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Atomisation of Chamfering Machine Operations

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Abstract

Previously for gear tooth chamfering machines were used and that machines are manually operated. To atomized this manually operated machines we can used the hydraulic mechanism or pneumatic mechanism to apply force on the top side of the gear plate i.e. vertically downward force to clamp gear plate fixed where amount of applied force must be greater than the amount of cutting force. If this applied is less than cutting force then the gear plate will not have a steady state. Here application of hydraulic mechanism is suited as compare to pneumatic mechanism considering cost, heat transfer capacity and leakage problem.

In this paper we will discuss how we can use hydraulic system for imparting force on the gear plate in vertically downward direction. Also we will design the required components that will require automating the whole system unit and focus to build whole system such that we can make human interference in the working is very less.

Keywords- *Tooth Chamfering machines, hydraulic systems, Cutting force.*

1. Introduction:

So by using the hydraulic force from upper side we can hold the gear plate with fixture or the base of the chamfering tool. And important point is that the amount of applied force must and always be greater than the cutting force amount for no deviation of the gear plate also this will avoid the vibration of the system. As studied previously, we can apply the hydraulic force on the gear plate as shown in below Fig 1.

Providing the proper work holding platform in or on fixture is an important part in any kind of machining operations performed on the work component under operations. Using this way the automation plays a vital role in providing a fast and reliable way of the clamping system of the work piece or gear plate which will also reduce the cycle time of clamping and increase in accuracy and that why decrease the possible damages to the work piece that under operations. In simple words proper holding of the work piece is important before any machining operation.

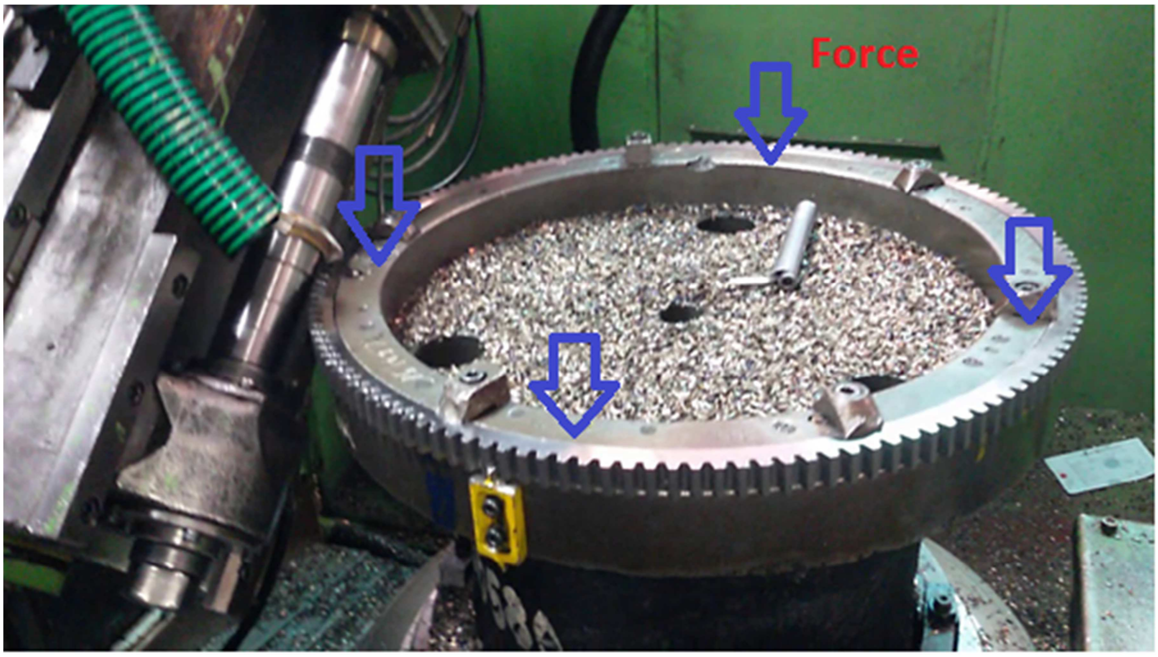

Fig 1 – Possible loading conditions

2. Design Approach:

Considering above condition, we have prepare one assembly having below parts and will assembled this with existing gear chamfering machine. This new assembly will help us to apply vertical load on the top side of the gear plate and using this mechanism, we can apply external load of required quantity. Parts of this new assembly are as below:

1. Hydraulic cylinder
2. Fixture Plate
3. Piston Rod
4. Adapter Plate having Hub
5. Bolts required for joining or assembling the components.

