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Mechanism and PLC Design of Twin Spindle Drilling Machine - A Innovative Approach

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***Abstract*— The author of this paper has taken an initiative with keen interest to design an entire newly Twin Spindle Head Drill Machine currently not available in commercial market, to be exclusively used for Flange manufacturing along with other supplementary manufacturing options. The author in this paper had explained the conceptual Design of the machine and its mechanism, electrical system, PLC, interlocking and safety system.**

***Index Terms*— Clutch, Feed screw, Indexing, PLC, Spindle, Twin head.**

I. INTRODUCTION

Kinematic system in any machine tool is comprised of chain(s) of several mechanisms to enable transform and transmit motion(s) from the power source(s) to the cutting tool and the work-piece for the desired machining action .The kinematic structure varies from machine tool to machine tool requiring different type and number of tool-work motions. The present commercially viable drilling machines has limitations with respect to number drill heads and precision problems in drilling holes at the given Pitch Circle Diameter with the low cost machines. A single head has also low Production volumes and automation problems for the conventional machines.

A number of sincere attempts have been made by various Machine Tool Designers for designing low cost machine with simple automation without CNC system for high precision and mass production especially in Drilling machines but results were not too futile. A simple single head drilling utility machine has been designed by HMT Bangalore accompanied with various features, but the price of machine doesn't make it affordable for the Vendors, who serve as feeding unit to large ventures.

The author of this paper has taken an initiative to Design the affordable, precision, and mass production Drilling machine on simple PLC and basic design concepts which will be viable especially to small and medium workshops, which are specially engaged in Flange manufacturing. The author through this paper has put forwarded a unique concept of Twin Spindle Drill Head machine, to which feed is given through a single motor and drill is rotated by separate motors. The entire feeding Design, work holding system, Gear Box system is unique one. The paper will immensely benefit the designer and Machine Tool Manufacturer as such Practical and simple Design is not being currently available.

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II. Literature Survey

" Ref. [1]" Parallel Machine Tool is a new type of machine tool which was firstly shown at the 1994 International Manufacturing Technology Show in Chicago by two American machine tool companies, Giddings & Lewis and Ingersoll. These machine tools, named Hexpod, were based on the paradigm of the spatial six degrees of freedom (DOF) parallel manipulator. The parallel machine tool technology promises to offer manufacturers a number of advantages relative to conventional machine tools, such as a higher stiffness-to-mass ratio, higher speeds, higher accuracy, reduced installation requirements, mechanical simplicity, and high flexibility.
" Ref. [2]" The 6-DOFs Stewart platform is one PMT configuration that has been used in a number of new Machine Tool designs at the beginning of the birth of PMT. For machining applications, disadvantages of the Stewart platform include a complex workspace, limited orientation range of motion and a requirement of six actuators for a 5-DOFs task (milling, drilling and similar operations). Moreover, there are some disadvantages for the parallel kinematics itself, such as the forward kinematics cannot be described in closed-form, and the dimensional design is difficult, and so on. For these reasons, many researchers begin to pay their attention to less than 6 DOFs PMTs especially hybrid PMTs
"Ref. [3]" The required path accuracy of machine tools designed for micromachining is sufficiently provided by state-of-the-art machine tools, but they typically have limited feed drive dynamics. Various micro machining processes, e.g. micro-drilling, demand high jerk movements of the feed axes. The justification of additional expenses for direct drives is beyond question when high gains of the position control loops (K factors) as well as high jerk values are needed and at the same time additional masses and process forces are low. Hence, direct drives are predestined for highly dynamical micro drilling machines. "Ref. [4]" When attaching direct drives, the mechanical components of the drive system are not limiting the position controller's bandwidth, as in the case of using electro-mechanical drives . Here, the machine tool frame limits the practicable controller bandwidth and the maximum jerk value. "Ref. [5]" The present design concept for machine tool structures aims at maximum stiffness and high eigen frequencies. This leads not only to huge and heavy frames with adverse weight/workspace ratio but the frequency content of the excitation has high energy even at the high eigen frequencies.

