Curved rotary module for modular construction of motion structures

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BIOGRAPHICAL NOTES

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KEY WORDS

Modular Machine, Rotation Module, Robotic Manipulator, Curved Rotary Module, Modular Construction, Robot Workspace, Serial Robot

ABSTRACT

The article deals with the mechanics of modular machines and examines in detail the parameters of the principle of joining newly designed curved rotary modules into

homogeneous serial kinematical chain with five degrees of freedom of movement. The result of analysis is generated workspace built on the basis of 60° curved rotary module with unlimited rotation for a serial kinematical structure with homogeneous 5DOF.

INTRODUCTION

The idea of modular principle of machines is not new [6]. In the past there have been many creative and innovative ideas from which the amount of time is transformed into a real functioning machine. In the field of motion structures with modular serial construction, there are some innovative solutions to many well-known and unknown companies, for example.: SCHUNK, Epson, Yamaha. These concepts give a chance to build machines for the handling, processing and other tasks as seen in Fig. 1.

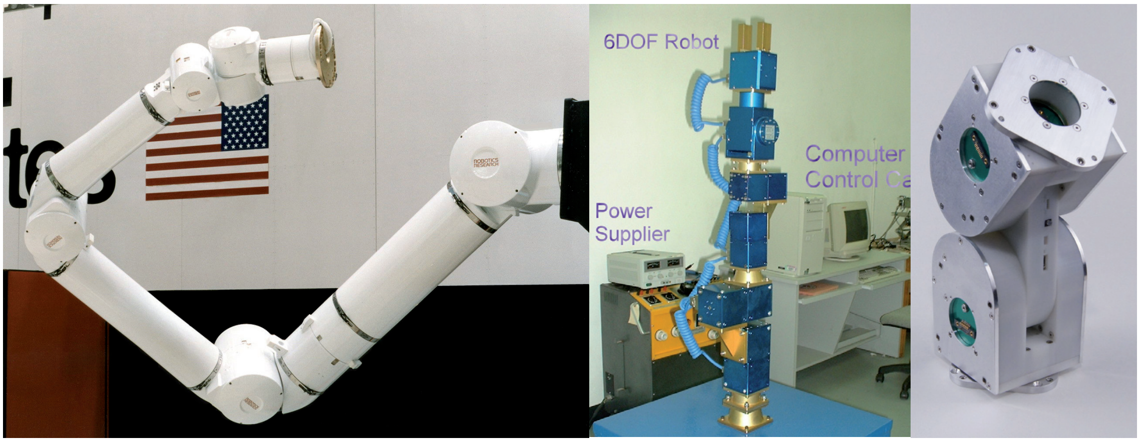

Fig. 12 *Modular serial structures*

Known modular systems also offer a range of modular motion units. These modules are characterized by different attributes, parameters and sizes. Modules can be translational, rotational, and other rare cases. The main weaknesses of these modules include the limitation of rotational movement and greater complexity of design.
From these facts suggest limiting it to the prescribed limits of the range of motion (rotation in the range max. 270 degrees, translational motion in the range of 350 mm, and so on). The resulting movement possibilities of cinematic chain composed of these modules have a limited range of rotational movement. This eliminates the shortcomings hereinafter referred rotation module for the construction of modular machines.

1 Principle of Design Solutions

Rotation module, designed for modular construction machinery, allows merge these modules and the creation of kinematic chain with theory of any number of degrees of freedom of movement, able to perform controlled motion [1]. Its internal structure consists of a body, interlink and clamping plate, which performs a rotational movement over the body, as seen in Figs. 2, 3. In the body of a rotary module is stored servomotor and reducer. Servomotor is equipped with incremental encoder and an electromagnetic brake.

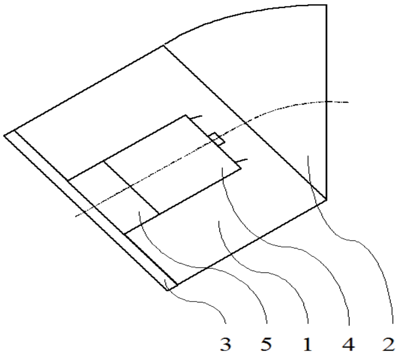

Fig. 2 *Sketch the basic layout of the internal rotation module*

Clamping plate of rotation module is attached to the body through a rotary motion tie of one degree of freedom of movement and it is located on the clamping mechanism for connecting interlink to the next module (modules in the chain). This rotary motion linkage is unlimited range of motion [11]. Interlink of rotation module is geometrically curved and includes a bayonet fixing mechanism for connecting of clamping plate of the previous module (modules in the chain). Angle of curvature determines the scope and characteristics of the working space of the modular machine assembled from these modules.

