Design and Development of Compact Vertical Machining Centre

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Abstract : In machine tool industry, it is necessary to appropriate utilization of space, so that productivity should be more along with the less amount of space consumption. With a view of space consumption related to machines and operations, conventional machines reduced in their sizes with no change in the efficiency of the operations. Vertical machining centers (VMC) usually large in size, Bharath Fritz Werner Limited BFW has already manufactured some of the compact form of machines with the series called 'XTron'. This paper presents a new machine of XTron series called XTron-433 machine which has all the specification which other machines of this series possess, along with the guiding and transmission systems. The XTron-433 is produced so that even mid scale industries could afford it, along with that its compact in size it doesn't consume much place. The studies were carried out to ensure perfect parts for the Compact Vertical Machining Center i.e, XTron-433.Here design of XTron 433 includes designing of operations and selection procedure for Linear Motion guideways (LM Guide), Ball screw and beltdrives.

***IndexTerms* - Vertical machining centre; XTron-433; Compact; machine.**

I. INTRODUCTION

Manufacturing is the modern movement which changes over crude material into helpful item. The deduction of the word produce signifies "by hand". As the intensity of the hand apparatus is constrained for little procedure, presently the manufacturing is overwhelmingly performed by the utilization of machines. Manufacturing innovation includes every one of the strategies for molding the crude material to definite item. Metal cutting machines join higher accuracy contrasted with metal shaping machines (Eg: press, expulsion and moving machines). Machine apparatuses establish about 70% of the absolute working manufacturing machine industry.

The advancement of machine device has begun with the development of chamber which was changed to a roller guided diary bearing. Antiquated Egyptians utilized this method for conveying stones from quarry to building site. First profound opening penetrating machine was created by Leonardo da Vinci in 1452. In 1953, numerical control innovation was presented which was achievement for the development of computer numerically controlled (CNC) machines.

The successful design in machine tool requires,

1. Mechanics of machining which involves magnitude and direction of the cutting tool forces.
2. The machinability of the different materials which is to be processed.
3. Material composition of the part used in machine.
4. Manufacturing techniques used for the production of machine tool part economically.
5. Durability and capability of different machine tool materials.

Productivity can be enhanced by incorporating following technique

1.Increasing the feed and speed of a machine.
2.Enhancing available power of the machine
3.Using various tools for machining various work pieces simultaneously.
4.Increasing the level of automation for the machine tool operative units.
5.Incorporating modern control technique such as NC and CNC.
6.Selecting the machining processes properly based on the machined part material, shape complexity, accuracy and surface finish.
7.Introducing jigs and fixture to enhance the cycle time of the product.

II. MATERIAL SELECTION

In order to avoid usage of varieties of materials which causes many inconveniences and cost escalation, both at inventory and manufacturing. BFW has rationalized and up-graded its raw materials with following consideration.

a. Capabilities of satisfying design requirement
b. Ease of manufacturing
c. Availability of specified quality material.
d. Cost of Material

Based on above considerations, the raw material, used in BFW has been classified as under.

A. Steels

While selecting steels, due consideration is given to steels specified in IS 11185 (specification & technical supply conditions for hot rolled & forged steel bars for use in machine tool industry).

Steels have been classified as follows

i. Plain carbon steels- C1 & C1A
ii. Low alloy steels- C1B & C3R
iii. Free cutting steels- C4 & C1F
iV. Spring steels- C7 & C8
V. Case carburising steels- C2M & C2R
Vi. Flame/ Induction hardening plain carbon steels – C1 & C1A
Vii. Nitriding steel- N1
Viii. Tool steels- T3 & T5

Only one grade mild steel (IS 2062) has been selected which is used especially for weldments.

B. Ferrous Castings

Ferrous castings of two grades of steels (S1 & S2), four grades of grey cast iron (G1, G2, G3 & G4) three grades of SG iron (SG1, SG2 & SG3).

C. Non-Ferrous Castings

Non-ferrous castings consist of three grades of copper base alloys (B3, B4 & B6) & two grades of aluminum alloys (A1 & A2).