We have model all the above parts in the ProE Wildfire 5.0 with the dimensions calculated in later sections and assembled them to get one complete unit. We can call this unit as hydraulic subunit of the automated chamfering machine. This unit will mostly help for application of force on the gear plate to hold the gear plate on cutting or we can say chamfering platform with any deviation and reduce the vibration of the existing system. It also reduces the human interference in the operation of the chamfering machine and reduce or we can say remove use of C and L clamps or nut and bolts for manual tightening of the gear plate. After combining all the above parts we can have one unit assembly as below shown in fig 2:

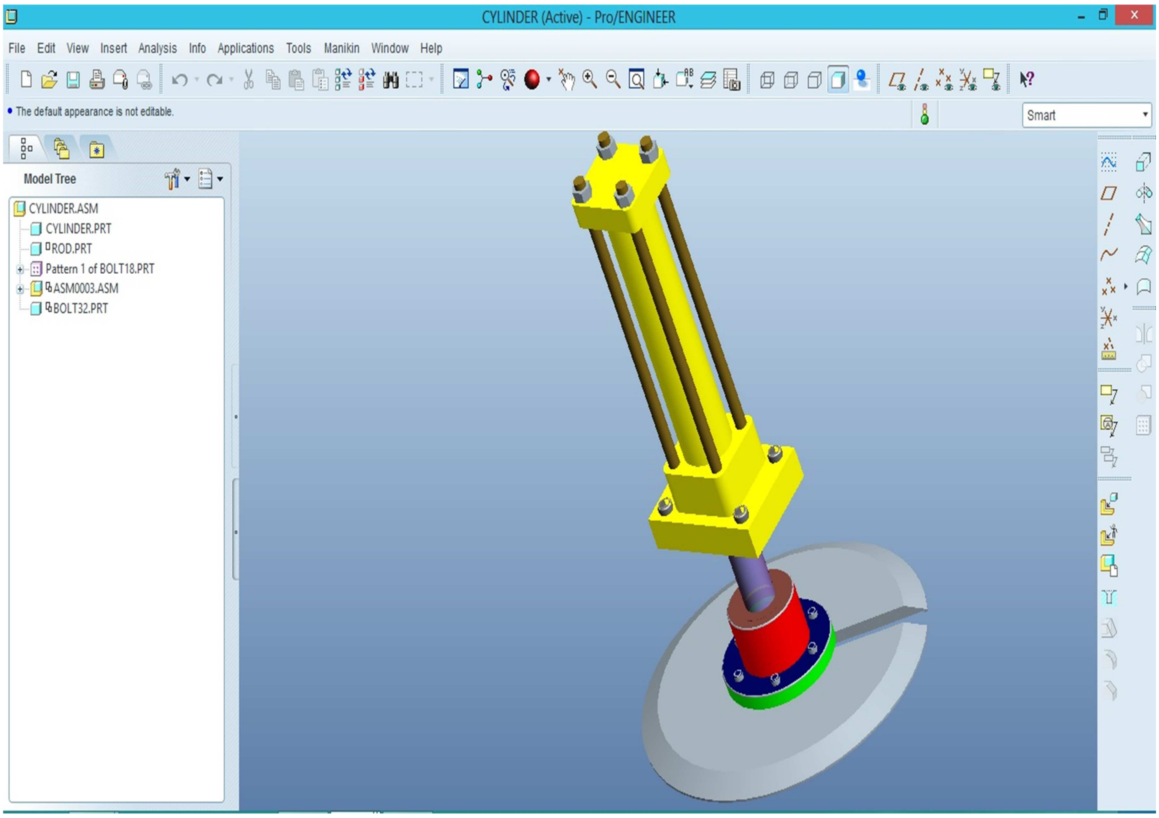

Fig 2 Assembly of the Hydraulic Unit

3. Parts of Hydraulic Systems:

A hydraulic system consists of the following parts

3.1 Cylinder barrel: The main function of cylinder body is to hold cylinder pressure. The cylinder barrel is mostly made from a seamless tube. The cylinder barrel is ground and/or honed internally with a typical surface finish of 4 to 16 micro inches. Normally hoop stress is calculated to optimize the barrel size.

3.2 Cylinder base or cap: The main function of the cap is to enclose the pressure chamber at one end. The cap is connected to the body by means of welding, threading, bolts, or tie rod. Caps also perform as cylinder mounting components [cap flange, cap trunnion, cap clevis]. Cap size is determined based on the bending stress. A static seal / O-ring are used in between cap and barrel (except welded construction).

3.3 Cylinder head: The main function of the head is to enclose the pressure chamber from the other end. The head contains an integrated rod sealing arrangement or the option to accept a seal gland. The head is connected to the body by means of threading, bolts, or tie rod. A static seal / O-rings are used in between head and barrel.

3.4 Piston: The main function of the piston is to separate the pressure zones inside the barrel. The piston is machined with grooves to fit elastomeric or metal seals and bearing elements. These seals can be single acting or double acting. The difference in pressure between the two sides of the piston causes the cylinder to extend and retract. The piston is attached with the piston rod by means of threads, bolts, or nuts to transfer the linear motion.

3.5 Piston rod: The piston rod is typically a hard chrome-plated piece of cold-rolled steel which attaches to the piston and extends from the cylinder through the rod-end head. In double rod-end cylinders, the actuator has a rod extending from both sides of the piston and out both ends of the barrel. The piston rod connects the hydraulic actuator to the machine component doing the work. This connection can be in the form of a machine thread or a mounting attachment.

