Design & Development of Articulated Inspection ARM for in House Inspection in a Torus

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Abstract— Magnetic confinement of plasma can be achieved using a device Tokamak. Concept of Tokamak confinement is also been tried to develop a fusion reactor. Reactor environment is of high hostile for human intervention due to radiation from activated atoms. For any kind of maintenance works Remote operation is necessary. An attempt was made to arrive at a concept of using articulated inspection arm to check the components if any damage or replacement required during shutdown operation of reactor machine. Proof of concept towards Design and development of articulated inspection arm for Torus Vessel was carried out & a robot having multi link joint with a camera mounted on the end point and also an arm having three degrees of freedom was attempted. The concept was materialized developing an articulated inspection robotic arm.
Keywords: Tokamak, Multi link robot, Gears, D.C. motor, potentiometer, ITER (International Thermonuclear Experimental Reactor)

I. INTRODUCTION

The environment of the fusion reactor demand robots for carrying out various maintenance tasks both in vessel and outside the vessel of a fusion reactor. The in vessel tasks during shut down of the machine include inspection, removal, fixing & transportation of components. The environment inside is hostile due to high level of radiation as it involves deuterium tritium resulting in release of high speed 14mev neutrons & tritium. Neutrons bombard the in vessel components resulting in activation of comprising atomic structure of materials used. The tritium interaction with the materials also makes human entry prohibited.
Development of special purpose robot for special tasks for fusion reactors an international requirement.

A. Articulated Inspection Arm

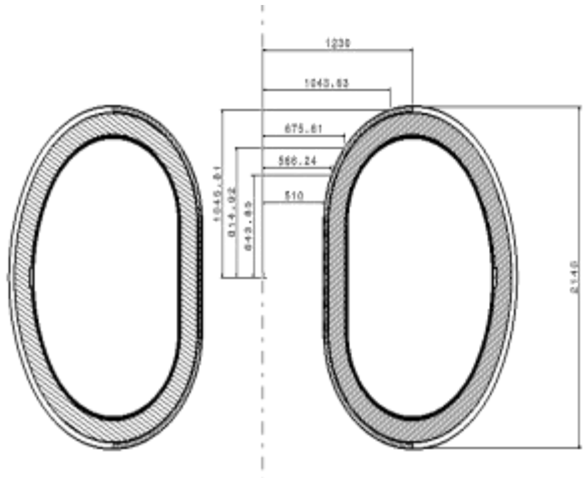

Fig. 1: Tokamak vessel, IPR[4]

The concept of articulated inspection arm with multi-link arm robot having 3 degree of freedom was taken as a task. The aim was to use camera attached with end-effecter & multi-link arm having capability to carry out inspection inside vessel. Vessel with toroidal cross-section (as shown in figure-1), was taken as inspection task using articulated arm (as shown in figure-2).

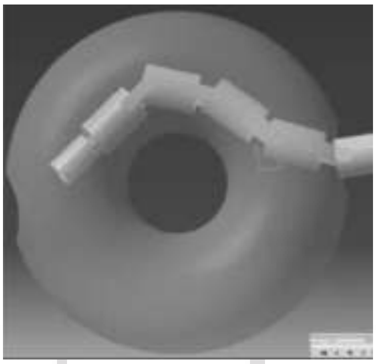

Fig. 2: in vessel inspection

For in vessel inspection, vessel dimension and cross section area is shown in figure-1. Link dimensions and material is defined in Table No.-1. To carry out inspection inside vessel, link has 2 degree of freedom which has camera mounted on it. The complete system has three links. Link dimensions are taken according to working area in vessel& accordingly arm length is optimized. Figure-2 shows position of arm inside vessel.

II. DESIGN OF ARTICULATED ARM

Design calculations are based on strength of material. Inspection arm is like cantilever beam and load calculation is based on robot anatomy.
The design & concept of articulated arm are:
Degree of freedom:- 3

1) Weight of arm:- 4.58Kg (only arm)
2) Pay load capacity:- 300 gm
3) Number of modules:- 5 (Table shows specification of one module)
4) Rotational joint (horizontal):- +/- 90°
5) Rotational joint (vertical):- +/- 90°

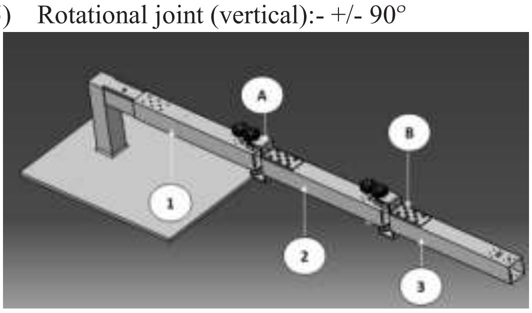

Fig. 3: Geometric model of AIA with segment and joint

The equations used in the calculation to determine the torque required for any given joint is described below. The equations used are as follows:

$$\tau = F \times L \qquad N \cdot m$$

And object weight,

$$W = m \times g \qquad kg$$

Thus, resulting in torque

$$\sum T = 0 = (F \times L) - \tau \quad N.m$$

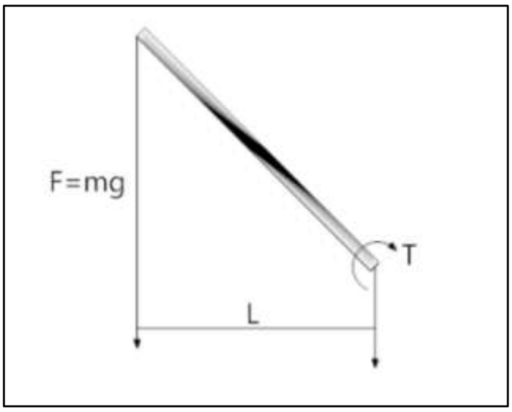

Fig. 4 Load acting on link

Name of component	Quantity
High torque D.C. motor, 32 kg-cm torque	1
Spur gear (Pair)	1
Bearing with block	2
Square plates	2
Shaft	1
Potentiometer	1

