Pistons produced by additive manufacturing enable new applications for existing reciprocating compressors

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Components produced by additive manufacturing are gaining in significance not only in development and prototype construction – they are increasingly becoming suitable for use in end products. In this respect, components produced by additive manufacturing are not subject to the restrictions on conventional manufacturing technologies – such as milling or grinding – and can instead be designed to be significantly more suitable for function and load. This opens up new opportunities for design and application which up until now have only been able to be realised using common methods with a great deal of complexity, if at all.

At its location in Balingen, Baden-Württemberg, Germany, Mehrer Compression GmbH produces dry-running reciprocating gas compressors for a wide variety of gases and applications. The special feature of these compressors is that piston and piston rod are firmly fixed together, and the rotary motion of the crankshaft is transmitted through a connecting rod with crosshead joint in a linear lifting movement, which drives the piston rod and piston. This elaborate design allows for the gas chamber and crankcase to be separated from each other so that the gas can be compressed in an absolutely oil-free manner. The piston can do its job with PTFE elements for piston rings in a simple cylinder.

A question was raised about how an existing double-acting reciprocating compressor, whose pistons are today made of aluminium, can be fitted with stainless steel pistons. This will enable the dry-compression of aggressive gases that would otherwise attack the aluminium. With this option, the scope of application of existing compressor architectures can be expanded considerably. A simple replacement would not do. A steel piston would have around three times the mass of an aluminium piston of the same design, which would have resulted in an unacceptable strain on the overall structure in operation.

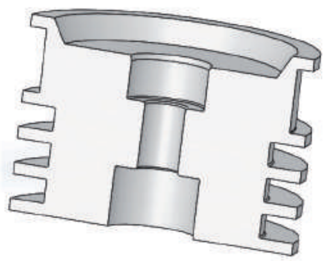

Fig. 1: 3D model of the original piston made of aluminium

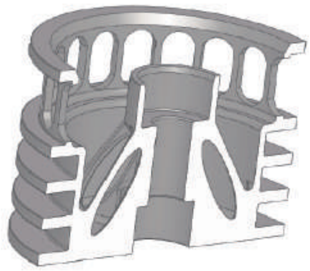

Fig. 2: 3D model of the mass-optimised piston made of stainless steel

So the task was to design a steel piston that had the same mass as the original aluminium piston and could be attached to the same piston rod. In this project, this design task was initially approached in three manual optimisation steps (see Fig. 1 and Fig. 2). Material was gradually removed from areas where it was not being used for the stability or design of the piston. In comparison with the initial model, this resulted in a delicate structure that had only 3% more mass than the aluminium piston with the same function. In terms of the application and overall function of the compressor, this value is negligible.

The resulting shape was exceptionally well-suited to additive manufacturing methods, thus providing us with a newly acquired freedom of design. The pistons themselves were produced in a power-bed-based laser melting process, and subsequently the grooves for the piston and guide rings were machined to ensure the necessary precision and surface quality for the correct support of the PTFE elements. (Fig. 3 and Fig. 4)

