

Design and Analysis of Automatic Mechanism for Conventional Slotting Machine

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Abstract— The slotting machine is used for cutting key slots, cutting grooves of various shapes, for external and internal gears and profiles. Initial capital investment of the small scale industries is very low so it is not affordable to buy a CNC slotting machine. The small scale industries are using conventional slotting machine in which there is a lack of automation so there is inaccuracy, worker fatigue and production rate is also low, so it is necessary to find an alternative of CNC slotting machine by providing automatic mechanism in conventional slotting machine. This improved slotting machine can increase the productivity and quality of the product with affordable price. The small scale industry can optimize their production.

Key words: Conventional Slotting Machine, Automatic Mechanism

I. INTRODUCTION

The slotting machine is a reciprocating machine tool in which, the ram holding the tool reciprocates in a vertical axis and the cutting action of the tool is only during the downward stroke. The main aim of this paper is to focus on automation in conventional slotting machine at least cost. After attaching the automatic mechanism in conventional slotting machine worker do not have to repeat the operation. After loading the W/P the worker have to only pre define the desired no. Of slot required on the W/P. The w/p will rotate automatically with the help of mechanism provided in the machine in desired angle pre-defined by the worker. Workers do not need to load/unload W/P. so that less time required in machine operation. Reduced worker fatigue. W/P to be arranged at pre-defined position, so that accuracy should high. Production rate increased.

A. Construction

The slotting machine can be considered as a vertical shaper and its main parts are:

- 1) Base, column and table
- 2) Ram and tool head assembly
- 3) Saddle and cross slide
- 4) Ram drive mechanism and feed mechanism.

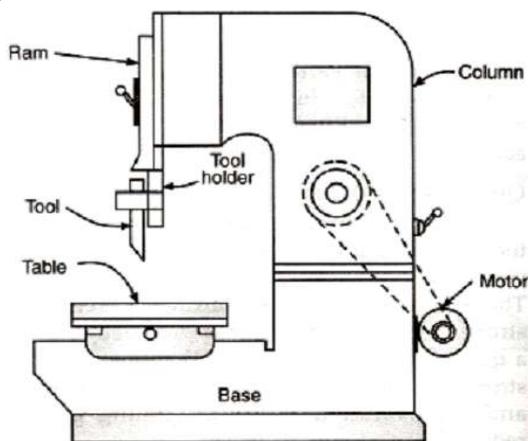


Fig. 1: block diagram of conventional slotting machine

The base of the slotting machine is rigidly built to take up all the cutting forces. The front face of the vertical column has guide ways for Tool the reciprocating ram. The ram supports the tool head to which the tool is attached. The work piece is mounted on the table which can be given longitudinal, cross and rotary feed motion.

II. DESIGN METHODOLOGY

A. Schematic Diagram of Automatic Mechanism

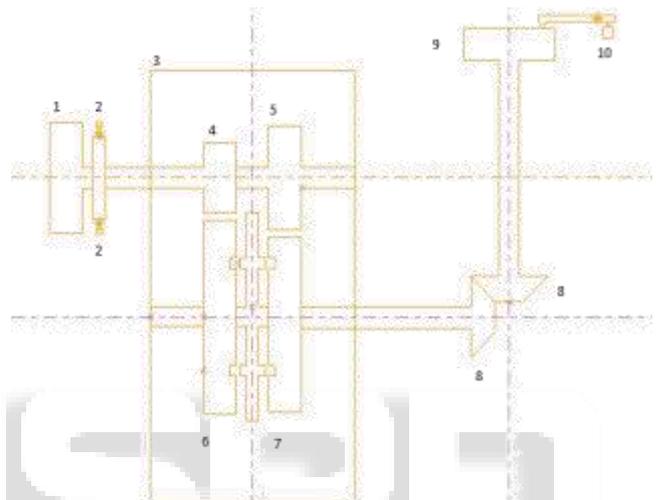


Fig. 2: schematic diagram of automatic mechanism

1) Different parts of mechanism

- 1) Stepper motor
- 2) Limit switch
- 3) Gear box
- 4) First pinion gear
- 5) Second pinion gear
- 6) First spur gear
- 7) Second spur gear
- 8) Bevel gear
- 9) Chuck
- 10) Solenoid chuck lock

