INVESTIGATION FOR NECESSARY INEQUALITIES FOR THE TURNABILITY OF THE DRIVING SHAFTS OF A PLANAR MECHANISM

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Abstract: This study focuses on the turnability analysis of MMD (Multi Motion Drive) Machine, in general, of a planar parallel 3-RRR robot with three synchronously driven cranks. There are simple geometric characterizations for both by coplanar carrier lines of the arms or additionally by particular coplanar parallels. Finally, some inequalities investigated, which are necessary conditions for the turnability of the driving shafts.

Keywords: Planar mechanism, completely turnability, singularity of constrained motion, simulation of movement

Introduction

A kind of such mechanism were first introduced and analyzed by Can (2012) and Can & Stachel (2014) and by Can (2015). These are high-speed planar mechanisms with modifiable compulsory courses based on parallel robots simultaneously driven cranks. It was with Software Packages ***Maple*** demonstrated by Can & Canay (2016) that the question whether the cranks of a given mechanism are completely revolvable cannot be answered in terms of dimensions of the mechanism. The problem can only be cleared from case to case by a numerical analysis. Here a particular diagram is very useful which also indicates reverse poses as well as bifurcations of the constrained motions.

In the following, it is given definition and graphical methods for the geometrical construction and design of the mechanism:

Definition

The basic principle involved in Multi Motion Drive (MMD) Technology consists of a synchronized vertical and horizontal movement, which results in a virtually elliptical needle tip path. Below is a needle punching machine of the company Dr. E. Fehrer, Linz/Austria (Figure 1).

Figure 1. Needle punching machine as a MMD

Consequently, the needles no longer stop the felt during penetration, thus creating excellent web quality. MMD also permits the infinite adjustment of horizontal advance even while needling is in progress. This MMD could be displayed as graphical as follows: Figure 2a shows below an indirect mechanism where the moving triangle is replaced by a line segment.

The motion is a curvilinear translation. In Figure 2b we see how the variation of the phase shift $\delta_b = \pi + \varphi$ acts on the trajectories. For $\varphi = 0$ all trajectories are aligned. The underlying dimensions are

$$\overline{A_0B_0} = 140\ mm$$
$$\overline{A_0A_1} = \overline{B_0B_1} = \overline{C_0C_1} = 22.5\ mm$$
$$\overline{A_1A_2} = \overline{B_1B_2} = \overline{C_1C_2} = 110\ mm$$

a)

b)

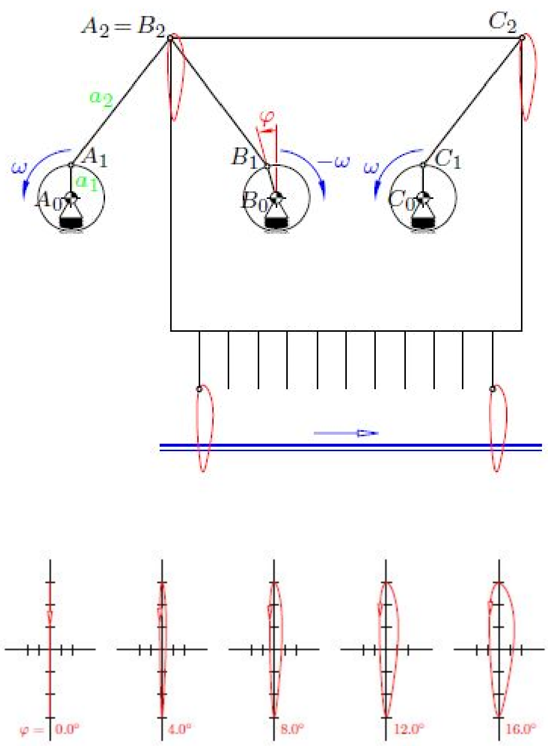

Figure 2. a) One of schematic design of MMD. b) The displayed variation on the trajectories

Demonstration of the Motion

After all analysis and synthesis in general form such planar mechanisms (see Figure 3), were exact investigated by Can (2012) and Can & Stachel (2014), below are given with SAM 6.1 Software Package demonstrated examples in Figure 4a, 4b and 4c, how the path curve shown by the motion of different chosen any desired mechanisms especially on C_2.