Homogeneous kinematic structure of a modular concept consists of several identical or identical type (eg. size or curvature of the diverging) rotary motion modules [12].

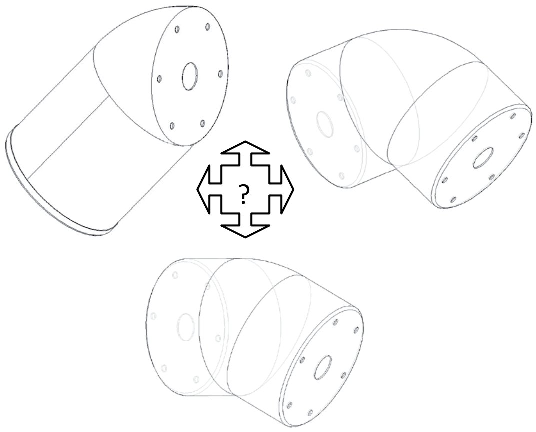

Fig. 3 *Modification of 3D models of a separate rotary module of varying degrees of curvature*

Links between all internal parts of the module and also between the individual modules are fixed (except rotary links between the body and clamping plate), sufficiently rigid and unable to pass the required mechanical load. Communication equipment intended for control are proposed as a wireless, eg.: WiFi, Bluetooth and so on. Electronic communications modules with accessories should be positioned into the body of the module. Connection of individual modules should be realize in terms of flexibility by bayonet method.

Example of 3D display modular manipulator with 6 degrees of freedom of movement is shown in Fig. 4, which are used to build basic rotary modules. This series homogenous structure is characterized by its simplicity and not the most appropriate reachability within your workspace. To achieve the desired position to be extensive rotationing of many modules, which is relatively energy consuming.

Example of 3D display modular manipulator with 6 degrees of freedom of movement is shown in Fig. 5, when is used the extension part [9]. This part serves to increase the reach of kinematic chain and has no internal drive system. It is inserted between the modules and in this way, adjusts the characteristics of the working space and also reachability positioning member in the end of it. Except the extension member are also used rotating different modules with varying degrees of curvature. This method achieves a high flexibility and variability of working space and reachability of location is a function of mutual selection and arrangement of appropriate modules and extension parts.

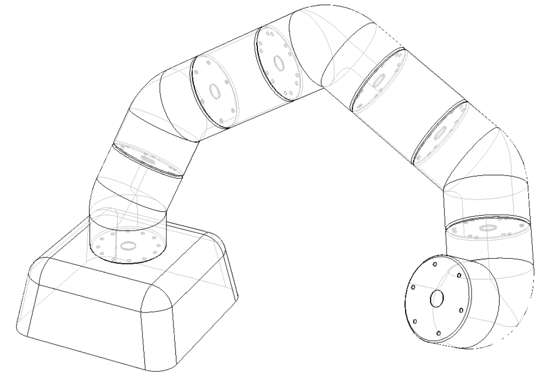

Fig. 4 *3D model of the modular machine, assembled from rotary motional basic modules, with 6 degrees of freedom of movement*

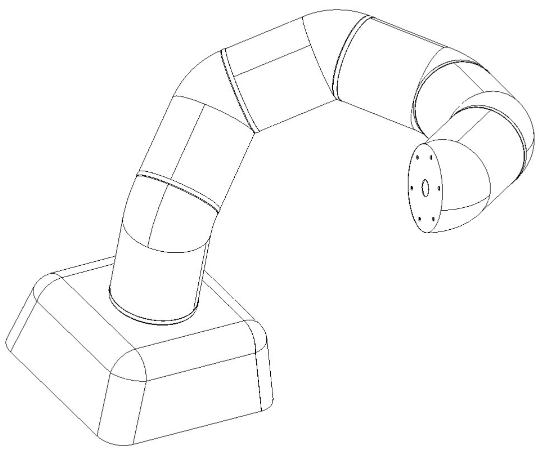

Fig. 5 *3D model with a modular machine using an extension part and adapted the basic modules with 6DOF*