Table 1: Component used in one segment

High torque dc motor was used as actuators. Joint between two segments is shown in figure-5 & 6

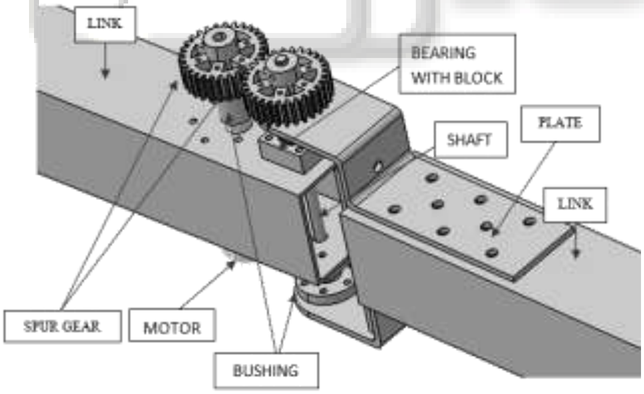

Fig. 5: joint between two Segments, CATIA model

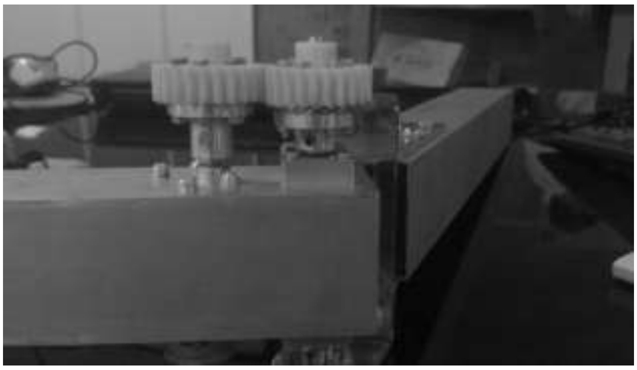
Fig. 6: Mechanical Gear drive system

Link No.	Length of link (m)	Weight (kg)	Joint specification
1	0.400	0.347	Fixed link
2	0.400	0.347	Joint-A (between link 1&2)
3	0.200	0.389	Joint-B (between link 2&3)
Total weight		1.083 kg without other assembly	

Table 2: Link dimension

Load and tension on joints are represented in figure-7. Three segments is shown in figure 7. Load and torque derive according to it.

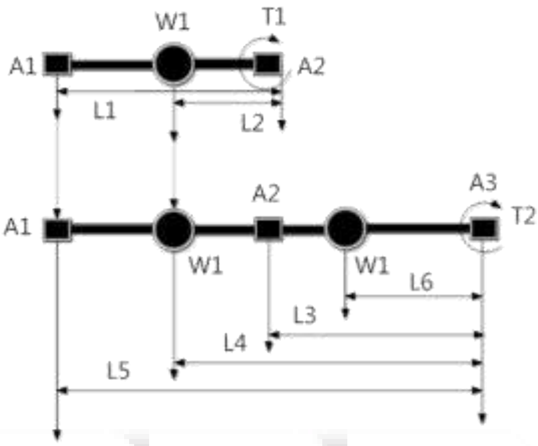

Fig. 7: Load and torque on joints

According to that load is derived from these equations.

$$\boldsymbol{T_1 = L_1 A_1 + \frac{1}{2} L_1 W_1 \quad N.m}$$

$$\boldsymbol{T_2 = [(L_1 + L_3)A_1] + \left[\left(\frac{1}{2}L_1 + L_3\right)W_1\right] + [L_3 A_2] + \left[\left(\frac{1}{2}L_3\right)W_2\right]}$$

A. Testing of AIA

Testing of AIA is done and different angle of arm is represented in Table-3 and figures (figure-8 to 11) shows experimental results.


Fig. 8: Position of arm-1


Fig. 9: Position of arm-3

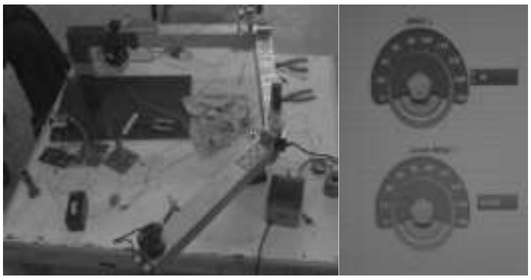

Fig. 10: Position of arm-3

Fig. 11: Position of arm-4

Position of arm	Angle Given	Current angle	Error	% Error
1	90	89.804	0.196	0.21
2	180	180.356	0.356	0.19
3	45	44.928	0.272	0.16
4	135	134.688	0.312	0.23
Average %Error				0.1975
Accuracy				99.74%

Table 3: Testing of AIA

III. CONCLUSION

From this paper, we can show our technical progress in developing inspection arm. As per experiment with AIA, multi links arm is designed according to vessel. An articulated inspection arm is a multi-link arm; first link has camera and, system has 3 degree of freedom which covers whole vessel area. It is offline operation for inspection.

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