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DESIGN FOR FOUR STATION ROTARY INDEXING TABLE USING PNEUMATICS

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Abstract - *Rotary indexing tables are used for accurate incremental indexing of a job to be machined or handled. It is used in various metal cutting and automation industries to perform many operations with precision and accuracy. This rotary indexing table will be used to primary move the component from one station to another in an accurate incremental order to perform various operations on it. There are many rotary indexing tables available in the market, but they are usually very expensive. At the same time most of the rotary tables in the market are powered either by electrical motors or hydraulics. Our company uses rotary indexing tables in many material handling equipment and custom made metal cutting machines. As of now we are using electromechanical rotary indexing tables, so this project is to develop an in-house rotary indexing table at low cost which will help us to bring the overall expenditure of the machine and reduce the dependency on vendors for the same. In this project, a new 4 station rotary indexing table will be designed along with a suitable mechanism, later on a mechatronics system will be designed to make it operational.*

***Key Words*: Automation, Indexing table, Pneumatics**

1. INTRODUCTION

Rotary indexing tables are being used for machining and automation of various processes from past few decades. We will be looking at its uses in automation industry primarily. The current project focuses in the following application areas: Automation Industry-Pneumatics can be used in any place with very less capital expenditure. They are relatively cheaper than hydraulics or electromechanical devices. So a rotary indexing table working on pneumatics will be a great aid to the low cost automation industry. Machine Tool Industry-Even though the presently proposed table will be less accurate when compared to standard models available in the market, given its low cost it can be used as a fixture in less accurate custom made tools. Special Purpose Machines-This table can be used in special purpose machines for machining, assembling or pick and place operations at low cost with a reasonable accuracy.

1.1 Objectives

Understand the present models of rotary indexing tables available and to see the various mechanism used by them to get the indexing accuracies. Designing a four station a rotary indexing table powered by pneumatic actuators using rack and pinion for its drive along with one way clutch bearing for continuous motion. Using basics of control systems to operate the pneumatic system to index the rotary table accurately.

2. LITERATURE REVIEW

A rotary table is a precision work positioning device used in metalworking. It enables the operator to drill or cut work at exact intervals around a fixed (usually horizontal or vertical) axis. Some rotary tables allow the use of index plates for indexing operations, and some can also be fitted with dividing plates that enable regular work positioning at divisions for which indexing plates are not available. A rotary fixture used in this fashion is more appropriately called a dividing head (indexing head).

One of the very first and common designs of indexing mechanism is simply utilizing two toothed coupling halves essentially consisting of two ring members having facial teeth disposed towards one another so that the two may be enmeshed to carry the indexable machine tool member relative to a fixed machine tool member. One very common such toothed coupling arrangement is produced on machines generating a Curvy tooth form, which is well-known in the art. Many other tooth forms may be employed as well to obtain the degree of precision registration necessary in the coupling. A common problem exits with the use of two multi-tooth coupling halves, which may be readily be seen in that the coupling can be indexed only to increments which are multiple of the tooth spacing. For example, when using 72 tooth coupling, having tooth spacing of 5˚, one is limited to discrete index increments of 5˚ or multiples thereof. A second problem exists in the use of a two part coupling arrangement as described, in that axial movement must be provided to the one coupling half to separate the coupling prior to index. This requirement of separable coupling halves supports a heavy machine member and thus requires great lifting power. Further, it is sometimes possible on movable machine tool members for chips to pack up between the relatively movable members. A novel improvement in the area of toothed index coupling mechanisms is shown and described in U.S. Pat. No 3,618,426, of Fisher, wherein three locating and locking elements are employed in the index mechanism. In the Fisher patent, a first coupling half having facial teeth is secured to a machine slide, and a second relatively movable coupling half having facial teeth, is mounted concentric to the fixed coupling half and rotatable movable thereto. The angularly movable coupling half carries an indexable machine member to discrete angular increments when indexed, and a third coupling half having facial teeth disposed towards the first and second coupling members, is moved into and out of meshing engagement with the fixed and rotatable coupling elements when indexing is desired. By this manner of design therefore, the indexable machine tool member need not have any axial movement relative to the fixed coupling half, since the third coupling elements acts as a keying means and it alone is moved in an axial fashion relative to the fixed and rotatable coupling halves. They are one of the earliest models of rotary tables used which use complex mechanisms as discussed. Thereafter various types of mechanical, electro-mechanical, electronic rotary indexing mechanisms were developed and they are known for providing incremental rotation of a shaft through a selected angular increment. Mechanical devices include pawl and ratchet assemblies in which a first pawl rotated a ratchet and a second pawl maintains the rotated ratchet at its end-of-movement position and detent mechanisms in which a resiliently biased detent member engages the rotated member at selected detent positions. Electrical actuators, typically in the form of solenoids and other electro-magnetic devices, have been adapted to drive mechanical mechanism to provide increased control. Lastly, electronic rotary indexing devices have used drive motors, usually of the stepper motor type, and shaft position sensor to provide a wide range of control including control of the size of the rotary increment and the precise end of movement location of the rotated member. While prior rotary indexing mechanisms and devices have been satisfactory, many of the mechanical and electro-mechanical mechanisms do not provide for the precise end-of-movement position of the rotated member or an ability to adjust the end-of-movement position. Additionally, some prior devices apply a non-uniform force to the rotated member as it is incremented. Electronically controlled indexing motors and their related control circuitry do provide precise incrementing and end-of-movement position control but are oftentimes too expensive for many applications. Hence there is a need for cheap and accurate rotary indexing tables.

