Design of a Smart Gripper for Collaborative Robots

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***Abstract*— In recent years, robotic gripper is widely used for different tasks in various fields. A gripper is a device which enables the holding of an object to be manipulated. Grippers operate with industrial robots for handling and manipulation of objects. Grippers also operate with hard automation for assembling; micro assembling, machining and packaging. The objective of this work is to design a smart robotic gripper for collaborative robots for the use in machine tending and retail warehouse applications. The smart gripper is a electrically operated using a DC servo motor. The gripper is designed to accommodate a laser sensor module, force sensor, CMOS camera and infrared sensor. The CMOS camera gives the pose of the object to the robot and aligns itself to the object. the The IR sensor mounted in the jaw can detect the if the jaws are centered to the object, it can detect is the object falls during the cycle. The gripper can measure the gripping force in order to pick objects of different material. The gripper also has intermediate position control using the time-of-flight range sensor.**

Keywords—Gripper; Collaborative robots; Servo motor; Rack and pinion; Jaws.

I. INTRODUCTION

Gripper is a part of the robotic hand and physically interacts with the environment. Grippers are utilized to grasp object, usually the work part, and hold it during the work cycle [1]. The grippers available in the market do not detect if object is picked or not, if the object falls during the cycle and they donot have vision system [2]. Robotic grippers started in an industrialized environment where they could neither see nor feel. These grippers lacked intelligence, but were able to function satisfactorily because they operated in a structured environment where the robot's surroundings and the object of manipulation were constructed for robotic applications. Nowadays they are used for applications such as service robots and prostheses where the grippers have to interact with various objects, many of which are of unknown shape, form and material strength. The demands of a robotic gripper has evolved exponentially and has led to the development of intelligent grippers [3]. The purpose of this particular project was to develop a two-jawed robot gripper of a conventional configuration with the ability to alter its applied force in a controlled m a n n e r . This was seen as being an appropriate extension to the capabilities of a conventional robot gripper, giving it the ability to handle a wide variety of objects requiring a range of gripping forces. Thus, objects which are fragile requiring a delicate purchase could be handled as readily as robust, heavy objects requiring a firm gripping force. The ultimate aim was to achieve this variability in gripping force from within the robot control system itself through the use of a force feedback controlled electro-mechanical gripper [4]. The grippers available in the market do not detect if object is picked or not, if the object falls during the cycle and they do not have vision system. There are many various designs of robot claw-type end-effectors to choose from. Industrial claws often use pneumatic actuators and have powerful grip but minimal displacement for a very specific operation. These pneumatic actuators are almost exclusively made from metal and are quite heavy, making them unsuitable for the current arm [5].

II. OBJECTIVE

To design a smart robotic gripper and select the necessary sensors required for the use in machine tending and retail application.

Fig1: Collaborative Robots

A. *Problem Statement*

- Current robotic Grippers do not give feedback of whether the object is picked or if the object falls during the cycle, they are not ROS(Robot Operating System) supportive and cannot accommodate external sensors.

Fig2: Existing Grippers

B. *Gripper Specifications and requirements*

The specifications and requirements are set by doing customer survey on their use cases and other grippers in the market. The following requirements are set for the grippers

- Type of actuation- Electric DC Servo
- Gripper stroke-70mm
- Payload-3Kgs
- Can be used with-Universal and Hanwha Robots
- Gripper mechanism-Rack and pinion.
- Smartness - object center alignment, object pick and fall detection, gripping force feedback, gripping stroke feedback and to accommodate a camera.

III. WORKING PRINCIPAL

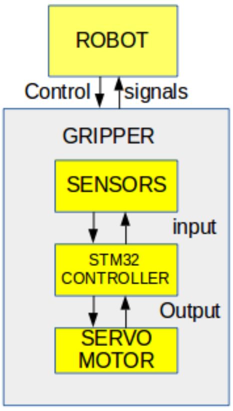

Fig3: Working Mechanism

The camera placed in the gripper gives the visual feed of the object placed for machine tending within the field of view of the camera. The image taken by the camera is given to the deep learning and image processing algorithm running in a separate PC. The algorithm gives the exact pose value of the centroid of the object placed within the field of view to the robot controller. The robot aligns the gripper accordingly and opens the jaws and picks the object, only when the IR sensor senses the object. The required force is applied depending on the material of the object and it is obtained by the force sensor placed in the jaws. The force required is given as input in the robots teach pendent.

IV. DESIGN

The main criteria in designing a gripper are stroke and payload. In order to grasp an object there must be sufficient gripping force to be produced by the gripper. The gripping force required to pick a object is calculated as follows.
Gripping force required by the gripper to carry to a payload is given below.

A. Gripping Force calculations:

Gripping force = $Fg = m \times (g+a) \times s/\mu \times n$

Fg = gripping force
m = mass of object
g = acceleration due to gravity
s = factor of safety
μ = coefficient of friction
n = number of fingers or jaws

$Fg = 3X(9.8+1)X3/0.64X2$

$Fg = 76N$

B. motor selection: The required gripping force in a gripper is generated by the actuation mechanism, which is a DC servo motor in this case. Selecting the motor with appropriate torque is very important as it directly influences the gripping force. The torque required is calculated as shown below.