III. WORKING

- 1) In conventional slotting machine gearbox assembly attached with column and locking mechanism and solenoid valve with PLC controller fitted with base of slotting machine. In Gear box mechanism stepper motor connected with pinion gear shaft through disc which is held between stepper motor and gearbox assembly. Both side limit switch attached on periphery of disc at 180 degree, output shaft of gearbox is connected with chuck through bevel gear.
- 2) If stepper motor rotated 360 degree then pinion gear shaft also rotate same degree, both pinion gear fixed on shaft so that both gear rotated 1 revolution, here no. of teeth on pinion gear are 40 and 30 respectively, both gear are connected with spur gear having no. of teeth are 80 and 90 respectively. If clutch is engaged with

first spur gear then 360° rotation of first pinion gear becomes 180° rotation of spur gear. Here output shaft is directly connected with dividing head, so that $1/2$ rotation of dividing head and 2 slots produced in work-piece periphery. If clutch is engaged with second spur gear then 360° rotation of second pinion gear becomes 120° rotation of spur gear. so that $1/3$ rotation of dividing head and 3 slots produced in work-piece periphery.

- 3) If limit switches on disc which actuate then after half rotation of stepper motor, rotation will stop and pinion shaft rotates only 180° . So that first pinion gear rotates 180° becomes 90° rotation of spur gear as well as dividing head so 4 slots produced in work-piece periphery. And with the help of second spur gear engagement 6 slots produced in work-piece periphery.
- 4) During starting of non-ideal stroke the solenoid valve actuates and locked the work-piece. During ideal stroke solenoid valve off and un-locked the work-piece. At that time cutting tool away from the workpiece and chuck will rotate with the help of gear box. With the help of this mechanism automatically 2, 4, 3, 6...different slots can be produced on work-piece as per requirement

IV. LIST OF PARTS USED IN MECHANISM

- Stepper motor
- Limit switch
- Gearbox assembly
- Locking mechanism

A. Stepper Motor

A stepper motor is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor position can then be commanded to move and hold at one of these steps. Advantages of step motors are low cost, high reliability, high torque at low speeds and a simple, rugged construction that operates in almost any environment.



Fig. 3 stepper motor

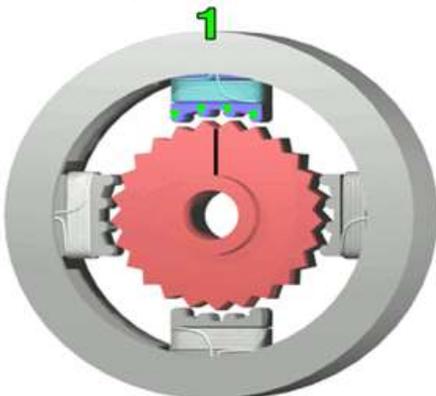


Fig. 4 magnetic rotor

B. Limit Switch

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.



Fig. 5: Limit Switch

C. Gear Box Assembly

Gearbox assembly consists of a pinion gear, spur gear, clutch mechanism, shafts. The smaller gears on the right hand side are the pinion gears and are fixed in relation to each other (They rotate as one unit). Both pinion gears are fixed on one shaft at particular distance, both gears having different number of teeth. Pinion gears fixed on shaft which is directly connected to stepper motor. This assembly and wonder how it could possibly work, which is understandable, given that the gears are apparently fixed in relation to each other.



Fig. 5 pinion gear & spur gear



Fig. 6 gear box part

This is where the spur gears on the left come in, as they are held onto the transmission shaft, or as it is generally referred to, the lay shaft, in two totally different ways; The uppermost (Second) spur gear is mounted onto the shaft with a ball raced metal housing, the inside of which contains a clutch system, but is otherwise free to rotate on the shaft. Both spur gears freely rotate on main shaft; the main shaft is connected to dividing head mechanism through bevel gear, between two spur gear clutches to be operated. With the help of clutch engaged or disengaged to spur gear different two speeds to be obtained.

D. Locking Mechanism:

A solenoid is described as a coil of wire usually wrapped around a metal core. When the solenoid receives an electric

current, it creates a magnetic field that can become useful in controlling locks, water pressure, air pressure, clamps, and the like. This solenoid valve is used here for locking chuck So here Solenoid valve is connected by PLC controller .PLC controller sends signals to the stepper motor and locking mechanism simultaneously. So when the one slot is completed in a work piece, controller send's signal to solenoid valve to unlock chuck and then stepper will rotate the chuck to predefined position. After rotation of the chuck to predefined position, PLC controller send signal to solenoid valve to lock the chuck.



Fig. 7: PLC programme

E. Solenoid Valve

The valve is controlled by an electric current through a solenoid in the case of a two-port valve that is switched on or off. A solenoid valve is an electromechanically operated valve.