D. Non-Ferrous Wrought Alloys

This consists of two grades of copper alloys (EBZ & NB1), one grade aluminum alloy (A3).

Selection of Materials for Different Components in Machine Tool Manufacturing

XTron machine series are usually done by using Carbon steel grade C1 & C1A

III. DESIGN OF OPERATIONS

Different operations are designed which are going to be performed by this compact VMC to design the power of spindle and motor at each operations, operations performed in this VMC are Face milling, End milling, Boring, and Tapping.

A.Face Milling

Considering the conditions for face milling operation are, Diameter of the cutter D =150 mm, No of inserts / teeth Z=7, Cutting speed v = 80 m/min, Feed per teeth Sz = 0.2 mm, Depth of cut t = 3 mm, Width of cut b =120 mm, Approach angle x = 60 deg, Radial rake angle r = 0 deg, Unit power U =0.045 kW/cc/min, Correction factor for flank wear kh = 1.200, Correction factor for radial rake angle Kr = 1.130. U, Kh and Kr values are taken from the tables 269, 270 and 271 respectively from the Central Machine Tool institute CMTI Data handbook. Efficiency of transmission E= 0.9% (motor to spindle transmission)

Feed per minute Sm

$$Sm = Sz \times Z \times n \quad (3.1)$$

Values that are calculated with the help of above conditions of operations are, Spindle speed (rpm) n=148.544 rpm, Feed per minute Sm=207.96 mm/min, Material removal rate Q= 74.86 cc/min, Power at spindle N=4.56 kW.

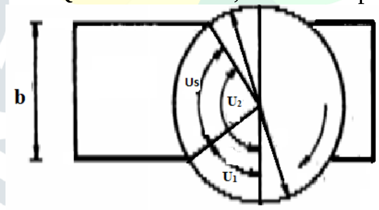

Figure3.1 Face milling

Figure 3.1 show the angles for the face milling which is referred from the CMTI Data handbook
Angles from the figure 3.1 Us=106.260
Angles from the figure 3.1 U1=36.870
U2=U1+Us =36.870+106.260= 143.130

Average chip thickness $as = 57.3 \times Sz \times \sin x \times (\cos U1 - \cos U2)/Us$ (3.2)

$as = 0.149mm$

Power of motor $Nel = N/E = 4.56/0.9 = 5.07$ Kw (3.3)

B. End Milling

Considering the conditions for end milling operation are, Diameter of the cutter D =16 mm, Cutting speed v = 70 m/min
No of inserts/teeth Z = 4, Feed per min Sm = 700 mm/min, Depth of cut t = 1.5 mm,Width of cut b =16 mm, Radial rake angle r = 0 deg, Unit power U =0.04 kW/cc/min,Correction factor for flank wear kh = 1.200 Correction factor for radial rake angle Kr = 1.130. U, Kh and Kr values are taken from the tables 269,270 and 271 respectively from the CMTI Data handbook. Efficiency of transmission E= 0.9% (motor to spindle transmission)

Material removal rate Q,

$$Q = b \times t \times Sm/1000 \quad (3.4)$$

Values that are found from the above mentioned conditions are, Spindle speed (rpm)n= 1392.60 rpm, Feed per teeth Sz = 0.1256 mm/min, Material removal rate Q= 16.80 cc/min, Power at spindle N=0.91kW, Average Chip thickness as = 0.02 mm, Power of motor Nel=N/E=0.91/0.9=1.01kW

C. Boring

Conditions for designing boring operations are, Diameter of the Bore D =150 mm, Cutting speed v = 70 m/min, Feed per revolution S = 0.13 mm/rev, Depth of cut t = 4 mm, Approach angle x = 90deg , Side rake angle g = 0 deg, Unit power U =0.09

kW/cc/min Correction factor for flank wear kh = 1.30 Correction factor for radial rake angle Kr = 1.13, Efficiency of transmission E= 0.9% (motor to spindle transmission) U, Kh and Kr values are taken from the tables 269, 270 and 271 respectively from the CMTI Data handbook
power at spindle,

$$N= U\times Kh\times Kg\times Q \qquad (3.5)$$

Values that are calculated with the help of above conditions are, Spindle speed (rpm) n=148.544 rpm, and Feed per minute Sm=19.310 mm/min, Material removal rate Q= 36.4 cc/min, Feed per revolution x = 1.57 rad (deg to radians) avg chip thickness as = 0.13 mm, power at spindle N= 4.81 kW, and the Power of motor Nel = 5.347 kW

