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Proposal of Modular Robotic Arm from DSM Modules

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Abstract This article describes the system model for combining DSM modules from SPINEA Company to the higher functional units. The outcome is a modular robotic arm with six degrees of freedom. The work area can be changed depending on change the length of the individual arms. In the design robotic arm was used three sizes of board modules DSM 110, DSM 70 and DSM 50. The proposed modular robotic arm can be used as an action extension for service robots or as an auxiliary arm of the wheelchair.

Keywords: *DSM modules, robotic arm, kinematic structure, DOF*

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1. Introduction

DSM system model is based on structure of the rotary positioning modules. Based on the system model it is possible to propose a preliminary model system for joining DSM modules into functional units suitable for deployment in various areas of industry and services.

2. The Principle of Compiling the Kinematic Chain of DSM Modules

System model for connecting modules DSM into higher functional units describes the concept of solutions containing (DSM module / modules, input flange, interconnect flange, output flange), and also describes the basic principles of assembled units, Figure 1.

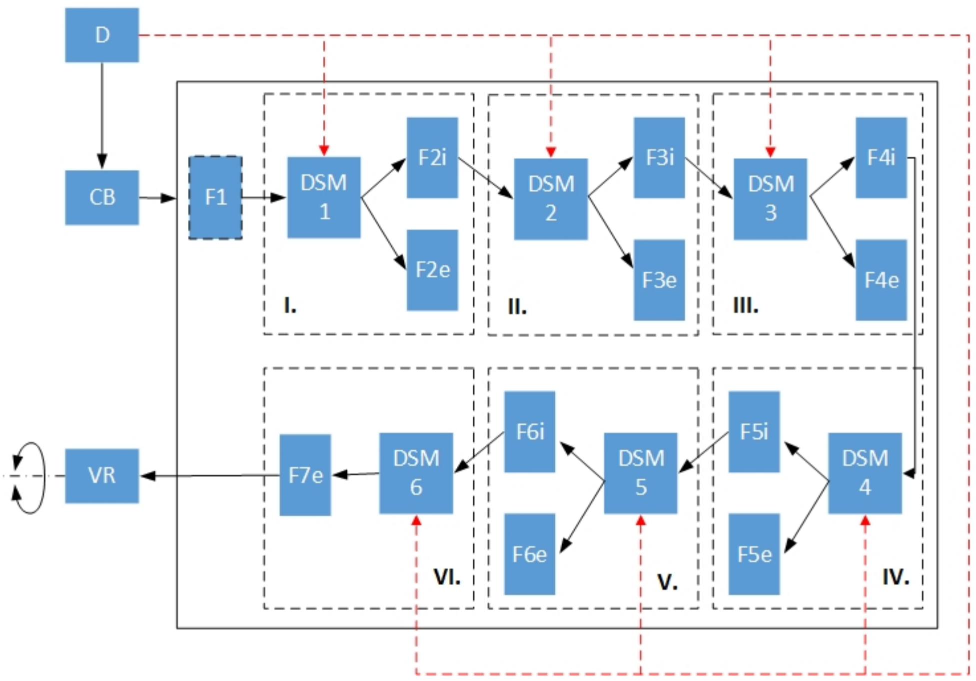

Figure 1. System model for functional unit based on DSM

Legend of Figure 1 [1]:

- ***D*** - *drive* (primary energy, output of drive system),
- ***CB*** - *control block (device for editing drive signals),*
- ***F1*** –*input flange* (flange for connecting the modular model DSM to the base of machinery, equipment, working table, end flange of the robot or service robot),
- ***DSMx*** – *rotary positioning module* (sizes 50, 70 and 110),
- ***F2i*** to ***F6i*** – *interconnect flange* (flange allowing interconnection of individual modules DSM each other),
- ***P2e*** to ***P7e*** – *end flange* (flange located on the last module DSM, is used to connection),

- ***VR*** *– output element* (mechanical element / interface for connection DSM as higher functional unit),
- ***I.*** *– DSM module with 1 DOF,*
- ***II.*** *– DSM modules with 2 DOF,*
- ***III.*** *– DSM modules with 3 DOF,*
- ***IV.*** *– DSM modules with 4 DOF,*
- ***V.*** *– DSM modules with 5 DOF,*
- ***VI.*** *– DSM modules with 6 DOF.*

