DESIGN AND MANUFACTURING OF SEMIAUTOMATIC PAPER CUTTING MACHINE

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Abstract: In this paper, the design and development of semi-automatic paper cutting machine is presented. The machine is developed to achieve higher accuracy, compact and robust design for efficient use of floor space and to achieve independent action of paper holder and paper cutter. It refers to manual paper holder and paper size adjustment with electric power supply to actuate cutting action makes it semiautomatic. The machine consists of electric motor, cutter, gearbox, belt and pulley, lead screw, handwheel and frame. It is also equipped with hardware sensors for safety purpose. It is capable of cutting stack of paper with very ease which is very useful in planning a path to the desired cutting destination.
Keywords: Paper, power supply, handwheel, cutter, machine.

INTRODUCTION

The paper cutting process is a main part of the all paper and printing industries. Paper is a thin material produced by pressing together moist fibers of cellulose pulp derived from wood, rags or grasses, and drying them into flexible sheets. The evolution of the cutting machine has been rapid and distinctly marked in all its essential features, from the oscillating plough to the vertical stroke, to the shear stroke, to the double-shear stroke; from a single-rod pull-down of the knife (by a chain, by a cam, or by a crank) to the two-rod pull-down by cams, rolls, slots, slides, to the cranks which give a fixed dependable stroke; to the cranks which give a fixed dependable stroke, and at the same time pull the knife endwise; from swinging-link shear to a straight-line shear; from man-drive to power-drive; from driving by power fixtures in front and outside the frame to fixtures located back and underneath; from low piles to high piles; from hand clamp to power clamp, to self clamp, to automatic clamp, finally to friction adjustable pressure clamp. There is need to cut paper to give them the final desired size and form. Number of such machines are available in market with their unique design. This paper cutting machine is also has its unique features. With this paper cutting machine better accuracy can be achieved. In this machine the paper holder holds the paper first then cutter comes down to cut the paper i.e. an electric driven cutter and manual operated paper holder is provided, hence time for judging cutting edge increased and causing better accuracy. Its compact design makes it possible to use floor space efficiently.

DESIGN CALCULATIONS OF MACHINE

1. Cutting force calculation

Electric motor -1440 rpm [single phase] 1 HP=746W

$$F_c \times R = \text{Torque available at blade } T = \frac{60\times1000\times0.746}{2\pi 6.67} = 1068.51 \text{ N-m}$$

$$F_c = \frac{1068.51}{R} = \frac{1068.51}{65\times0.001} = 16438.65\text{N} = 16.43\text{kN}$$

Fig.1 Force calculation on UTM machine. (It gives 10.54 kN of maximum force to cut paper of 40 mm thickness.)

2. Design of belt and pulley

P = 0.746 kW, n_1= 1440 rpm, n_2= 600 rpm, let f_a= correction factor according to service = 1.1

Design power = f_a × transmitted power, $P_d = 1.1 \times 0.746 = 0..820$ kW

It is observed that the point with coordinates 0.82 kW and 1440 rpm is located in region of the A-section belt. Therefore, for this application, cross section of V-belt is A.

$$\text{Speed ratio} = \frac{1440}{600} = 2.4$$

The minimum pitch diameter for smaller pulley d =75mm and minimum pitch diameter for bigger pulley

$$D = 75\times2.4 = 180 \text{ mm}$$

Pitch length of belt, let centre distance c=250 mm

$$L=2c + \frac{\pi(d+D)}{2} + \frac{(D-d)^2}{4c} = 2(250) + \frac{\pi(180+75)}{2} + \frac{(180-75)(180-75)}{4\times250} = 911.57\text{mm}$$

Assume standard pitch length as L=990mm

For corrected centre distance

$$L = 2C + \frac{\pi(d+D)}{2} + \frac{(D-d)^2}{4c}, \quad 990=2C + \frac{\pi(180+75)}{2} + \frac{(180-75)^2}{4C}, \quad 2C^2 - 589.45C + 2756.25 = 0$$

C = 289.97 mm, Let C= 290 mm … standard corrected centre distance.

Let, F_c = 0.88…..correction factor for belt pitch length

Finding wrap angle, $\alpha_s = 180 - 2\sin^{-1}\left(\frac{(D-d)}{2C}\right)$ or $\alpha_s = 159.14°$

Therefore, correction factor for arc of contact, F_d=0.95

Power Rating, P_r = 0.91 + 0.17 = 1.08 kW

Finding No. of belt= $\frac{(p\times fa)}{(Pr\times fc\times fd)} = \frac{0.746\times1.1}{1.08\times0.88\times0.95}$ =0.2819 or = 1 belt.