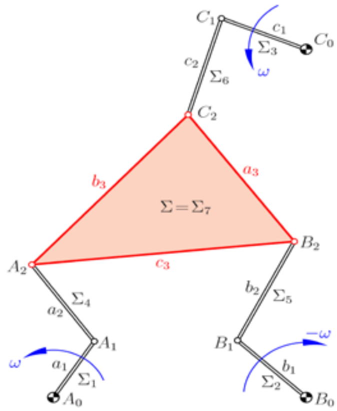

Figure 3. A planar parallel indirect mechanism

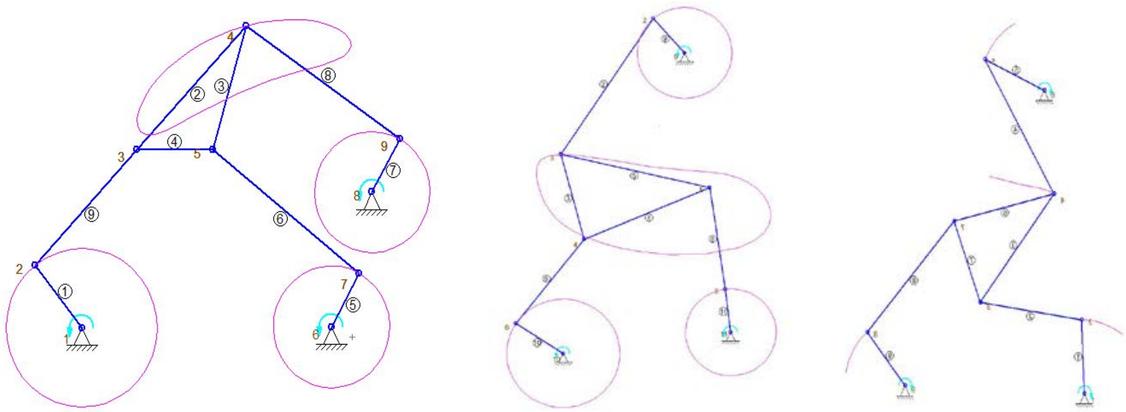

Figure 4 a), b) and c). Three examples which are demonstrated with SAM6.1

Here is graphical solutions and algebric solution for turnability such mechanisms, which is discussed by Can (2012, 2015).

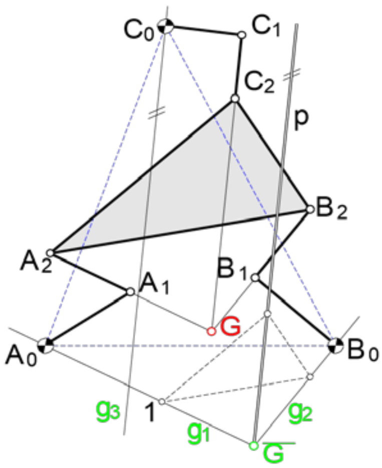

Figure 5. Singularity on the mechanism causes reverse motion

Graphical Solutions

- **Reverse Motion (Singularity)**

A pose (see Figure 5) obtained by the mechanism is ***singular*** $\Longleftrightarrow$ the lines A_1A_2, B_1B_2 and C_1C_2 are concurrent.

The position ($p \parallel g_3$) only at $\omega = 0$ movable $\Longleftrightarrow$ ***reverse motion***.

