DESIGNING A SMALL SCALE FUNCȚIONAL ARTICULATED ROBOT MOTOMAN MODEL

GUȚU Marius[1], NICOLESCU Adrian[2]
[1]Faculty: FIIR, Specialization: Robotics, Year of Study: Masters I, e-mail: marius.gutu98@yahoo.com
[2]Professor PhD, Faculty: FIIR, Dept. Robots and Manufacturing Systems
Coordinator: Prof. dr. Ing. **Adrian NICOLESCU**

Abstract: The present study describes the internal structure of an articulated industrial robot, more specifically the robot's orientation system and one joint from the positioning system. The reference model is produced by the company Motoman, specifically Motoman MH215II. Among the items shown are 2 of the 4 gearboxes designed, one of which is of hollow shaft construction to allow the intermediate drive shafts of the numerically controlled axes 5 and 6 to pass through. The working environment used was Siemens NX. The construction is designed to allow the robot to be manufactured using additive manufacturing technology (3D printing).

Key words: Motoman, Robot, 3D Printing, Articulated robot, Cycloidal gearbox,

1. Introduction

The idea behind the work came from the desire to fill a void, to satisfy a need. Designing a small-scale robot that follows the mechanical construction solutions used in industrial robots to be used as an educational model for student training. For this reason, a model produced by Motoman [1] was chosen because of its complex mechanical design. The positioning system uses a distributed drive scheme, the motor is connected to the cycloidal gearbox which drives the moving element. The orientation system uses a centralized drive scheme. All the motors are mounted at the end of the robot’s second segment. The motion is being transferred using intermediary shafts, gear assemblies and cycloidal drive.[2]

Most of the robot’s components will be 3D printed using FDM of SLS technology.

Fig. 1 Reference Model - Motoman MH215II

2. Current Status

The fist revision of the articulated robot was designed and manufactured during the diploma work project, more specifically the numerically controlled axes 5 and 6 were completed, these also being the most complex [2], [3]. The designed robot had several issues which have been corrected in the present version. In order to highlight the changes made to the 3D CAD assembly, a comparison between the previous and the present constructive solution was made [3].

