SIX-LINK GRIPPER FOR CYLINDRICAL OBJECTS

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SUMMARY: The importance of concentric handling of cylindrical objects is stressed. Reliability of clamping is underscored as a criterion in gripper design. The need to develop grippers that are rugged, compact, and which are able to apply large grasping forces, in addition to satisfying the requirement of concentric gripping of cylindrical objects is emphasized. A pneumatically actuated, force-intensifying six-link gripper is introduced that also features concentric gripping. Optimization of the configuration of the gripper is described, and results are discussed. It is concluded that the optimized gripper possesses favorable features, when compared to the initial solution, as regards its operational range as well grip-force intensification characteristics. Several finger configurations for the gripper are addressed.

Key Words: Concentric gripping, design, force, gripper, link, robot.

INTRODUCTION

As a rule, grippers of industrial robots comprise rigid links, and are linkage-actuated (1). Fingers may undergo rotation, as in scissors-type grippers, or translation, as in the case of rack-and-pinion drives, or curvilinear translation (CT), as in the case of using a parallelogram mechanism. Transformation of the linear input from a pneumatic or hydraulic actuator into rotary finger motion is generally carried out by means of lever-type mechanisms, and by rack-and-pinion arrangements. Surveys of grippers currently in use are available (2,3).

As for the workpieces that robotic grippers handle, cylindrical workpieces have been identified (4) as the predominant ones in the manufacturing industry, followed by those with prismatic shapes. About 98% of all parts involved in machinery can be handled by a two-fingered gripper (5).

The prevailing state of the art of gripper technology as regards the handling of cylindrical workpieces is essentially represented by the rack-and-pinion type gripper, which comprises two rigid fingers that are translated by means of rack-and-pinion arrangements. Due to the inherently fragile and bulky nature of the rack-and-pinion type gripper, it is concluded (4) that this gripper is mechanically unfit for harsh industrial environments. Researchers are at work currently, trying to come up with suitable substitutes (4,6-9). The idea is to succeed the line-contact rack-and-pinion arrangement by the sturdier surface-contact designs that employ prismatic or pin-joints.

During this replacement process it would be desirable naturally, not to compromise on the main strength of the rack-and-pinion gripper, i.e., its ability to grip cylindrical objects concentrically. Concentric handling of cylindrical objects is a vital gripper requirement, and is related to the avoiding of the perturbance of wokpieces of different diameters during the grasping process by, say-V-notched fingers.

An alternative gripper is the curvilinear translation (CT) gripper. This device maintains the parallelity of its jaws

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during closure, and therefore can handle work pieces of prismatic shapes. Because of the curvilinear nature of the jaw-closing action, however, concentric gripping of cylinders of various diamaters is normally not possible.

Ways are addressed (4) to design special jaw contours to enable the concentric handling of cylindrical workpieces regardles of their diameters by CT grippers. Being all pin-jointed, these are simpler in construction and are more rugged than most of the existing (rack-and-pinion type) parallel-closure grippers. It is shown (4) that tilting-jaw and CT grippers achieve very similar concentric gripping effects. But the CT gripper is simpler mechanically than the tilting-jaw gripper, and is there fore to be preferred.

It is noted (4) that scissors or tongs-type grippers are also capable of concentric gripping when fitted with the same jaws as the CT gripper. Although the scissors or tongs-type grippers are simpler than the CT gripper, they are not as versatile, since they cannot easily handle prismatic workpieces.

We must point out in summary, that the rotational finger type as well as curvilinear-translation (CT) type grippers that have been proposed as substitutes for the rack-and-pinion gripper do not strictly and sufficiently meet the requirement of concentric gripping. More specifically, the requirement that rotational-finger type and CT grippers be able to handle cylindrical objects concentrically is tantamount to compelling the designer to custom-design fingers with complicated curvilinear finger contours (4).