D. Tapping

If tapping is being done with the thread diameter of D=30 mm and Spindle speed n = 30 mm, Cutting speed v = 2.83 m/min, Thread pitch p=2 mm, Material factor K =2.32 Efficiency of transmission E = 0.90 %
Values that are calculated with the help of above conditions are, Spindle speed n=30.03 rpm, Power at spindle at 60% of thread engagement N_1=0.19 kW, 75% of thread engagement N_2= 0.2722 kW, 90% of thread engagement N_3=0.36 kW, and the Power of motor Nel= 0.4 kW
Spindle speed,

$$n=\frac{v\times 1000}{\pi D} \qquad (3.6)$$

Spindle power,

$$N_1 = \frac{0.231\times D\times p^2\times n\times K}{10^4} \qquad (3.7)$$

By the above things we can easily observe that motor power required for these operations are 5 kW or below that.

IV. Selection Procedure

4.1 Ball Screw

A ball screw is a mechanical linear actuator that makes an interpretation of rotational movement to linear movement with little friction. A threaded shaft gives a helical raceway to ball heading which go about as an accuracy screw. Just as having the option to apply or withstand high pushed burdens, they can do as such with least inward grinding.

Table 4.1 Results of Ball screw

	X –axis	Y-axis	Z- axis
Axial load Fa	2026.518 N	3325.568 N	3279.782 N
Permissible axial load P_1	9604.876 N	44444.44 N	44444.44 N
Service life	2.66 years	0.56 years	2.316 years
Motor Torque T_{rms}	2657.82Nmm	4361.545Nmm	4297.115Nmm

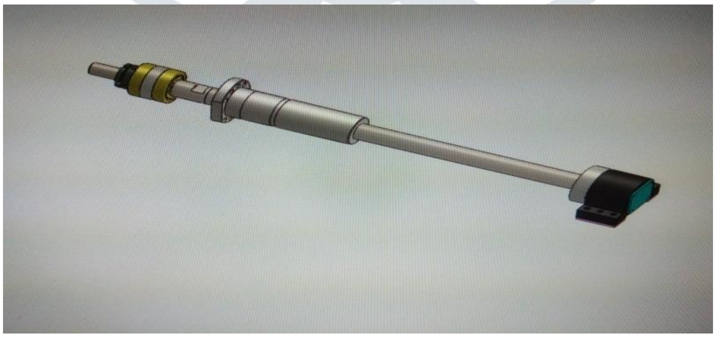

Figure 4.1 Ball screw design

4.2 Linear Motion Guide

Linear guideways gives linear movement by re-coursing moving components between a profiled rail and a bearing block. The coefficient of friction on a linear guideway is just 1/50 contrasted with a traditional slide and they can take loads in every direction. With these highlights, a straight guideway can accomplish high precision and enormously improved moving accuracy.

Table 4.2 Results of LM Guide

	X-axis	Y-axis	Z-axis
Applied load P_{avg}	956.474 N	1250.52 N	1622.50 N
Nominal life L	494963.322 km	399848.89 km	167615.27 km
Service Life	2.45 years	2.65 years	1.10 years

