Review on Selection of Rotary indexing mechanism for high productivity

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Abstract—*Now a days machining of component within single setup is more important concept for manufacturing of any product. As single set up machining results dimensional and geometrical tolerance within specific limit, this concept with specific product like rotary table, indexing table, work holding devices, special jig and fixtures etc. with machining center is more predominate. Single setup concept will increase productivity with cost effectiveness and consistent accuracy.The paper deals with the rotary indexing mechanism which is used for getting angular motion in required time. Different types of indexing mechanism are available in market like cylindrical cam with roller follower, duplex worm gear based, and Geneva mechanism. The Paper covers in designing of indexing mechanism, cam and follower and its motion curve is major part for creating its profile for getting particular indexing with required time, accuracy and cost.*

Keywords- indexing mechanism, accuracy, cam motion curve

I. INTRODUCTION

In today's competitive manufacturing scenario, production equipment and processes play a critical role in determining productivity. The challenge is to maximize the output with given resources. In achieving higher productivity, it is necessary to improve the ratio of the output earnings to the total input cost, covering men, machines, tools, depreciation, rent, power, etc. The challenge is to find best ways to get through machine by reducing cost, increasing accuracy and less time. Efforts must be made to reduce the number of setups wherever feasible. These results in the direct Benefit of avoiding the multiple handling involved if done in too many set-up. However, this calls for additional features like indexing arrangements on the machine, with further investment. This option needs to be weighed carefully against the lost time in changing set-ups on the machine and the multiple loading times charged to the component's production cost, whether done on one machine or on multiple machines. The hidden benefit is superior component accuracy, as inter-related dimensions of different set-ups are achieved without any disturbance in between. This contributes to productivity, as it eliminates scrap and non-conformances.

Indexing mechanism are used in rotary table to index parts and components in defined, angular increments so that they can be machined, worked, or assembled in multiple operations. Tables consist of a circular steel plate, one or more spindles, a drive system, and pins that hold parts and components in place. Indexing mechanism has either fixed or adjustable indexing angles. During each revolution, the table stops for a specified period of time so that an operation can be performed at each station.[1]

Indexing mechanism is powered by pneumatic and electric motors, hydraulic drives, and manual actuation. Drive mechanisms can be located above, below, behind, or to the side of the table surface. Pneumatic mechanisms are suitable for small and medium loads. They are powered by one of more pneumatic cylinders, each of which represents an index. During the return stroke, a pawl locks the table in place. With some devices, the pawl can be adjusted to change the number of indexes. Electrically-powered mechanism is generally faster than pneumatic devices and can handle heavier loads. Rotary Indexing mechanisms that are powered by hydraulic drives use a pressurized fluid that transfers rotational kinetic energy. Manually-actuated mechanism often includes a hand crank or are loosened, turned, and adjusted by hand. For the larger sized tables drive motor (servo motor) in combination with reduction gear box and reduction pinion and gear ring.[1]

Different type of indexing mechanism are available in market like Geneva mechanism ,worm gear based mechanism cylindrical cam and follower based mechanism .In above indexing mechanism its necessary to increase productivity which is necessary for industry. Compare to other mechanisms, the structure of cam follower mechanisms are relatively compact. These mechanisms also have some special features such as: high loading capacity, low noise, low vibration, and high reliability. Hence cams have widely been used in various automatic equipments in industry. Typical usages of cam mechanisms are used in automatic assembly lines, paper processing machines, packing machines, and many other automated manufacturing devices. In selecting an indexing mechanism for a specific application, generally the parameters for its index time and inertial moments of work pieces with its table loaded at the output shaft must first be specified. To meet the total required output torque, the cam shaft torque atthe demanded rotational speed should be estimated based on the number of dwells of acomplete circle at the output shaft, index period, dimensional parameters, and the selected orsynthesized motion. In addition, to ensure a proper design for such a cylindrical cam and follower mechanism, the cam profile has to be determined so that its pressure angles, surfacecurvatures, contact stresses, and load–life can be characterized. As a result, a motor and itsreducer with an appropriate rotational speed and torque can be decided to satisfy the totalrequired output torque of a indexing mechanism. For driving the output shaft andsatisfying the required output torque, the needed cam shaft torque is transmitted through the direct contact between the cam and its engaged roller follower.

