Abstract

A Dual 5-bar on circular track robot for *Additive Manufacturing (AM)* is disclosed here. The robot comprises two Scara configuration robots joined together to form a closed chain 5-bar mechanism (1). This closed mechanism is placed on a serial linkage comprising a linear and a revolute joint (2). The parallel 5-bar mechanism offers the robot sturdiness and accuracy, while the serial chain offers higher manipulability. Both of these act as a hybrid mechanism benefitting from the advantages of each other. The Dual system works in collaboration on a circular track (3), giving the robot an expanded workspace for its operation.

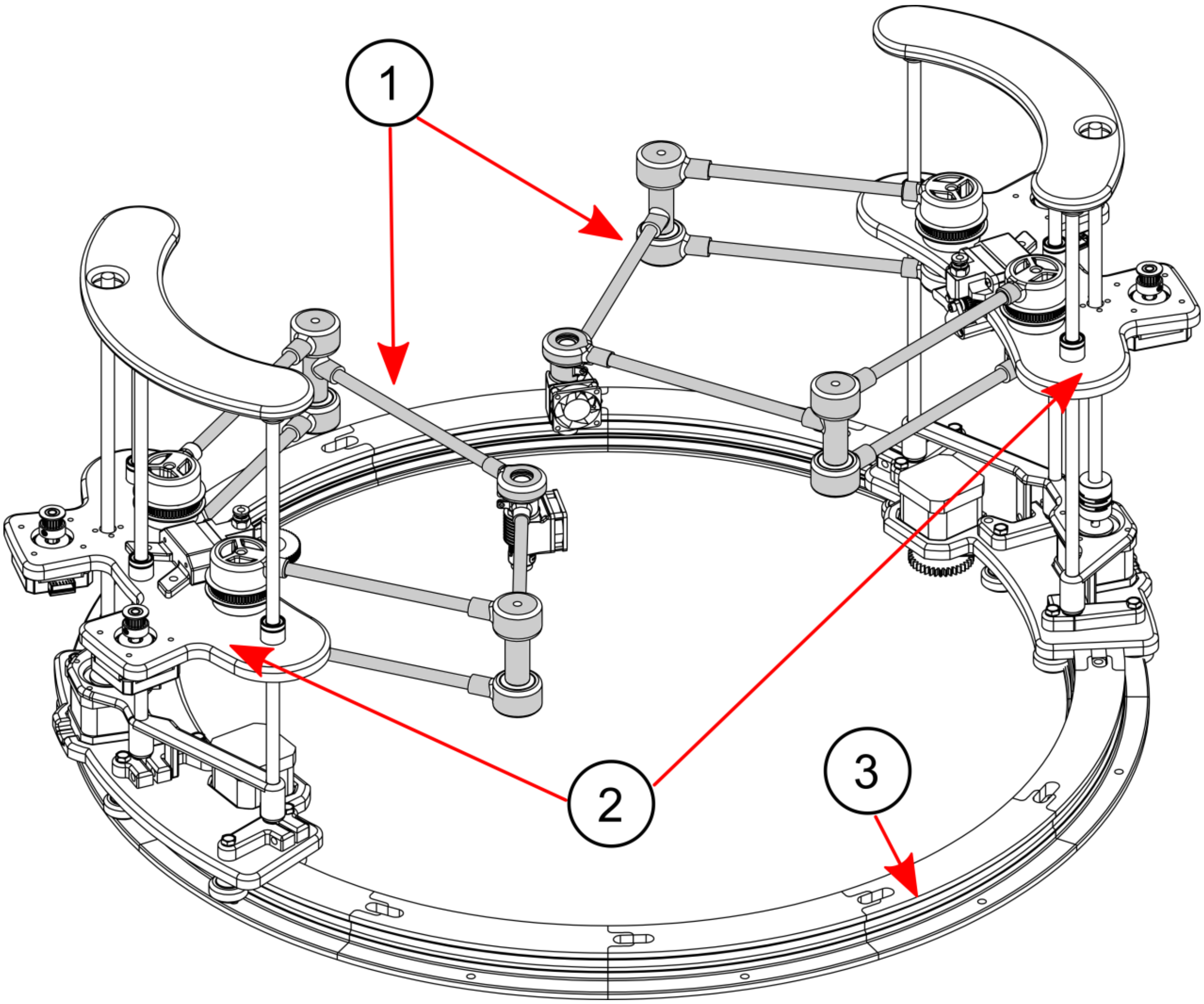

Figure: **01**

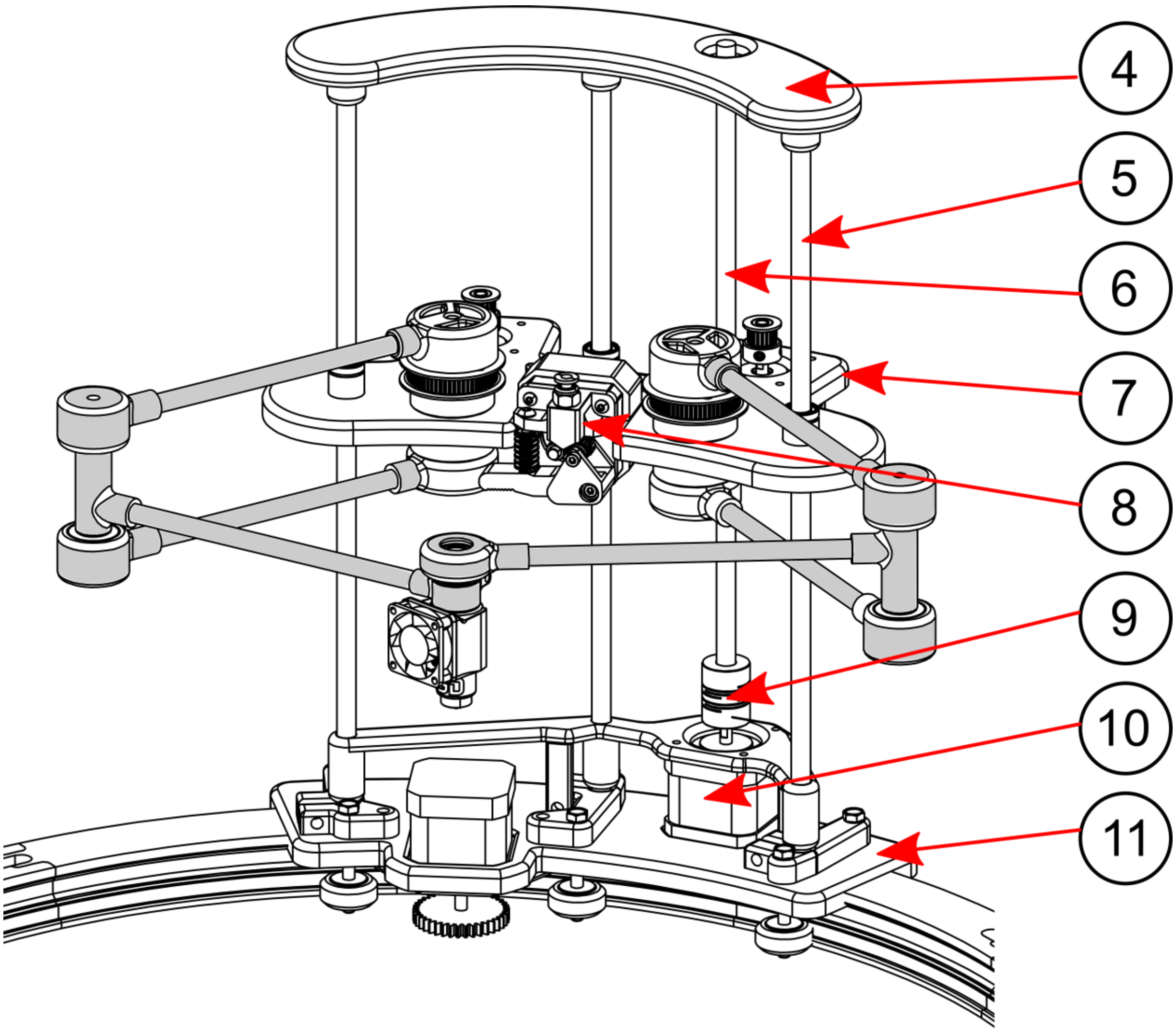

Figure: **02**

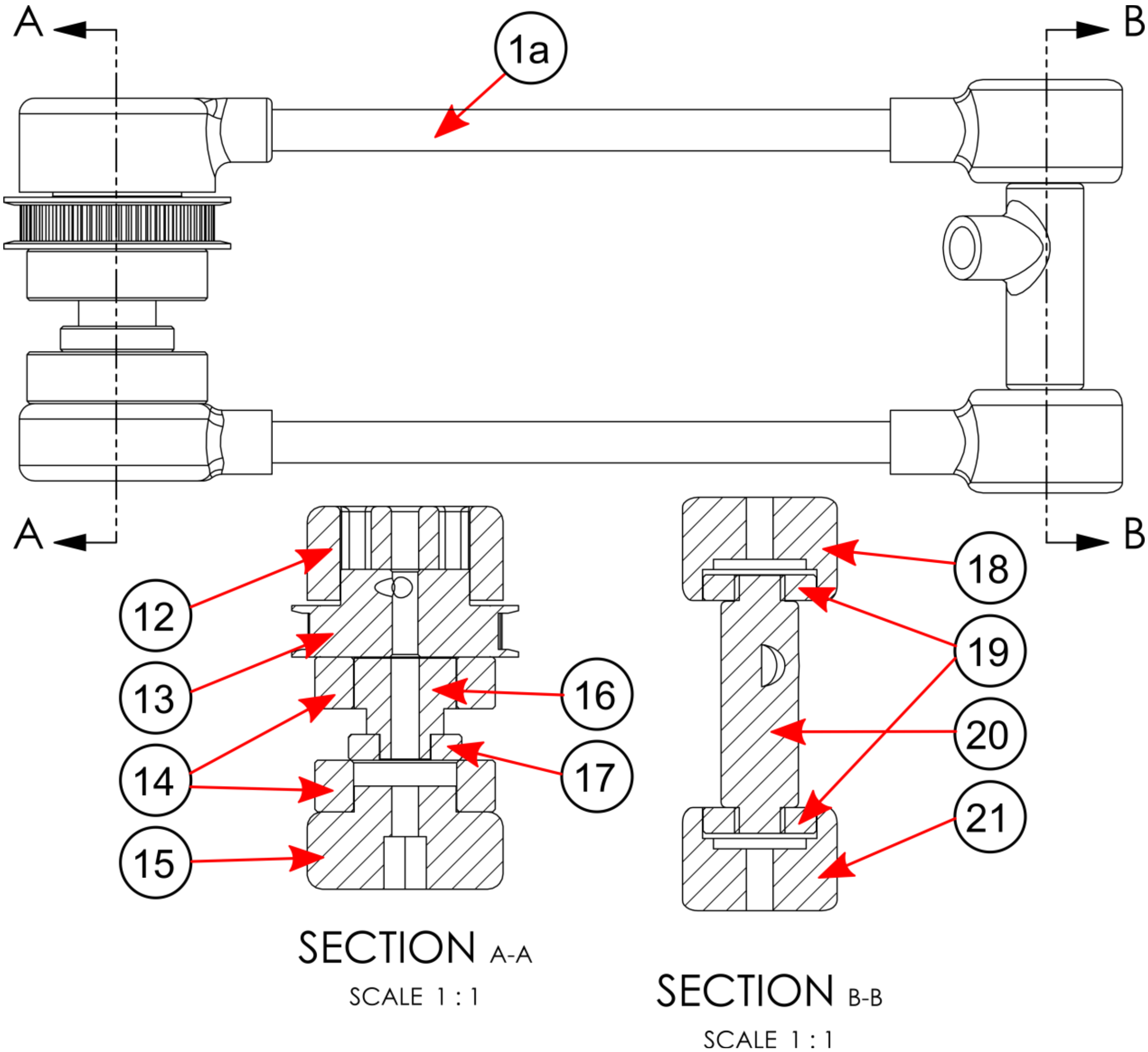
A
B
1a
A
B
12
13
14
15
16
17
18
19
20
21
SECTION A-A
SCALE 1 : 1
SECTION B-B
SCALE 1 : 1