FORCE CONSIDERATIONS

The reliability of clamping is a significant criterion in gripper design, i.e., the workpiece must not fall out of the jaws, and must be stable in its orientation. The intensification of the clamping force is, for most products, the only practical way to improve the reliability of clamping (7). This is especially true for strong and stiff parts, such as steel forgings, large castings, bar stock, and thick-walled tubes. Strong grips are also required where the gripper is to perform technological operations, such as assembly operations, where insertion of parts into seats may require considerable axial forces.

Champing force may be increased by increasing the capacity of the drive, or alternatively, a means may be used to intensify the available force. Because most grippers have pneumatic drives, an increase in power normally involves an increase in dimensions, and hence in weight.

A major priority in contemporary gripper development is to evolve improved designs that are rugged and compact, and which are able to apply large grasping forces, in addition to satisfying the requirement of concentric gripping of cylindrical objects. Mannaa and associates (8) propose a set of design criteria for grippers. Theirionditons imply, in part, that (a) the work-piece, irrespective of

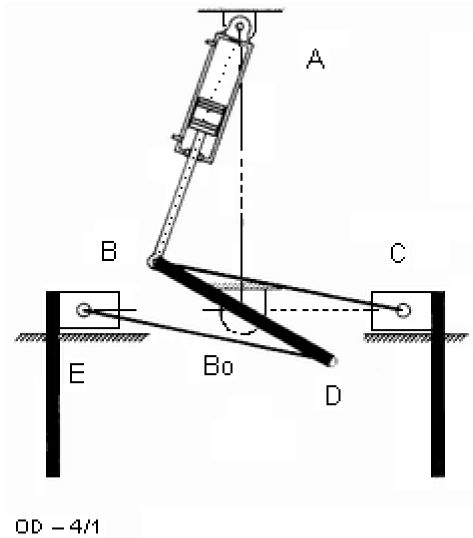

Figure 1: A concentric gripper with force intensification.

its diameter, will not be disturbed during the gripping process and, that (b) the fingers will not be required to possess special jaw profiles other than a V-notch. They further stress the desirability of evolving-new gripper

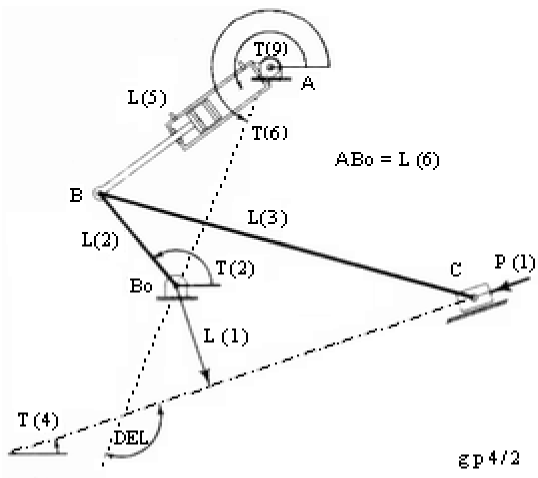

Figure 2: General layout of the gripper to be optimized.

designs that embody force-intensification techniques for the purpose of securing reliable grips.

Resolving for pneumatically-actuated linear actuators as inputs, Mannaa and associates (9) investigate the behaviour of a number of original gripper designs that conform to their design criteria (8), Figure 1 (9) shows a compact six-link mechanism with a linear input, and which meets all design criteria. We continue the study of this mechanism below.

GRIPPER OPTIMIZATION

Consider the general configuration of Figure 2, where member AB represents a swinging linear actuator, and the finger is assumed to be an integral part of slider C (Figure 1). T(2) and T(9) are the inclinations of the rocker BoB of length L(2) and the actuator of variable length L(5), respectively. T (4) is the angle that the slider axis makes with the horizontal. All angles are positive as shown. DEL is the fixed angle between T (4) and the inclination T (6) of the length L(6) of frame Abo. Ecentricity L (1) and piston force P (1) are positive as shown.