II. COMPARISON OF INDEXING MECHANISM

Inindexing mechanism different type of indexing mechanism available but widely worm gear based and cam and follower based mechanism used in rotary indexing table. For selecting between the above mechanisms, manufacturing cost and accuracy are the major parameters to be considered. In worm gear based mechanism rotary table cost around 2 lakhs to 2.5 lakhs and its accuracy is 15arc second and other cylindrical cam with roller follower mechanism cost 2 to 3 % less than worm gear based mechanism and its accuracy 12 arc sec.For selecting rotary indexing mechanisms which increase productivity with single setup, less time for indexing and less cost in cam and follower based mechanism is prominent.

B.Santoshkumar and N.Chandrashekhar Reddy suggested about the design and analysis of CNC Rotary table. They had discussed that CNC rotary table is important to enhance the productivity of and a work holding device on a machining centre used to position the components in any desired position to carry out machining on different faces of the component. They designed a CNC rotary table of size 500 x 500 mm to support and hold components weighing up to 8000 N for machining. Designed rotary table by authors had give positional accuracy of ±10 seconds with a rotational speed of 30 rpm. They focused on the design and selection of critical components like servomotor, worm gear mechanism, worm gear support bearings, bellow coupling, table support bearings, angle encoder and lock nut for preloading the bearings to meet the requirements of the rotary table. They analyzed existing geometry such as housing and pallet supporting components with ANSYS Software and determined that weldment structure is best for housing component and ribbed structure is best for pallet for rotary table. [1]

This is helpful for selection of major components like servomotor, gear, bellow coupling, table support bearings, angle encoder and lock nut for preloading the bearings and also helpful that weldment housing is best for housing of rotary table.[1]

Suresh Sanap, Ketan Jagtap, KeshavNandurkar developed globoidal cam mechanism in which globoidal cam with cylindrical rollers mounted its turret of its indexing mechanism and checked in the different operating condition which motion curve is best for very smooth indexing with minimizing vibration.[2]

There are applications in which the motion of mechanism is dictated by a special function it has to perform or by the motion of an associated mechanism .However, for high speeds efficient performance is essential to select a dynamically suitable cam motion law.[2]

III. MOTION LAWS (MOTION CURVES)

The output motion is a normalized function of the input rotation. Mathematical expressions to produce suitable follower motions are known as cam laws. There are well-known laws used for cam motions, all of which has virtues and vices. The problem is to decide which law is best suited for a particular application, or which law can be used as a standard for a wide variety of applications in different machines without departing vary from ideal. Rotary indexing mechanism Motion curves for index drives provide superior velocity, acceleration and input characteristics. The acceleration and input characteristics greatly affect the accuracy and life of index drives. Improvement of these characteristics is necessary for high-speed and high-accuracy index drives. Three motion curves considered,[2]

A. Modified Constant Velocity (MCV)
B. Modified Trapezoid (MT)
C. Modified Sine (MS)

A. Modified Constant Velocity Curve (MCV)

The constant velocity curve has a straight line displacement at constant slope. It also has the smallest cam for a given rise and provides a long stroke action. The cycloidal curve or parabolic curves have been utilized depending on the cam speed, mass of the follower, and work performed by the machine. To obtain a lower peak figure of velocity, the peak of the velocity curve should be flattened. This is to provide the constant velocity period with acceleration of zero.[2]