Figure: **03**

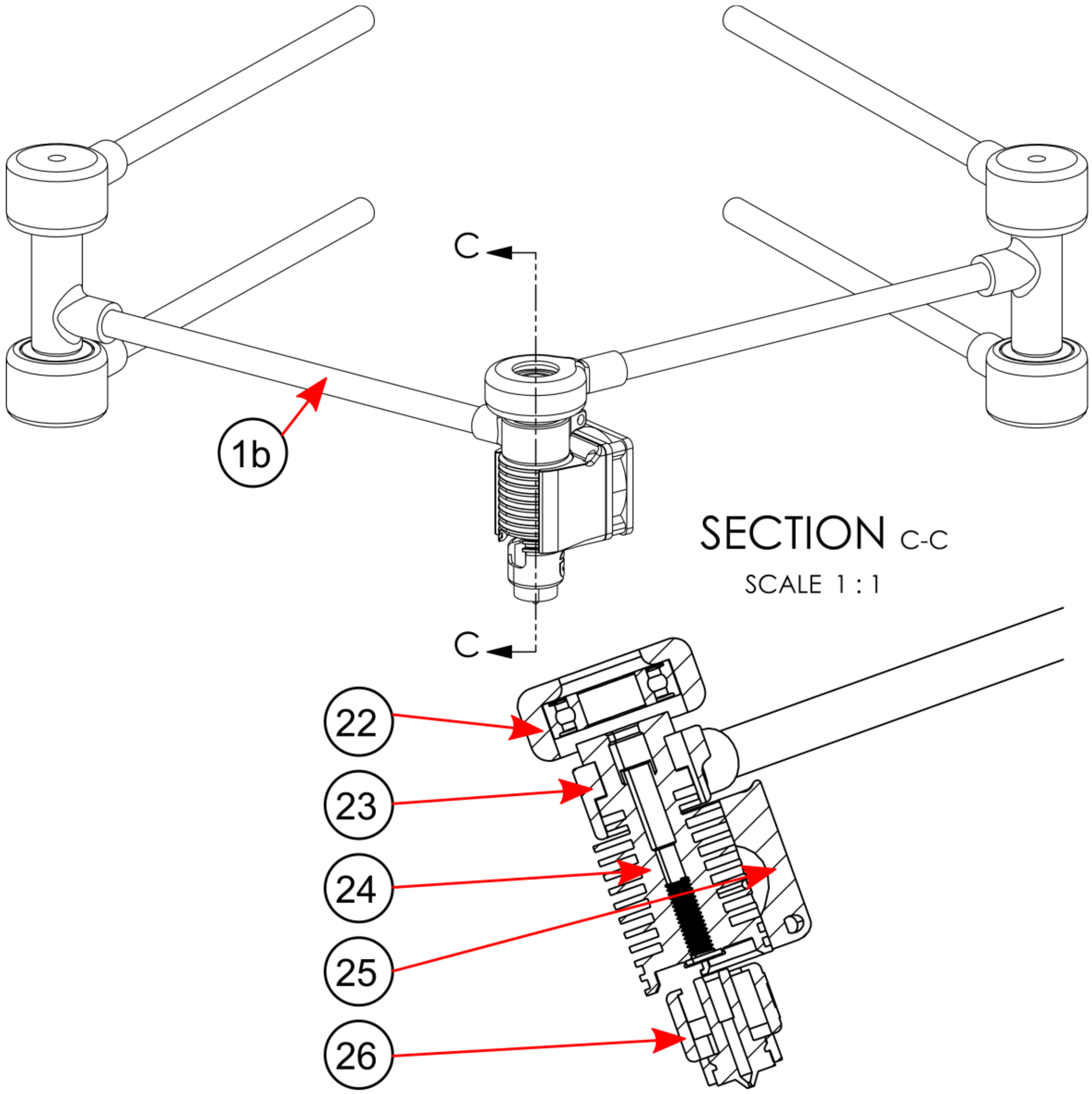

Figure: **04**

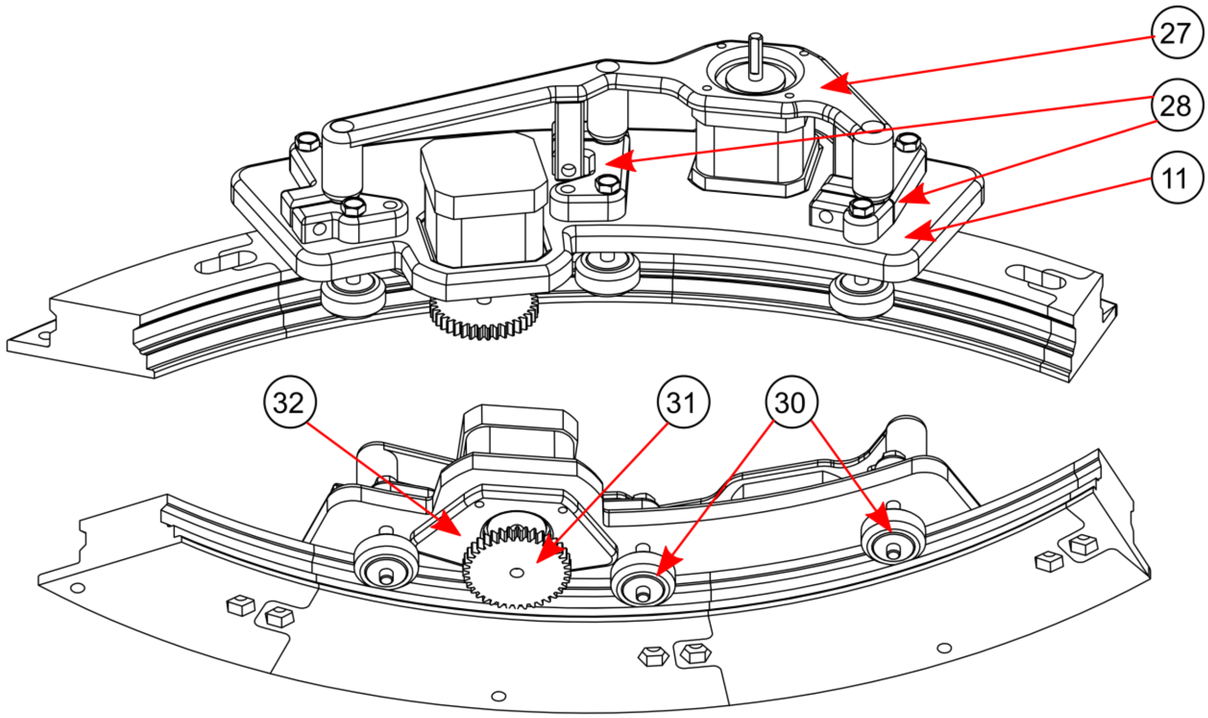

Figure: **05**

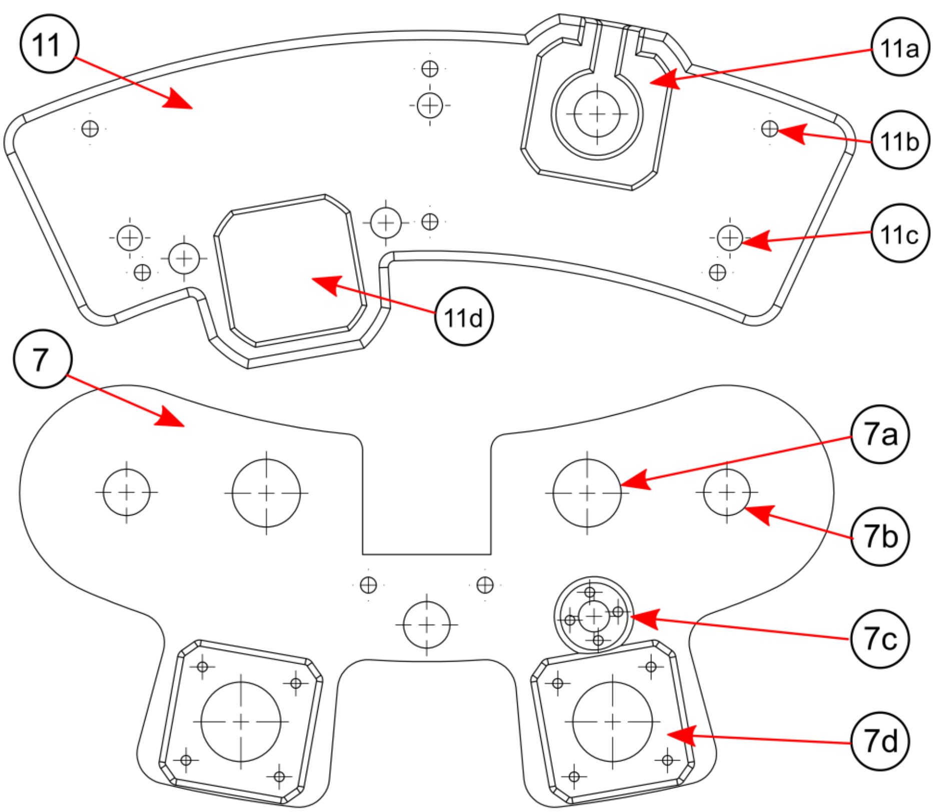

Figure: **06**

Technical Field

The present invention, disclosed herein, relates to the Hybrid Kinematic Collaborative Additive Manufacturing process, specifically to 3D print any object by Fused Deposition modeling of the suitable plastic materials.

Background of the Invention

Additive Manufacturing (AM) is a significantly developed process with various new techniques like VAT Photopolymerization, Material Jetting, Binder Jetting, Material Extrusion, Power Bed Fusion, Sheel Lamination, and Direct Energy Deposition. Out of all these processes, Material Extrusion is the most common, basically the Fused Deposition Modelling technique in this area. The robotic setup in the patent explores a new area in the design of the mechanism of additive manufacturing. The usual machines currently available