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学 位 論 文 の 要 旨

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学位論文題目

Optimal Design Method of Spiral Pulley for Full Range Effectiveness in Balancing Performance

（全可動域において平衡性能を有効化するためのスパイラルプーリー最適設計法に関する研究）

Robots play an important role in compensating for gravitational force in order to reduce the burden on workers. Because of their dependability and durability, energy-saving passive mechanisms are commonly used in assistive robots. A spiral pulley and spring couple is one such mechanism, which is a compact and dependable solution for providing constant assistive force. A spiral pulley's shape has a predetermined changing radius to balance the spring's increasing restoring force as it extends. This allows the mechanism to exert a constant torque within its designed range. The calculation of the spiral pulley's shape is a critical aspect of such a mechanism. The mechanism can provide a more optimal balancing ability with a more accurate calculation. The cable tension variation along the cable attached to the pulley is taken into account when designing an innovative spiral pulley in this study. The balancing performance of the proposed pulley is evaluated by its accuracy in providing balanced torque and effective range. A comparative experiment using a conventional spiral pulley confirms the effectiveness of the proposed spiral pulley.

On the other hand, manufacturing industries now use industrial assistive robots to carry around many heavy tools, cargoes, and other objects. Some robots are designed to transport objects that are too heavy for workers to move on their own. These robots are typically large and have enormous capacities. Some robots are designed to target lighter objects in order to reduce the burden on workers who must carry those objects. Considering their dependability and durability, energy-saving passive mechanisms are commonly used in assistive robots. Many researches have been conducted regarding balancing weight with mechanisms. One such mechanism is a spiral pulley and spring couple, which is a compact and reliable solution to provide constant assistive force. Springs can store energy passively, and a spiral pulley can balance the changing restoring force of the spring.

Various studies have investigated mechanisms to balance the changing restoring force of the spring while the spring is stretched or compressed. Previous studies have confirmed that the coil spring with spiral pulley mechanism is effective in converting varying spring force

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into constant balanced torque. However, the conventional spiral pulley is designed based on the assumption that torque on a pulley is provided by the two ends of the cable attached to the pulley, ignoring the intermediate tension change along the cable inside the range in which the cable is attached to the pulley. The cable tension remains the same from the spring end to the starting point on the pulley. It then changes due to the static friction applied to the cable from the pulley until the cable reaches the end of the attached range. From the point where cable is no longer attached to the pulley, the cable tension remains the same until the output point. Considering this tension change, to produce a more accurate spiral pulley design, an innovative spiral pulley kinetic model that considers the cable tension variation along the cable within the attached range is introduced.

In this study, we firstly introduce an innovative spiral pulley kinetic model to exert a more accurate balanced torque at the output side of the spiral pulley. The goal is to develop an innovative spiral pulley that considers the force change along the attached cable to achieve optimum accuracy in converting decreasing spring force into increasing balanced torque. A self-balancing system is set up for experiments with both conventional and innovative spiral pulleys. To compare the innovative spiral pulley model with the conventional model, experiments are conducted with the self-balancing system, and both pulleys are evaluated based on the accuracy with which they balance torque and effective range.

Then, we developed a self-weight compensation device for the purpose of reducing the load when moving and holding the breaker by manual downward breaker work. We proposed a method to determine the shape of the spiral pulley from the height of the demotion work. The effectiveness verification experiment demonstrated that the self-weight compensation can be performed at an arbitrary height within the designed equilibrium range, and that the load can be reduced in the moving/holding operation of the breaker machine with the developed self-weight compensation device.