Efficiency of belt drive-

Torque available at pulley on motor

$$T(\text{N-mm}) = \frac{60\times1000000\,kw}{2\pi n} = \frac{60\times1000000\times0.746}{2\pi\times1440} = 4947.06 \text{ Nmm}$$

$$4947.06 = (F_1 - F_2)r = (F_1 - F_2)\times\frac{75}{2}$$

$$F_1 - F_2 = 131.92 \text{ N}$$

Power available at driven pulley

$$P = 2\pi nT/60 = (F_1 - F_2)r(2\pi n/60) = (131.92)\left(\frac{0.180}{2}\right)\left(\frac{2\pi\times600}{60}\right) = 745.99 \text{ watt} = 0.7459 \text{ kW}$$

therefore, effi. = $\frac{o/p}{i/n} = \frac{0.745}{0.746}$ =0.98 =98%

3. Design of Gears

Design of worm-

Material used is cast iron.

Let, P = 0.746kW, l_N = Normal lead, λ = Lead angle, $\phi = 20^0$, n=600rpm, V.R.= 30:1, x=90mm

ISSN: 2231-5063.

$$\cot^3\lambda = V.R. = 30 \text{ or } \cot\lambda = 3.12$$

$$\lambda = 17.77^0$$

$$\frac{x}{lN} = \frac{1}{2\pi}\left(\frac{1}{\sin\lambda} + \frac{V.R.}{\cos\lambda}\right)$$

$$l_N = 16.25\text{mm}$$

Axial lead, $l = l_N/\cos\lambda = 17.06$mm

Axial pitch of thread on worm, $P_a = l/1 = 17.06$mm

$m = P_a/\pi = 17.06/\pi = 5.4$mm or $m = 5$mm

Axial pitch of thread on worm, $P_a = \pi m = 15.71$mm

Axial lead of thread on worm, $l = P_a \times 1 = 15.71$mm

Normal lead of thread on worm, $l_N = 15.71\cos 17.77 = 14.96$mm

Corrected centre distance x, $\frac{x}{lN} = \frac{1}{2\pi}\left(\frac{1}{\sin\lambda} + \frac{V.R.}{\cos\lambda}\right)$

$x = 82.8$ mm

Let, D = P.C.D. of the worm,

$\tan\lambda = \frac{l}{\pi D} = \frac{15.71}{\pi D}$

Design of worm gear-

Number of teeth on worm gear, $T_G = 30 \times 1 = 30$

P.C.D. of worm gear, $D_G = m \times T_G = 5 \times 30 = 150$mm

Face width, $b = 2.15\, P_a + 5 = 38.7$mm

$D_a = m(T_G + 4\cos\lambda - 2) = 159.05$mm, $D_f = m(T_G - 2 - 0.\,4\cos\lambda) = 138.1$mm

Design of helical gears-

For EN36 Material, Let $s_{ut} = 1100$ N/mm^2, BHN = 341, Cs = 1.25, P = 0.746 kW, $n_1 = 20$ rpm, i=3, $\psi = 25^0$, $\alpha = 20^0$ and $Z_p = 25$ therefore $Z_g = 25 \times 3 = 75$

$d_p = \frac{Zp(Mn)}{\cos\psi} = (25)(2.5)/\cos 25 = 68$mm, $d_g = \frac{Zg(Mn)}{\cos\psi} = (25\times3)(2.5)/\cos 25 = 206$mm

$M_t = \frac{kw \times 60 \times 1000000}{2\pi N} = \frac{0.746 \times 60 \times 1000000}{2\pi \times 20} = 356188.76$ Nmm

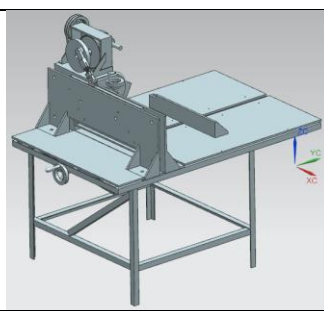
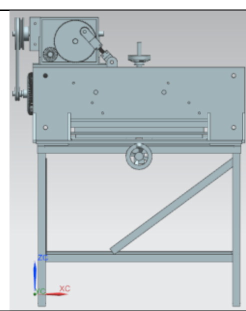
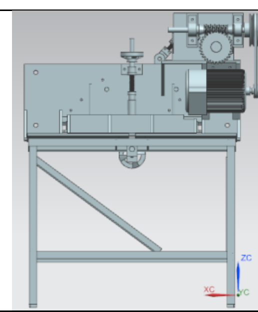
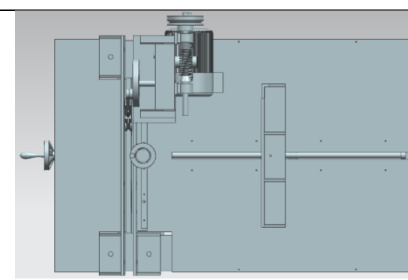
$d_p = \frac{Zp(Mn)}{\cos\psi} = \frac{25(Mn)}{\cos 25} = (27.58 m_n)$ mm, $P_t = \frac{2Mt}{dp} = \frac{2\times356188.76}{Mn(27.58)} = (25829.49/m_n)$ N