3.6 Seal gland: The cylinder head is fitted with seals to prevent the pressurized oil from leaking past the interface between the rod and the head. This area is called the seal gland. The advantage of a seal gland is easy removal and seal replacement. The seal gland contains a primary seal, a secondary seal / buffer seal, bearing elements, wiper / scraper and static seal. In some cases, especially in small hydraulic cylinders, the rod gland and the bearing elements are made from a single integral machined part.

3.7 Seals: The seals are considered / designed as per the cylinder working pressure, cylinder speed, operating temperature, working medium and application. Piston seals are dynamic seals, and they can be single acting or double acting. Generally speaking, Elastomeric seals made from nitride rubber, Polyurethane or other materials are best in lower temperature environments, while seals made of Fluorocarbon Viton are better for higher temperatures. Metallic seals are also available and commonly use cast iron for the seal material. Rod seals are dynamic seals and generally are single acting. The compounds of rod seals are nitride rubber, Polyurethane, or Fluorocarbon Viton. Wipers / scrapers are used to eliminate contaminants such as moisture, dirt, and dust, which can cause extensive damage to cylinder walls, rods, seals and other components.

3.8 Limit Switch: In electrical engineering a limit switch is a switch operated by the motion of a machine part or presence of an object. They are used for control of a machine, as safety interlocks, or to count objects passing a point. A limit switch is an electromechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection. Limit switches are used in a variety of applications and environments because of their ruggedness, ease of installation, and reliability of operation. They can determine the presence or absence, passing, positioning, and end of travel of an object. They were first used to define the limit of travel of an object; hence the name "Limit Switch."

3.9 Pressure measurement

Fig 3.3 Bourdon pressure gauge

The Bourdon pressure gauge uses the principle that a flattened tube tends to straighten or regain its circular form in cross-section when pressurized. Although this change in cross-section may be hardly noticeable, and thus involving moderate stresses within the elastic range of easily workable materials, the strain of the material of the tube is magnified by forming the tube into a C shape or even a helix, such that the entire tube tends to straighten out or uncoil.

