Compliant Mechanism Research and Design

ME 297 Research Project

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I. Abstract

The basis of this project was to model, design, and test several planar compliant mechanisms aimed at amplifying the input mechanical motion. Such compliant mechanisms use flexure hinges (which are slender, flexible portions that bend and enable relative rotation of two adjacent rigid links) instead of classical joints. The goal was to design and test several models to generate a compliant mechanism producing the greatest amount of amplification as possible while remaining within the limitations of the material that was chosen for the physical testing. Another design objective was to achieve a dual-symmetry output which was parallel to the input. Major differences between the different models chosen for physical testing are focused on the flexure geometry because of the wide range of output variations produced by minor changes in the flexures. ANSYS fininte element analysis software was utilized for the design analysis of several different models, but one basic design with the aforementioned geometric variations proved to generate the best results for the desired objective. The fabrication, done by wire electric discharge machining (EDM), of the final designs was in progress at the writing of this report; therefore, the physical testing and comparison between experimental results and theoretical data will be completed at a later time.

II. Introduction

The intention of this research project was to study a class of compliant planar mechanisms designed to substantially amplify the mechanical motion at the input ports, and alter the design parameters as necessary to produce maximum displacement amplification. The output amplification was to be achieved through a design objective of implementing two stages of displacement amplification which will produce a motion that is fully parallel to the input motion. Compliant mechanisms use flexible portions, generally known as flexure hinges, instead of classical rotation and translation joints; their elastic deformations – usually of bending or torsion – enable the relative motion between rigid links. Compliant mechanisms have advantages such as compactness, no assembly (because the adjacent links are monolithic), no maintenance, no friction losses, and precise motion. The basic design objective is schematically represented in Figure 1 which is shown below.

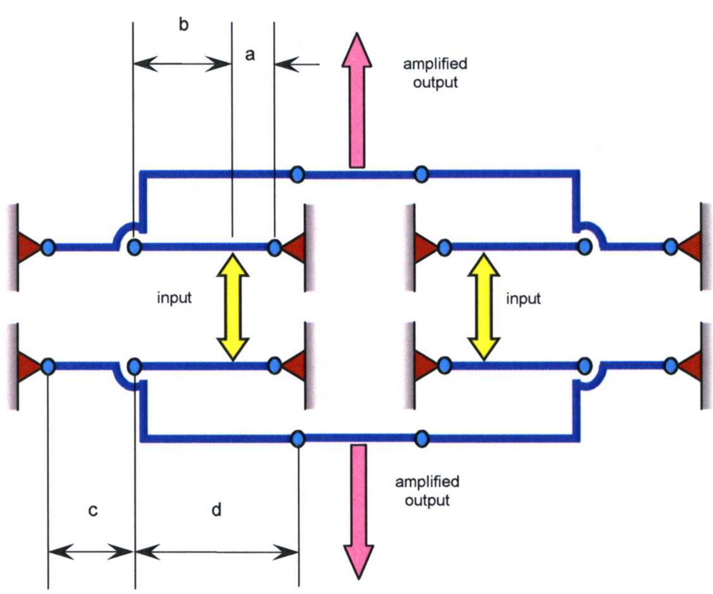

Figure 1. Double-symmetry uni-directional motion-amplification mechanism

III. Analysis

Theoretical data for the different variations of compliant mechanisms was generated through ANSYS finite element software which is a powerful software tool that allows the designer to do a complete design and analysis from this one platform. The software has three main categories which were used for the design project. The preprocessor mode establishes the material properties, geometric modeling, element meshing, and force applications. The solution mode performs the actual analysis of the designed mechanism. General postprocessor mode is then accessed for all the required data such as: shape deformations, maximum stress values, and displacement measurements. Maximum stress values are the key design restriction because they are generated at the flexures. Figure 2 below shows the combined (Von Mises) stresses at the flexure hinges on both stages of the compliant mechanism. Note the larger stresses at the second stage.

