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A Geometrical Modular Design for Handling of LPG Cylinders using Nested Kinematic Robotic Gripper

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Abstract

Objectives: Novel design of Robotic gripper by means of epicyclic gear arrangement and incorporation of this mechanism for quick and efficient handling of domestic LPG gas cylinders from supplier end to consumer end. **Methods/Statistical Analysis**: Many researchers and robot manufacturing companies highly concentrate the new design of grippers and invent the smart grippers which is operated by means of efficient mechanisms and advanced techniques. In this paper discusses the modular design of a new robotic gripper operated by means of the epicyclic gear arrangement. **Findings:** Presently, domestic fuel LPG cylinders are loaded and unloaded manually from trucks. Loading and unloading LPG cylinders is involving lots of labour and sometimes cause finger crush and other disability to the personnel. This invention is particularly useful in unloading and unloading of empty and filled gas cylinders from vehicles such as trucks in a desired pattern and ensures safety and efficient handling. A geometrical model is developed and this device is helpful to a large extent for the handling of LPG cylinders meant for domestic purpose and this device will serve for the quick disposal of LPG cylinders to the consumers and safety of personnel is considered. Automation of this device may lead to higher investment. To meet the low capital investment, this device has to be partially mechanized. **Application/Improvements:** Epicyclic gear train is used for speed reduction purpose only. In this novel design, actuation of grippers is made possible by placing a suitable gripper in the planet gears. Gripper is mounted in planet gear eccentrically. This gripper is specially designed for loading and unloading the domestic LPG cylinders from trucks. Grippers are arranged in a required pattern for bulk handling of Large number of LPG cylinders. Locking and unlocking of grippers with LPG cylinders is mechanised in a supporting frame.

Keywords: Epicycle Gear Grippers, LPG Cylinders, Robot Grippers

1. Introduction

The industrial robots are one of the most versatile automatic devices for accurate, better, more modern and harmless automation technique under the field of innovation in Mechatronics systems. Requirements of robots in today's precision components manufacturing scenario are very high. Application of industrial robots is growing therefore commercial and technological advantages of various applications in industry like welding, spray painting, material handling, Pick and place operations, palletizing, loading and unloading and etc[1]. One of the most important topics in the design of new industrial robotic manipulator is the design of its end effectors. Most of the situations that happen in construction are caused by critically designed[2,3] .

Now a day Robot manipulators are being used internationally to increase quality and meet the customer requirements. A robotic gripper is an important component of a robotic manipulator.

There are many different types of gripper mechanism and grippers are available along with the massive number of specialized tools for manufacturing operations and household applications and variety of risky tasks done by the robots easily with a high degree of freedom as shown in Figure 1. These grippers design considerations are the most important factor for measuring the robot performances. Designers need to emphasis on how the object

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manipulator will be used in the real application and take this into account[4]. Some common factors to be considered while designing the gripper for particular tasks are mentioned below. The performance and the accuracy of the robot characteristics majorly depend on the effective design of the end effector design. Also in this paper the design calculations of the new gripper mechanism and advantages are clearly explained[5].

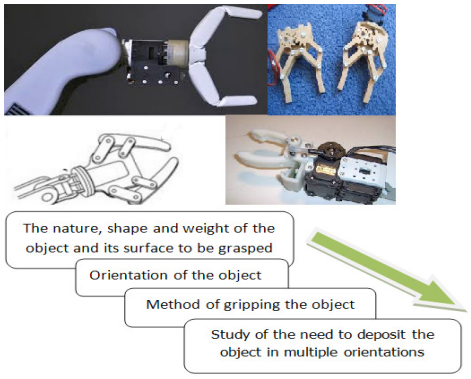

Figure 1. Essential design considerations of gripper design.

2. Equipment used for Loading and Lifting of LPG Cylinders – Present Scenario

STS are a UK based specialist handling equipment manufacturer they have designed a new ergonomic design of handling the gas cylinders solving all the practical problems through gas cylinder trolleys. In their system the operator pushes the gas cylinder forward direction slightly, and then he pushes the trolley to the cylinder. This was done very simply because the trolley has two small strong front rotating wheels that allow it to move forward position even when it is vertical[6].

The operator then pulls back on the cylinder until the trolley is on 4 wheels. They found the effort needed to do move the cylinder is only 15 kg also they proved the operator does not have to support the load at all the time. If the operator wants to climb a kerb with the trolley they simply push back on the handles to raise the front wheels was enough.

KOSAN CRISPLANT Company from Denmark shown in Figure 2. They devised totally three robotic systems used for the loading and unloading of LPG cylinders at a time three cylinders were lifted, thereby reduced the amount of man works and hours needed for the completing the tasks[7]. The cell contains the designed robot and the paint delivery system with cylinder rotation mechanism. Usually the cylinders were hung from a monorail type conveyor system, flow through a paint booth and make contact with a belt drive system that causes the cylinders to rotate at 100 RPM. They used the sensors for sensing the presence of the cylinder and give signals to the robot to paint the cylinders with high efficiency. This system excludes the need for a human operator to be in the paint cell[8].