3.10 Hydraulic Power Pack: It contains below parts,

1) Electric motor
(2) Hydraulic pump.
(3)Intake submersed filter.
(4)Suction filter pump.
(5) Pressure relief valve.
(6) Pressure gauge.

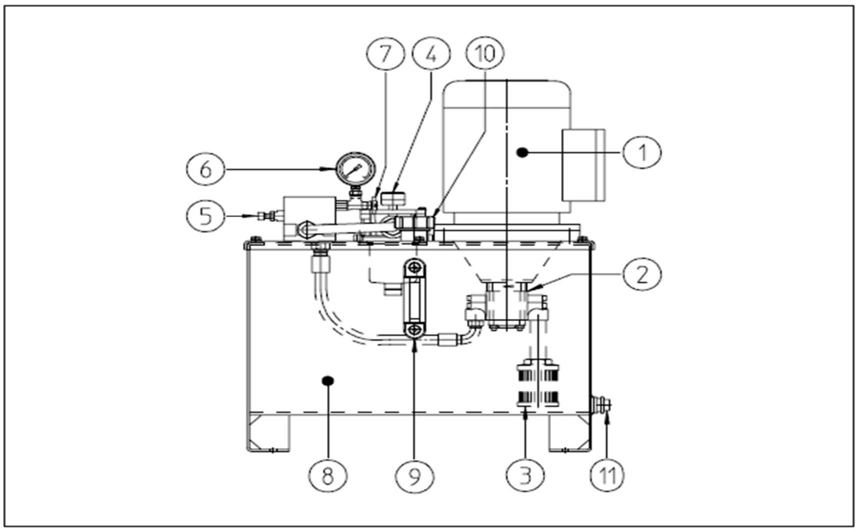

Fig 4 Hydraulic Power Pack

(7) Shut-off valve.
(8) Reservoir with visual oil level.

4 Designs of System Components:

4.1 Hydraulic Cylinder

Material selection
Generally C50 is used for cylinder
Tensile strength = 720N/mm^2 … (PSG Design Data Book Page No. 1.10 & 1.12)
Yield strength = 460N/mm^2
Now, for designing cylinder we have to know cutting force required for chamfering operation.
To start with, let us find out cutting force per tooth:

1) Cutting force(F_c)

w= width of chamfer in mm
d_c= depth of cut in mm
τ_s= ultimate shear stress of work material, N/mm^2
α= rake angle
μ= coefficient of friction
ϕ= shear angle
λ= friction angle

Now,

$\lambda = \tan^{-1}(\mu)$;

$\lambda = \tan^{-1}(0.5)$;

$\lambda = 26.56$

Using the lee and Shaffer shear angle relationship, ϕ works out to be 28.43^0. Thus,

$F_c = \frac{w \times dc \times \tau s \times \cos(\lambda - \alpha)}{\sin\phi . \cos(\phi + \lambda - \alpha)}$

(Ref. book manufacturing science by Amitabh Ghosh page no.231-242.)

$= \frac{5.5 \times 3 \times 400 \times \cos(26.56 - 12.5)}{\sin 28.43 . \cos(28.43 + 26.56 - 12.5)}$

$F_c = 18315.96N$

1) Operating pressure(P)

P= working pressure in N/mm^2

A= cross sectional area of cylinder in mm^2

$= \frac{\pi}{4}(d_i)^2 = \frac{\pi}{4}(80)^2 = 5026.56mm^2$

Thus,

$P = \frac{F}{A}$

$P = \frac{Fc}{A}$

$= \frac{18315.96}{5026.56}$

$= 3.643 N/mm^2$

$= 3.643 \times 10^6 \times 10^{-5}$

$= 36.43$ bar

2) Thickness of cylinder tube(t)

d_i =bore diameter in mm

s_{ut} =tensile strength

P_i=internal pressure in N/mm^2

$\sigma\ all$=allowable tensile stress

FOS = factor of safety =4

$\sigma\ all = \frac{sut}{fos} = \frac{720}{4} = 180\ N/mm^2$

$t = \frac{di}{2}\left[\sqrt{\frac{\sigma\ all + p}{\sigma\ all - p}} - 1\right]$ ………… (Ref. Book of hydraulic maintenance page no 264, 265)

