Manual Mobility Chair for Children with Lower Limb Impairments with Optimized Construction Designed for Manufacturing using Generative Technologies

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Doctoral dissertation - summary

This doctoral dissertation concerned the interdisciplinary research of several areas: mechanical engineering, ergonomics, topology optimization and additive manufacturing. A multidisciplinary approach was used to construct and create a prototype of a manually propelled mobility aid, which helps children with motor impairment of the lower limbs aged from approximately 9 months to approximately 4 years to move independently.

Literature review examines the history and development of wheelchairs construction and also shows a market analysis of available products dedicated to children.

Key topics related to the research include case studies of topologically optimized products and manufacturing technologies for producing optimized structures, especially by using FDM additive technology.

The scope of the dissertation includes design, technology and research. The first part concerns the engineering design process from the conception phase to the manufacturing of a fully functional mobility chair prototype by using FDM technology. Research analyzes the process of topology optimization of the infill material distribution inside individual vehicle components (while maintaining previously designed external form) in the context of various loading conditions. All the forms of the vehicle elements obtained in this way were computationally verified using the finite element analysis at various load cases.

As previously mentioned, the main design goal of the dissertation was to construct a manual wheelchair intended for children with lower limb dysfunction, which, when propelled manually, will provide children with independence when moving around. The mobility aid is designed with necessary adjustable features to ensure ease of use considering the changing size of the growing user.

Research focuses on the application of topology optimization as a software tool to obtain the desired infill distribution inside functional vehicle components.

The main criterion for topology optimization of the elements' infill was to reduce their weight while maintaining their strength and desired functionality.

In addition, the mobility chair has been designed to be manufactured using the most popular generative technology today - FDM.

The main scientific goal of the dissertation was to assess the effectiveness of topology optimization of material distribution inside vehicle components at all stages of the processes: design and manufacturing. A separate issue was the assessment of the impact of FDM printing parameters on the strength and quality of the obtained elements. The research included a number of simulations of various infill configurations of 3D printed components and assessment of their impact on the mechanical properties.

The analysis of the obtained results shows that the use of topology optimization allows for the desired weight reduction of components while maintaining their strength and functionality. Virtual models of elements were designed including all features characteristic for FDM manufacturing and topologically optimized structure. These are the forms of models containing an accurate 3D representation of the infill structures, which are the outcome of Boolean operations of the combination of the forms derived from topology optimization and grid infill with a density of 20%. Such models have been FEM analyzed. The results of the numerical analysis were compared with models with a standard infill (grid type with a density 20%), full models and shell models. Comparison of the results allowed us to assess the effectiveness of the method used. The analysis of the research results confirmed the validity of the theses:

1) It is possible to manufacture a fully functional rehabilitation device using the most common and relatively cheapest additive technology - FDM, which affects the final price and popularizes the possibility of producing this type of device.

2) Topology optimization of the infill of functional elements - manufactured using FDM additive technology - made it possible to obtain an infill structure that was sufficiently durable in the context of defined load cases and allowed for minimizing the weight of the device.

The conclusion from the conducted research confirms promising prospects for the use of topology optimization and FDM printing technology in the design and manufacturing of functional elements. Furthermore, this dissertation demonstrates the feasibility and potential of using FDM additive

technology in the design and manufacture of a fully functional rehabilitation device for children.

Further research should focus on the optimization of FDM printing processes and the validation of the developed design and analysis methods in practical industrial applications. In addition, further stages of research related to a manual mobility chair should involve carrying out physical strength tests of individual elements.

Key words: *mobility aid for children with disabilities, Mechanical Engineering, Rehabilitation Engineering, Computer-Aided Design, CAD, 3D Printing, Additive Technologies, Topology Optimization, Design, Human-Centered Design, PLA, FDM.*