Torque = T = F x r
F – gripping force
r – radial distance
Fg = 50.6N
T = 5.159x2.5
T = 13Kg-Cm

C. *Stroke calculations:*

The gripper is a parallel jaw gripper which has a rack and pinion mechanism for linear motion. The stroke of the gripper depends on the distance travelled by the rack when the pinion completes 180degrees of rotation. This is determined by using the below mentioned formula.
Distance travelled by the rack = number of rotations of the pinion x pi x pitch diameter of the pinion.
Distance travelled by the rack = 0.5 x 3.142 x 25.4
=39.99mm.
The above calculation shows the distance travelled by a single rack. The combined movement produces a stroke length of 80mm, however the gripper is designed for a stroke length of 70mm electronically and has a mechanical stopper.

D. *Linear speed:*

motor no load speed at 6.0V = 1.6sec/360deg.
For half rotation = 0.84secs.
Linear speed of gripper at no load = 0.84sec.

E. Selection of guideways: The linear guide-ways were selected based on the size and functionality for the design. IGUS TS-01-20 rail and WW20 linear block was choosen.

F. *Design of jaw mount:*

The jaw mount is designed to hold the rack in place, and is connected to the LM block for linear motion. It transfers the linear motion of the rack to the jaws. It is designed to coincide the jaws by removing the offset distance between the jaws due to the pinion. The jaw mount is fixed with the jaws at the top and also accommodates a Time of flight IR sensor for measuring the distance between the jaws.

G. *Design of jaws:*

The jaws is the vital part of the gripper which holds or grasps the object to be manipulated by the robot. Designing and choosing the material for the jaws is thus very important. The jaws will take the gripping force generated during the grasp, and hence it must be having higher yield strength to prevent plastic deformation or failure. Hence bending stress is calculated for the jaws and jaw mount to select the material for the jaws and jaw mount.
Bending stress of the jaw mount.

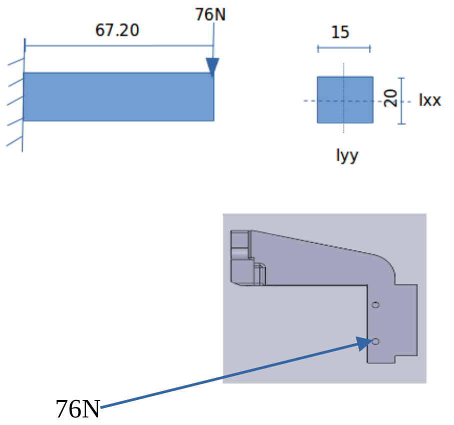

Fig4: Bending stress of jaw mount

- Bending stress = $\frac{M\,Y}{I}$

M = moment of inertia about a fixed point.
Y = distance from fixed point
I = moment of inertia about an axis.

$$I_{xx} = \frac{b\ h^3}{12} = \frac{20\ X\ 15^3}{12} = 5625mm4$$

$$\text{Bending stress } \sigma_x = \frac{MY}{I} = \frac{76\ X\ 67.20\ X\ 7.5}{5625} = 6.80MPa$$

$$I_{yy} = \frac{h\ b^3}{12} = \frac{15\ X\ 20^3}{12} = 10000mm4$$

$$\text{Bending stress } \sigma_y = \frac{MY}{I} = \frac{76\ X\ 67.20\ X\ 7.5}{10000} = 3.80MPa$$

Material used for jaw plate: Al-2024 whose yield strength is 75MPa respectively.

F. Bending stress of jaws;

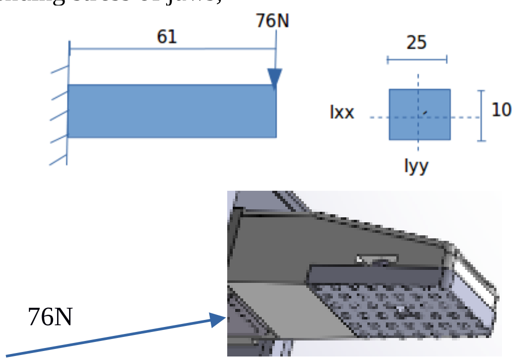

Fig5: Bending stress of jaw

$$I_{yy} = \frac{h\ b^3}{12}$$

$$I_{xx} = \frac{25\ X\ 10^3}{12} = 2083.33mm4$$

$$\text{Bending stress } \sigma_x = \frac{M\ Y}{I} = \frac{76\ X\ 61\ X\ 5}{2083.33} = 11.12MPa$$

$$I_{yy} = \frac{hb^3}{12}$$

$$I_{yy} = \frac{10\ X\ 25^3}{12} = 1085.06mm4$$

$$\text{Bending stress } \sigma_y = \frac{MY}{I} = \frac{76\ X\ 61\ X\ 5}{1085.06} = 21.36MPa.$$

Jaw material–aluminium-2024 whose yield strength is 75MPa and hence the design is safe by a factor of safety 3.