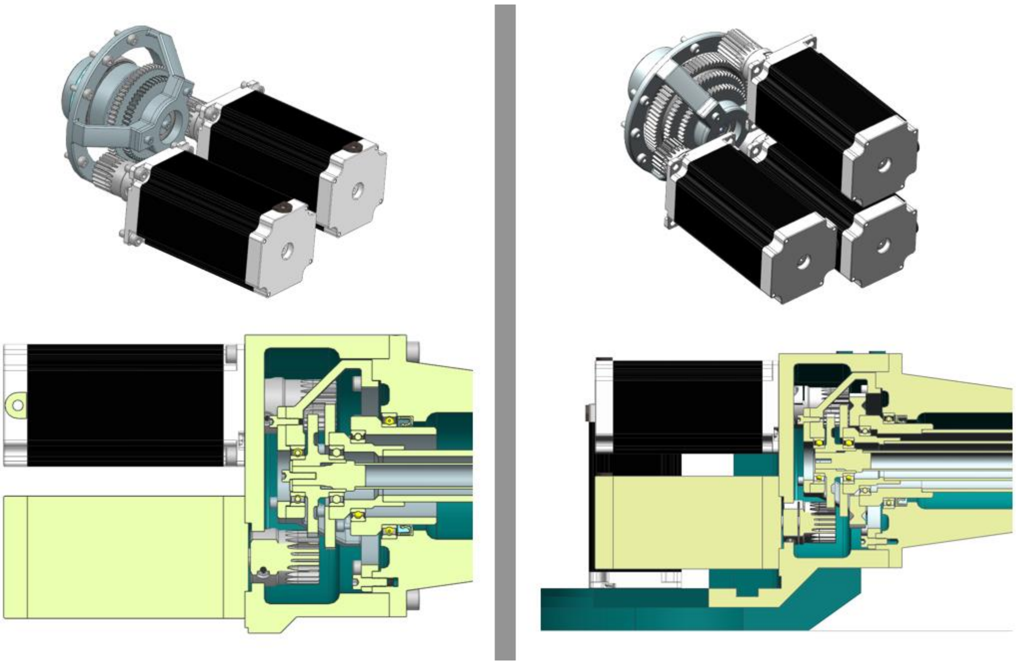

Fig. 2 Drive area for the orientation system

To drive the numerically controlled axes 4, 5 and 6 which materialize the robot's orientation system, NEMA stepper motors [4] will be used for two reasons. Simplicity of control and low price. Each motor has a pinion attached to the output shaft, which in the current solution uses a split bushing design for mounting, compared to the first solution where 3 set screws were used to secure the pinion to the shaft. The problem with the previous solution was vibrations. During operation the vibrations generated by the mechanical structure caused the set screws to unscrew. Thus, the motor shaft would rotate freely in the pinion bore. The previous assembly was completed. The motor for 4th joint and the gear assembly required to transfer the movement from the motor to the intermediate shaft were added. Nevertheless, there is still room for improvement. The sealing solutions used for the motor and pinion assembly needs to be added in order to prevent lubricant leaks.

