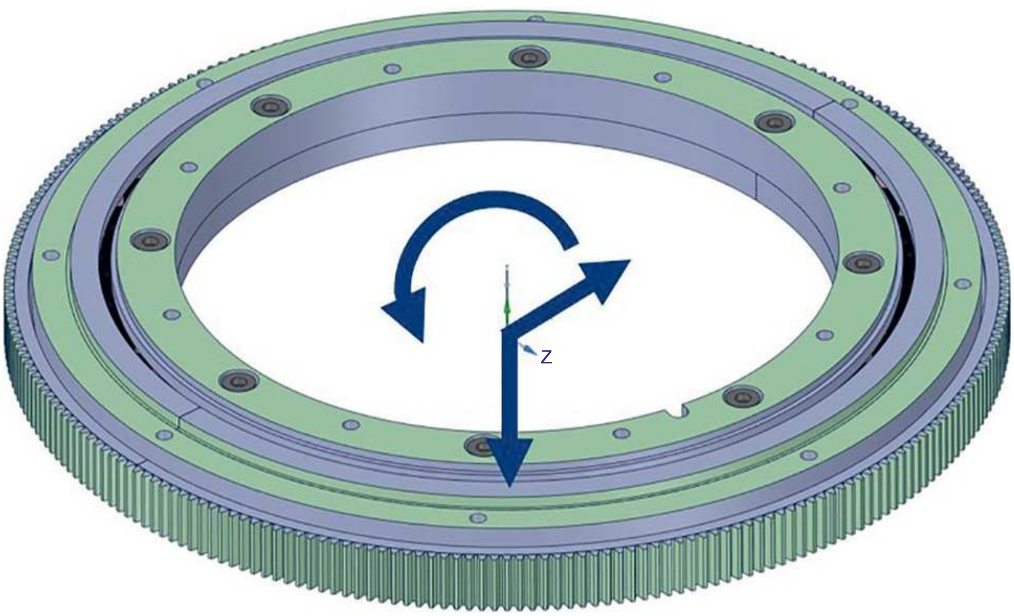


CADFEM Extension Rolling Bearing inside Ansys automatically modifies the model so that the simulation can provide optimal results with regard to the stiffness behavior of the rolling bearing.



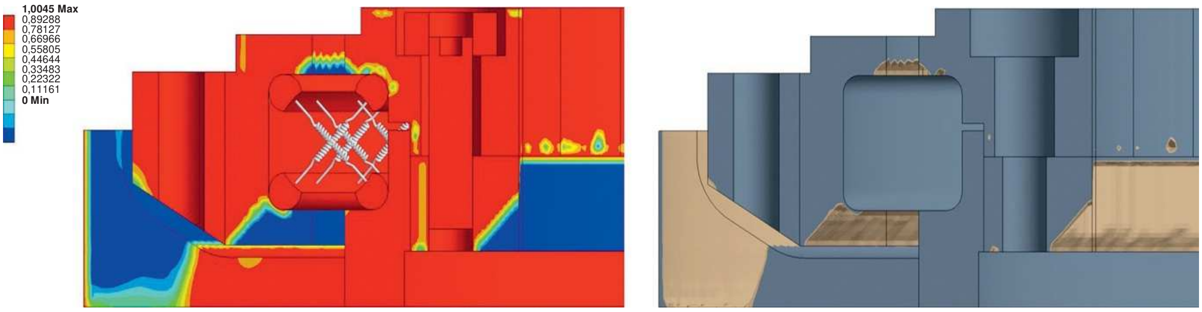
Bearing forces can be determined quickly and easily with Rolling Bearing inside Ansys

Franke also provided the loads on the bearing. Two cases were calculated: First, the real loads from flight operations and second, the significantly higher loads that are embedded in the approval regulations. In addition, the bending moments in the bearing had to be taken into account.