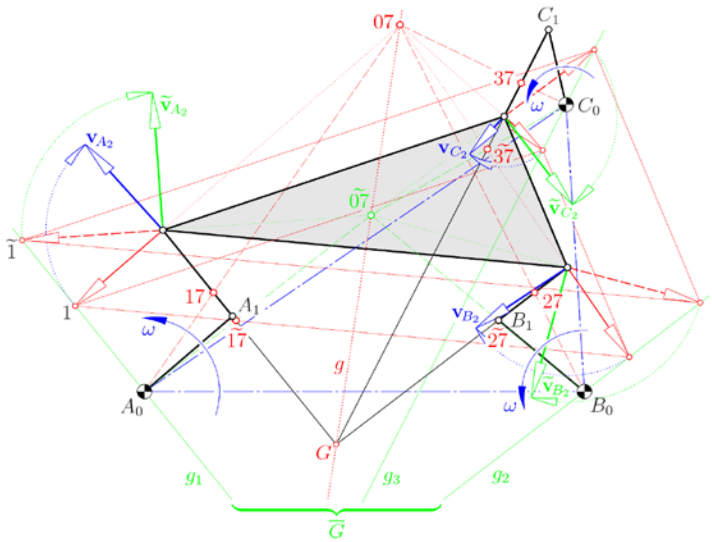

Figure 6. Two-fold singularity on the mechanism causes branch point

- **Branching (Two-fold singularity)**

Such a pose (see Figure 6) is even ***twofold singular*** $\Longleftrightarrow$

the respective parallels g_1, g_2 and g_3 are concurrent with the common point $\overline{G}$,

the lines A_1A_2, B_1B_2 and C_1C_2 are concurrent with the common point G ($p = g_3$, ***branching***).

- **Standstill**

A pose (see Figure 7) has a standstill $\Longleftrightarrow$ $A_1A_2 \cap B_1B_2 \cap C_1C_2 = \emptyset$ and $A_0A_1A_2$, $B_0B_1B_2$, $C_0C_1C_2$ collinear.

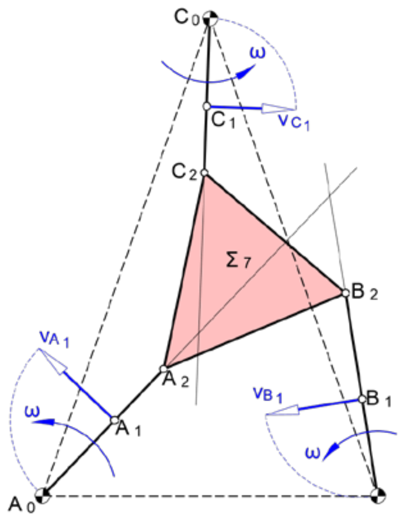

Figure 7. Standstill position

Turnability of the Driving Shafts

There are necessary conditions for the turnability of the driving shafts:

The distance $\overline{A_1B_1}$ between the endpoints of the cranks A_0A_1, B_0B_1 must not exceed the sum of distances $\overline{A_1A_2}$, $\overline{A_2B_2}$ and $\overline{B_1B_2}$, i.e.,

$$max\{\,\overline{A_1B_1}\} \leq a_2 + b_2 + c_3.$$

On the other hand, the inequality

$$min\{\,\overline{A_1B_1}\} \leq c_3 - a_2 - b_2$$

must be satisfied, which of course is trivial under $c_3 < a_2 + b_2$. By the way, because of equal angular velocities of the cranks, for extreme distances $\overline{A_1B_1}$ (see Figure 8) it is necessary that

- in the case of direct mechanism the connecting line A_1B_1 is parallel to A_0B_0;
- in the indirect case the line A_1B_1 must pass through the midpoint of A_0 and B_0.