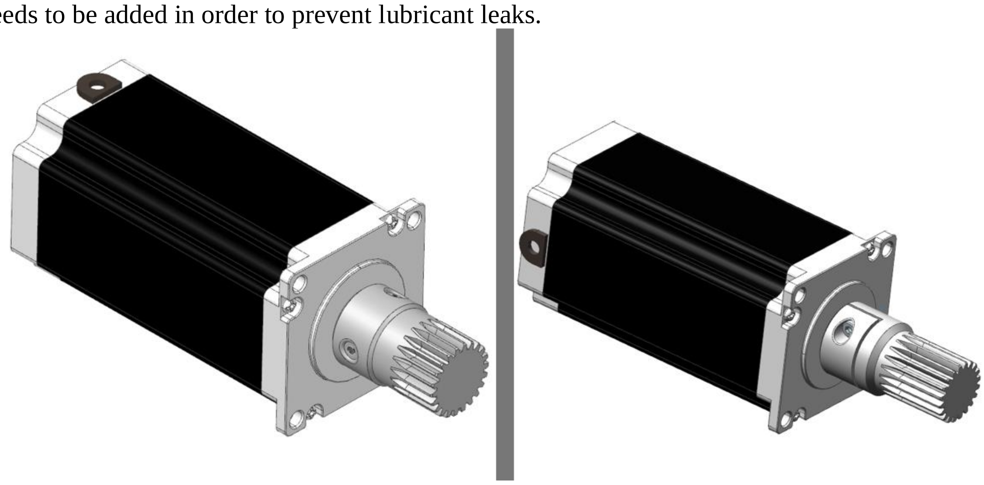

Fig. 3 Motor assembly

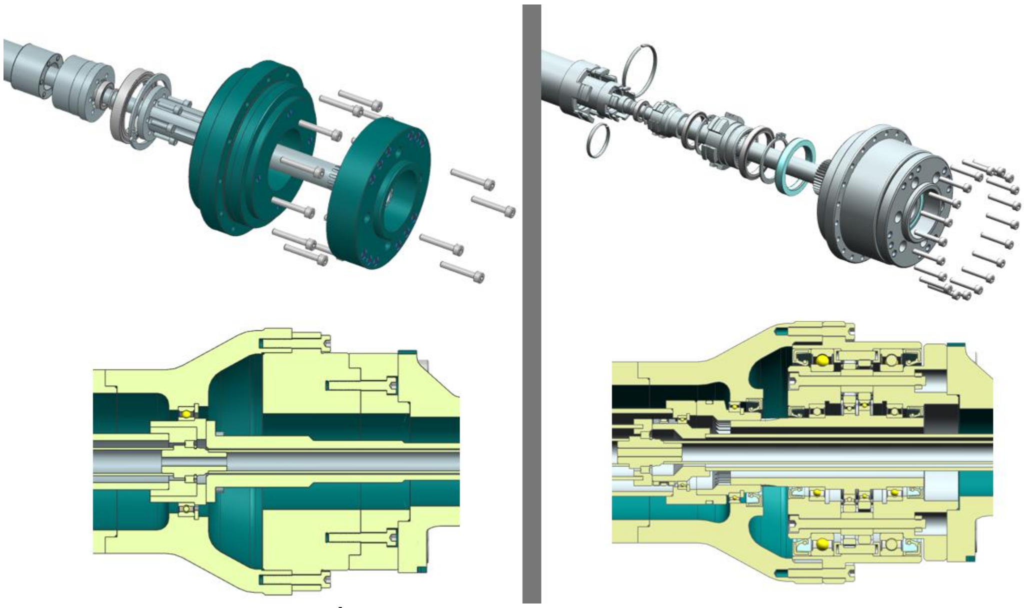

Fig. 4 4th joint and intermediate shafts assembly

The robot's second segment central area has been completely redesigned. To this end, a 1/42 transmission ratio cycloidal gearbox in hollow shaft construction has been designed to allow the intermediate shafts required to transmit motion to axes 5 and 6 to pass through.[3], [5]

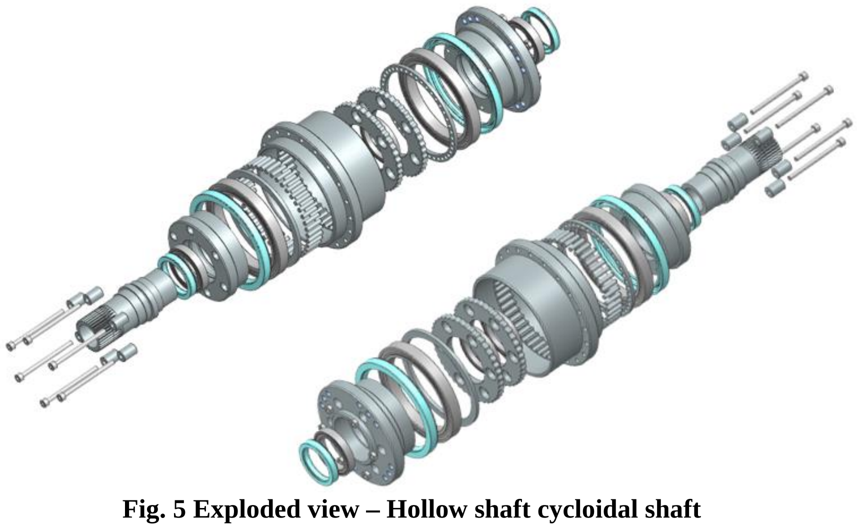

Fig. 5 Exploded view – Hollow shaft cycloidal shaft

Designing such a gearbox comes with several challenges. [3] The biggest challenge being limited space. In the current version, Rotary oil seals are used to seal the gearbox (colored blue in the image above) but considering the geometrical accuracy that can be achieved through additive FDM manufacturing, this is not the best solution. For this reason, two other constructive solutions will be explored, the first being the use of O rings for sealing the system. The limitations of using such a solution are the low peripheral speed of the shaft and the very low surface roughness. The surface on which the Oring is mounted must be polished to prevent damage to the seal. The second solution is the use of felt rings. They are a cheap and reliable sealing solution.

Another aspect to consider is the output flange of the gearbox. [3] Because of the robot's wrist weight and the positions of its center of gravity, the flange is subjected to high bending moments. For this reason, simply 3D printing the part is not a viable solution. Two solutions are presented: using metal inserts to increase the part's mechanical properties or manufacturing the part from aluminum or a composite material made from resin and fiberglass.

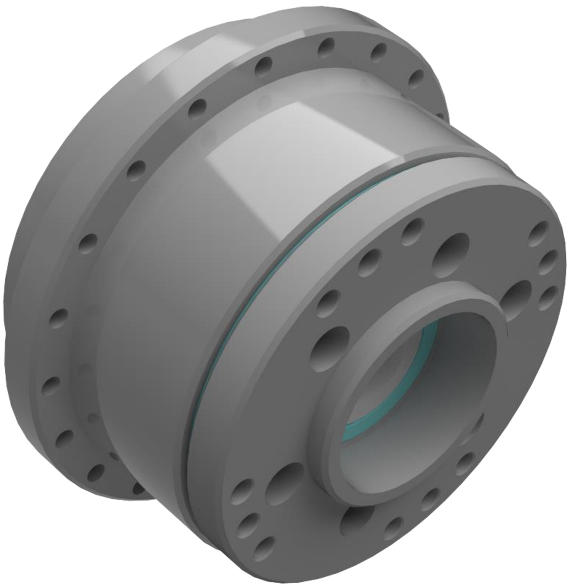

Fig. 6 Isometric View – Hollow Shaft cycloidal drive

As for the intermediate shaft assembly, each of the 3 shafts has a bearing mounted on them. To allow such a design, the shafts for the 4th and 5th joints were split in two parts and assembled by means of a jaw coupler integrated in the flanges of the two parts. An elastic ring is used to axially secure the two parts.

