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Article / Book Information

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Title(English)	Novel Kinematic Pairs Composed of Elastically Constrained Two Curved Surfaces
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 系 機械 コース	申請学位（専攻分野）： Academic Degree Requested	博士 （ 工学 ） Doctor of
学生氏名： Student's Name	木村 直人	指導教員（主）： Academic Supervisor(main)	岩附 信行 教授
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This dissertation entitled "Novel Kinematic Pairs Composed of Elastically Constrained Two Curved Surfaces" consists of the following 6 chapters.

Chapter 1 "Introduction" presents the background and objective of this research. Linkage mechanisms with lower pairs tend not to have the number of design parameters enough to generate the desired motion and to have complex structures. Conventional cam mechanisms also cannot generate complex spatial motions. However, higher pairs to generate complex spatial motions can be manufactured with the latest manufacturing technologies such as additive manufacturing. Because of this background, novel kinematic pairs composed of elastically constrained two curved surfaces to generate complex spatial motions are proposed to extend the synthesis of spatial mechanisms. They are called "elastically closed pairs". The objective of this research is described to develop the "Spatial Rolling Contact Pair (SRCP)", the "Flexibly Constrained Pair (FCP)" and their active kinematic pairs, which are kinds of elastically closed pairs, and to synthesize spatial mechanisms with them. Related researches are also introduced, and contributions of this research are described.

Chapter 2 "The Spatial Rolling Contact Pair" presents on the development of the SRCP, which is a 1-degree of freedom (DOF) kinematic pair where a link can generate the specified spatial trajectory while rolling on another link in contact at a line with each other. For designing it, a method to derive rolling contact surfaces between the links to generate the specified trajectory is proposed. A hybrid elastic constraint composed of flexible bands and linear springs and its design method are also proposed to suppress both slippage and separation between the links. Some examples of spatial-path generators with the SRCP are designed and prototyped, and their performances are analytically and experimentally examined. As a result, it is confirmed that the exact spatial-path generation of a mechanism with 1 DOF, which has not been achieved so far, is possible with the SRCP.

Chapter 3 "The Active Spatial Rolling Contact Pair" presents on development of the "Active" SRCP (ASRCP), which is constructed by replacing linear springs of the SRCP with active elastic elements such as flexible linear actuators. For designing it with a large motion range, a method to optimally arrange active elastic elements between the links to maximize a transmission index is proposed. Besides, a control method for the ASRCP to generate the ideal rolling motion by using the actuation redundancy is proposed. Some examples of the ASRCP with different types of active elastic elements are designed and prototyped, and their performances are analytically and experimentally examined. As a result, it is confirmed that the ASRCP can generate the specified trajectory accurately in its compact structure.

Chapter 4 "The Flexibly Constrained Pair" presents on the development of the FCP, which is a multiple-DOF kinematic pair which has flexible kinematic constraints due to the difference in stiffness between two links. The FCP consists of two curved surfaces kept in contact at several points by linear springs, and the difference in stiffness is made by contact forces between the links and elastic forces of linear springs. For designing the FCP with the specified kinematic constraint, a method to reduce the stiffness in main-DOF by arranging linear springs optimally and a method to implement the specified stiffness in the sub-DOF by designing contact surfaces are proposed. Some examples of the FCPs with different main motions are designed and prototyped. Then, it is confirmed that they have the specified flexible kinematic constraints by some experiments. In addition, synthesizing a flexible robot with a simple structure is achieved with use of multi-directional flexibility of the FCPs. It is prototyped and examined by analysis and experiments. As a result, it is confirmed that the robot has adequate motion accuracy and multi-directional flexibility to absorb large external force.

Chapter 5 “The Active Flexibly Constrained Pair” presents on the development of the “active” FCP (AFCP), which is an underactuated active pair where the FCP is antagonistically driven with one more active elastic element than the number of its “main-DOF”. For designing it, the method to optimally arrange active elastic elements for the underactuated pair based on a transmission index is proposed. A method to specify the stiffness required to perform the specified task in main-DOF and the stiffness to have both flexibility and motion accuracy in sub-DOF is also proposed. In addition, a method to analyze the kinetostatic motion between the links is proposed to evaluate the motion accuracy. Some examples of the AFCP are designed and analyzed, and it is confirmed that the balance between motion accuracy and flexibility can be controlled by adjusting the specified stiffness in sub-DOF. Finally, they are fabricated, and their performances are examined by analysis and experiments. As a result, it is confirmed that the AFCP has flexibility, adequate positioning accuracy, and robustness against external forces in its compact structure.

Chapter 6 “Conclusion” summarizes the achievements of this research and describes future challenges of this research.