3. DEVELOPMENT PROCESS

As discussed before, this project is about developing a low cost rotary indexing system using pneumatics. This was chosen as topic since we manufacture special purpose machines and material handling equipment in which we use rotary indexing tables most of the times. Presently we are purchasing it from the rotary indexing table manufactures. Rotary indexing tables are expensive and need specific electrical components for it to run since the rotary tables which we presently use run on electro-mechanical systems like shown below in Fig 1. But our machines mostly run on pneumatics other than the rotary table, which run on simpler and cheaper electrical components. So it will help us save in both ways by manufacturing it and reducing the costs on the electrical components.

Fig -1: Cam driven electromechanical rotary table

After a few brain storming sessions it was decided that Ratchet and Pawl mechanism will be used for getting the repeated accuracy for each time the table indexes. As per this a sample design was created. After studying the design as shown in Fig 2 was made. After looking at the profile of the ratchet it was decided that it is too difficult to achieve the required accuracy of the profile and at the same time this system needs a cam attached to the ratchet. Both the cam and ratchet cannot be manufactured as a single part. Two different parts are to be made and fastened during the assembly. Hence this design was rejected since the in-house manufacturing team wasn't sure about the accuracy of the ratchet and even the in-house machinery wasn't capable enough to manufacture it.

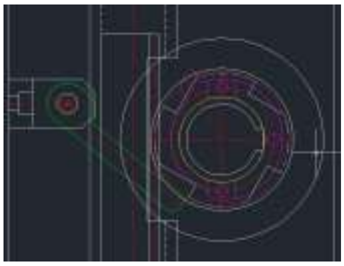

Fig -2: Top view of pawl & ratchet mechanism
Ratchet is in magenta and Pawl in green

In this system a single pneumatic cylinder moves a guided rack which in turn moves the pinion. Pinion has a one-way bearing inside it and is assembled onto the main shaft. On the main shaft, the ratchet is placed above the pinion. The ratchet is fixed to the cam. A spring loaded pawl is independently placed on the side to match the profile of the ratchet. The cam pushes the pawl at the start of each index and allows the ratchet to move forward. And this cycle repeats, the accuracy is all dependent on the profile of the ratchet. The profile needs to be created on an EDM wire cut machine which is not available in-house and the machine accuracy of the vendors can go for a toss. Hence this system was rejected. Post this, it was decided that a simpler and an easier mechanism should be used. A new proposal was designed after a prolonged brain storming session and a simple mechanism was chosen for the same. In this design instead of one pneumatic cylinder, two cylinders will be used. One of them is to drive the rack and the other cylinder will be used as a stopper for accurate indexing. Based on this principle, a new design was created as shown in Fig 3.

Fig -3: Top view of new design with stopper block and cylinder

In this system, rack moves forward with the help of a pneumatic cylinder and in turn rotate the pinion. A one way bearing is fitted inside the pinion and these both are assembled onto a guided main shaft. The guided shaft is connected to the table top plate. This table top plate has four stoppers. There four stoppers are separated by 90˚ each accurately. Once the cylinder feed is given the rack moves and rotates the pinion. Pinion fitted with the one way bearing only allows the main shaft to move in one direction. The main shaft rotates in table top plate in return. The stopper block as shown in Fig 3 has a stopper hammer. This hammer moves up and down with the help of a pneumatic cylinder. The stopper hammer moves up once the rack leaves its initial positon after a certain time delay. This stopper hammer collides with one of the four stoppers and tables get indexed accurately. Once the processes of all the stations are over the stopper hammer goes down and the rack moves forward again. This keeps on repeating and this how the table works.