In order to maintain low production cost and to achieve high mechanical properties the main body for each of the shafts will be made from aluminum tubing. At each end 3d printed flanges will be attached.

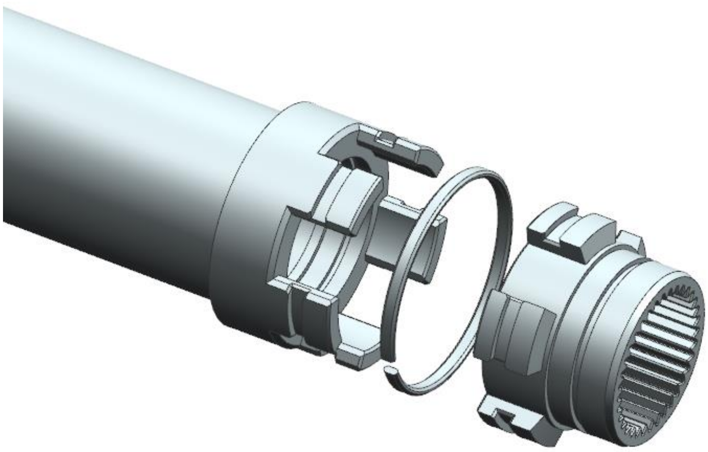

Fig. 7 4th joint intermediary shaft – Jaw coupler

The robot's wrist has not undergone major changes. Several windows have been added to allow viewing of the gear assemblies. The cycloidal drives for the 5th and 6th joints have been completely redesigned. The main problem regarding the 6th joint gearbox was the poorly designed cycloidal discs. At the slightest load the discs would slip because of their geometrical shape. The system has been redesigned. In order to define the shape of the new cycloidal discs mathematical equations were used that take into account the modulus, the number of teeth and the tooth height reduction coefficient. The current gearbox transmission ratio is 1/27.

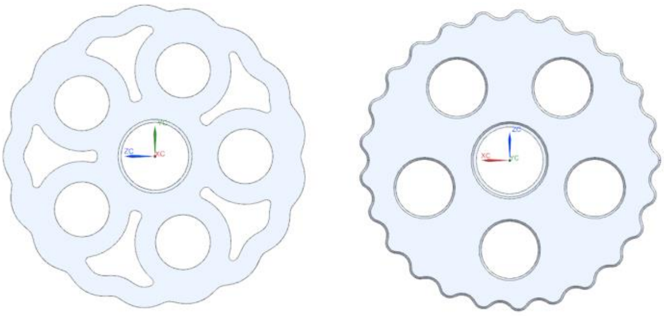

Fig. 8 Cycloidal Discs - 1st revision and 2nd revision

The 5th joint cycloidal drive has been updated. The pins that were originally modeled into the housing body were replaced with DIN 7 pins. Small changes were made to the output pins, the cycloidal discs were redesigned. The current transmission ratio is 1/69.

