Additive Manufacturing of a topology optimized lightweight part of a humanoid robot

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ABSTRACT

Due to its high design freedom and flexibility, Additive Manufacturing is often used as an alternative to the conventional manufacturing. In order to be competitive, as many advantages of additive manufacturing as possible should be used. Lightweight construction is one of the biggest advantages of Additive Manufacturing. However, implementing lightweight design for AM requires different product design approaches compared to conventional development.

To achieve the lowest possible part volume combined with a high strength, it is possible to optimize the topology. At first, stresses in the part are localized by means of a numerical simulation. Subsequently, by comparing them with a reference, high and low-loaded regions can be separated. Thus, a targeted volume reduction can be implemented. In order to be able to respond to the restrictions of the manufacturing processes, these must be considered before the optimization.

This paper presents a procedure for a production-oriented simulation and topology optimization for the SLM process (Selective Laser Melting). An approach to optimizing the topology is presented with regard to technical as well as economic aspects. In doing so, methods for the quantitative assessment of success factors are used.

Since various procedural restrictions exist for the SLM process, such as anisotropy or thermal distortion, these must be considered before the topology optimization. This is done by adjusting the simulation and optimization parameters. Through this adaptation, it is also possible to take into account the previous assembly concept and to improve it by an integrated design. In order to comply with required tolerances, both a thermal and mechanical post-processing is necessary. This in turn must already be considered in the optimization task.

This approach is illustrated by the optimization of the topology of the pelvis of "Sweaty", a humanoid robot. This robot was developed by students and is able to play football. He is a participant in the annual RoboCup, where he is currently Vice World Champion. In a previous study, three different materials were already evaluated. Among these is a novel high-tech material called Scalmalloy, which is evaluated and selected for this case study. This material has been developed for the aircraft industry and provides excellent properties in terms of density and strength.

Two design variants were developed using topology optimization and iteratively optimized by adjusting the parameters. These each have different mounting concepts. Finally, the design variants were compared in terms of weight, stiffness and costs to find the best technical and economical solution. For this purpose, an economic analysis was carried out to evaluate the costs and benefits. This design solution was subsequently validated and manufactured using the SLM process.