4. ASSEMBLY AND WORKING

The following preliminary data was considered before designing the 4 station rotary indexing table:

1. Diameter of the top plate (d): 400mm
2. Thickness of the top plate (t): 20mm
3. Mass of top plate(m): 19.72kgs (d= 400mm & t= 20mm)
4. Height of the top plate from base (h): 276mm

All these parameters are taken from the previous equipment we made so that this table can be used for similar equipment. These parameters mentioned above are preliminary data and they form certain constraints for designing this rotary table. Many more factors and data needs to be considered before designing and detailing this rotary table. A rotary table has various parts and they are explained with the help of drawings of the sub-assemblies designed for this rotary table. So this rotary table has 4 subassemblies, namely: Rack and Housing sub-assembly, Transfer shaft sub-assembly, Stopper block sub-assembly, Top plate sub-assembly. These are the four subassemblies when assembled together make this rotary table complete mechanically. The rack and housing sub-assembly is the one in which the bottom bearing and rack guide are assembled onto. Then the cylinder with its mounting bracket and rack are guided into the rack guide and fastened. In the transfer shaft sub-assembly the main shaft of the rotary tables is assemble with deep groove ball bearing, one way clutch and pinion with one more one way bearing inside it. This shaft rotates and moves the indexes the rotary table. Here the linear motion gets converted into rotary motion. Stopper block sub-assembly is for stopping the rotary motion provided by transfer shaft at the exact location needed as per the requirement. This comes with a cylinder and guided hammer block. Then the final sub-assembly is top plate sub-assembly, in this the top plate along with the adapter and four stopper bushes are fastened and assembled onto the rest of the table to complete the rotary table assemble. The assembly drawing of the rotary table is shown in the Fig 4 below.

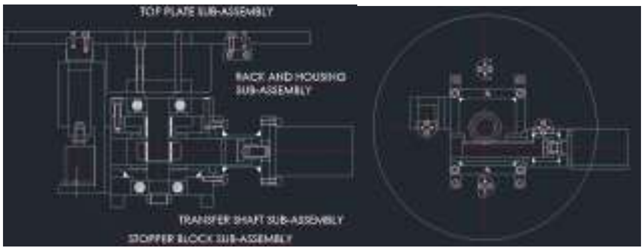

Fig -4: Front & Top view of rotary table

4.1 Rack and housing sub-assembly

Rack and housing sub-assembly is the most basic sub-assembly onto which the all the other sub-assemblies are fastened and fixed. This sub-assembly has the main housing bracket, onto which rest of the parts are fixed. This is a welded bracket which is open from top. Onto this bracket rack along within the rack guide are assembled from the left side. Over this the cylinder mount bracket along with the rack cylinder and it's connector are fastened onto the housing. A deep grove ball bearing is fitted into the bore provided on the bottom side of the housing bracket. All of these are mounted on the housing mounts; these mounts are provided to fasten the whole rotary table onto a base or a frame. With this the sub-assembly of rack and housing sub-assembly is complete.

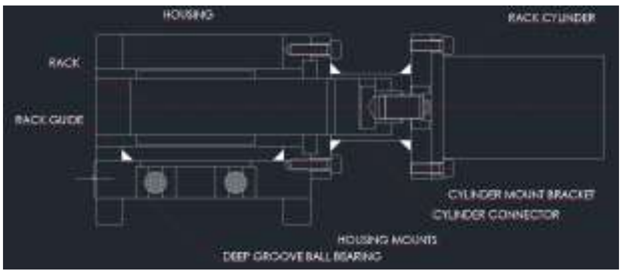

Fig -5: Rack and housing sub-assembly

4.2 Transfer shaft sub-assembly

This is the main shaft onto which various components are assembled and this sub-assembly by which the linear motion of rack and its cylinder gets converted into rotary motion of the rotary table. Firstly, a deep groove ball bearing is press fitted into the top plate. The clutch housing along with the press fitted one way bearing is fastened from bottom side onto the top plate which is already press fitted with deep groove ball bearing. Both these components are assembled and pressed from the bottom side of the transfer shaft till the deep grove ball bearing inside the top plate touches the flange of the transfer shaft. Then pinion along with a press fitted one way bearing is again assembled and pressed from the bottom side of the transfer shaft till the pinion crosses the circlip groove provided on the transfer shaft to hold pinion in its place. Then the circlip is fitted in its groove to complete the transfer shaft sub-assembly.

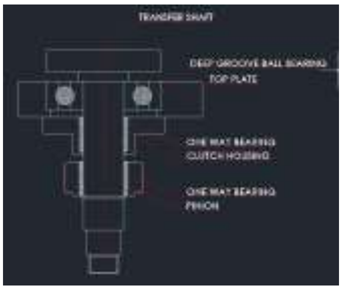

Fig -6: Transfer shaft sub-assembly

4.3 Stopper block sub-assembly

This sub-assembly is for stopping the rotary table accurately at its required position. In this rotary table, unit indexes four times before a rotation is complete and this is achieved by this stopper block sub-assembly. This sub-assembly has five parts. The stopper hammer is fixed to the stopper cylinder and this is inserted and fixed on the stopper block. To guide the hammer a cover plate is fixed to the stopper block, which guides and covers the stopper hammer. This sub-assembly is fixed to the rack and housing sub-assembly on the left side and spacer is inserted in between then for any adjustments during the assembly. With this the stopper block sub-assembly is complete.