2 Mathematical Description of Structure

For the mathematical description of a serial kinematic chain is best to use Denavit-Hartenberg principle of deployment of joint chain to the coordinate systems [2]. This deployment will achieve particulate transformation matrices (1). This transformation matrix "Ab0" describes the position and rotation of the first couple coordinate systems, thus the current position of the base "b" and the first module "0" in Fig. 6, where q1 and q5 are common variables. In our case, the steering angles of rotary modules and take their values in the interval $(0,\ 2\pi)$. Variables lx1 and lx2 represent distance of local coordinate systems according to the principle of D-H principle. Variable "a" represent the angle of curvature of the module used in this case was used 60° angle. Further transformation matrices in order of the other members of the kinematic chain are analogous to the shape and functions are gradually variables q2 and q5. In order to get the overall transformation matrix is necessary transformation matrix between neighboring coordinate system multiplied "Ab0" and "A01", resulting in a total transformation matrix of great complexity. Relationship (2) reflects the partial transformation matrix between the base "b" and the second movable member in order-rotating module, "1". After multiplying all the sub-transformation matrices of type "A" there

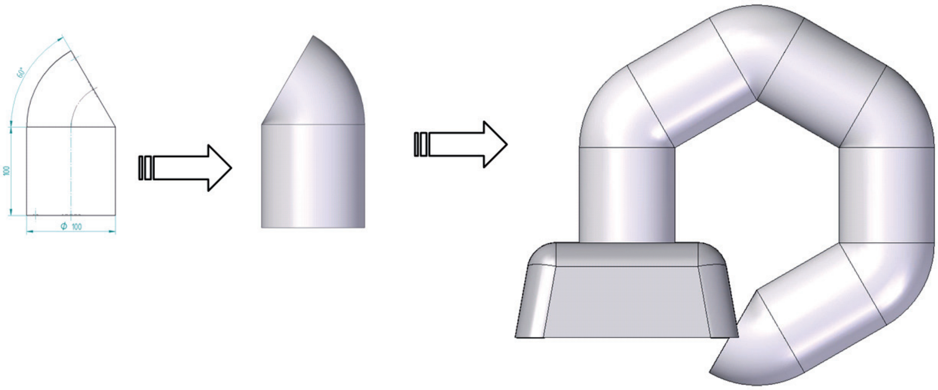

Fig. 6 *3Composition of homogeneous serial kinematical structures with 5DOF*

$$A_{b0}(q_1,q_2,q_3,q_4,q_5,q_6)=\begin{pmatrix}\cos q_1 & -\sin q_1.\cos a & \sin q_1.\sin a & l_{x1}.\cos q_1\\ \sin q_1 & \cos q_1.\cos a & -\cos q_1.\sin a & l_{x1}.\sin q_1\\ 0 & \sin a & \cos a & l_{x2}\\ 0 & 0 & 0 & 1\end{pmatrix} \quad (1)$$

$$T_{b1}(q_1,q_2,q_3,q_4,q_5,q_6)=A_{b0}(q_1,q_2,q_3,q_4,q_5,q_6).A_{01}(q_1,q_2,q_3,q_4,q_5,q_6)=$$

$$\begin{pmatrix}\frac{3.\cos(q_1-q_2)}{4}+\frac{\cos(q_1+q_2)}{4} & \frac{3.\sin q_1}{4}+\frac{\cos q_1.\sin q_2}{2}-\frac{\cos q_2.\sin q_1}{4} & \frac{\sqrt{3}.\cos q_1.\sin q_2}{2}-\frac{\sqrt{3}.\sin q_1}{4}-\frac{\sqrt{3}.\cos q_2.\sin q_1}{4} & 150.\cos q_1+75.\sin q_1+150.\cos q_1.\cos q_2+75.\sin q_1.\sin q_2\\ \frac{3.\sin(q_1-q_2)}{4}+\frac{\sin(q_1+q_2)}{4} & \frac{\cos q_1.\cos q_2}{4}-\frac{3.\cos q_1}{4}+\frac{\sin q_1.\sin q_2}{2} & \frac{\sqrt{3}.\cos q_1}{2}+\frac{\sqrt{3}.\cos q_1.\cos q_2}{4}+\frac{\sqrt{3}.\sin q_1.\sin q_2}{4} & 150.\sin q_1-75.\cos q_1-74.\cos q_1.\sin q_2+150.\cos q_2.\sin q_1\\ \frac{\sqrt{3}.\sin q_2}{2} & \frac{\sqrt{3}.(\cos q_2+1)}{4} & \frac{1}{4}-\frac{3.\cos q_2}{4} & 25.\sqrt{3}.(3.\sin q_2+1)\\ 0 & 0 & 0 & 1\end{pmatrix} \quad (2)$$