It is assumed that a constant force of 1000 units is applied by the actuator in the direction T(9) (Figure 2). The length L(2) of the rocker is unity. The object is to determine that gripper configuration which maximizes the grip force over the entire range of operation of the gripper. The objective function, therefore, involves the lengths L (1), L(3), and L (6) as well as the angles DEL, T (2) and T(4). L(5) is to be considered as an input variable. It is to be noted that the grip force will be opposite in direction to the indicated direction of P (1) for external gripping, and that T(6)= T(4)-DEL.

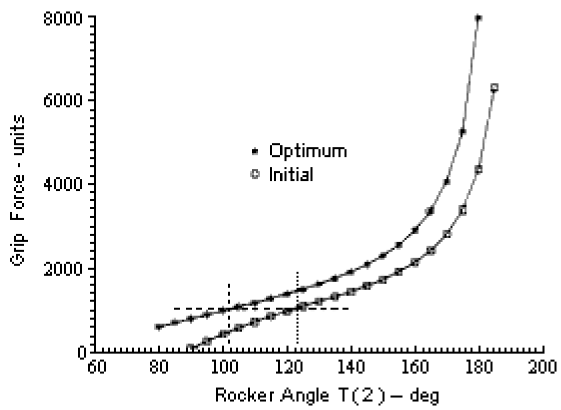

Figure 3: Grip force in the initial and optimized gripper.

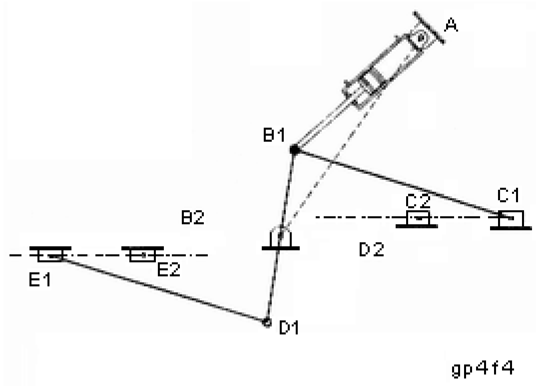

Figure 4: Final configuration of the optimized mechanism.

The optimum configuration of the gripper can be shown (10) to be as follows: L (1) = -0.21, L(3)=2.56, L(6)= 2.77, DEL=125°, and T (4)=1°. Figure 3 depicts the variation of grip force with rocker angle T(2) on the optimized gripper (Figure 4) along with a gripper of the initial dimensions L (1)=-1, L (3)=5, L (6)=2, DEL= 91.7°, and T (4)=0° (not illustrated).

SIZING OF THE OPTIMIZED GRIPPER

Scrutiny of Figure 3 makes it clear that grip force exceeds the 1000 unit mark at about T(2)=100°. Grip force continues to rise above this value as T(2) increases, reaching the 5000 unit level when T(2)=175°. The rate of increase of grip force above T(2)= 175° is observed to be very high, until the toggle position is reached.

Clearly the application of extremely large grip forces may damage either or both the workpiece and the gripper. Since such a situation is to be avoided, we resolve to limit the working region of the gripper to rocker angles between 100° and 175°. In practice the jaws will be free to move in the region 80° to 175°, the preliminary region from 80° to 100° being for pre-gripping play between the fingers and the workpiece. Motion of the gripper beyond T(2)=175° will be prevented by means of a mechanical stop.