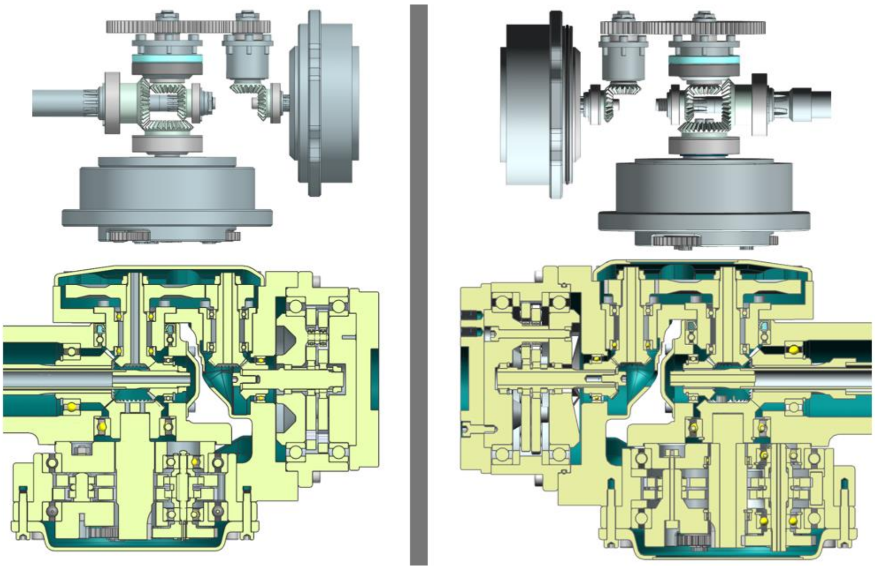

Fig. 9 Articulated robot wrist

The construction of the 3rd numerically controlled axis is much simpler compared to those previously presented. It includes only the drive motor, the cycloidal gearbox and the driven element.

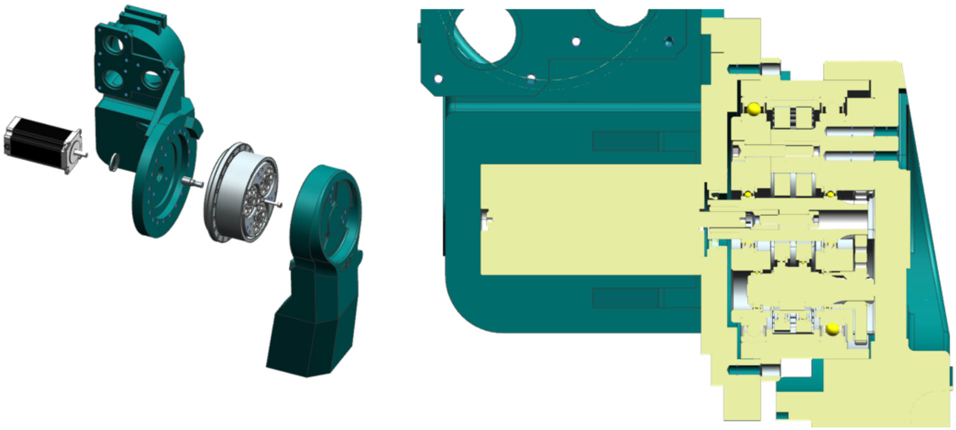

Fig. 10 3rd Joint mechanical structure

Off all the cycloidal drives presented in the current paper, the 3rd joint's gearbox is the most complex. [5] The larger size allows for a different solution to be adopted.

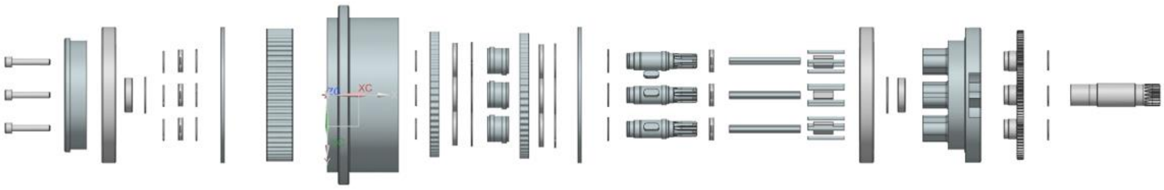

Fig. 11 3rd Joint Gearbox – Exploded View

Motion is transmitted from the main shaft to the three planetary shafts via a gear assembly with 1/3 transmission ratio. To withstand the shear and torsional stresses each of the 3 shafts has a hexagonal metal core. Motion transfer from the shafts to the cycloidal discs is achieved by means of eccentric bushings. These are mounted on the shaft by means of parallel keys and are secured axially between a shoulder and a retaining ring.