$t = \frac{80}{2}\left[\sqrt{\frac{180 \ +3.6}{180 \ -3.6}} \ -1\right]$

t=8.07mm

Based on the design calculations we have selected the hydraulic cylinder tie rod construction. Bore dia.80×45×225 MM stroke front flange mounting W.P 160 Bar (for auto clamping**)**

4.2 Bearing Selection

We know that axial load = Fa =19500N
Radial load = Fr =0N
Equivalent bearing load = Pe

Pe = [x × v × Fr + Y × Fa] × Ka

….. (Ref. Machine Design by V. B. Bhandari Page no. 571)

Pe = [1×1×19500+1×0] × 1

Pe = 19500 N

Generally machines used for continuous operation, bearing life are selected as 20000 hours.

……. (Ref. from design data book page no. 4.3).

Thus,

Lh_{10}=20000 hrs

N = 3rpm

$L_{10} = \frac{Lh10 \times 60 \times n}{106}$

$L_{10} = \frac{20000 \times 60 \times 3}{106}$

L_{10} =3.6million rev.

$L_{10} = (\frac{c}{p})^3$.... (Ref. Machine Design By V. B. Bhandari Page no. 572)

$C = 19500 \times 3.6^{\frac{1}{3}}$

C = 29886.06N

As per industrial applications medium load bearing are selected for hydraulic system and also for safety of design **51110** bearing is selected.

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Thrust ball bearings single direction

d 3–300 mm

Dimensions d	D	H	Basic load rating dynamic C	Mass	Designation
mm			kN	kg	–
50	70	14	25,5	0,16	51110
	78	22	49,4	0,37	51210
	95	31	88,4	0,94	51310
	110	43	159	2,00	51410
55	78	16	30,7	0,23	51111
	90	25	61,8	0,59	51211
	105	35	104	1,30	51311
	120	48	178	2,55	51411
60	85	17	35,8	0,20	51112
	95	26	62,4	0,65	51212
	110	35	101	1,35	51312
65	90	18	37,1	0,33	51113
	100	27	63,7	0,78	51213
	115	36	106	1,50	51313
70	95	18	37,7	0,35	51114
180	225	34	135	3,50	51136 F
	250	56	296	8,60	51236 M
190	240	37	172	4,05	51138 F
	270	62	332	12,0	51238 M
200	250	37	168	4,25	51140 F
	280	62	338	12,0	51240 M
220	270	37	178	4,60	51144 F
	300	63	351	13,0	51244 M
240	300	45	234	7,55	51148 F
	340	78	462	23,0	51248 M
260	320	45	238	8,10	51152 F
	360	79	475	25,0	51252 M
280	350	53	319	12,0	51156 F
300	380	62	364	17,5	51160 F

SKF 101

Table 1 Thrust Ball Bearing Selection Table

4.3 Design of Bolt

Generally, **plain carbon steel (C45)** is used for making bolts.

… (PSG Design Data Book Page No. 1.10 & 1.12)

To design bolts under compression total load is taken into consideration

Total Load is =19500 N

Generally initial nut is tightening by force equal to half of the external force.