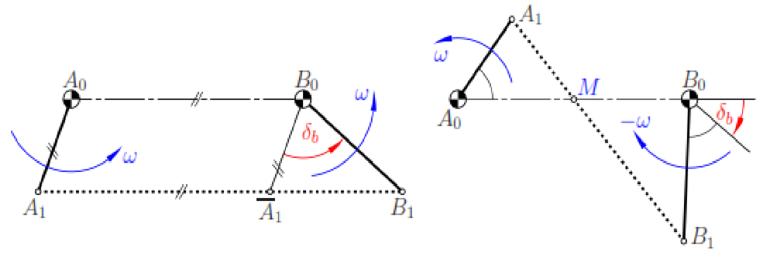

Figure 8. Positions with extreme distances $\overline{A_1B_1}$ for direct and indirect case

For the mechanisms can be expressed with the following theorem in terms of the dimensions a_0, b_0, …, b_3, c_3, δ_b, δ_c and guarantees that the active bars A_0A_1, … are fully turnable.

Theorem 1. Generally, the following inequalities are necessary conditions for a fully turnability of direct case of such kind mechanism:

$$min\{|c_3 - a_2 - b_2|, |c_3 + a_2 - b_2|, |c_3 - a_2 + b_2|\} \leq \left|c_0 - \sqrt{a_1^2 + b_1^2 - 2a_1b_1cos\delta_b}\right|;$$

$$c_0 + \sqrt{a_1^2 + b_1^2 - 2a_1b_1cos\delta_b} \leq a_2 + b_2 + c_3,$$

$$min\{|a_3 - b_2 - c_2|, |a_3 + b_2 - c_2|, |a_3 - b_2 + c_2|\} \leq \left|a_0 - \sqrt{b_1^2 + c_1^2 - 2b_1c_1cos(\delta_c - \delta_b)}\right|;$$

$$a_0 + \sqrt{b_1^2 + c_1^2 - 2b_1c_1cos(\delta_c - \delta_b)} \leq a_2 + b_2 + c_3,$$

$$min\{|b_3 - c_2 - a_2|, |b_3 + c_2 - a_2|, |b_3 - c_2 + a_2|\} \leq \left|b_0 - \sqrt{a_1^2 + c_1^2 - 2a_1c_1cos\delta_c}\right|;$$

$$b_0 + \sqrt{a_1^2 + c_1^2 - 2a_1c_1cos\delta_c} \leq a_2 + b_2 + c_3 \blacksquare$$

On the other hand, the numerical solutions with *Maple* of mechanism produces two real solutions sets in interval t =[0, 360^0] which demonstrated in Figure 9. There are to be observed that common points both of the solution sets mean branching position, vertical tangents mean reverse motion position of the mechanism.

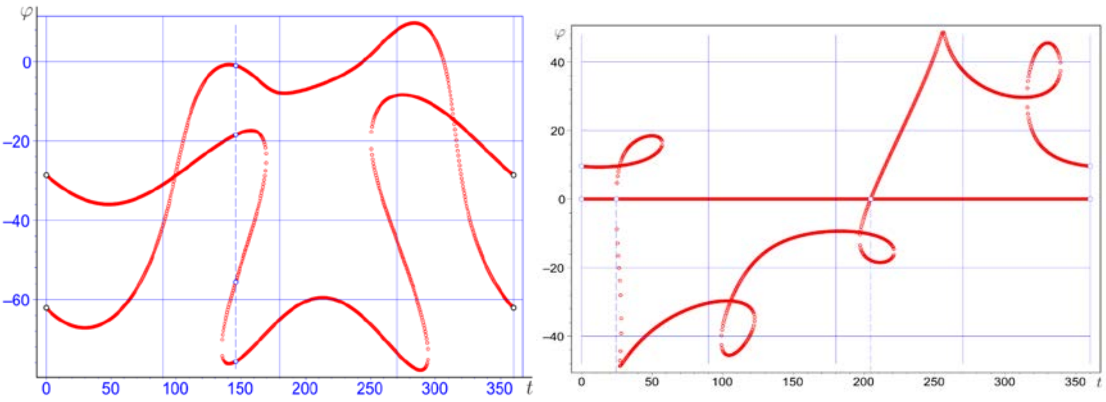

Figure 9. Common points: branching; Vertical tangents: reverse motion, Horizontal line: standstill

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