Figure 2. Robot for lifting the cylinders using grippers.

3. Modular Design of Gripper for a LPG Cylinder Lifting

The cylinders are to be arranged in a compact pattern during loading into the trucks and unloading in the specified yards. To keep the cylinders in a required pattern a base having a circular shallow base in the required matrix form can help quick alignment of gas cylinders to suit with a modular frame matrix pattern. This pattern as a whole can be clamped onto a modular type structure and this structure can be lifted using gantry type crane or a telescopic boom shown in Figure 2 and 3.

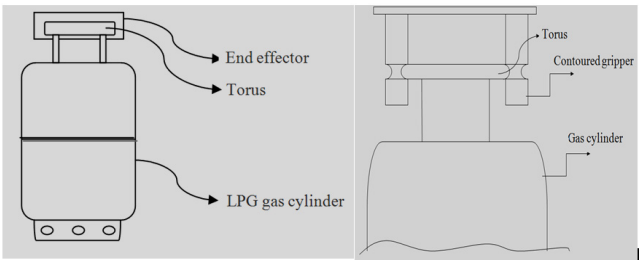

Figure 3. The integral assembly of epicyclic gear gripper on the cylinder top.

Gripping surface shape is designed according to the shape of the objects that are lifted by the grippers. This end effector is designated a task to lift a gas cylinder. On the top of the gas cylinder, a torus shaped ring is welded to the cylinder. The negative impression of the torus is shaped to hold the cylinder firmly. In this design, a semi-circular shape is grooved on the cylindrical part of the end effector. The planetary gear train is used for the actuation of grippers. The sun gear shaft is given the drive. This sun gear meshing with three planetary gears and internal or ring gear. In the planetary gear, a gripper is fixed eccentrically[8]. A ball bearing is used to couple this gripper with planetary gear. These three planetary gears are at 120 degrees apart. When the sun gear revolves, the planetary gear rotates around the sun gear. The resulting locus of the gripper which is epicycloidal with respect to sun gear in now changed with respect to space. The locus of the curve is shown in Figure 5 and 6. From the figure it is clearly proved the required motion of the gripper in the space coordinates. This type of motion needs to actuate the gripper my means of the high torque stepper motor shown Figure 4 and 5.

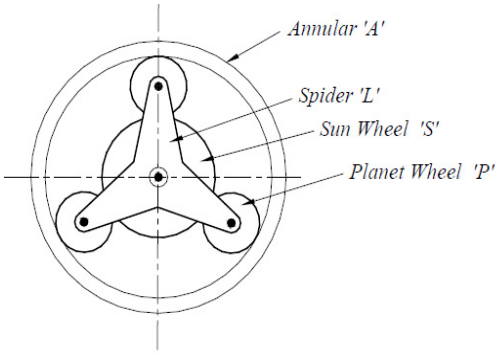

Figure 4. Epicyclic gear train mechanism.

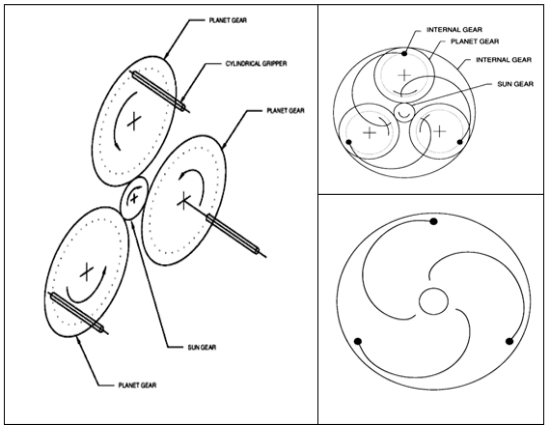

Figure 5. Outer extreme position of gripper for one cylinder.

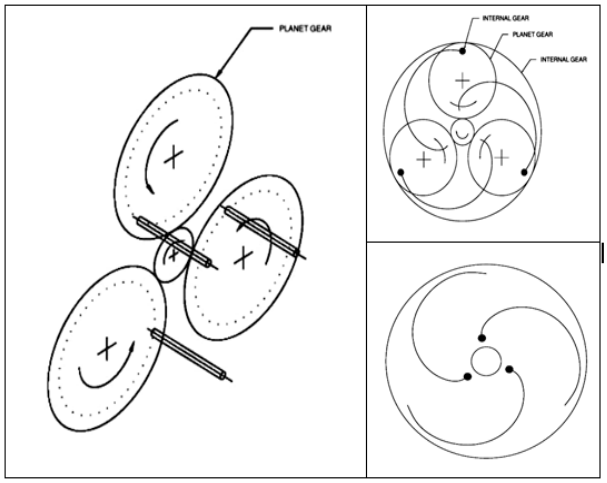

Figure 6. Inner extreme position of gripper for one cylinder.