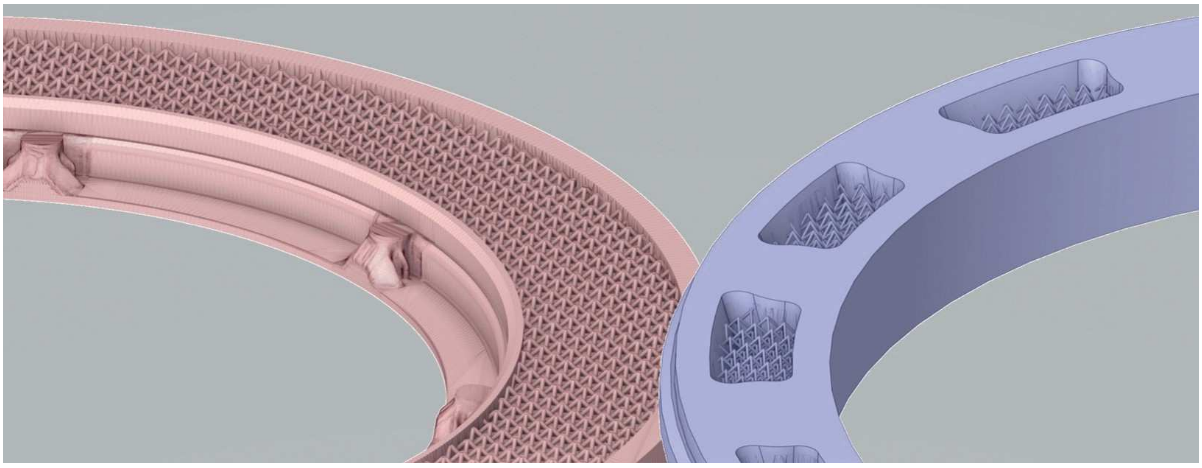
Eine wesentliche Vorbereitung der Topologieoptimierung ist die exakte Lastfalldefinition.

After defining all loads and the invariable geometry areas of the bearing, the topology optimization was started. An interesting result of the calculations with Ansys was that in a larger area of the basic body only negligible stresses occurred and the material at these points was removed by the topology optimization.



In the topology optimization, areas are removed (shown in blue) that do not play a role in stability.

Hollaus imported the optimized geometry into the SpaceClaim CAD system integrated in Ansys. There, the corresponding area was filled with a lattice structure, because this leads to higher stiffness at very low weight.