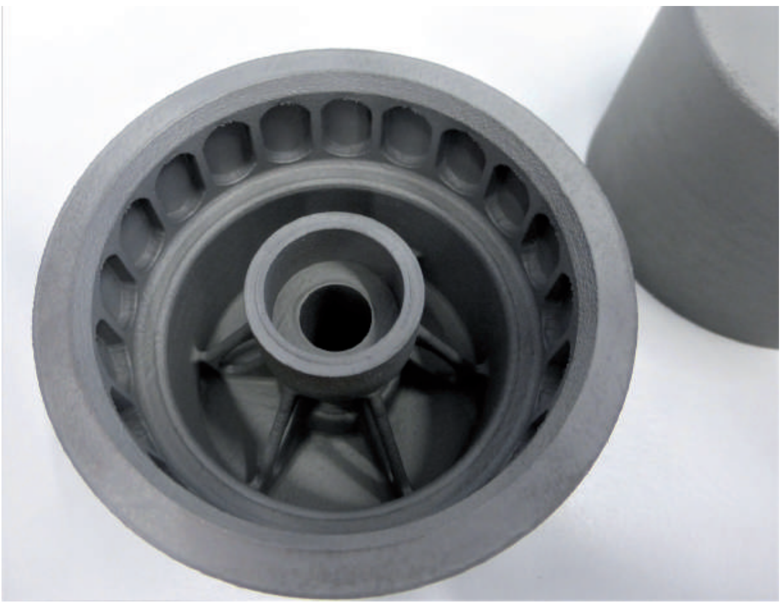

Fig. 3: Stainless steel piston workpiece made by additive manufacturing

Fig. 4: Piston workpiece made by additive manufacturing undergoing machining of the piston ring grooves and the guide ring groove

Fig. 5: Installation-ready stainless steel piston with three piston ring grooves and a guide ring groove

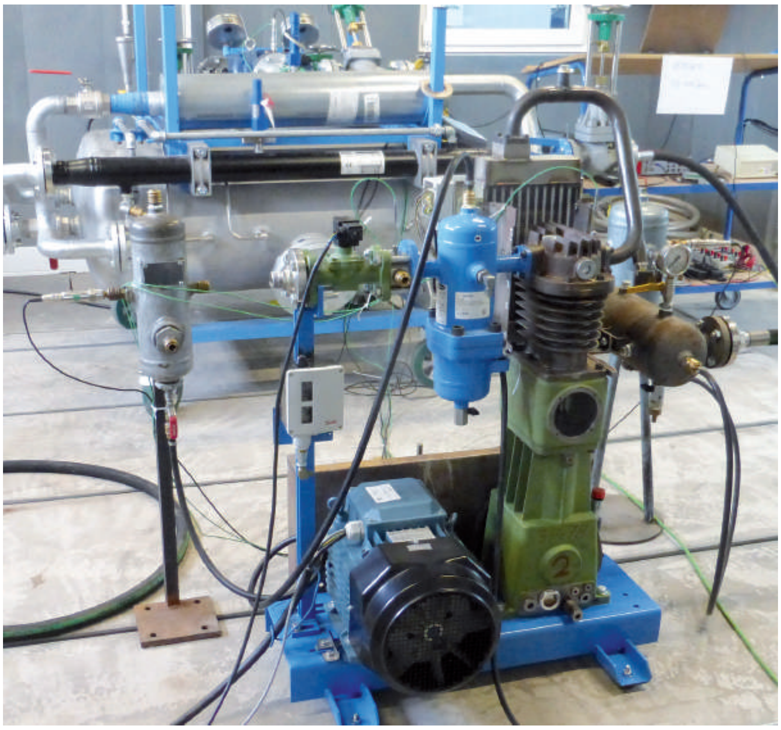

Fig. 6: Test compressor with piston test specimens in the test field.

The pistons produced in this way then passed the first loading tests with air on a test compressor (Fig. 6).

The project was a complete success. The results up until now show no traces of overload when compared to the standard design with aluminium pistons. In the next step, the steps that have been performed manually up until now are to be automated using finite element optimisation processes and expanded to further materials.

Summary and outlook

Instead of a very time-consuming reconstruction, with its freedom of design, the additive manufacturing process of the company provides the option of installing individual parts into an existing compressor architecture, whereby the arising problem is resolved many times more efficiently and profitably. It is therefore technically practical to produce individual parts using the additive manufacturing method. It was possible to avoid a reconstruction, achieve a material saving of 2/3 of the mass and produce the individual part much more cheaply than with stainless steel casting.

Through this relatively easy-to-achieve expansion of the product range, the compressor manufacturer is expecting new application opportunities for existing compressors in the future. In the future, the design optimisation that has been performed manually up until now is to be automated using finite element optimisation processes and expanded to further materials and sizes.

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