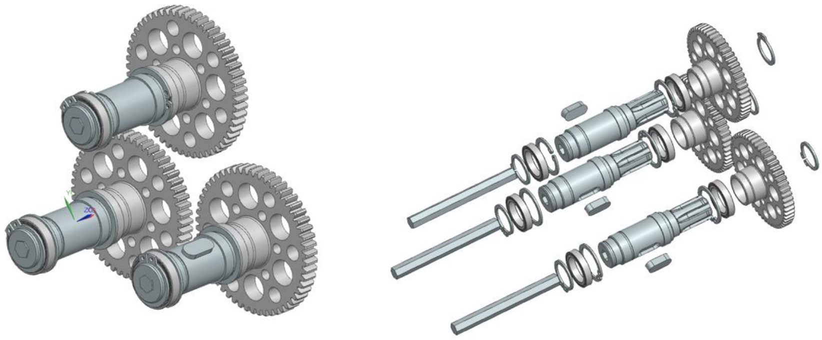

Fig. 12 Intermediary Shafts assembly

The cycloidal discs meshes with the pins mounted inside the housing. They are secured in the housing by means of two supporting rings. In order to achieve high life service life, the supporting ring will be manufactured from steel or another wear-resistant material like IGUS Iglidur.

The oscillating movement of the cycloidal disc will be transferred to the output shaft by means of 3 trapezoidal section pins. Such a design reduces the number of components of the assembly.

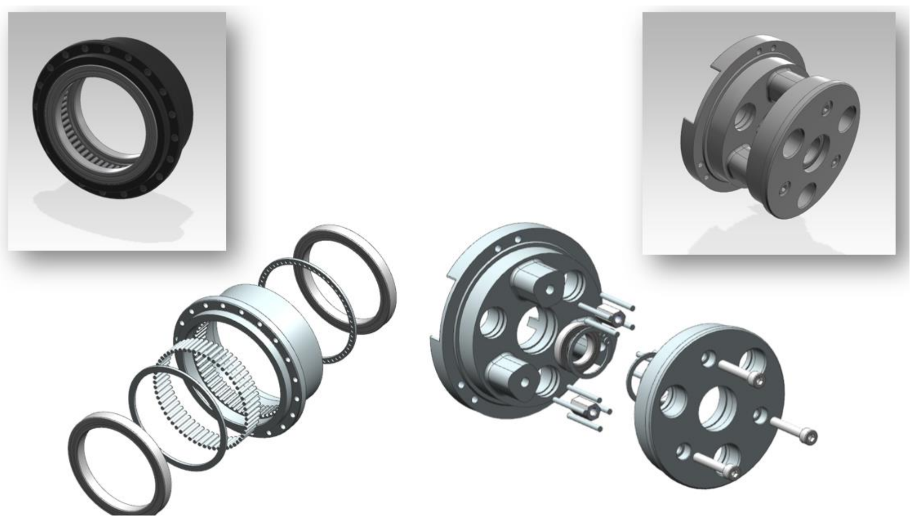

Fig. 8 Housing and Output Flanges Assembly

3. Conclusions

In conclusion, the present study details the improvements to the articulated robot. The mechanical structure of the guidance system has been defined. Work is currently underway to define the specific mechanical structure of the positioning system. Compared to the initial structure, the cycloidal gearboxes have been optimized, the orientation system has been completed with the 4th joint. The next step of the project is defining the sensors for the orientation system, followed by the start of the prototyping process. The next challenging task will be designing the 1st segment of the robot. Because of the high bending moment, steel inserts will need to be added.

4. References

[1]. *** MH215II_MH250II Robot Datasheet (2017), Yaskawa America Inc. https://www.motoman.com/getmedia/71c07c7b-f918-454a-b80b-51fa333679b2/ MH215II_ MH250II.pdf.aspx

[2] Nicolescu A. F., (2020). Design and operation of industrial robots. Calculus algorithms for industrial robots optimum design and operation conditions checking (in Romanian). Politehnica Press, ISBN 978-606-515-916-7, CIP BNR 2020-14500, Bucharest

[3] Gutu M., (2021). Robotic cell with complex automation for machining parts with revolute surfaces (in Romanian). Diploma work, FIIR, Politehnica University of Bucharest.

[4] *** Superior Electric and Danaher Motion Stepper Motors, Danaher Motion GmbH & Co. KG. https://users.obs.carnegiescience.edu/crane/pfs/man/Electronics/Superior-StepMotors.pdf

[5] *** Precision Reduction Gear RV^{TM}, Nabtesco Precision Europe GmbH. https://precision.nabtesco.com/en/member/download/f/catalog/33319