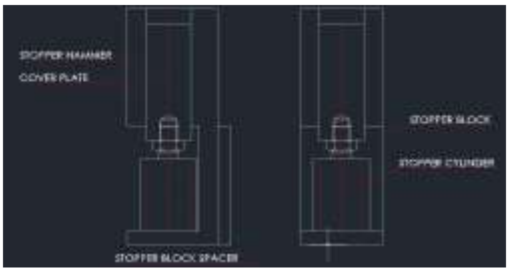

Fig -7: Stopper block sub-assembly

4.4 Top plate sub-assembly

This is the final sub-assembly with four parts. The top plate is fixed onto the adapter. The top plate has four bored holes to accommodate four stopper bushes which are fixed with stopper pads. These stopper pads come with fitting allowance for any adjustments during the assembly stage for accurate end position of each index of the table. So the four stopper bushes are fastened and fixed into the bottom side of the top plate.

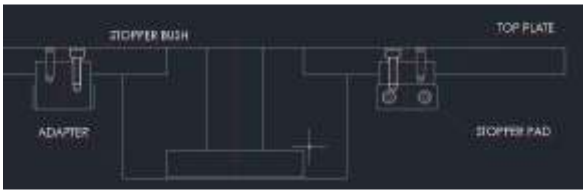

Fig -8: Top plate sub-assembly

4.5 Final assembly

After all the sub-assemblies are ready, first the transfer shaft sub-assembly is press fitted into the deep groove ball bearing of the housing sub-assembly. It is completed hammered into the deep groove ball bearing till the bottom step of the shaft rest on the bearing. Then a lock nut is fastened onto the shaft to constrain the shaft from moving up and down. Then the top plate assembly is fixed onto the top side of the transfer shaft. After this the stopper block is fastened from the left side to complete the assembly. The stopper space is reworked to match the center of the stopper hammer to the center of the stopper bush. Then the stopper pad is reworked to make sure that the unit aligns with the station when indexed. This is done for all the four stopper pads at the same station. With this reference the other three stations are to be aligned for this rotary indexing table.

4.6 Working

The aim of this project is to make a simple four station rotary indexing table using pneumatics. To achieve this two pneumatic cylinders are used. All the parts and mechanisms are kept simple to make this as a low cost equipment. All the provisions for adjustments and replacements for the worn out parts is also provided in this design. So basically, the rack cylinder moves the rack which is guided in the rack guide. When the rack moves, it in turn rotates the pinion. The pinion is fitted with the one way bearing and assembled onto the transfer shaft. This one way bearing allows rotation of the shaft only in one direction. The shaft rotates and moves the top plate along with it. In the meantime the stopper cylinder moves the stopper hammer goes up and waits for the stopper bush with the stopper pad to hit it. Once this collision takes places, the stopper hammer holds its position and the rack cylinders goes back to its initial position. The return stroke of the rack doesn't impact the pinion as the one way bearing doesn't allow the pinion to rotate backwards. Once the rack goes back, the table is free to rotate backwards as there is no positive connection between the pinion and the shaft, to avoid this one more one way bearing is provided in the clutch housing. This one way bearing makes sure that the return motion of the transfer shaft doesn't not occur any time. Once the rack goes back the stopper hammer goes down when the next cycle starts, so that it can allow the rack to rotate the table for the next cycle. And this goes on. This is the working of this simple four station rotary indexing table using pneumatics.

5. RESULTS

The design of four station rotary indexing table has been modeled and designed in AutoCAD software. The design has claimed to manufacture with low cost automation with pneumatics and the performance has increased as per client requirements.

6. CONCLUSION

It is possible to manufacture a four station rotary indexing table using pneumatics at low cost with simple parts and mechanisms. There is clear difference in costing. This newly designed table is clearly cheaper when compared to the previous tables which we used earlier. The accuracy of this table is comparable to the previous tables we used.

7. FUTURE SCOPE OF THE PROJECT

There is still a lot of work to do for completing the design and detailing of this four station rotary indexing table using pneumatics. This is still at the stage of design proposal and needs to be analyzed further to proceed with manufacturing. Various loads and forces acting on the table are to be studied and then the detailing needs to be started. This is for the mechanical part of this table. The pneumatic circuit needs to be designed and control systems needed to control and operate this four station rotary indexing tables are also to be designed. So this project is still at the preliminary stage and needs a lot of inputs to complete it.

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BIOGRAPHIES

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