$C_v = \frac{5.6}{5.6+\sqrt{v}} = 0.6391$ for v = 10 m/s, $P_{eff.} = \frac{CsPt}{Cv} = (60623.11/m_n)$ N

$Z'_p = \frac{Zp}{\cos^3\psi} = 33.58$, Therefore, Y= 0.369, $\sigma_b = \frac{Sut}{3} = 366.67$ N/mm^2, $S_b = m_n b \sigma_b y$

$m_n = 2.5$ and $b = 10\, m_n = 25$mm

CONSTRUCTION OF MACHINE

			
Isometric view	Front view	Backside view	Top view

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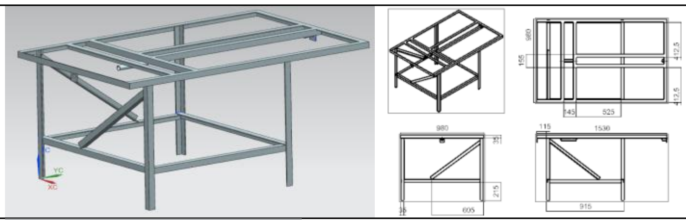
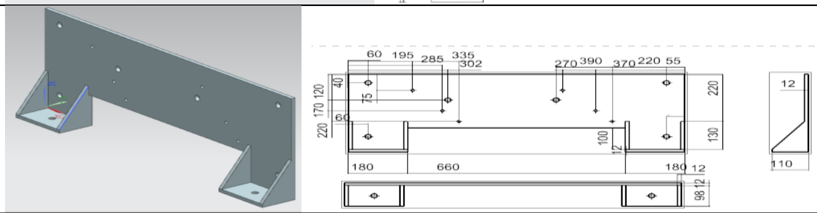
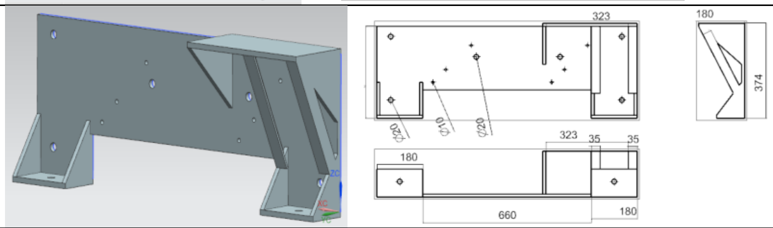
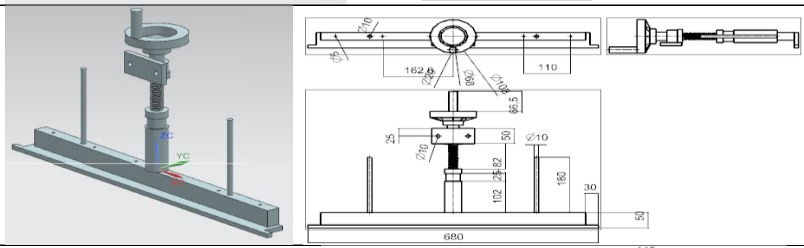
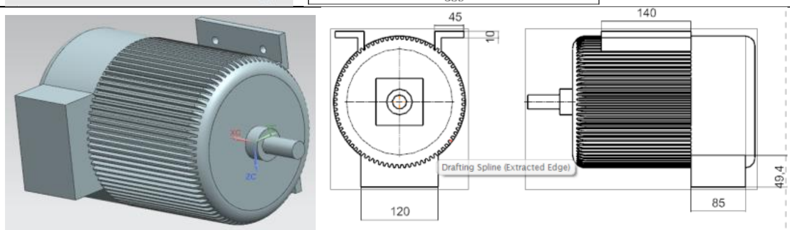
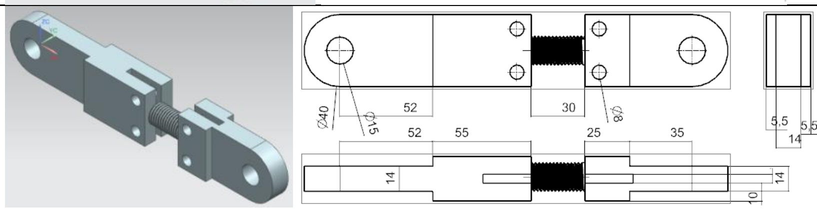
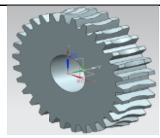
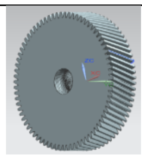
Name of Part	Description	Drawing
Frame	Length = 1690mm Width = 990mm Hight = 770mm Material = EN8	
Front side plate	Length = 1020mm Width = 12mm Hight = 350mm Material = EN8	
Back side plate	Length = 1020mm Width = 12mm Hight = 350mm Material = EN8	
Paper holder assembly	Length = 680mm Width = 50mm Material = EN8	
Motor	1 HP, 1440rpm, 1 phase	
Push rod	Length = adjustable Width = 40mm Material EN 8	
Worm wheel	30 teeth, 150mm P.C.D., Width = 38mm Module = 5mm Material C.I.	
Helical gear 1	75 teeth, 200 P.C.D., Width = 25mm Material En36	