F_i =P/2=9750N

For plain carbon steel S_{yt} = 360 N/mm^2

Stiffness of bolt(k_b)

$$= \left(\frac{Ab \times Eb}{Lb}\right) = \left(\frac{\pi}{4} \times d^2\right)\frac{Eb}{Lb}$$

$$= \left(\frac{\pi}{4} \times d^2\right)\frac{207\times10^3}{40}$$

$$= \left(\frac{\pi}{4} \times d^2\right)\frac{207\times10^3}{40}$$

$$= 4064.445 d^2$$

Stiffness of connecting member

$$A_m = \frac{\pi}{4} \times ((3d)^2 - d^2)\frac{207\times10^3}{40}$$

$$= 2\pi d^2$$

$$A_{m1} = A_{m2} = 2\pi d^2$$

For C.I Plate

$$k_{m1} = \left(\frac{Am1 \times Em1}{Lm1}\right)$$

$$= \left(\frac{2\pi d2 \times 100\times10^3}{25}\right)$$

$$k_{m1} = 25132.74\ d^2 \text{ N/mm}$$

Now,

k_{m2}=($\frac{\text{Am2}\times\text{Em2}}{\text{Lm2}}$)

=($\frac{2\pi \text{d2}\times 100\times 10\text{^}3}{15}$)

k_{m2} = 41887.90 d^2N/mm

Resultant Stiffness in Member (k_m),

$\frac{1}{\text{km}}=\frac{1}{\text{km1}}+\frac{1}{\text{km2}}$

$\frac{1}{\text{km}}=\frac{1}{25132.74\ \text{d2}}+\frac{1}{41887.90\ \text{d2}}$

k_m=15707.96 d^2 N/mm

Total load is to be shared by 4 bolts

$$P=\frac{19500}{4}=4875N$$

Resultant force on connected member is

F_m=($\frac{\text{km}}{\text{kb+km}}$)P-Fi

F_m=($\frac{15707.96\ \text{d2}}{4064.445\text{d2}+15707.96\ \text{d2}}$)4875-9750

=-5.877×10^3 N

Therefore connected member are in compression

F_b=($\frac{\text{kb}}{\text{kb+km}}$)P+Fi

F_b=($\frac{4064.445\text{d2}}{4064.445\text{d2}+15707.96\ \text{d2}}$)4875+9750

F_b =15379.2N

Bolt size

$\sigma\ all=\frac{\text{Syt}}{nf}=\frac{360}{4}$=90 N/mm^2

$\sigma\ all=\frac{\text{Fb}}{Ac}$

$90=\frac{15379.2}{Ac}$

Ac =170.88mm2

Ac=$\frac{\pi}{4}\times$ dc^2

170.88=$\frac{\pi}{4}\times$ dc^2

dc=14.75mm

Now,

d=$\frac{\text{dc}}{0.84}=\frac{14.72}{0.84}$= 17.55mm

d=17.55 ~ 18mm

So, M18 Bolt is selected.

Designation	Pitch, mm	Major or Nominal Diameter, mm	Effective or Pitch Diameter, mm	Minor or Core Diameter, mm		Stress Area, mm^2
				Bolt	Nut	
M8 × 1	1	8.0	7.350	6.773	6.918	39.2
M10 × 1.25	1.25	10.0	9.188	8.466	8.467	61.6
M12 × 1.25	1.25	12.0	11.184	10.466	10.647	92.1
M14 × 1.5	1.5	14.0	13.026	12.160	12.376	125
M16 × 1.5	1.5	16.0	15.026	14.160	14.376	167
M18 × 1.5	1.5	18.0	17.026	16.160	16.376	216
M20 × 1.5	1.5	20.0	19.026	18.160	18.376	272

Table 2 Bolt Selection Table from Machine Design by V. B. Bhandari

5 Advantages:

The atomized chamfering machine with hydraulic system has below advantages:

- It increases productivity of existing system.
- It reduces fatigue to operator.
- It reduces cycle time.
- As work stations are independently, every station can operate at its own rhythm i.e. no interferences of station with another station.

6 Conclusions:

Initially the gear tooth chamfering was manually, we modified the entire operation in to automatic process by developing hydraulically operated automated gear tooth chamfering system. We can reduce machining time around 40 to 50% by adding this new hydraulic mechanism in the existing system of tooth chamfering machine and provide some sort of relief to the workers. It will also reduce human requirement for the chamfering of the gear tooth.

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