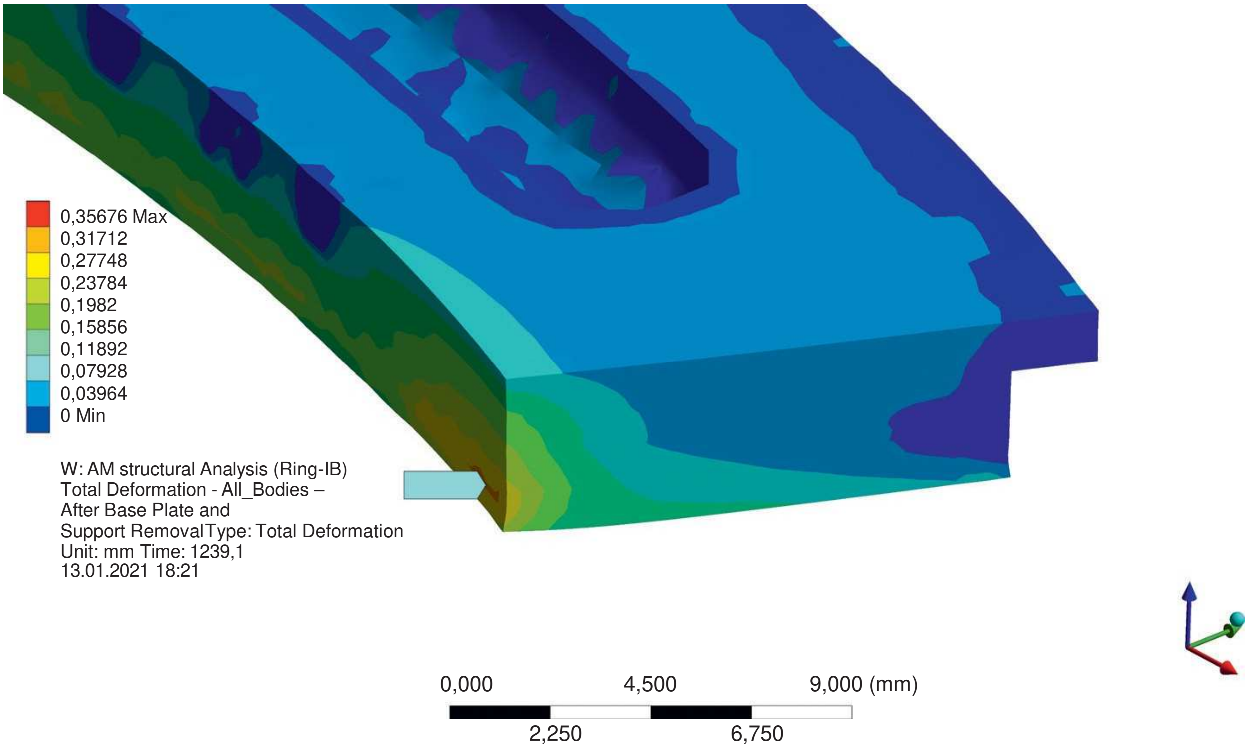


Lattice structures give the cavities additional stability.

With the topology optimization, it was possible to reduce the weight of the 3D-printed bearing body by a further 16 percent compared to the conventionally manufactured counterpart, which was already highly optimized - a very good result.

A second important area of application for simulation is the printing process itself. In metal 3D printing using the powder bed process, focused laser beams are used to introduce the energy required to completely melt the metal powder particles at the desired locations. Rapid cooling rates and high temperature gradients create strong stresses in the workpiece. To enable heat conduction during the additive manufacturing process and to absorb the resulting forces and stresses, “support structures” are required. On the one hand, support structures are therefore