III. Motivation

The drilling machine commercially available in the market has a limitations of drilling hole in pitch circle diameter. The costly jigs and fixtures are to be used and as the PCD changes new fixtures are required, moreover the production time is too high. The CNC commercial machine can overcome this problem but is not affordable for small and medium scale industry. In keeping the following limitations point a motivational challenge was to design a Twin Head Pitch Circle Drilling Machine, which is capable of doing same effective operation as CNC machine but with lest cost, ease in operations and low maintenance.

IV. Problem Domain

The design of the machine involves number of complexity in Mechanical design, Electrical wiring, PLC, Tooling design etc. The mechanical design of the machine should be a compact one with standard selection of materials and should be very safe, maintenance free. . The machine cycle is to be automatically controlled through various PLC commands and the system is to be designed by means of various proximity switches and relay control for turning ON and OFF the various drive motor and clutches as per the requirement and has to operate in synchronizing cycle.

V. Problem Definition

The task is to design a machine with twin spindle head which can operate simultaneously for drilling holes at a variable Pitch circle diameter with a high accuracy and precision. The machine is to operate at higher speed and feed in auto-cycle mode so that entire cycle operates in automatic mode. The machine is to be designed in absence of costly controller and drive card and only on basis of simple sensors like proximity switches and relay with high cost affordability.

VI. Statement

The task is to Design a machine capable of drilling two holes simultaneously in a flange at 180 degree apart at variable Pitch Circle diameter distance and the entire drilling cycle has to operate in automatic mode.

VII. Innovative Content

Design Principle: Pitch Circle Drilling Machine (PCDM) is a Special Purpose Machine (SPM) designed for drilling two holes simultaneously in a circular component at high speed. The two holes are drilled simultaneously by means of two separate Spindle head (Twin Head) which hold the drill tool and are feed against the work piece at an angle of 180 degree. An outline schematic diagram Fig 1 simply demonstrates the arrangement of various machine elements of Pitch Circle Drilling Machine. The machine has two independent spindles which enclose in a sub-assembly units mounted in a cast Iron bracket and are placed on two separate slides viz. Slide left and Slide right. These two slides can move horizontally on Slide main, the distance between the slides can be adjusted through Ball nut and Ball screw assembly and is equal to the Pitch circle Diameter of the job. The Main slide unit holding the both slide is mounted on the column of the machine by means conventional Wedge and Dowell pin arrangement. The main slide unit can be independently moves in a vertical direction through Ball screw and Ball nut assembly acting as a feed screw. The rotary drive to the spindle to perform the drilling operations is provided by means of separate electric motors to each spindle which can be operated individually through electric panel. The main slide is controlled through separate clutch mounted between the Gear box and Main slide.
The work holding arrangement is versatile in nature and can be held in number of ways. A rotary Indexing Table is provided which can be indexed according to the numbers of hole required to be drilled in the component and through clamping pin arrangement the table can be locked at the during the operations, the locking mechanism is a through Gear and pin arrangement. The job can be hold in a chuck, which will be mounted directly on the rotary table.

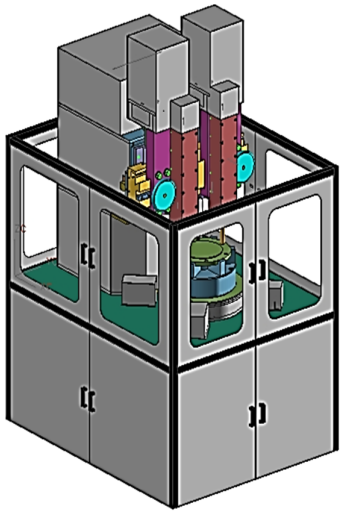

Fig 1: Layout of Machine in 3D view

IX. Problem Formulation Or Representation Or Design

Working cycle : The machine is designed on automation cycle controlled by PLC unit where only input required for operation such as job thickness, pitch circle diameter, speed, feed are to be provided and machine will automatic perform all the operations in a sequential manner without any manual interference. The system to be affordable is controlled through logical gates only without any costly computerized drive control units.
Fig 2 shows a schematic arrangement of the machine.The distance between the left and Right slide is adjusted to the diameter of Pitch circle diameter. The accurate setting of the distance is done by means graduation disc provided at the front face of the spindle. The main feed slide is driven by means of geared

