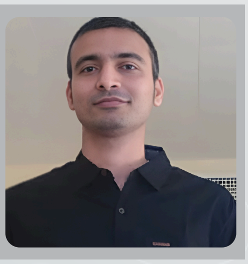
Topology Optimization and Pneumatic Soft Grippers



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These days, the use of soft grippers is constantly increasing as they ensure insignificant or no damage to gripping objects [1]. Such grippers are made with material that has Young's modulus in the kilopascal to megapascal range, and they perform their tasks using elastic deformation. They are typically actuated via different means; the most sought-after currently is actuated using pneumatic load [1]. However, because of the lack of a systematic approach, these grippers are designed using manual/ad-hoc methods, which greatly depend on the designer's ability, experience, and expertise. A systematic method, such as topology optimization, to design such grippers will help increase their applications [1].

Topology optimization (TO), a systematic computational technique, provides an efficient way to arrange material layout within a given design domain while optimizing the desired objective with the given constraints. The finite element method is used to solve the associated partial differential equations. Each element is assigned a design variable that varies between 0 and 1. A design variable of 0 and 1 implies the element's void and solid phases, respectively. The optimized design is expected to be made up of design variables with 1. A pneumatic load is a design-dependent load that can change direction, location, and/or magnitude. Thus, dealing with such loads while considering their design-dependent nature is challenging [2, 3] in a TO framework. Kumar et al. [2] proposed a novel method to deal with fluidic design-dependent pneumatic load in a TO setting. The approach uses Darcy's law with a conceptualised drainage term to model the evolving nature of the pneumatic load while considering the discretised system as a porous medium. Herein, we demonstrate the efficacy of this method for designing a pneumatically actuated soft gripper. Various MATLAB codes, such as TOPress [3], SoRoTop [4] and TOPress3D [5] for pedagogy purposes, have been developed using the method presented in [2]. A soft gripper can consist of three to four fingers, depending on the applications and the required grasping action. Each finger contains a set of pressurised chambers that deform to provide the motion necessary for the soft gripper.

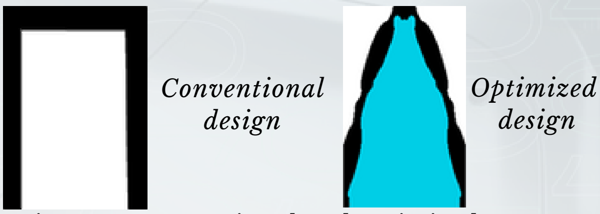

Figure 1. Conventional and optimized pressure chambers. The optimized chamber is obtained using the SoRoTop MATLAB code [4].

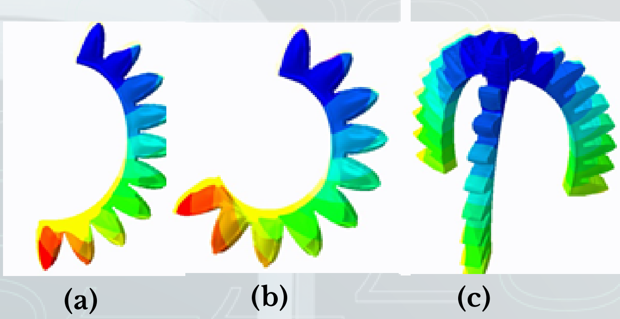

Figure 2. Deformation profiles of the single finger and a soft gripper with three fingers

A conventional soft finger consists of rectangular pressure chambers [1]. To increase performance and automate the design method, a unit pressure chamber of the finger can be optimized, considering it a compliant mechanism actuated by pneumatic load [1]. The optimised chamber is eventually sequentially combined to create a finger for the grippers. We use the SoRoTopMATLAB code [4] to design a soft finger unit (Fig.1). The optimized chamber is different than its conventional counterpart. The optimized design is extracted, extruded, and sequentially combined to create a finger of the soft gripper. The deformation profiles are shown in Fig. 2a-b. A softgripper with three fingers is also depicted in Fig. 2c. Therefore, we believe that TO can be exploited smartly to design different types of soft robots for various applications.

References

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