important for the success of the printing process, but on the other hand they are also cost drivers due to the material and time required.

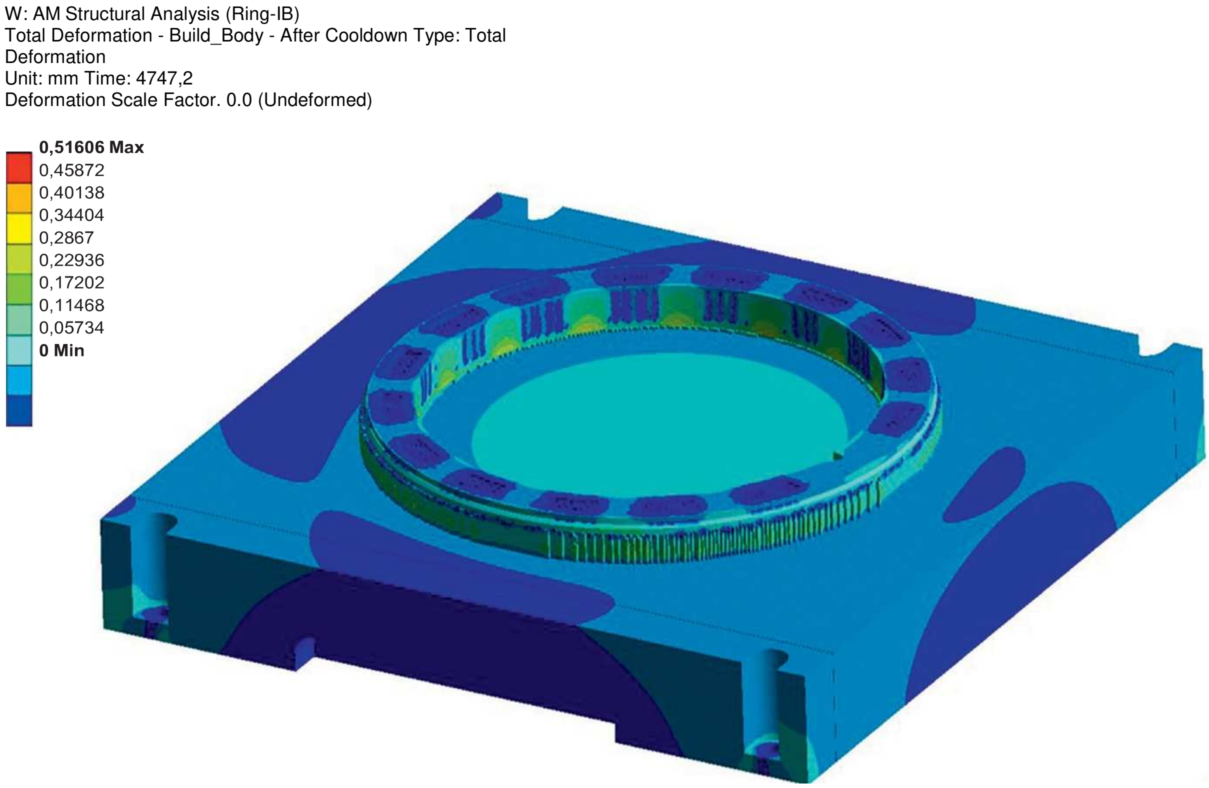
Hollaus clarifies: “In the simulation with the Ansys Additive Suite, we work with material parameters that were obtained in lengthy test series. By the way, some of the material data included in the scope of delivery of the Additive Suite were developed by Rosswag Engineering. With this data, we achieve a very accurate representation of what is really happening. This pertains to, for example, the formation of the melt pool when the laser beam hits the powder, or the distribution of heat by the respective scan strategy for the individual layers. In order to minimize distortion, we don’t work in a line, as with a plastic filament printer, but the laser beam jumps back and forth over the entire print area.”