motor which rotates in the clockwise direction and through gearing and clutch arrangement is provided to the feed screw. The feed screw rotates in anticlockwise direction which in turns drives the main slide in vertical downward direction. The slide holding the spindle drill is provided the rotary motion through separate motor. The drilling operation is started as soon as it touches the work piece and is continued till the preset depth of drilling has been reached. As the final depth is achieved the sensor through logical unit turns on the reverse clutch and the slide moves in upward direction. As soon as the initial set point is achieved the forward clutch turns on and the slide moves again in downward direction. As soon as slide moves in upward direction the rotary table will be indexed at required degree, so that new position can be worked out. The chips are flushed out with coolant and are collected in separate tray provided at the bottom. The rotary table basically indexed through motor and the locking of table during operation is done through locking pin which is of same shape as gear shape and locks in the tooth width. The unlocking, rotation and locking of the rotary table is through PLC unit.

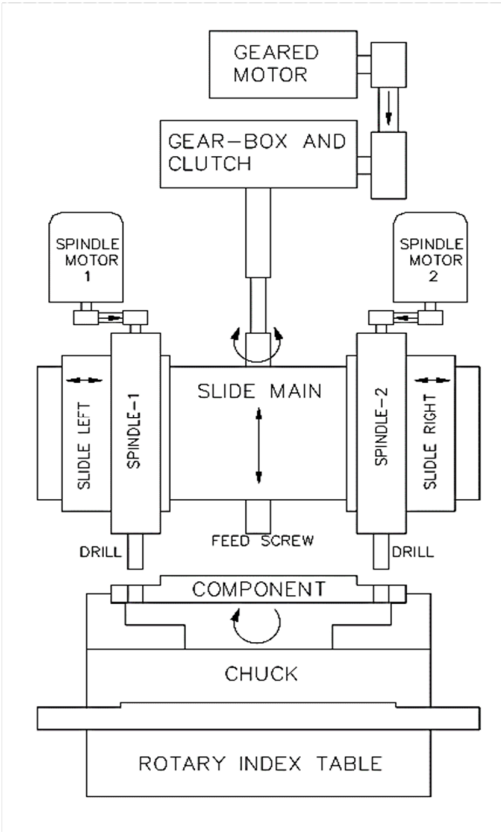

Fig 2 Working Cycle Diagram

X. SOLUTION METHODOLOGIES OR PROBLEM SOLVING

Specifications of Machine:

Hole Diameter	:	14 to 30mm
Hole Depth	:	60mm Max.
P.C.D	:	150mm Min. (Work Dia.200mm) 450mm Max. (Work Dia.500mm)
No. of Holes	:	1 to 24
Drill	:	Sandvik Coro drill with replaceable inserts
Spindle RPM	:	400 to 1600
Spindle Power	:	4kW x 2 Spindles
Cutting Speed	:	40-70 m/min.
Cutting Feed	:	0.08-0.12 mm/rev.

Feed Power : 1.8kW
Spindle Motor : Model No. BN112M4 (4-Pole), 4kW.
Feed Motor : Geared Motor 1.8kW, Output RPM-58
Coolant Motor : 0.37kW
Control : Programmable Logic Controller
Rotary table : 24 positions Electro-Pneumatic Controlled
Accuracy : +/- 0.05mm

