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Design and production a special machine for manufacturing of regular polygons

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Abstract. For mass production of similar workpieces, the time of production and dimensional accuracy are important parameters. Accessibility to suitable quality and accurate dimensional tolerances are obtained through the use of appropriate machines and applying of right parameters. In this research, a suitable mechanism has been designed to produce the regular polygons around the circumference of circular workpieces. Meanwhile the working conditions, both the tool and the workpiece rotate around their axes and by touching the tool blades to the workpiece, the final workpiece is machined in a short time (lower than 30s) according to tolerances required. Reaching to high precision and accurate shape of workpiece is due to the use of accurate machine elements in the mechanism. In this machine, more than 150 parts such as mechanical, pneumatic, hydraulic, and electrical parts have been elaborately designed and used. In addition, presence of PLC, proximity sensors, and solenoid valves equipped by machine were attributed to production of each workpiece in desired time.

Keywords: regular polygons, design, production, mechanism, PLC controller

1. INTRODUCTION

In manufacturing industries, machines which have ability to produce high quantity of workpiece, generally called automatic machines [1]. Majority of these machines such as Swiss-type automatic screw machines which is used for turning the clock parts, can only produce a workpiece with high quality in a minimum time; however, by changing the mechanical parts, can limitedly change the type of produced workpiece [2]. In this research, the main goal is manufacturing of an automatic machine which can produce regular polygons around the rods in a short time. Figure 1 shows the workpiece.

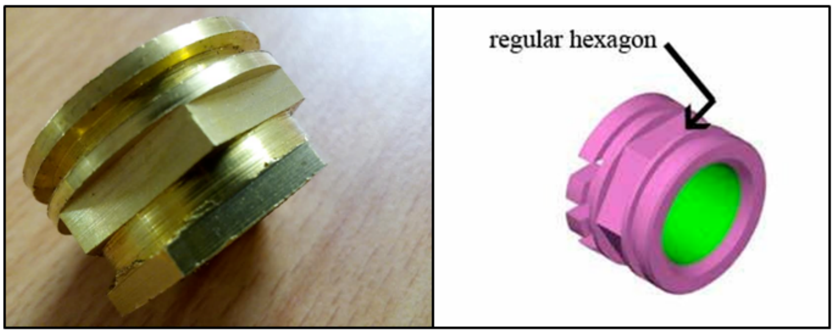

Figure 1. Production of regular hexagon around the workpiece.

Application of these workpieces is for polypropylene pipes and water connections. For manufacturing of this machine, there has had no information and this machine with its special application, has been designed and manufactured for first time.

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It must be taken into account which there are miscellaneous methods for producing of polygons, for instance, using of divider which increases the time and never complies with economical policies. In addition, there is possibility of production the polygons by forging and die cast processes, but high expenditure for making the die plus to net and maintenance the machine will restrict the using of them.

2. DESİGN OF MACHİNE

There are unique relationships in design of a tool which can produce polygon. The ratio of rotational speed between the tool and workpiece as well as the number of tool blades will result in production of different polygons. During the performed studies, it was revealed that tools with three blades can produce hexagon, also, tools with four and five blades can produce octagon and decagon respectively; however, to this time, it has not been recommended any solution for producing of two-sided polygon. Furthermore, by changing the rotational speed with same tool blades, the different polygons will be produced. For example, if a tool has had three blades and the ratio of tool rotational speed to workpiece to be considered 3:1, the enneagon will be produced in replace of the hexagon. In the present work, to produce the hexagon, a tool with three blades has been used and the ratio between the tool and workpiece has been considered 2:1, i.e. by two degrees rotating of the tool, the workpiece rotates one degree.

In the initial step, a relationship must be obtained between the diameter of the tool and workpiece, because the diameter of workpiece which the standard hexagon is produced from that is constant (SW: 28 mm) and only changeable parameter is tool diameter. In fact, if a ratio can be found between the diameter of the tool and workpiece, the main step of design has been done. Fortunately, during the design and calculation steps, the accessibility to this ratio was obtained.