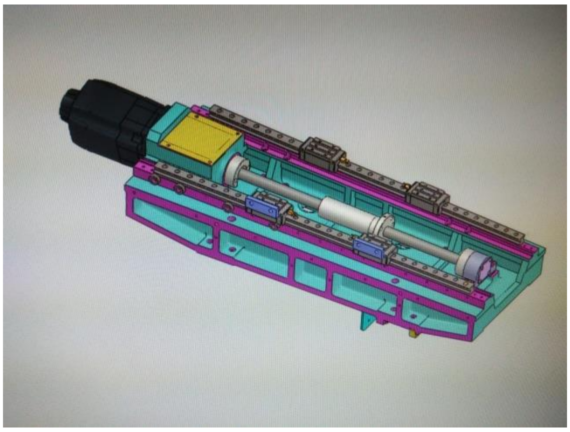

Figure 4.2 Design of LM guide

4.3 Belt Drive

Belt drive**,** in machinery, a pair of pulleys attached to usually parallel shafts and connected by an encircling flexible belt (band) that can serve to transmit and modify rotary motion from one shaft to the other. Most belt drives consist of flat leather, rubber, or fabric belts running on cylindrical pulleys or of belts with a V-shaped cross section running on grooved pulleys.Type of belt is 5MR where 5 indicate pitch

Table 4.3 Data for designing Belt drive

Sl.No	Data	Values
1.	Width of belt W	40 mm
2.	Speed N	6000 rpm
3.	Pitch circle diameter of larger pulley D	114.59 mm
4.	Pitch circle diameter of larger pulley d	70.02 mm

The exact centre distance is determined by trail using the belt pitch length formula. The pitch length increment of a positive belt is equal to a multiple of the belt pitch.

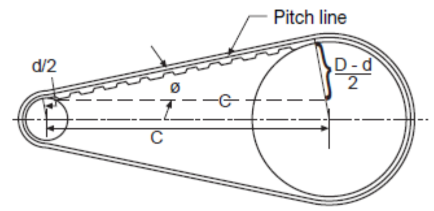

Figure 4.3 Pulley Centre Distance

Belt drive designed based on the above above available data and obtained, Centre distance=C= 205 mm, Belt length L_p = 702.252 mm, Teeth in mesh Z_m= 20.47 ≈ 21, Span length S = 203.785 mm,Actual centre distance =315.33 mm.

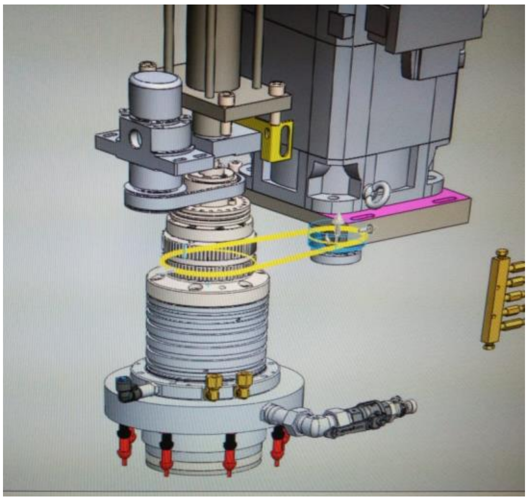

Figure 4.4 Design of beltdrive

V. CONCLUSION

In this paper, VMC XTron-433 has been designed to form a compact vertical machining centre. The 3D modelling was carried out using Solid Works software. The design process includes selection procedure and design of different operations. The need for ease of manufacturability and ease of assembly has resulted in selection of appropriate ball screws Belt drives and LM guide. Motor of power 5.5 kW is chosen based on ease of required amount of torque and economic operation. Two sets of hydraulic cylinders are used for lifting pallet as well as to drive the rack and pinion and thereby rotate the pallets.

The parts are selected on the basis of selection procedure calculations and their service life is also calculated with the help of THK catalogue, THK stands for Toughness, HighQuality and Know-how and spindle power is designed for each operation which are going to be performed on XTron-433. Axial load and torque on each axis of each parts of the XTron-433 is designed. The mechanisms were covered with proper sheet metal to avoid entry of coolant oil and deposition of metallic chips and other small particles.

FUTURE SCOPE

- The designed XTron-433 has the dimension of Floor space width 1800 mm depth of 2020 mm and height of 2500 mm. It is smallest or compact among all other series of XTron machines.
- XTron-433 has overall height of 2500 mm.This can be optimized and made more compact for better portability and wide range of usage.
- The selection procedures are completed in this project and Structural analysis can be carried out to know whether stresses and deflections are within satisfactory level as per machine tool standards. Also this will help in optimizing the weights of parts to minimum possible value.

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