A ball bearing is used to couple this gripper with planetary gear. These three planetary gears are at 120 degrees apart. When the sun gear revolves, the planetary gear rotates around the sun gear. The resulting locus of the gripper which is epicycloidal with respect to sun gear in now changed with respect to space. The locus of the curve is shown in Figure. From the Figure it is clearly proved the required motion of the gripper in the space coordinates. This type of motion need to actuate the gripper my means of the high torque stepper motor shown in Figure 7 and 8.

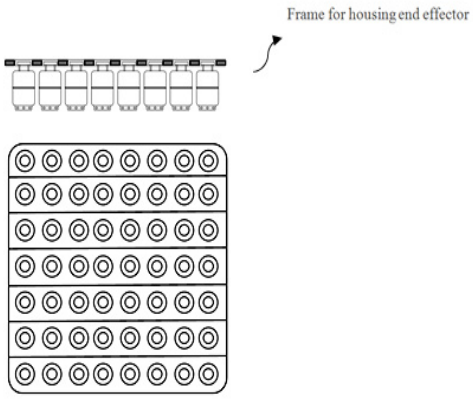

Figure 7. Framed structure for lifting gas cylinders, housing, and end effector in 8x8 nested patterns.

4. Design Calculations

Epicyclic gear gripper design:

Module being the same for all meshing gears:

T_A = PCD of A / module

$T_A = T_S + 2T_P$

When A is fixed:
$n-(T_S/T_A)\, m = 0$
i.e $T_A = mT_S$

m=110/30=3.667 revolutions in 3 seconds make the sun gear speed 73 rpm.

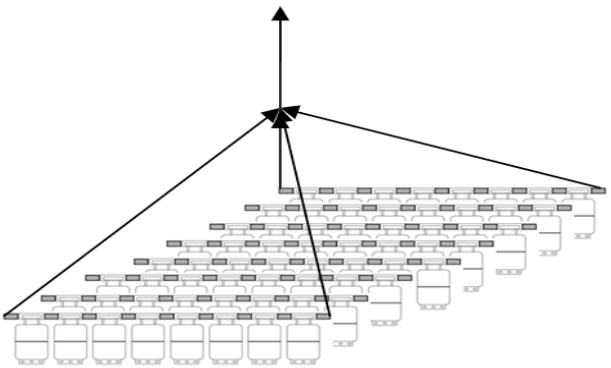

Figure 8. Lifting of 8x8 matrix pattern framed structure along with gas cylinders.

Here the number of teeth in gear train shown in Figure 4 and 5. is calculated and shown in Table 1 to get the required gripper jaw locus which is epicycloidal.

5. Principle of Gripper Actuation

In this design, gripping force is not important. As the cylinders are lifted vertically, the end effector is to be designed to take the vertical load. Other factors to be considered include the speed of the end effector jaws and holding of cylinders by the gripper on power failure may not be critical because clamping is ensured before lifting the weight.

Eight end effectors in a straight line housed in a structure form a modular type. This modular frame can be interconnected according to the desired pattern of gas cylinders which are to be either loaded or unloaded from trucks. This geometrical model can be redesigned so as to handle and transport the commercial gas cylinders also. For this, the dimensions of the gripper model need to be changed to suit the size and shape[9].

While loading into the modular type structure, the LPG cylinders are to be arranged in a pattern, shown in Figure 7 and 9 and it can be liftedas in Figure 8. For lifting this entire pattern, a gantry type can be employed. Another option is the use of telescopic boom. The telescopic boom will move the structure in the horizontal direction[10]. This telescopic boom can be augmented with Scott Russell Straight-Line Mechanism to enable the movement in the vertical direction.

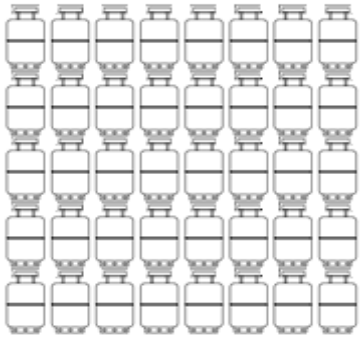

Figure 9. Stacking of 8x8x5 nested pattern of gas cylinders loaded in truck.

6. Conclusion

For handling large numbers of cylinders, this modular structure can be added to suit the desired nesting pattern. The gas cylinders are to be to be arranged in a pattern only once because it does not require rearrangement of the pattern again. The pattern does not get disturbed after unloading of trucks and again loaded on trucks and thus saving a lot of rework and time. To keep the cylinders in

Table 1. Number of teeth calculation for Epicyclic gear gripper

Operation	Spider arm **L**	Sun wheel **S** T_S	Planet wheel **P** T_P	Annular wheel **A** T_A
Arm L is fixed and Sun wheel S is given +1 revolution	0	+1	$-(T_S/T_P)$	$-(T_S/T_P) \times (T_P/T_A) = -(T_S/T_A)$
Multiply by m (S rotates through m revolution)	0	m	$-(T_S/T_P)m$	$-(T_S/T_A)m$
Add 'n' revolutions to all elements	n	$m+n$	$n-(T_S/T_P)m$	$n-(T_S/T_A)m$

a required pattern a base having a circular base in the required matrix form can help quick alignment of gas cylinders to suit with a modular frame matrix pattern.

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