Component deformations can already be detected and evaluated before printing

“Nevertheless, a laser beam applies heat to the material extremely selectively - that's the whole point, after all, to be able to print fine details,” Hollaus continues. “That's why the printed parts have to be fixed in place using support structures so that they don’t warp or even bend upwards, where they then collide with the coater lip when the next layer is applied. On the other hand, these structures have to be removed manually and consume material, so a balance has to be found between too little and too much support structure. For this purpose, pressure parameters such as speed and exposure time of the laser can be varied, but also the orientation of the component in space. It’s exactly this optimal setting that we determine with the Additive Suite and thus avoid any misprints.”

Hollaus worked closely with Philipp Schwarz, Rosswag's project engineer, to simulate the printing process. Schwarz recalls the collaboration, “Each of us contributed our experience. For example, we selectively added material to the geometry calculated by CADFEM at the points where machining was necessary, such as in the bearing seat. We also defined the positioning in the installation space and the support structures. Then the overall model went back to CADFEM for simulation of the construction process.”

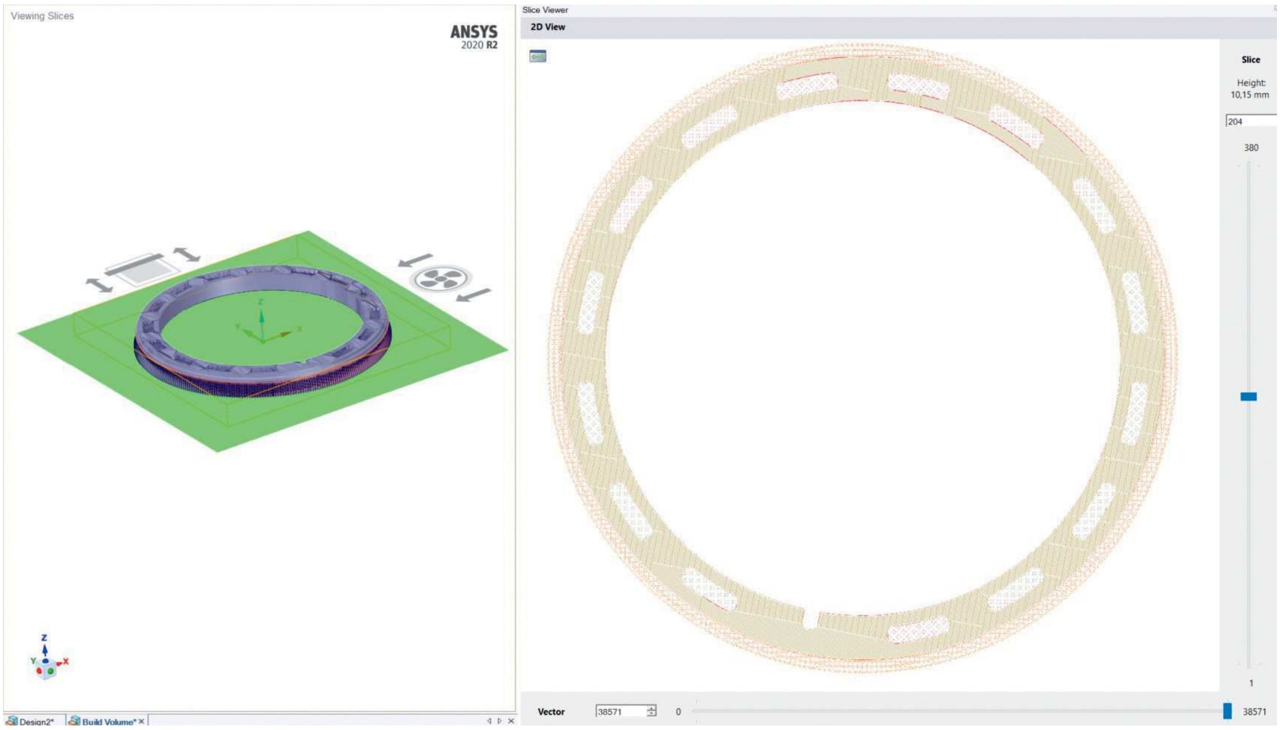


With process simulation, all components of 3D printing are taken into account: Component, supports and building panel.

Hollaus adds, “In the Additive Suite, we were able to calculate the construction process layer by layer and thus find the optimal manufacturing settings that would allow the bearing bodies to be produced reliably, precisely and with as little rework as possible - which was then confirmed during printing at Rosswag.” Schwarz agrees: “That’s right, the three components could be printed without any complications. For the current prototypes, we used the standard material AlSi10Mg. However, in the next step we are also thinking about new alloys that are not yet available in the Additive Suite. In the past, we have already been able to add our own material models to the Additive Suite in close cooperation with Ansys. Working out all the theoretical and experimental data for the material model of a higher-performance aluminum alloy would be the next big step in this project.”

Schwarz then generated the data in Ansys Additive Prep for the SLM Solutions metal 3D printing system, on which all the parts were manufactured. The finished printed bearing bodies were then shipped to Franke, where they were in turn processed and completed with the bearing components - wire rings, rolling elements and housing. Franz Öhlert, design engineer at Franke, explains the machining process: “The CNC milling machine is used to machine the seats for the wire rings, the contact surfaces of the two inner ring parts with the outer ring, and the points where the bearing is connected to other components. Until now, it has not been possible to print these surfaces so cleanly that they can be used without further machining.”

Other than the kickoff meeting, which was able to be held as a real meeting shortly before the lockdown in March 2020, nearly the entire project ran under Corona conditions. Further arrangements were then made via Microsoft Teams. The 3D representations from Ansys proved their worth as a means of communication. Thanks to the coloring of the 3D models with the different stresses in the component, problem areas could also be clearly communicated in the video meeting and solutions found.



The SLM file is generated in Ansys and can be read directly from the machine or simulation

The simulation shows in advance what the finished component will look like.

Franz Öhlert is very satisfied with the cooperation in the partnership: “It is true that this was not a real customer order, but we wanted to find out on our own initiative which savings could be achieved with topology optimization and additive manufacturing. It was nevertheless a very realistic collaboration, and we would have cooperated with Rosswag and CADFEM in real projects as well (which we have already done).