Fig. 8 Solenoid Valve

V. ANALYTICAL DESIGN OF GEAR

A. Pinion and Spur Gear Formula

TO FIND	HAVING	FORMULA
metric module	pitch dia. and no. of tooth	$M = PD/N$
pitch diameter	module & no. of teeth	$D = M * N$
outside diameter	module & no. of teeth	$OD = (N + 2) * M$
diametric pitch	Module	$DP = 25.4 / M$
circular pitch	Module	$C = M * 3.14$
Addendum	module known	$A = M$
Duodenum	diametric pitch	$1.157 / DP$
whole depth	module known	$2.157 * M$
thickness of tooth	module and outside dia.	$T = PD * \sin 90 / N$

Table 1: Formulas for Gears

B. Measurement of Tooth Thickness [2]

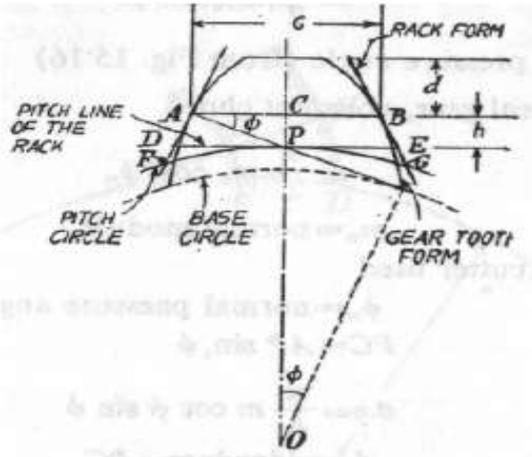


Fig. 9: measurement of tooth thickness

AB = Constant chord

$$c = AB = 2AC$$

$$= \frac{\pi}{2} m \cos^2 \phi \rightarrow \phi = \text{pressure angle}$$

$$d = \text{addendum} - PC = m \left[1 - \frac{\pi}{4} \cos \phi \sin \phi \right]$$

C. Numerical Calculation of Gear Box Part

1) Design for gear and pinion for stage 1:

Design parameters:-

Teeth of gear = 90

Teeth of pinion = 30

Centre distance = 150 mm

Power = 1.492 KW

Material: steel

$$\sigma_{ut} = 315 \text{ MPa}$$

$$\sigma_e = 420 \text{ MPa}$$

$$\sigma_{es} = 616 \text{ MPa}$$

$$C = 114$$

ϕ (pressure angle) = 20

$$E_p = E_g = 110 \text{ MPa}$$

Here material used for pinion and gear is steel so that we have to design a small part so, Design of pinion

$$D_g/D_p = T_g/T_p = N_p/N_g = 90/30 = 3 \dots\dots\dots \text{eq. (1)}$$

$$D_g + D_p = 2 * \text{center distance} = 2 * 150 = 300 \text{ mm} \dots\dots\dots \text{eq. (2)}$$

Sol. eq.(1) & (2)

$$D_p = 75 \text{ mm} \ \& \ D_g = 225 \text{ mm}$$

Now,

$$\text{Module } m = D_p/T_p = 2.5 \text{ mm}$$

$$V = \frac{\pi D N}{60} = 0.196 \text{ mm/sec}$$

$$K_v = \frac{3+V}{3} = 1.06$$

Now,

$$\sigma_{ut} = \frac{\omega t * K_v}{b m y}$$

$$\text{Where, } \omega t = \frac{P}{V} * C_s = \frac{1492}{0.196} = 7612 \text{ N}$$

$$\text{Now, } y = \pi (0.154 - 0.912/T_p) = 0.388 \text{ mm}$$

So we get, $b = 26 \text{ mm}$

Now, we know that Dynamic load,

$$\omega_D = \omega_T + \omega_I$$

$$= 7612 + \frac{21V(BC + \omega t)}{21V + \sqrt{BC + \omega t}} = 8018.99 \text{ N}$$

Now, we know that Static load,

$$\sigma_e = \frac{\omega_s * K_v}{b m y}$$

$$\omega_s = 9992.83 \text{ N}$$

Now, we know that Wear load,

$$\omega_w = D_p * b * Q * K$$

$$\text{Where } Q = \frac{2(V.R)}{V.R + 1} = 1.5$$

$$K = \frac{(\sigma_{es})^2 * \text{SIN} \phi}{1.4} \left(\frac{1}{E_p} + \frac{1}{E_g} \right) = 1685.47$$

$$\omega_w = 4929 * 10^3 \text{ N}$$

So, $\omega_D < \omega_s < \omega_w$

That condition satisfies. So, the design is SAFE

2) Design for gear and pinion for stage 2:

Design parameters:-

Teeth of gear = 80

Teeth of pinion = 40

Here material used for pinion and gear is steel so that we have to design a small part

Design of pinion

$$D_g/D_p = T_g/T_p = N_p/N_g = 80/40 = 2 \dots\dots\dots \text{eq. (1)}$$

$$D_g + D_p = 2 * \text{center distance}$$

$$= 2 * 150$$

$$= 300 \text{ mm} \dots\dots\dots \text{eq. (2)}$$

Sol. eq.(1) & (2)

$$D_p = 100 \text{ mm} \ \& \ D_g = 200 \text{ mm}$$

Now,

$$m = D_p/T_p = 2.5 \text{ mm}$$

$$V = \frac{\pi D N}{60} = 0.26 \text{ mm/sec}$$

$$K_v = \frac{3+V}{3} = 1.08$$

$$\text{Now, } \sigma_{ut} = \frac{\omega t * K_v}{b m y}$$

$$\text{where, } \omega t = \frac{P}{V} * C_s$$

$$= \frac{1492}{0.26}$$

$$= 5738.46 \text{ N}$$

$$\text{Now, } y = \pi (0.154 - 0.912/T_p)$$

$$= 0.411 \text{ mm}$$

So we get, $b = 19.25 \text{ mm}$

Now, we know that Dynamic load,

$$\omega_D = \omega_T + \omega_I$$

$$= 5738.26 + \frac{21V(BC + \omega t)}{21V + \sqrt{BC + \omega t}}$$

$$= 6196.70 \text{ N}$$

we know that Static load

$$\sigma_e = \frac{\omega_s * K_v}{b m y}$$

$$\omega_s = 7649.48 \text{ N}$$

We know that, Wear load

$$\omega_w = D_p * b * Q * K$$

$$\text{Where } Q = \frac{2(V.R)}{V.R + 1} = 1.33$$

$$K = \frac{(\sigma_{es})^2 * \text{SIN} \phi}{1.4} \left(\frac{1}{E_p} + \frac{1}{E_g} \right) = 1685.47$$

$$\text{so we get, } \omega_w = 4315 * 10^3$$

So, $\omega_D < \omega_s < \omega_w$

That condition satisfies. So, the design is SAFE

Parameter	1 st	2 nd	1 st Spur	2 nd Spur
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	Pinion gear	Pinion gear	Gear	Gear
Pitch circle	100	75	200	225
Tooth	40	30	80	90
Pressure angle	20	20	20	20
Addendum	5mm	5mm	5mm	5mm
Dedendum	5mm	5mm	5mm	5mm
outside diameter	105mm	80mm	205mm	230mm
Diametric pitch	10.16mm	10.16mm	10.16mm	10.16mm
Module	2.5	2.5	2.5	2.5
Tooth thickness	3.92mm	3.92mm	3.92mm	3.92mm