are cartesian and delta types, with slight modifications in their axis setups. One can also find Scara and other robotic serial kinematic chains used for additive manufacturing. But here, a combination of both serial and parallel kinematic chains have been used, working as a hybrid setup.

The parallel chain gives more accuracy and rigidity to the robot, whereas the serial chain gives more maneuverability and dexterity to the system. The circular track allows the robot to expand its workspace in the entire circular region covered by the track. Also, moving on the track acts as a redundant actuator, giving the robot an extra degree of freedom. If one sees the plots of manipulability without the track and with the track, there is an apparent increase in the overall manipulability of the system.

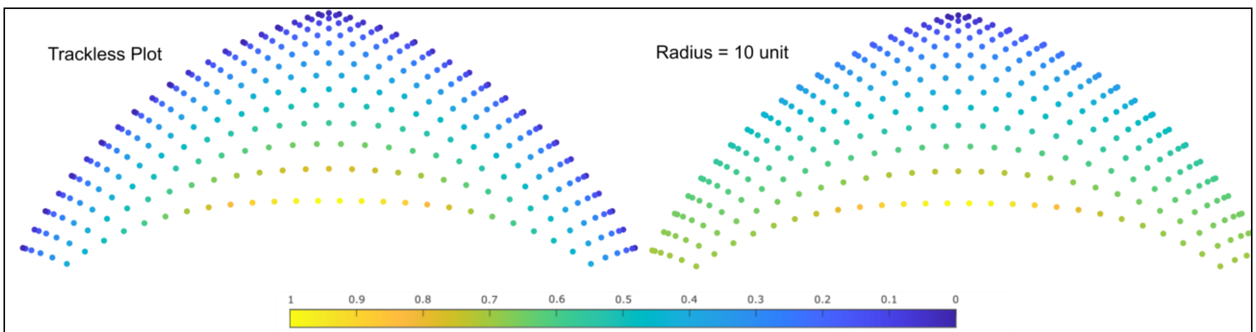

Figure: **07**

Fig. 7 shows a scaled version of the plot. We are taking the **arm link lengths (1a) and (1b)** to be 5 units and the radius of the **circular rail (3)** to be 10 units. Manipulability is represented using a color palette of blue being the least (zero) value and yellow being the highest (one) value. We can see that the low manipulability regions at the boundary of the trackless plot significantly decrease as we move the robot on a circle of a particular radius. Blue dots become greener, becoming more manipulable areas in the initially confined workspace. Also, as we are moving the system on a rail, the total workspace is considerably increased. Thus, the robot has an extended workspace with increased manipulability.

Having a larger workspace is a very beneficial outcome in the Additive manufacturing industry. The benefit of increased manipulability can be applied to tasks where the robot needs to perform its work without losing its maneuverability. There may be cases where instead of manipulability, load, or force is considered, the same concept can be applied here as well.