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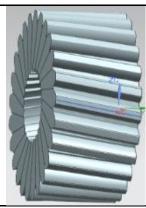
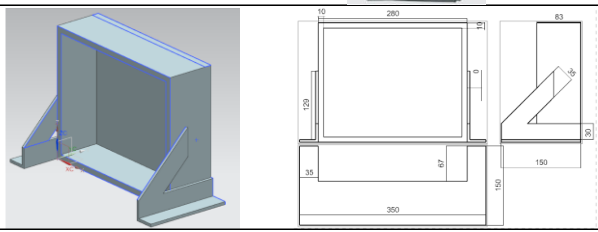
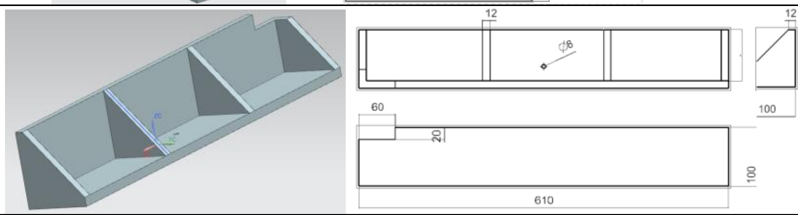
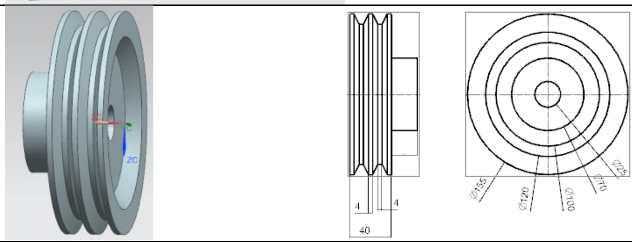
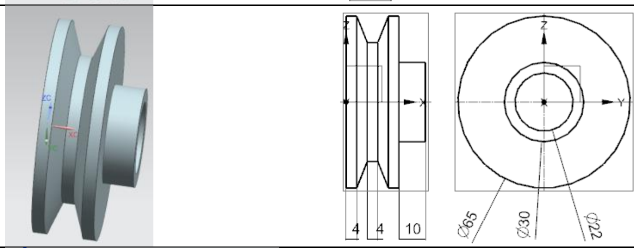
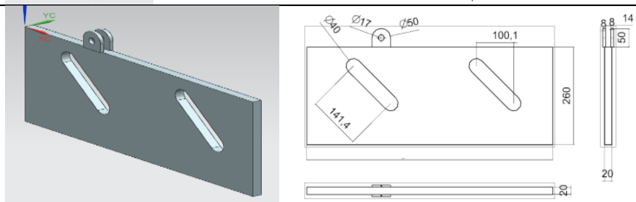
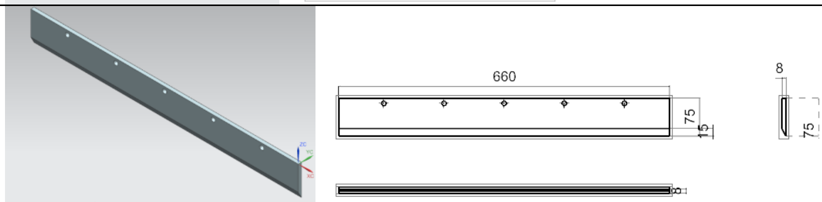
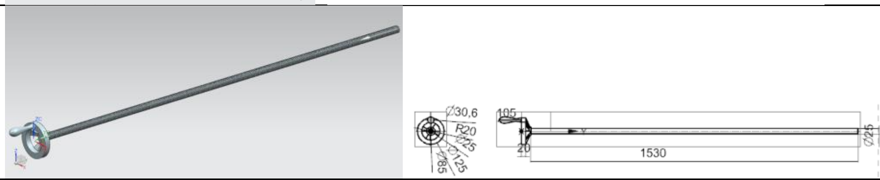
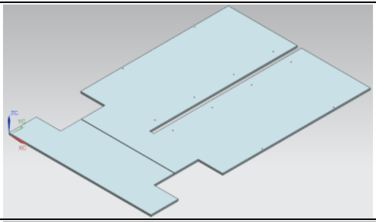
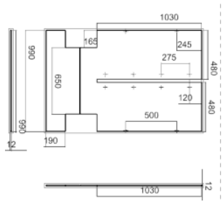
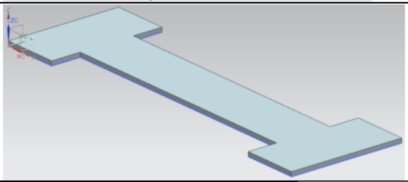
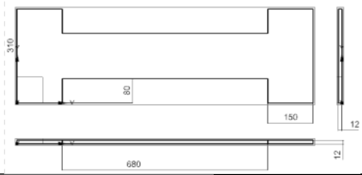
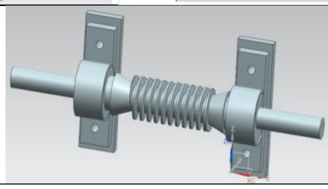
Helical gear 2	25 teeth, 65 P.C.D., Width = 25mm Material En36	
Gearbox casing	Length = 280mm Width = 95mm Hight = 225mm Material En8	
Adjuster plate	Length = 610mm Width = 100mm Hight = 100mm Thickness = 12 mm Material -plywood	
Driven pulley	Width = 40 mm Diameter = 180mm	
Driving pulley	Width = 20 mm Diameter = 75mm	
Cutter holder plate	Length = 660mm Width = 20mm Hight = 260mm	
Cutter	Length = 660mm Width = 8mm Hight = 75mm Material- spring steel	
Lead screw and handwheel	Length = 1690mm	