B. Modified Sine Curve (MSC)

The modified sine curve is a combination of quarter sine wave curves. In terms of its torsional action, the change from positive to negative torque occurs in over 40 percent of the travel time. This attribute makes this curve attractive as a choice in moving large masses such as indexing intermittent stations. Its lower torque and power demand make the modified sine curve one of the best choices of curves.[2]

C. Modified Trapezoid Curve (MTC)

A trapezoidal acceleration curve is composed of a parabolic motion combined with the cycloidal Curve. This combination reduces the maximum acceleration at the expense of somewhat higher jerk values. The modified trapezoidal curve is popular in industry. However, it has one objectionable characteristic: the torque goes from positive maximum to negative maximum in 20 percent of the travel time.[2]

Sr No	Data	Symbol	Unit	Case I	Case II
1	Application type	-	-	Start stop	Start stop
2	Cam Index period	θ	Degree	270	270
3	Weight of dial plate	Wd	Kg	40	225
4	Diameter of dial plate	D	M	0.95	1.2
5	Total Wt of work station	Ws	Kg	35	200
6	Radius of curvature	Rs	M	0.34	0.55
7	No of stations	S	-	4	4
8	Index time	t2	Sec	1.61	2.87

Table-1: Input Data for Different Cases

Motion Curve /parameter	Modified Sine MSV		Modified Trapezoidal MTC		Modified Constant Velocity MCV	
	Data I	Data II	Data I	Data II	Data I	Data II
Inertia I	8.559	101.00	8.559	101.00	8.559	101.0

Kg-m^2						
Angular Acceleration rad/sec^2	5.959	1.875	5.270	1.6585	8.632	2.71
Peak output Torque T Nm	51.00	189.4	45.10	167.50	73.88	274.3
Radius of gyration K	0.3378	0.487	0.337	0.4875	0.337	0.4875
Input Torque i/p-Nm	30.05	111.6	26.57	98.71	43.53	161.6
Input Power P i/p- hp	0.234	0.488	0.207	0.4343	0.339	0.708
Maximum Jerk m/sec^3	1741.7	307.7	1540.1	272.13	5049.4	888.3

Table –2: Results of Motion Curves

D. RESULTS FOR THREE MOTION CURVES

For comparison applications of Case I and Case II globoidal cam indexing mechanism produces controlled output acceleration /deceleration because its output shaft is at all times tightly connected to its input shaft, making the output rotation a strict function of the input Output torque and jerk are minimum for MT curve for both applications. Time period 1 is assumed for both the data in which index angle is 270 degree for input motion and 90 degree foroutput motion. From the centesimal scales prepared for Modified Sine, Modified Trapezoid, Modified Constant Velocity motion curves graph of cam angle and jerk values are obtained. The graphs obtained are shown in[2]