For the purposes of the present study it was decided to select L (2) as 80 mm. This results in an actuator stroke of about 118 mm. The dimensions of the gripper become, accordingly,

L (1)= -17 mm L(2)= 80 mm L(3) 205 mm

L (6)= 222 mm T(4) = 0.1° T(6) = -125°

It is demonstrated readily that the corresponding total "stroke" of each finger is about 84 mm. The total working

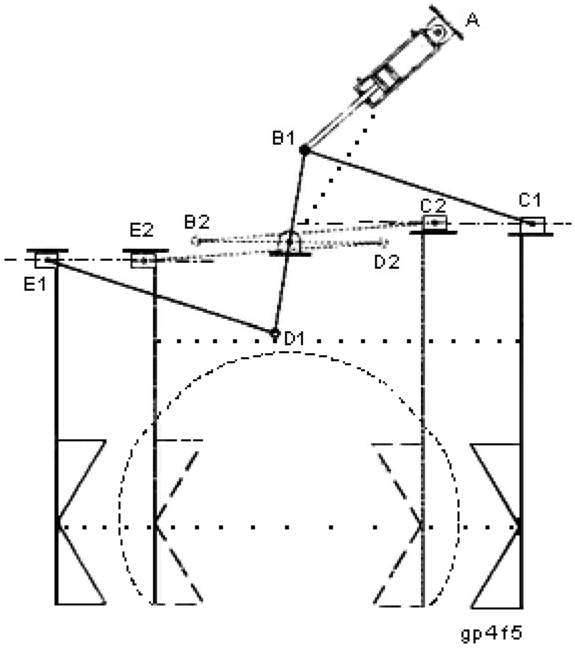

Figure 5: Configuration A for V-notched fingers.

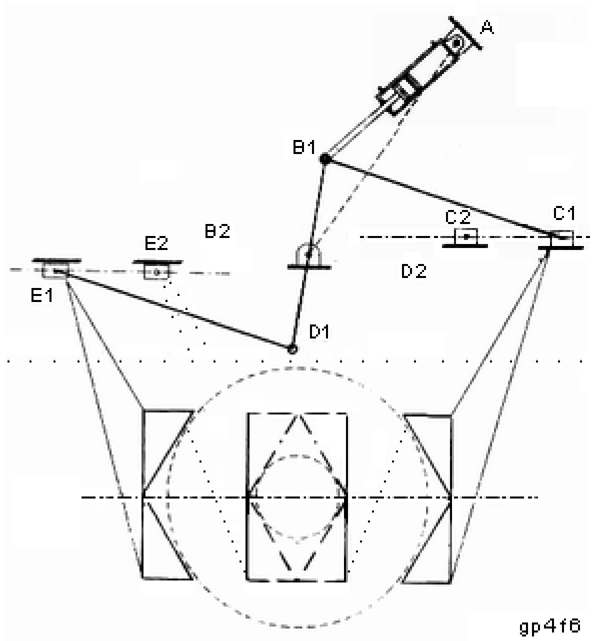

Figure 6: Configuration B for V-notched fingers.

stroke per finger, within which workpieces may be gripped, is observed to be 50 mm. This indicates that as far as finger stroke is concerned, the gripper is capable of gripping workpieces within a spectrum extending from a given minimum diameter D to that of a maximum diameter D+100 mm.

Figure 4 is a scale drawing of the final configuration of the optimized gripper at its extreme positions for gripping.

CONFIGURATION OF FINGERS

Referring to Figure 5, it becomes clear that the workpiece (shown dotted) must not approach the gripper base beyond the horizontal dotted line due to possible interference by the rocker. Assuming that the fingers are fashioned as vertical rays that emanate from the sliders (Configuration A), it is concluded that the maximum and minimum allowable diameters of the workpieces are represented by the two dotted circles for the notch-and-finger configuration shown. The minimum worpiece diameter in this case is about 190 mm, and the uppermost diameter is in the region of 280 mm. The maximum diameter is limited by the horizontal dotted line. The distance of the notch vertex from the rocker pin is 240 mm.