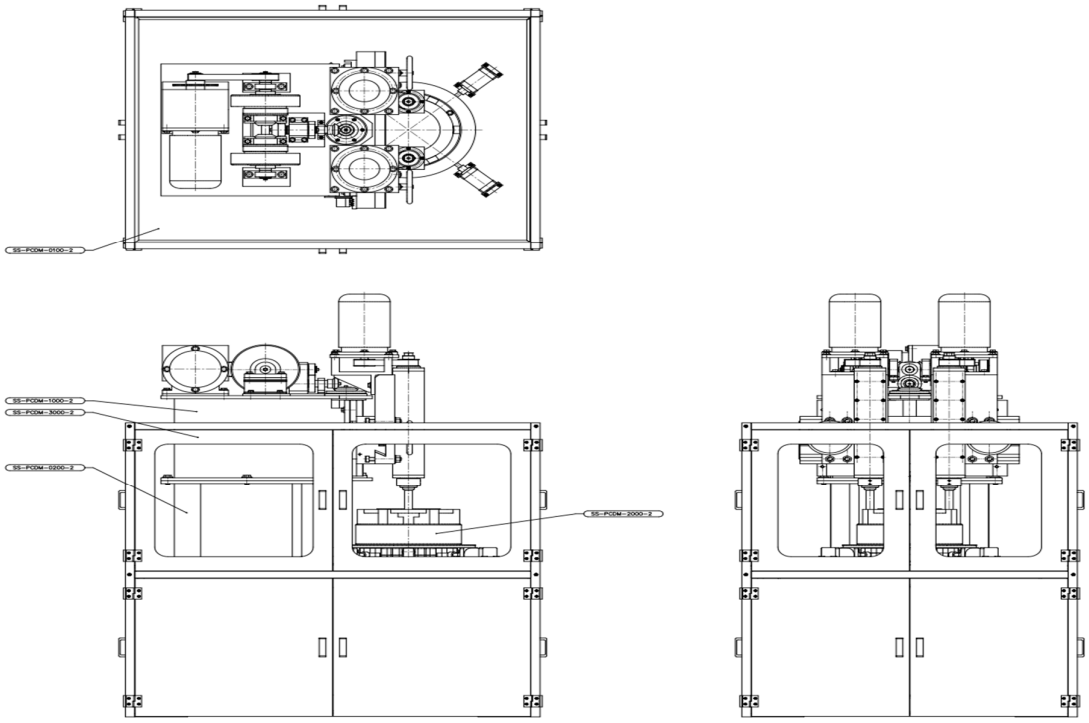

Fig 3: Elevation and Plan of Twin Spindle Machine

XI. Electrical and PLC Unit Design

The electrical diagram illustrates the simplified design of the electrical drives. The machines cycle works on basic PLC unit instead of complicated control system due to limitations of operations. The electrical wiring diagram as shown in the fig-4 shows the different motors and their connections. The machine cycle is automatically controlled through various PLC commands and the system is designed by means of various proximity switches and relay control for turning ON and OFF the various drive motor and clutches as per the requirement. The Table 1 indicates the basic Input and Output PLC commands used for the working cycle of CNC machine.

XII. Conclusions

The research paper provides a new and novel concepts for the new product development as currently the idea is out of public domain and will serve the need of Machine Tool Industry. The machine being very simple and compact one and due to availability of twin head the production output will be high as well as the cost involved will also be less. The machine tooling is very simplified and works on standard Delta drills with replaceable inserts and job setting is also simple in nature. The PLC and electrical design being very simple and no complicated programming is required as in CNC system and cycle time is at par with CNC and can be operated by semi-skilled labour. The mechanical and electrical system are well user friendly and can be easily maintained.