Thus, for reaching to relationships AutoCAD software was used. The symbols in this design are as follows: tool diameter (D), workpiece diameter (d), curve radius (R_C), centric distance of tool and workpiece (CD_1), and centric distance of workpiece and obtained radius (CD_2).

In figure 2(a) the tool and workpiece have been shown which they have interconnected. However, the value of entrance the tool to the workpiece is absolutely arbitrary and can be every value. In fact, the goal is reaching to the curve radius (R_C) that was defined it has the same value with CD_1.

As it is seen, a small circle has obtained in the contact point of the tool and workpiece and a line has been drawn from it to the center of tool circle. In this condition, if the line is rotated 2° clockwisely, a new small circle and line is repeatedly obtained between the tool and workpiece. Thus, if the line is frequently rotated in 2° clockwisely, new circles and lines with regular and curvature distances are created. By connecting the obtained points (center of small circles), a new circle with the radius of RC is created. The important tip is the same value of this radius (R_C) with the centric distance of tool and workpiece (CD_1). Figure 2 (b) shows this properly.

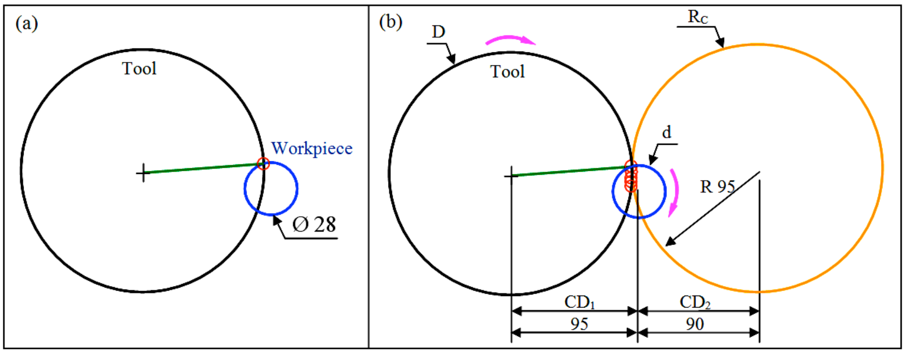

Figure 2. (a) Initial step to design the tool and the workpiece, (b) same value of RC and CD_1

By defining the points within the small circles, it was initially imagined that all points pass from a line, but the results were contrary. Then, to evaluate the results, spline and arc comments in AutoCAD were used and it was defined that all points were on an arc of a circle which its radius was equal with the centric distance of tool and workpiece (CD_1). Thus, by increasing the tool diameter, the distance of CD_1 is also increased.

It was firstly imagined during the touching of tool blades with the workpiece, the straight lines are created around the circle, and in addition, it is expected by touching the tool blade to the workpiece, a concave arc is created on the sides, but finally it was defined that touching the tool and workpiece contributes to the formation of convex are (figure 2). However, since all industrial workpieces have allowable tolerances, changing the range of these tolerances (value the convexity of SW) was obtained by changing the tool diameter or distance from blade to blade.

If the tool diameter is considered small, therefore, the centric distance between the tool and workpiece (CD_1) is also decreased and this is resulted in the more convexity of SW in workpiece, thus, by increasing the tool diameter, the CD_1 is consequently increased and the value of convexity will be reached to optimum values of tolerances recommended from customers. With regard to aforementioned details and for manufacturing the hexagon with SW of 28 mm, the radial distance of the tool was considered 76.4 mm. Figure 3 shows the final designed tool. It must be considered for manufacturing of hexagon in addition to rotational motion of tool and workpiece which rotate in a similar direction, another mechanism has been used for downward motion of the tool toward the workpiece that is described in the section 2. 2.