With six DSM modules can create model-type structure for a robotic arm with six degrees of freedom. Under the Figure 1 can be deduce functional links of the system elements in the form:

F1 - DSM1 - F2i – DSM2 – F3i/arm 1 – DSM3 – F4i/arm 2 – DSM4 – F5i – DSM5 – F6i/arm 3 – DSM6 – F7e – VR

2.1. Basic Parameters of the Modules

Relative disposition of the modules and their kinematics can vary depending on the characteristics of the used devices. The disposition can be vertical, horizontal or inclined, the numbers of rotation axes is limited only by the working area of the equipment in which they are installed.

Flange material (EN AW 2017) is similar to the module body. The properties of selected material are low weight, good workability, sufficient strength and rigidity. Each of the input, interconnection and end flanges has undergone stress analysis to ensure the stiffness of the proposed nodes of modular robotic arm.

Creating different configurations of robot arms is dependent on the action of load forces and type of the proposed arms. It was therefore necessary to establish maximum values burdensome moments and forces applied to the output flange or arm. The maximum torque and the forces exerted on individual DSM modules are defined their structure and composition. The specific values of the maximum loads DSM 110, 70, and 50 are shown in Figure 2 [3].

Connection holes at the module body are located on the back or bottom side of the module. Therefore, when stress analysis to take into account the manner and direction of loading. The forces and moments that are described in Figure 2 are shown in Figure 3.

	DSM module		Units	DSM 50	DSM 70	DSM 110
1.	Max. dimension DSM	b x b	[mm]	58x66	80x95	112 x 135
2.	Max. dimension body of reducer	ØA (a x a)	[mm]	55 x 55	Φ 70	Φ 110
3.	Length of DSM	L	[mm]	111	153,6	200
4.	Reduction ratio	i	--	63	57, 75	67, 89, 119
5.	Rated output torque	T_R	[Nm]	18	50	122
6.	**Acceleration and braking torque**	T_{max}	[Nm]	**36**	**100**	**244**
7.	Rated input speed	n_R	[rpm]	2000	2000	2000
8.	Cycle effective speed	n_{ef}	[rpm]	3000	2500	2500
9.	Max. allowable input speed	n_{max}	[rpm]	5000	5000	4500
10.	Lost motion	LM	[arcmin]	<1.5	<1.5	<1.0
11.	Average angular transmission error	ATE	[arcsec]	+/- 36	+/- 36	+/- 20
12.	Hysteresis	H	[arcmin]	<1.5	<1.5	<1.0
13.	Input inertia	I	$[10^{-4} kgm^2]$	0.006	0.061	0.16
14.	Torsional stiffness	k_t	[Nm/arcmin]	2.5	7	22
15.	Tilting stiffness	M_t	[Nm/arcmin]	4	35	150
16.	**Max. tilting moment (a2=0)**	$M_{c\,max}$	[Nm]	**44**	**142**	**740**
17.	**Max. axial force**	$F_{a\,max}$	[kN]	**1.9**	**3.7**	**13.1**
18.	**Rated radial force**	$F_{R\,max}$	[kN]	**1.44**	**2.6**	**9.3**

Figure 2. Basic parameters of DSM modules

FEM analysis focuses on static and dynamic analysis, result of a determination of the appropriateness of the proposed use of the material for the carrier body of module DSM. Load carrier body of the module is at the maximum torque values and burdensome forces acting on exactly reducers used in the construction of modules. 3D model of modules DSM 50, 70 and 110 is formed in CAD program /Creo 2.0 and FEM analysis is formed in module Pro / Mechanica. [6]

The resulting value of the tilting moment depends on the load DSM module from constituents radial and axial forces. The formula is as follows:

$$M_{C\max} = F_R.a + F_A.b \text{ [Nm]} \quad (1)$$

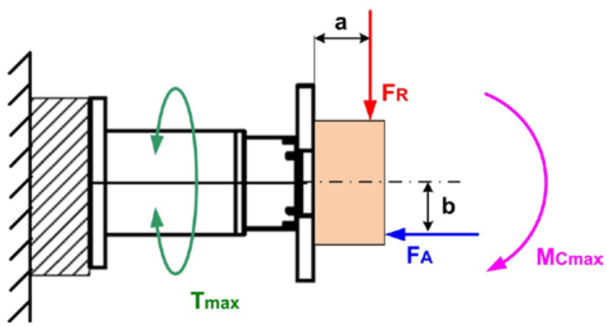

Figure 3. Illustration of the load forces and torques

3. Analysis of Possible Configurations of the Robotic Arm with 6 DOF

Configuration and connection modules can be created on the basis of connecting flanges allowing to create different configurations – from 2 to 6 axis devices. The number of potential compatibility for 6 axis robot arm is shown in Figure 4.