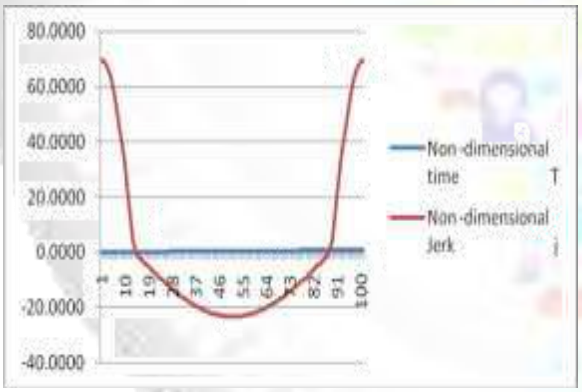

Figure 1: MSC

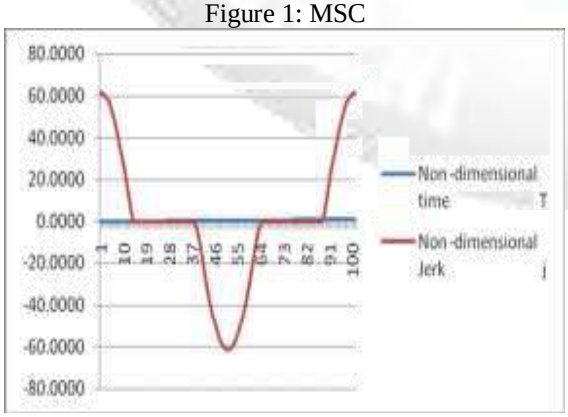

Figure 2: MTC

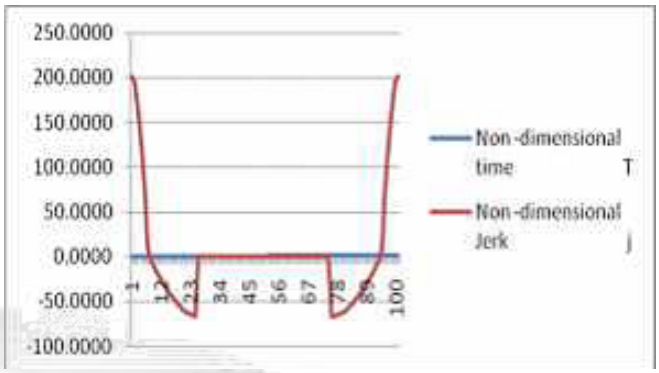

Figure 3: MCV

The above results help in selecting cam and follower motion curve in designing the cam profile and also for low load and high speed, modified sine motion curve is best for designing cam.[2]

Marian Funaru, Gheorghe Stan, Lucian Mihaila, Marius, Pascu, DragosAndrioaia suggested a new technical solution of the rotary table indexing mechanism used on milling machining centers, which offers a very high positioning precision, by using a curvic coupling and a hydraulically driven table clamp/unclamp mechanism.. The advantages of a reduced auxiliary time and reduced operating errors

They presented a precise rotary table indexing and clamping system. Indexing mechanism servo motor attached with pulse encoder which monitors the position and speed of machine tool table. The indexing mechanism of the rotary table offers a high precision and also high repeatability, by use of the precise curvic coupling and gear in the mechanism having maximum load capacity and which has a minimum indexing angle of one degree and gear and pinion shaft in transmission system manufactured in high accuracy.[3]

In this mechanism table clamp and unclamp is driven by hydraulically operated solenoid valve with proximity switch for quick and accurate position. [3]

M.B.Vaghela, V.J.Savsani, S.B.Jadeja suggested about the methodology of design and analysis of radial cam and globoidal cam of tool changing mechanism of ATC used in VMC with accurate motion by using DYNACAM 10 software.[4]

They suggested that Design and analysis of radial and globoidal cam using DYNACAM software is helpful for getting simultaneously two types of downward and upward and rotary motion of tool changing mechanism of ATC and find the kinetostatic force and toque, surface stress in cam follower and linkage design as per motion of cam. They had taken radial cam obtain very close displacement at shaft of tool changing mechanism, actual displacement is 115 mm and by using radial cam obtain 114.95 mm displacement shaft .To get exact 360 degree rotation of (270 clockwise and 90 anticlockwise) use a globoidal cam in tool changing mechanism.[4]

The design of cam help to prepare Geometrics drawing and model of cam which used to prepare maximum and minimum result of displacement, velocity, acceleration and jerk will use to determine the relative.[4]

IV. CONCLUSION

For selection of the indexing mechanism there are three motion curves MS, MT and MCV selected for study. From the result and analysis of motion curves, it is observed that for high loads and high speeds modified trapezoid is suitable, for low load and high speed modified sine is the best choice and for high load conditions and low speeds modified constant velocity is preferable. Comparing the two mechanisms, The cost of worm gear based indexing mechanism is higher and accuracy less ,and its generates backlash after long time and other cylindrical cam with roller follower gives better accuracy and its cost less as well as its not generate backlash so cylindrical cam with roller follower based rotary indexing mechanism best for rotary indexing table.

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