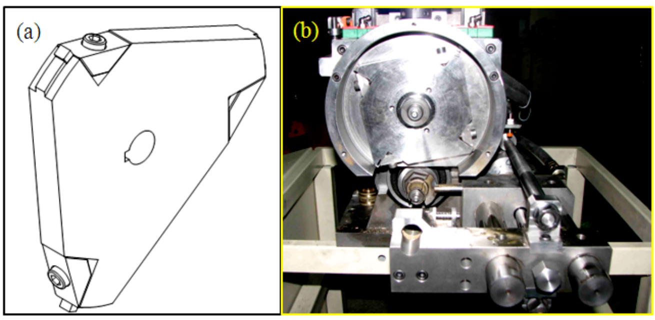

Figure 3. (a) Tool designed for hexagon turning, (b) tool used for octagon turning

2.1. The Mechanism of Clamping and Rotary Motion

Since the designed mechanism is a kind of automatic machine for machining of polygons, the time of machining is an important parameter. After the design, it was defined that this machine produces 1000 workpieces in every hour. Thus, the mechanism of clamping and holding must be designed in a way that prevent from the time dissipation. For designing the mechanism of clamping totally 30 parts were designed and manufactured as well as the hydraulic jack.

Firstly, the workpiece is embedded into the carriage and then the carriage is displaced by pneumatic force and inserts the workpiece into the clamping set. Figure 4 indicates an overview of carriage and embedded workpiece. As it is obvious, the workpiece is temporarily kept within the carriage by a pin that a spring has inserted behind it. Although, there is a groove in the workpiece before the machining that the pin of carriage is inserted within it and this helps to fix the position of workpiece. Furthermore, a sensor has been placed on the floor of carriage to detect the presence of workpiece and it gives comment to pneumatic jack for running the workpiece.

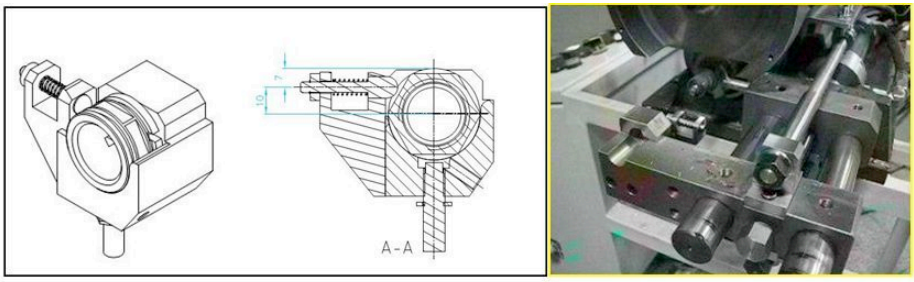

Figure 4. Method of clamping the workpiece in the carriage.

The set of clamping is based on the collet holding device, i.e. after positioning the workpiece around the collet, a moving shaft by a pneumatic jack goes backward and this contributes to opening the spring of collet and holding the workpiece in its position. The mechanism of clamping has been designed automatically, i.e. by locating the workpiece around the collet, a comment is sent by PLC (programmable logic controller) to the pneumatic jack and then the jack goes backward. Figure 5 shows the collet.

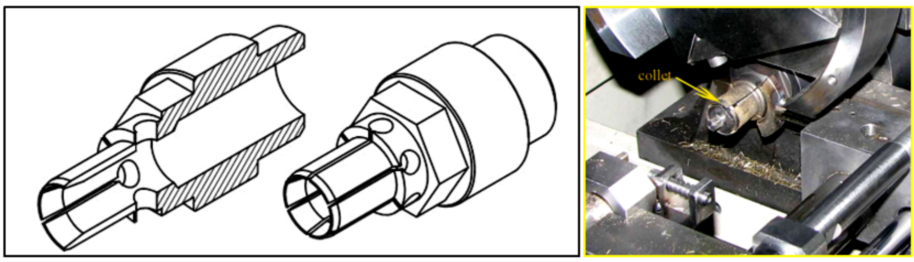

Figure 5. Collet.

For keeping the monotonous and soft motions without vibrations which are negative parameters and keep the workpiece out from required parameters, the thrust and deep groove ball bearings were used. The thrust ball bearing can absorb axial forces from both side and deep groove ball bearing can also eliminate axial and radial forces. Ball bearings are standard parts and can be selected from catalogs. Also, for holding these ball bearings and prevention from their rotation, the spring washer, pin, and adjustable screws were employed. Figure 6 indicates a section view of all clamping mechanism.