3 Identification of Workspace

To identify the shape and scope of workspace was necessary to define transformation matrices in a MathCAD program [3, 8] and also define the geometrical parameters: the curvature module a=π/3rad, module length l1=100mm, width module l2=100mm. The distance between the coordinate system is defined as a variable Lx1 and Lx2 (3, 4). It is necessary to define the scope of the local variable q1...q5 is from the interval $(0,\ 2\pi)$ and the step number is ½ rad.

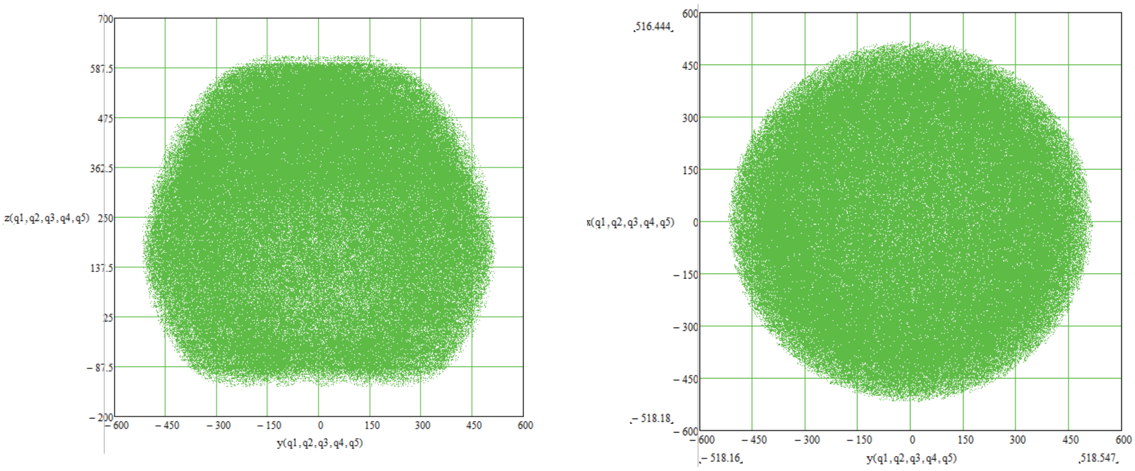

Fig. 7 *Workspace of modular serial kinematic structures with 5DOF the curvature of the building module 60°*

$$l_{x1} = 0{,}5.l_1.(1-\cos a) \qquad (3)$$

$$l_{x2} = l_2 + \frac{l_1.\sin a}{2} \qquad (4)$$

Formularization of the overall transformation matrix and the gradual substitution of the general variables q1 until q5 the specified steps to get around 33000 points. These points represent the final position in the end coordinate system rotating module. Their display in a suitably chosen Cartesian coordinate system we will likely shape, size and scope of workspace. Workspace of homogeneous serial kinematic structure of Fig. 6 is reproduced in Fig. 7.

4 Conclusion

The overall result of the described technical solution is a modular system for the building of modular machines assembled from identical or identical type (eg diverging of size or curvature) rotary motion units with unlimited rotation range of motion [7]. It is necessary to make more extensive analysis and find the best angle of curvature of the building module. This angle should be provide for widest possible range of workspace and also a good reachability of desired point in this workspace . On the other side should be provide the safe operation of that in any position of the kinematic chain can happen to self-collision kinematic structure [4]. It is probable that the varying degree of freedom of movement should always choose a different angle of curvature of the basic module [5]. Similarly it is probable that application-specific angle of curvature may be appropriate basic module other than that which is derived simulation in virtual terms [10,13].

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