When the fingers are tilted toward the center so as to touch each other at the closed position, as shown in Figure 6, the minimum workpiece diameter (shown dashed) is considerably reduced, and becomes about 65 mm for the same notch configuration. The maximum workpiece diameter (shown dashed) for Configuration B is 209 mm. These are to be compared with D_{min}= 190 and D_{max}= 280 mm of Configuration A, shown dotted in Figure 6 for ease of comparison. D_{max}-D_{min} is 90 mm in

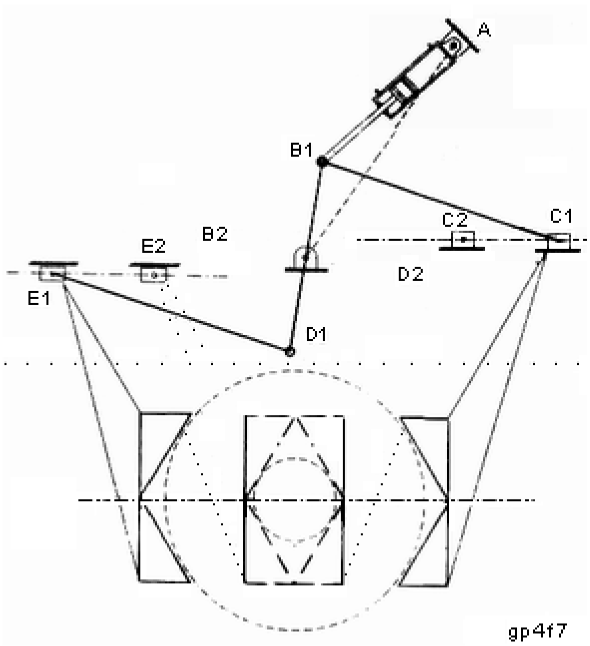

Figure 7: Configuration C for V-notched fingers.

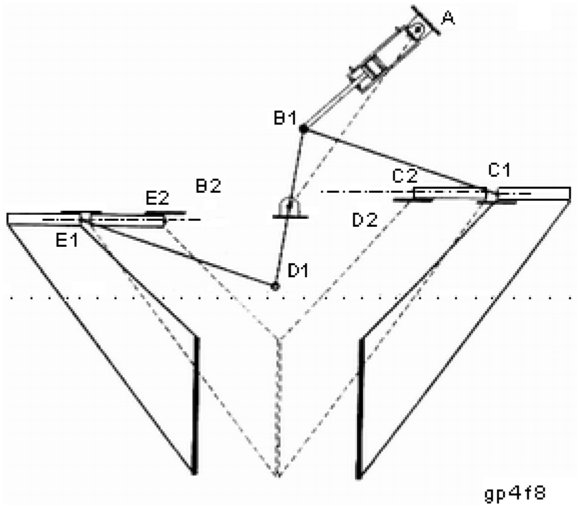

Figure 8: Jaw configuration for flat-faced fingers.

Case A, and this is improved to 144 mm in case B. The distance of the notch vertex from the rocker pin in Case B is also reduced and becomes 153 mm.

Figure 7 shows a refinement of Configuration B, where the distance of the notch vertex is brought closer to the gripper base, without affecting the D_{max} and D_{min} values. The distance of the notch vertex from the rocker pin thus becomes 116 mm.

A configuration that allows the handling of workpieces that have diameters smaller than 65 mm is depicted in Figure 8. Having flat-faced jaws, the configuration of Figure 8 allows the handling of cylindrical as well as flat and prismatic workpieces. The minimum jaw opening is zero, and the maximum opening is 160 mm.

Figure 8 further illustrates convenient ways to join the sliders to the fingers, and to connect the sliders to the driving of the bearing forces.

CONCLUSIONS

It is observed from Figure 3 that the resultant optimized gripper develops gripping forces that are, at all T (2) values, above those of the initial gripper. The optimized gripper is capable of producing grip forces higher than the actuator (input) forces over a range of about 75° of rocker rotation. This represents a 35% improvement over the corresponding range of the gripper of initial dimensions. When the range values in T (2) are converted into actual finger movement, however it is determined that the range of diameters that can be handled, by the optimized gripper is 77% greater than the corresponding range for the initial gripper.

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