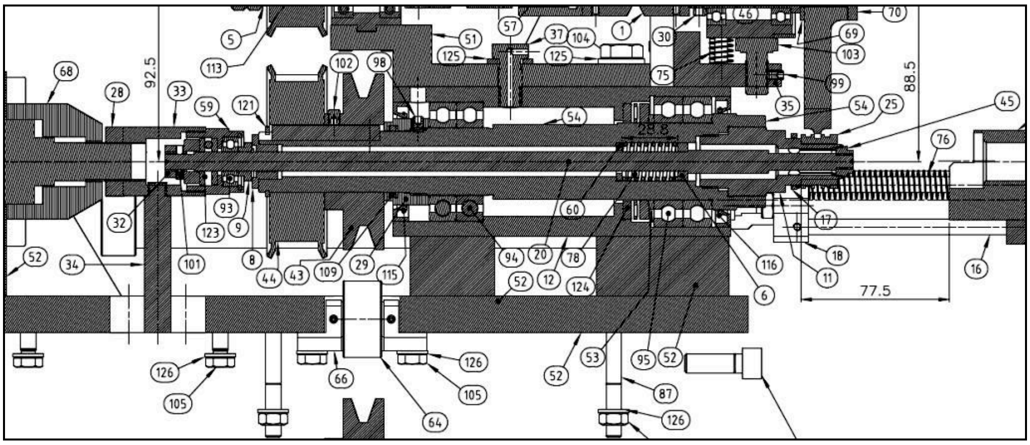

Figure 6. A section view of all clamping mechanism.

In design the mechanism of tool rotation more than 30 mechanical parts in addition to pneumatic jack (No. 14) which moves the tool toward the workpiece, have been used. Figure 7 illustrates a section view of this mechanism. The motion is transferred from the toothed belt (No. 44) to the toothed belt (No. 42) and it rotates the tool holder set. For rotation the set of tool holder and prevention from vibrations, it was fastened to the body by supports. For example, the support (No. 62) has kept the pulley shaft (No. 63) by two deep groove ball bearings (No. 91), therefore, meanwhile the rotation, the internal shells of these ball bearings are rotated and the external ones are kept constant.

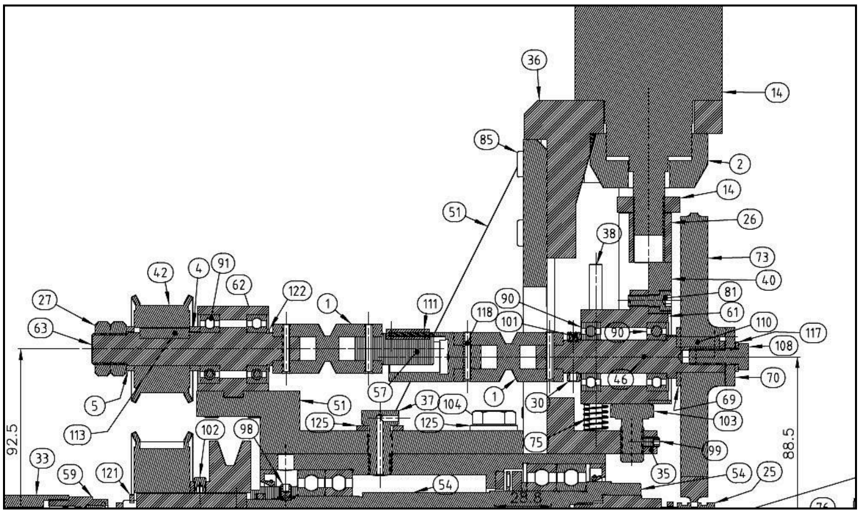

Figure 7. A section view of tool rotation mechanism.

