Design of an Inversion Machine Performing Fluid Transport

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Long Abstract

Introduction

The 6R-Bicard kinematics of a rotating cube chain is designed and a suitable distributed input power is transferred to the rotating oloid bodies. Such an mechanisms with rotatory and translationally motion components can be applied as a driving unit for a boat as it generates the motion of a fluid. Some detailed geometric and kinematic restrictions have to be considerations when developing a drive train for such a system. Conventional machine elements are used to design the machine which has a complex rotating and translating motion and harmonically variable rotation speed. A certain transport of fluid is produced by the harmonically variable rotation speed of the used six oloids. The inversion machine with the six rotating oloids is tested in an experimental set-up where the applied forces of the fluid and the transmitted power are analyzed.

1. Kinematics

The kinematics of a special arrangement of the 6R linkage, which is known as the Bricard mechanism, is used in this contribution. The kinematic equations and the constraints are known in the literature and for the evaluation simple kinematic models have been designed in the labs. The used kinematic chain starts from a cube removing two constraints at two opposite corners and inserting six revolute joints at the other corners with a proper orientation along an edge. For this special case of the invertible cube it has been discussed in [1] that the length of the diagonal is constant for the whole motion. If one side of the cube is fixed the motion of the diagonal of the cube describes the surface of an oloid and six oloids are generated by the three diagonals of the cube. The oloid is a special body which is produced as the convex hull of two circles in perpendicular planes when each circle contains the center point of the other. The geometric properties of such a body are described in detail in [2], where also some kinematic description of the rolling on a base plain is discussed. The center of gravity has a constant distance to the base plain. From this fact it can be concluded that a defined motion of six oloids on a cube chain with kinematically defined rotation and translation shows a corresponding position of the center of gravity and it can be derived that no resulting inertia force will occur. Due to the rotation speed unbalance forces can occur. For the realized complex design of the driving unit with the fixed rotation axis the rotation speeds of the six oloids show harmonic variation with time. The designed device is different to the mechanism discussed in [3] where only one body is rotated and the diagonal of the cube is fixed in space. The typical application is for mixing machines of fluids.

2. Design of the Drive Train of the Inversion Machine

Based on the above described kinematic relations of a 6R-Bicard mechanism a prototype has been designed. The main parts used are a differential gear, differential suspension and six oloid bodies on rotating shafts. The torque from the motor is transmitted by a special spur differential gear where the power is splitted in the planetary gear to a central shaft and a hollow shaft. The central shaft drives two guiding connecting rods with the following three timing belts and the rotating girdle shafts. The hollow shaft drives a spur transmission gear and a timing belt with a gear ration of 1:1 also followed by three timing belts and the rotating girdle shafts. Suitable connecting rods have been used in order to define a prescribed motion. A suitable housing is necessary as the inversion machine is designed to operate in a fluid. The prototype is shown in Fig. 1. The driving motor has a given torque and a corresponding rotation speed. With the described drive train with separation by a differential gear the rotation of the oloid bodies mounted on the shafts of the cube chain show periodic rotation speeds. For this resulting motion of the oloids a computational fluid mechanics simulation was performed, where the motion of the water results and different operating parameters have been analysed.

3. Measurements and Results

The constructed prototype of the described inversion machine is shown in Fig. 1. This machine was positioned so that the cube chain with the oloids was within a water filled tank which had a diameter of 2.5 m and a water height of 1.4 m. Measurements with different driving moments, rotation speeds and driving power have been performed. The driving force of the inversion machine has been measured by a force sensor and the driving power has been evaluated from the current supply. The measurement results for different rotation speeds of the cube chain shafts are shown in Fig. 2. With increasing rotation speed the driving force and the power consumption are increasing. The relative driving force is computed as the ratio of the driving force to the driving power. As can be seen the value for the relative driving force also increases with the rotation speed. Further test have to be performed in order to analyze the behavior of this prototype also in comparison with conventional driving units like propeller for boats and ships.

Figure 1. Realisation of the inversion machine

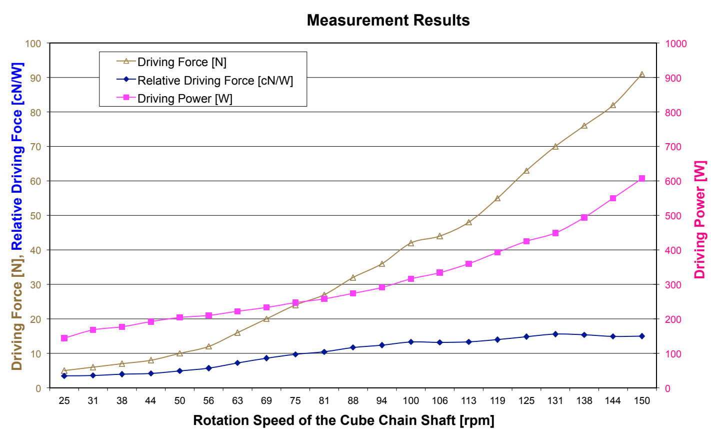

Figure 2. Measurements of forces and power on the inversion machine

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[2] Dirnböck, H.; Stachel, H.: The Development of the Oloid. Journal for Geometry and Graphics **1** (2), 105-118, 1997.

[3] Bràt, A.: A six-link spatial mechanism. J. Mechanisms **1**, 325-336, 1969.