Table 2: Conditions

VI. DESIGN AND ANALYSIS

A. Design of Gear and Gear Box[3]

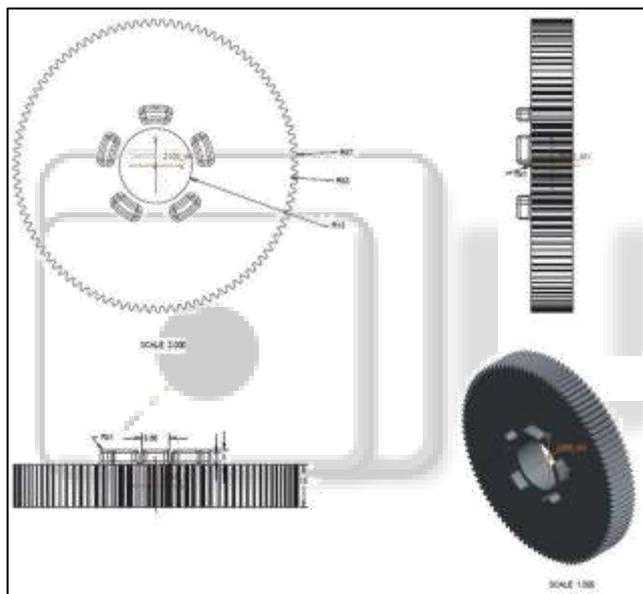


Fig. 10: Spur Gear

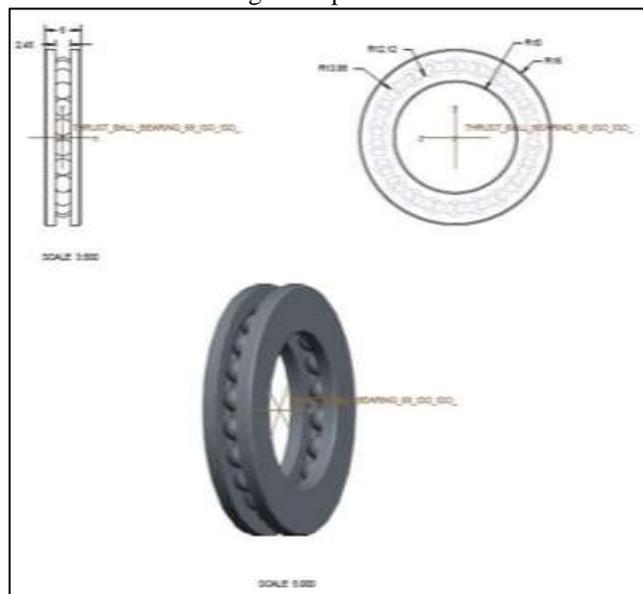


Fig. 11: Bearing

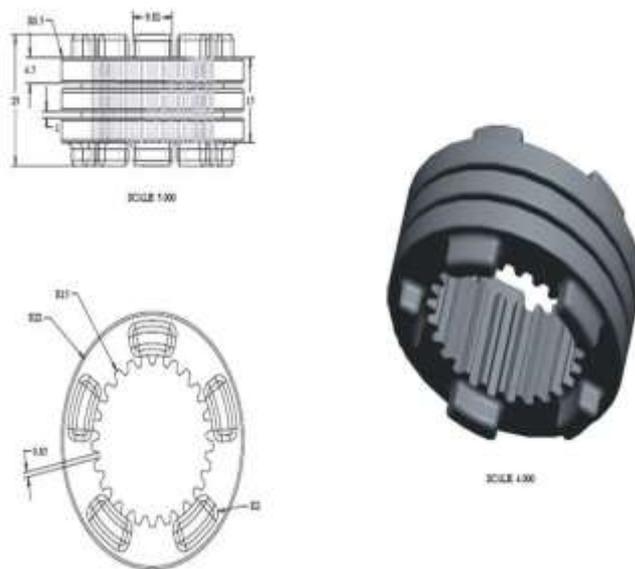


Fig.12 Dog clutch



Fig.13 Shaft

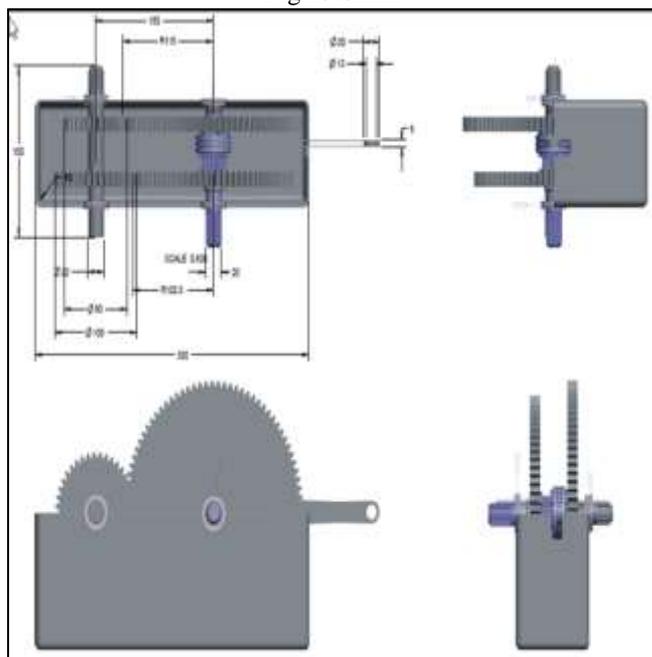


Fig. 14: Gear Box Assembly



Fig. 15: Gear Box

3) Gear-Box Body Analysis

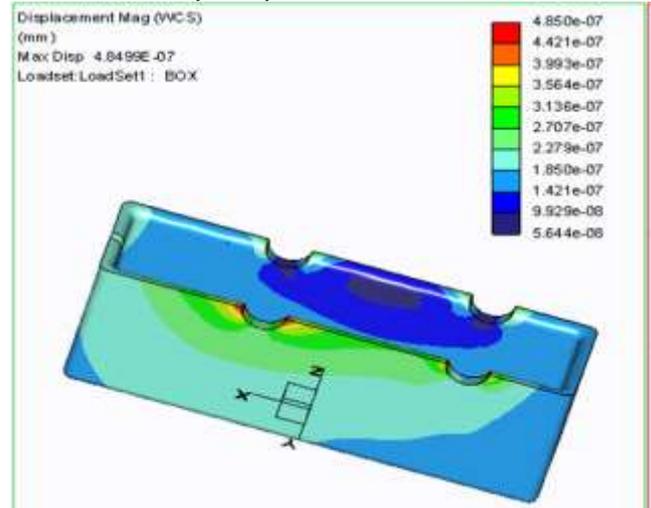


Fig. 18: Gear-Box Body Analysis

B. Gearbox Parts Analysis[1]

1) Spur Gear Analysis

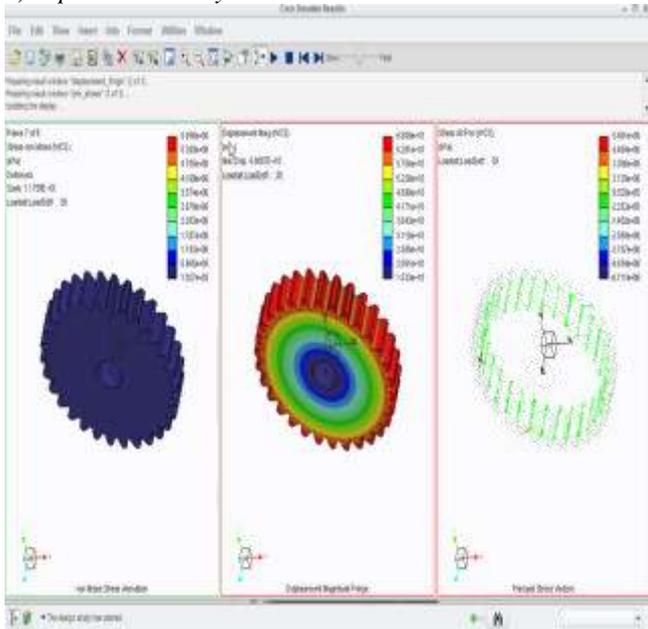


Fig. 16: Spur Gear Analysis

2) Gear Pair Analysis

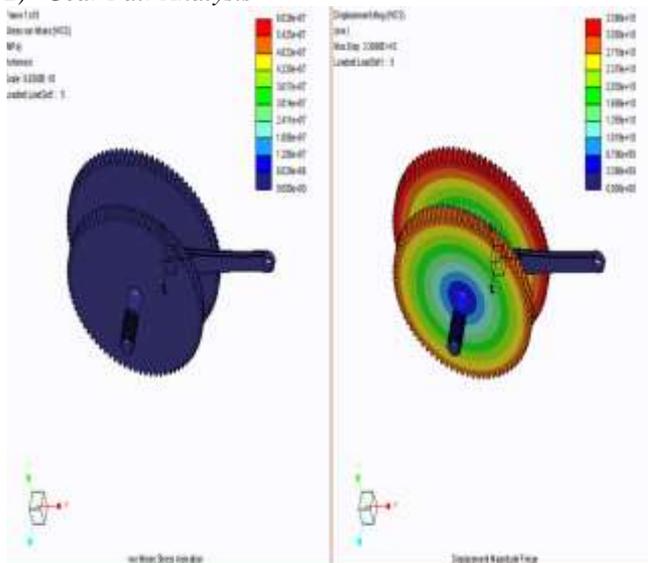


Fig. 17: Gear Pair Analysis

VII. CONCLUSION

Using this mechanism in slotting machine we can get:

- Better productivity
- Accuracy
- Precision with less worker fatigue
- Initial investment cost is low.

VIII. FUTURE SCOPE

This dividing mechanism can also be used in Drilling machine and Milling machine for automation. Precision machining and operational flexibility are features in automation. In future there is still scope of automation in sliding table for variable slotting depth and width with using different mechanism or electronic lift and feed. It is possible to select models with 1, 2, 3 or 4 controlled axes to best satisfy our production requirement. In slotting machine also we can add features like self-centring of chuck, pull-open safety enclosure, locking plate and safety protection.

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