2.2. Linear motion of the tool

When pneumatic jack (No. 14) moves downward, undoubtedly it shifts the set of tool holder downward, however, the pulley shaft (No. 63) has been fixed in some points and it cannot move when pneumatic jack moves downward. Thus, for solving this, a cardan shaft (No. 1) was used. When oblique angle between two axes is high, cardan shaft is a suitable option (usually an oblique angle between 5-15 ° is considered between two axes). When rotational speed is lower, the value of angle can be increased. In this condition, usually a universal joint is positioned between two axes. In this study, also a universal joint (No. 57) was used. This U-joint causes that both the driving and driven components to be located parallel, resulting in an equal speed between the two axes. Subsequently, when jack moves downward, the right hinge of universal joint that has connected to the tool axis (No. 46) goes downward but it preserves its coaxiality with left hinge. In this time, the tool blades touch the workpiece and by comments sent via PLC, it goes toward the target point and by an interval time in the target point, finally the form of hexagon is created around the workpiece.

With regard to Figure 7, a stopper (No. 103) has been screwed to the spring base (No. 35) and it has been fastened in its place by a socket screw (No. 99). This stopper has located in a place that tool cannot feed more than it. After downward motion of the tool until it reaches the stopper, it contracts two springs (No. 75) under the tool bearings (No. 61) and by omitting the air from the pneumatic jack (No. 14), the set of tool goes back to its initial point by spring force. Thus, the cycle of production the workpiece is frequently repeated by downward motion of the tool.

2.3. Other equipments

For transferring the workpiece toward the tool, a two-course pneumatic jack was used. This jack which has been manufactured by designer puts the workpiece around the collet by its backward motion, then it contracts the spring behind the ejector and after that the workpiece was machined during its time according to final tolerances, the contracted springs are opened by comments sent by sensors and in this time the ejector releases the workpiece into the tray. Figure 8 indicates this system.

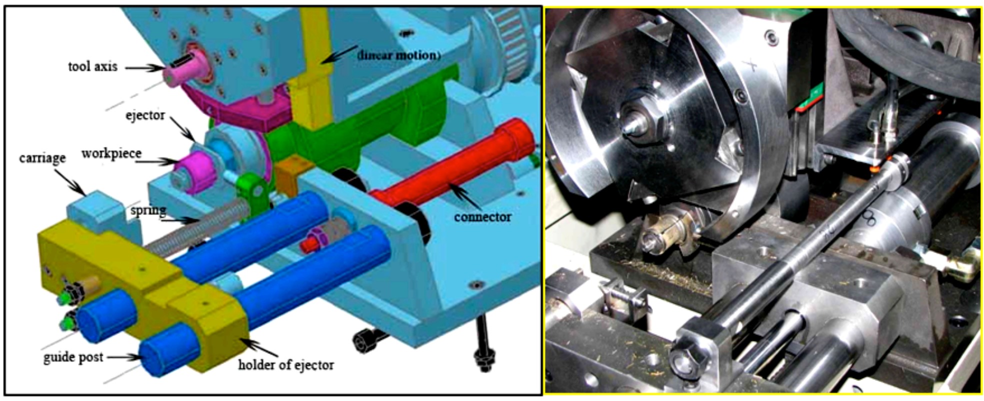

Figure 8. System elements for moving the workpiece.

With regard to figure 8, a part namely linear guide is seen. In fact, when the tool goes downward, this part keeps the linearity of the tool. They are standard parts and have more advantages than guide post, such as: lesser wear, lower clearance, more coincidence, lower cost and time of setup, and changeability. Therefore, providing some of standard parts is important than manufacturing and design of those.

Undoubtedly the design of this system has not enough precision without the usage of sensors and electrical circuits. The production of polygons has obtained by a programmed set within the machine. All comments are sent by PLC to hydraulic and pneumatic valves, while the sensors give the exact location of workpiece to the PLC. Figure 9 shows a view of these parts.