Summary of the Invention

The present invention, disclosed herein, is in context to Additive Manufacturing with the newly developed kinematic setup. The robot consists of a 5-bar parallel mechanism placed on a serial kinematic chain on a circular rail. The hybrid combination gives the robot both high accuracy and rigidity, as well as increased maneuverability and dexterity. There is a considerable increase in the workspace. This setup also allows for collaborative printing, reducing printing times considerably and doing multi-material additive manufacturing by two independent extruder setups.

Brief Description of the Drawings

The accompanying drawings constitute a part of the embodiments described herein.

Fig.1 schematically illustrates the isometric view of the Dual robotic setup used for collaborative Additive manufacturing.

Fig.2 schematically illustrates a single setup view with easily visible details of all the parts designed for the mechanism.

Fig.3 schematically illustrates a side view of the base link (1a) and the sectional view of the link joints.

Fig.4 schematically illustrates an isometric view of the end-effector arm link (1b) and the sectional view of the end-effector.

Fig.5 schematically illustrates the gantry setup on the circular rail (3).

Fig.6 schematically illustrates the two main base plate (11) and the vertical slide plate (7).

Detailed Description

Continuing with reference to drawings Fig. 1 the whole robot comprises two **5-bar mechanisms (1)** placed on **serial chain (2),** which moves with the help of a gantry system as shown in Fig. 5 on a **circular rail (3)**. A single robot Fig. 2 comprises a **top plate (4)** that covers the **smooth rods (5)** and gives support to the **lead screw (6)**. Then the vertical **sliding plate (7),** which houses two of the **Nema 17 motors (10)** at the back, the joints of the **base arm links (1a),** and the **MK extruder (8)** set up in between. The **lead screw (6)** is coupled with the z-axis **Nema 17 motor (10)** with **a coupler (9)** which also serves the purpose of reducing vibrations transferred from the motor. This whole system is supported by the **base plate (11),** which has the gantry system, as shown in Fig. 5 on a **circular rail (3)**.

Fig. 4 schematically shows the side view of the **base arm link (1a)** of the **5-bar mechanism (1)** and the sectional views of the main joints that make the robot's end-effector able to move in the x-y plane. The base arm joint comprises a combination of two **thrust bearings (14)** and a **radial bearing (17)**, held together with a **support piece (16)**, in between the **GT 60 gear (13)** and the **upper** and the **lower joint caps (12), (15).** The arm joint also has two **radial bearings (19),** which are held by the **upper** and **lower joint caps (18), (21),** and the arm link piece. This **arm link piece (20)** holds the **arm link (1b).** The sectional view of the end-effector can be seen in Fig. (4), with the **upper cap (22)** and the **nozzle holder (23)** forming the revolute joint and housing the **heat fin (24)**, the **cooling fan (25)** and the **nozzle heat end (26)** setup.

Fig, 5 shows two different views of the gantry setup, which comprises mainly of the **motor support (27)**, and the **smooth rod holders (28)**, placed on the **gantry plate (11)**. A separate circular axis motor holder (32) with a custom timing gear (31) for the circular axis movement is attached to the motor. The PLA **wheels (30)** fit in the notch of the **circular rail (3)** and enable the gantry to move in a defined circular path. The **gantry plate (11)** has special grooves made for the motors, as shown by **(11a)** and **(11d)**. The **M5 (11b)** holes are made to fix both the holders and the **wheels (30)**. The **10mm dia grooves (11c)** support the **smooth rods (5)**. Similarly, Fig. 6 also shows the vertical sliding plate (7) with grooves (7d) made to hold the motors that move the arms. A proper **slot (7c)** is made to house the lead screw nut. The **(7b) holes** are made for housing linear bearings, which move smoothly on the **smooth rods (5). (7a) holes** are for the base arm joints, as shown in Fig. 3 Section A-A.

We Claim

1. Development of a new kinematic mechanism additive manufacturing (3D printing)
    a. The new kinematic setup gives increased manipulability.
    b. Extends the workspace considerably.
    c. Allows new toolpath planning algorithms.
2. Dual collaborative additive manufacturing setup.
    a. Reduction in time thus enables faster printing.
    b. Multi-material 3D printing allows the printing of two different types of materials simultaneously from two independent extruder setups.
3. Collision-free working between the two systems for continuous 3D printing.