TABLE I. PLC INPUT AND OUTPUT DETAILS

PLC INPUT DETAILS		PLC OUTPUT DETAILS	
1000	Emergency	2000	Emergency Stop
1001	Manual cycle	2001	Manual cycle Lamp
1002	Auto cycle	2002	Auto cycle Lamp
1003	Auto start	2003	Spindle-I ON
1004	Auto stop	2004	Spindle-I OFF
1005	Coolant start	2005	Spindle-II ON
1006	Coolant stop	2006	Spindle-II OFF
1007	Machine lock key	2007	Home Position Lamp
1008	Spindle-I ON	2008	Feed motor ON
1009	Spindle-I OFF	2009	Feed motor OFF
1010	Spindle-II ON	2010	Feed clutch ON
1011	Spindle-II OFF	2011	Feed clutch OFF
1012	Feed motor ON	2012	Unlock solenoid
1013	Feed motor OFF	2013	Clamp-I solenoid
1014	Geared motor ON	2014	Clamp-II solenoid
1015	Geared motor OFF	2015	Clamp-III solenoid
1100	Index ON	2100	Clamp-IV solenoid
1101	Index position proxy	2101	Geared motor ON
1102	Unlock cylinder Reed switch	2102	Geared motor OFF
1103	Unlock cylinder - I Reed switch	2103	Coolant motor ON
1104	Unlock cylinder - II Reed switch	2104	Coolant motor OFF
1105	Unlock cylinder - III Reed switch	2105	Tower lamp green
1106	Unlock cylinder - IV Reed switch	2106	Tower lamp orange
1107	Feed in mm	2107	Tower lamp red
1108	Feed direction upwards	2108	Low air pressure lamp
1109	Feed direction downwards	2109	Limit position-I
1110	Feed clutch ON	2110	Limit position-II
1111	Feed clutch OFF	2111	Limit position-III
1112	Feed counter pulse	2112	Limit position-IV
1113	Pressure Switch	2113	Drill feed
1114	Limit Switch Position -I	2114	Rapid feed
1115	Limit Switch Position -II		
1200	Limit Switch Position -III		
1201	Limit Switch Position -IV		
1202	Unlock Cylinder reverse selector switch		
1203	Clamp cylinder –I reverse selector switch		
1204	Clamp cylinder –II reverse sel. switch		
1205	Clamp cylinder –III reverse sel. switch		
1206	Clamp cylinder –IV reverse sel. switch		
1207	Index counter pulse		
1208	Cycle count		
1209	Cycle count Reset		
1210	Drill feed sel. switch		
1211	Rapid feed sel. switch		

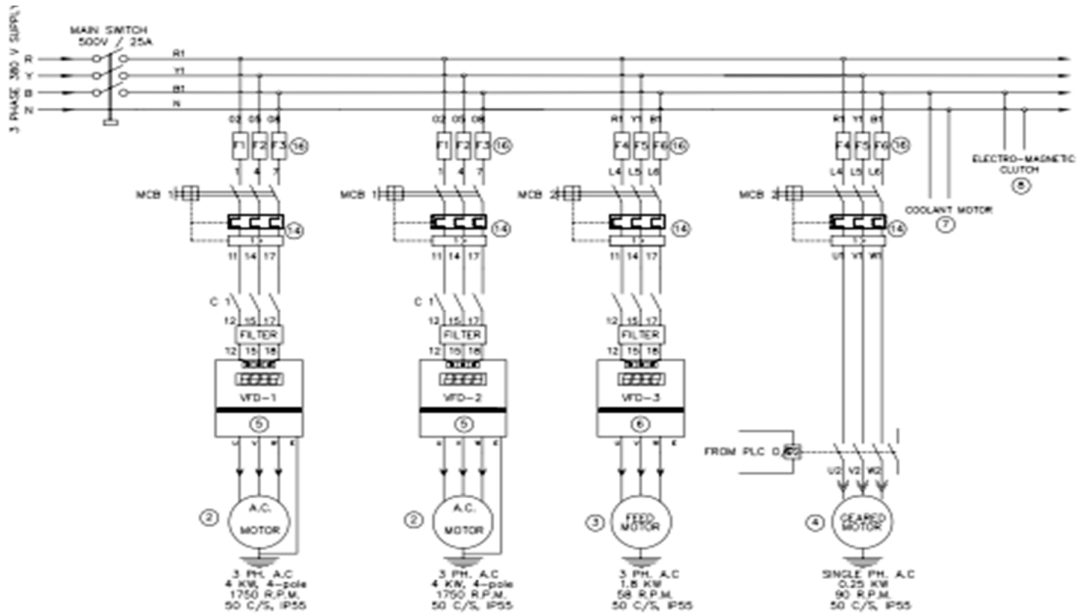

Fig 4: Wiring diagram of different drives used in machines

The paper will immensely benefit the small and medium scale industry as it will increase the productivity. The idea presented in this research paper can be further utilized for further development of this Twin spindle Drilling machine into Twin Head Milling machine.

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