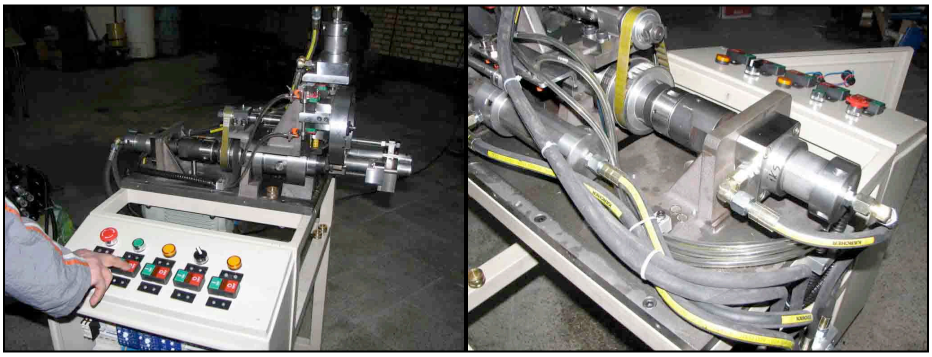

Figure 9. Hydraulic valve and hose along with the electrical box of designed mechanism.

For example, when the tool goes downward, the exact position of the tool is sensed by sensors inserted in the upper part of the machine and this position is sent to the solenoid valves. The circuit has a timer and according to machining time, the pneumatic jack holds the tool in the target point. When the machining time is finished, repeatedly solenoid valve sends comment and jack goes upward. All steps are exactly controlled by PLC. Also, motor and hydraulic pump are frequently worked by power pack. The proximity sensor has been shown in figure 10.

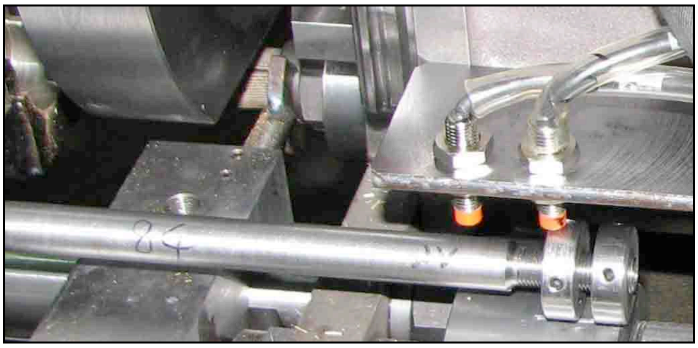

Figure 10. The proximity sensor used for moving the workpiece toward the tool.

As it was already mentioned, in addition to the design of main parts, a set of standard parts were also used for manufacturing the machine, such as: washer, bearings, spring retaining ring, spring washer, parallel key, shaft seal ring, screw, belt, and pneumatic and hydraulic parts. In figure 11 an overall view of the final machine is shown.

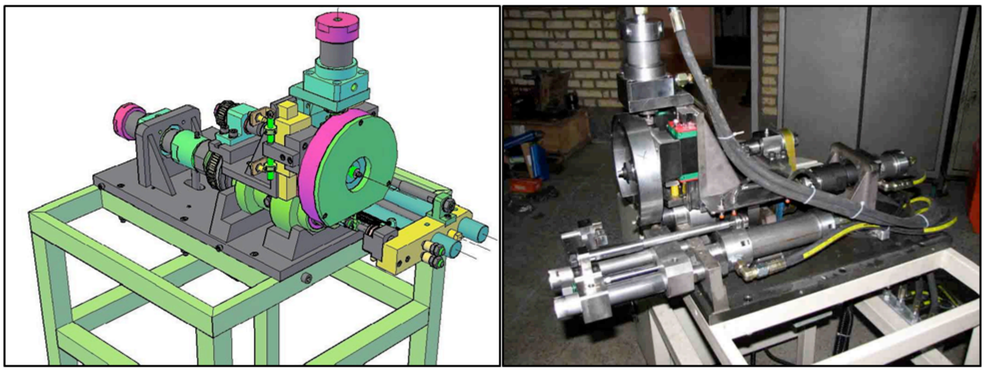

Figure 11. Final machine and mechanism.

3. CONCLUSİONS

The production of polygons was properly done by a set of mechanical, pneumatic, hydraulic, and electrical parts. Keeping right quality and dimensional tolerances after the machining was due to a balance produced between the parts of mechanism which has obtained by PLC, proximity sensors, ad solenoid valves. Therefore, design and production of innovative machines that contribute to the production of special workpiece can increase the efficiency and velocity in production industries.

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