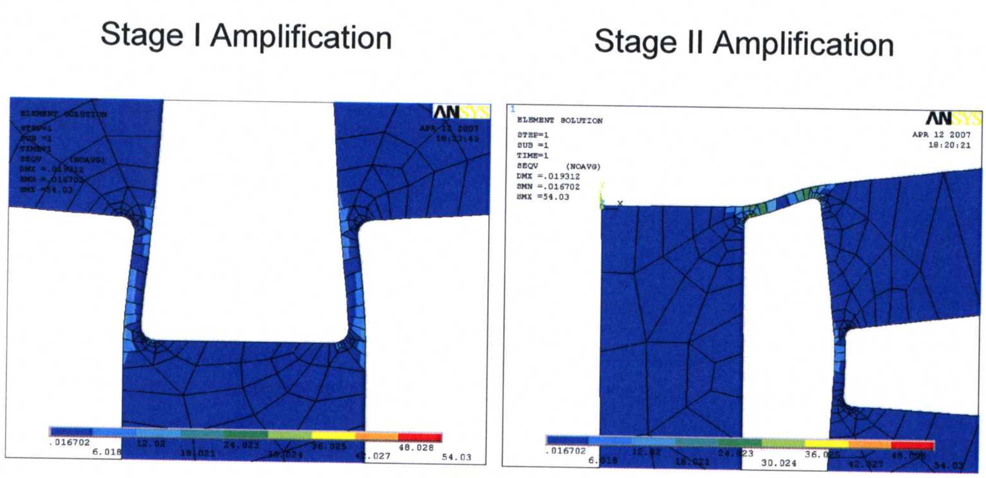

Figure 2. Flexure hinge stresses

After a basic mechanism is designed and the initial analysis is complete, parameters are changed within a log file program to quickly run another analysis. Through this process the basic model is varied until the optimized designed is obtained

IV. Results

Obtained results were as expected because of the different designs and a wide range of parameters applied. Amplifications ranged from zero on a poor design, up to 13:1 on the most successful design. The design with a low amplification highlights the importance of the geometric layout of the flexures. The most efficient geometric model was chosen to focus more effort and apply more parameter changes to maximize the amplification. Maximum amplification was accomplished with several changes made to the radius and the thickness of the flexures, and the optimum design have radii of 1 mm and a thickness of 1.1 mm. First stage amplification on this design was approximately 3.8:1 and the second stage was approximately 3.4:1. The final amplification results from the product of the two stages, giving the total of 13:1. This proved to be the optimum amplification attainable within the limitations of the project. A full geometric model representing the optimum design is shown below in figure 3.

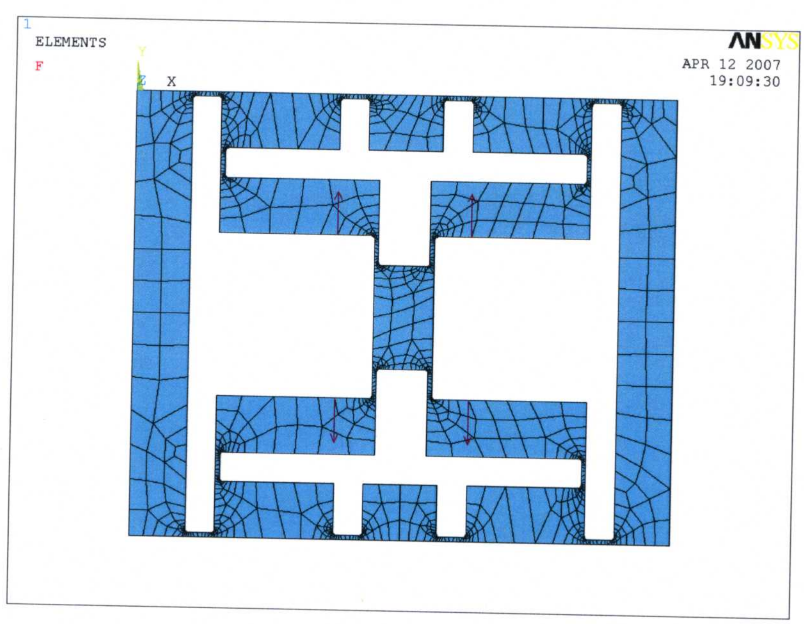

Figure 3. Complete model geometric representation

V. Conclusion

This research project generated very positive results utilizing the principles of compliant mechanisms to model and design a two – stage double – symmetry uni – directional motion – amplification mechanism. The obtained amplification of 13:1 shows how the two – stage design can be advantageous over a single – stage design, which would not be able to achieve an amplification value of this magnitude without first exceeding the material limitations. ANSYS finite element software is beneficial for the design process because the format allows the designer to quickly analize several different variations of any compliant mechanism model, and expedite to process of producing an optimum design for any given desired application. Through the use of ANSYS, the design objective was met and the final designs chosen were being manufactured at the writing of this report. Time constraints and logistics were major factors in attempting to complete this project in the required timeframe. Therefore, the physical testing of the compliant mechanisms will be done when they are received from the manufacturing facility. Results from the testing are expected be very comparable to the theoretical values from the ANSYS analysis, and the results will be recorded for later reference.

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