The main task of this application is to design intelligent positioning modules / robot arms. Solving these modules it is based on the use of intelligent drive consisting of a motor, precision gearbox and suitable sensor technology. Drives will range from two to six rotary axes. Motion control will be implemented on the basis of information obtained from sensors placed directly drives the positioning module and sensors from working environment according to the specific requirements for each application [2,4,7].

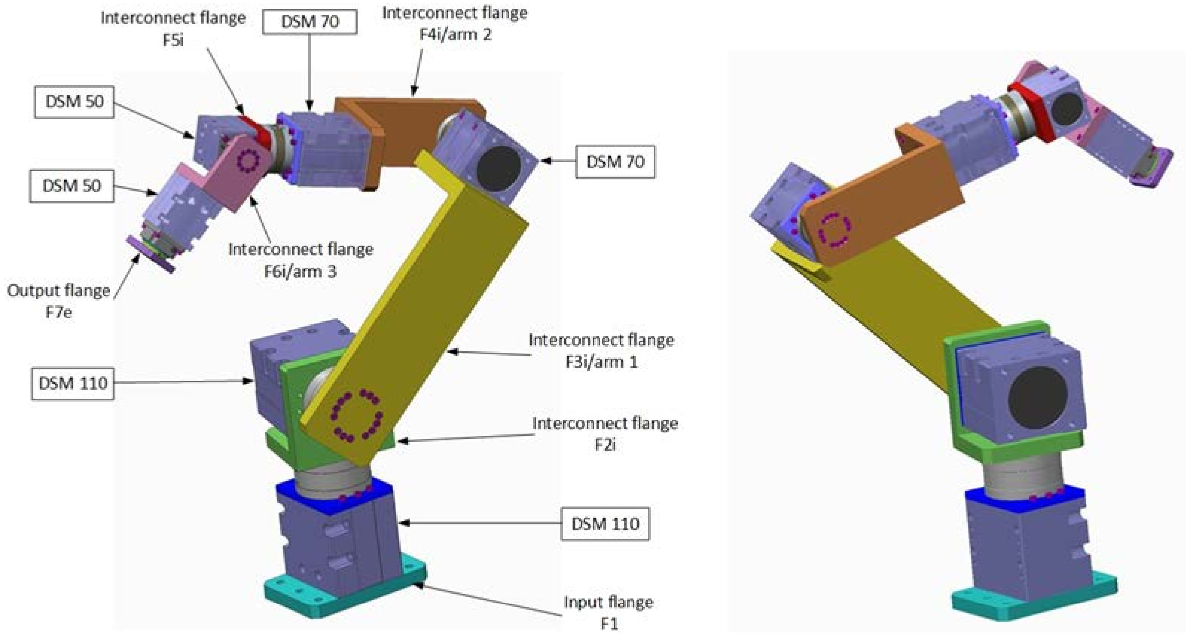

Figure 4. Kinematic structure of modular robotic arm from DSM modules

Figure 5. Wheelchair with modular robotic arm

In the kinematic structure modular robotic arm it can be changed the length of each arm depending on the application in which they will be deployed. The intelligent robotic arm can be used as a complement to motorized wheelchairs. With appropriate end effector on the robot arm can be manipulated with remote objects or pick up the object from the ground or table.

Figure 5 illustrates the application of a robotic arm placement on wheelchair. It can be control via first joystick and second joystick is used to control the wheelchair. Length of individual arms can be change depending on the application requirements [5].

Acknowledgement

The main aim was to design a system model for combining rotary modules DSM to higher functional units. In this case, it has been proposed a robot arm with 6 degrees of freedom. It is intended that this will be used as an auxiliary arm of the wheelchair. It allows a person with limited movement abilities to manipulate with objects in the work area using a robotic arm.

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