Our team - consisting of Franke’s bearing specialists, Rosswag’s experience in 3D printing and metal materials, and CADFEM’s simulation experts - was efficient and everyone was impressed by the pleasant collaboration. We achieved a great result with acceptable effort and will certainly be able to use the experience gained from this project in further practice.”

3D-printed bearing rings

Florian Hollaus is also very satisfied with the project: “We were able to show that we can simulate and optimize the manufacturing process so realistically with the Ansys Additive Series software, that the printing process took place without any problems. And the 16 percent savings in weight, on an already optimized component, illustrates what is additionally achieved with topology optimization and the freedoms of 3D printing.”

Philipp Schwarz concludes, “as an experienced service provider, we benefit from the manufacturing process optimization that we have implemented with CADFEM. Metal 3D printing requires very high investments in machines, materials, and know-how, so every avoided misprint leads to a noticeable saving. Ansys Additive Suite not only convinced us in this project, but has also been successfully used by us in our daily business for several years.”

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ABOUT FRANKE

In 1936, engineer Erich Franke invented a particularly space-saving rolling bearing. Instead of steel inner and outer rings, between which spherical or roller-shaped rolling elements run, Franke used ground wire rings. In 1949, the inventor founded his own company to manufacture and sell these wire-race bearings. In the 1960s, the wire races were integrated into stainless steel (or aluminum bodies) for the first time - lightweight construction made its debut in rolling bearing construction. In 1970, the Franke principle was transferred to linear motion; today, these linear systems contribute to about a quarter of total sales.

The wire-race bearings can be manufactured with somewhat lower precision and, therefore, very inexpensively as well as with very high precision, and thus more expensive. For example, when Franke bearings are installed in circular knitting machines, the focus is on price, while the huge bearings for the X-ray ring of computer tomographs have to be extremely accurate and at the same time very quiet. The possibilities for adapting the bearings to the application are almost infinite - rolling elements and housings made of different materials and geometries make lubricant-free or even food-grade bearing arrangements possible, among other things. Wire-race bearings from Franke are even used in outer space.

The flexibility of this technology enables a wide range of applications - the mechanical engineering and medical technology sectors each make up about one third of customers, respectively, while the last third of customers come from a wide range of industries. Today, around 280 employees work at the Aalen site, developing and manufacturing bearings with diameters of up to two meters. Only around five percent of the bearings supplied are ordered from catalogs, the rest are customized bearings.

www.franke-gmbh.com

ABOUT CADFEM

CADFEM GmbH was founded in 1985 and is one of the pioneers in the application of numerical simulation. It employs around 180 people at 6 locations in Germany and is part of the global CADFEM Group, one of the largest international providers of simulation technology.

CADFEM GmbH supports companies, research and university institutions in making the best possible use of the potential of numerical simulation in the entire product development process. As an Ansys Certified Elite Channel Partner, CADFEM relies on the leading technology from ANSYS, Inc. Because software alone does not guarantee simulation success, CADFEM customers benefit from a comprehensive range of additional products, services and knowledge - all from a single source.

www.cadfem.net/additive

ABOUT ROSSWAG

The family-run Rosswag GmbH was founded in 1911 and is a leading supplier of forged components. Since 2014, the Rosswag Engineering division has been drawing on over 100 years of experience in the processing of more than 400 different metal materials and expanding its range of services to include engineering services and additive manufacturing processes. The globally unique and holistic process chain was expanded in 2017 to include in-house metal powder production for material qualifications. As a result, more than 35 materials have now been qualified for additive manufacturing.

Since 2018, Rosswag has been cooperating with the software company ANSYS in process simulation for demanding manufacturing and qualification projects. From TÜV SÜD, Rosswag was the first company to be certified for both the production of metal powder and the series production of functional components in the additive manufacturing environment. Rosswag's research-intensive innovation strategy has been honored with numerous awards in recent years.

www.rosswag-engineering.de

More about Lightweight Design by Franke