Plywood	Length = 1530mm Width = 990mm Thickness = 12mm Material = plywood	 
I-section plate	Length = 970mm Width = 310mm Thickness = 12mm Material EN8	 
Worm and bearing assembly	Roller bearing, Worm D_o=50mm D_i = 32mm	

Overall Length = 1690mm, Overall Width = 1020mm, Overall Hight = 1400mm
Material selection depends upon mechanical, thermal, physical, chemical and electric properties of the material.

WORKING

Power is supplied to electric motor which rotates at 1440 rpm. This speed is reduced to 600 rpm with the help of belt and pulley arrangement. Further power transmitted through worm and worm wheel having high speed reduction ratio of 30:1, this reduces the speed upto 20rpm. Gearbox reduces this speed of 20rpm to 6.667rpm which is required output speed. At the end of the gearbox a wheel is attached Which is further connected to push rod which is attached to blade holder. As the wheel rotates the rod moves in reciprocating motion and carries the blade holder with blade or cutter Shearing motion resulting in cutting action. The ultimate aim of having independent cutter and holder motion is achieved by manually operated paper holder consisting of handwheel and lead screwwhile the cutter is actuated with the help of electric power supply. A lead screw and handwheel arrangement is provided to adjust the size of paper. Sensors are provided at cutting site for safety purpose. A flywheel detachable from driven pulley is also used in order to increase energy efficiency. As the cutter passes close to holder higher accuracy is achieved. Maximum of 50mm thickness stack of paper can be easily cut.

CONCLUSION

The ultimate aim of having independent cutter and holder motion is achieved by manually operated paper holder consisting of handwheel and lead screw while the cutter is actuated with the help of electric power supply. It may cut documents, fast and precisely. It is simple in construction. Quick response is achieved and continuous operation is possible without stopping. Easy blade change and Resharpenable blade increases life of machine.Optical cutting line increases accuracy **,** Automatic blade return from any position Two-hand operation makes the use of machine safe.

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