IV 3D model of gripper

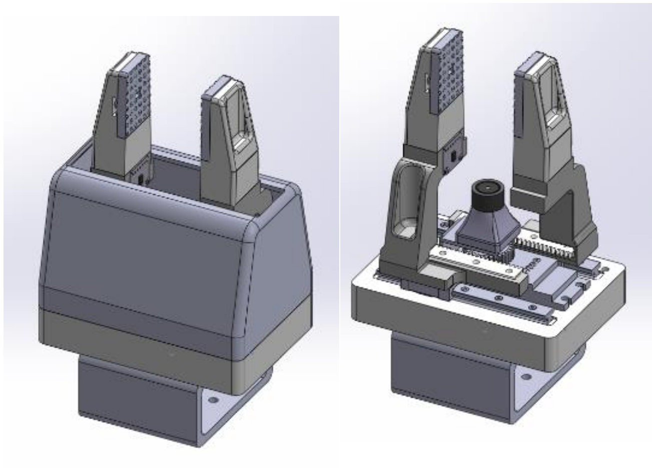

Fig6: 3D model of smart gripper

V Smartness in the gripper:

various sensors have been accommodated in the gripper to provide various feedbacks and make the gripper smart and hence achieve high efficiency in machine tending and retail applications. The following sensors have been integrated in the gripper.

1. Force feedback sensor to give the gripping force.
2. Time of flight IR sensor to sense the offset distance before grasping the object and to know whether the object is picked up or not.
3. IR range sensor to make the object centered to the gripper fingers, to detect if object is picked and to detect if the object falls during the cycle.
4. Camera to get the visual feed of the object and align accordingly.

A. Electrical circuit design: An electrical circuit consists of various electronic components like resistors, capacitor, diodes and transistors connected by a wire, through which current flows in the circuit. The electrical circuit was designed by choosing a controller for controlling the servo and and sensors. The controller choosen is a STM32 arduino board. The STM32 family of 32 bit Flash micro controllers based on the ARM Cortex M processor is designed to offer new degrees of freedom to MCU users. It offers a 32 bit product range that combines very high performance, real-time capabilities, digital signal processing, and low power, low voltage operation, while maintaining full integration and ease of development. The components of the circuit are connected based on their communication and operating voltages. The STM32 controller will be programmed to operate by taking inputs from sensors when it receives control signal from the robot and the written logic will give operate the servo motor accordingly which in turn moves the jaws.

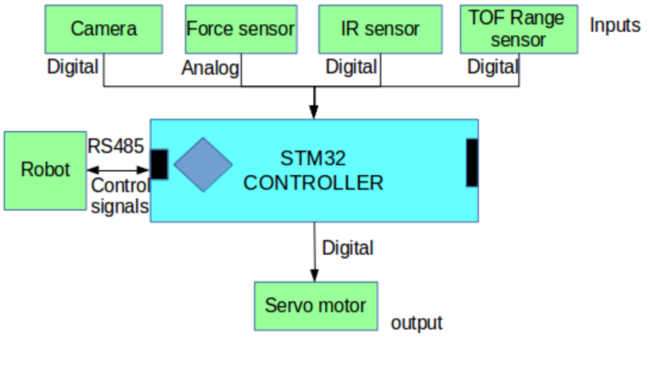

Fig 7: Electrical Diagram

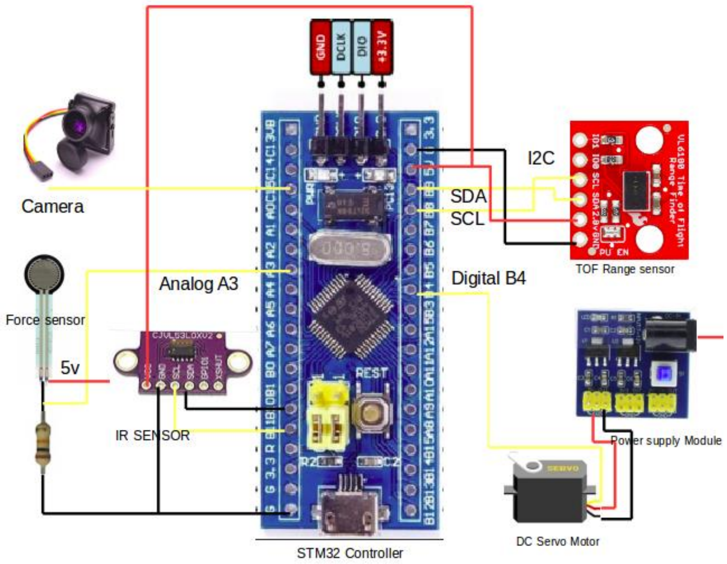

Fig8: Electrical wiring diagram

V. CONCLUSION

The customized design of the new robotic gripper will improve productivity and efficiency of robots in production and material handling applications in industries. The gripper is robust in design and will be manufactured and tested for the same. Further the gripper will be implemented with optical navigation sensor to detect slips and apply adaptive grasping.

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