Design and Analysis of Multi Spindle Drilling Head with Adjustable Centre Distance

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Abstract - *Most of the local brake part manufacturing industries in developing countries like India, still drill holes in casting part make by two or more drilling head on two or more number of machine. This accumulation constitutes a space problem and encourages idle time. A gang-drilling (or a multiple spindle drilling) machine that could perform all the drilling operations in one operation. In response to this, a Multiple-Spindle Drilling Head (MSDH) is designed. The machine was designed as an attachment (accessory) to a main drill from which it drives the power for its operations.*

Multi spindle head machines are used in mechanical industry in order to increase the productivity of machining systems. Such machines are equipped by spindle heads that carry multiple tools for performing machining operations. The most noteworthy aspect when using multi-spindle machines is the cycle time, due to parallel machining the total operating time is dramatically decreased. Added benefits include less chance for error, less accumulated tolerance error, and eliminate tools changes. In such a multi-spindle machine, a part to be machined is fixed on the table.

*Key Words***:** *Multi Spindle Drilling Attachment, Gear, Spindle, Shaft, Drill Holder Design, Analytical Calculations, Static Analysis.*

1.INTRODUCTION

Drilling is the most generally perceived machining process whereby the operation incorporates making round openings in metallic and non-metallic materials. Around 75% of all metal-cutting method is of the drilling operation. Drills generally have a high length to diameter proportion that is fit for making significant hole, however as a result of its flexibility, vital security measure ought to be taken to keep up accuracy and keep drill from breaking.

Drilled holes can be either through holes or visually blind holes. A through holes is made when a drill leaves the inverse side of the work; in blind hole the drill does not leave the work piece. During the operation, chips that are created inside the work piece must exit through the flutes to the outside of the device. As the chip is formed and removed towards the surface, it will produce friction. Friction subsequently warm is likewise created when the drill bit touch the work piece during the hole making process. In this way, chip transfer and cutting fluids are among the most essential components should be consider during this procedure. Regularly, holes created by drilling are greater than the drill diameter and relying upon its applications; the drilled holes will subjected to different operations, for example, reaming or sharpening to better surface complete and dimensional exactness.

1.1 Types of Drilling Machine

Based on construction

- Portable drilling machine
- Sensitive drilling machine
- Radial drilling machine
- Up right drilling machine
- Gang drilling machine
- Multi spindle drilling machine

Based on feed

- Hand power drilling machine
- Power driven drilling machine

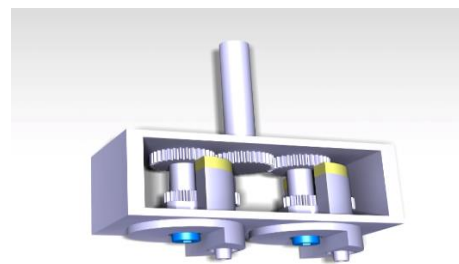## 3.3 Principle of Multi spindle Drilling Head

Fig -1.1: Multi Spindle Drilling Head

1. As the name demonstrates various multiple drilling machines have two spindles driven by a solitary power head and these two spindles holding the drill bits are fed into the work piece simultaneously.

2. The spindles are so constructed that their centre distance can be balanced in any position within the drill head depending upon the job requirement. For this reason, Allen bolt is used.

3. The power from the motor is transmitted by spindle to the centre gear. After that power at centre gear is transmitted to the drilling spindle by compound gear train.

1.2. Problem Definition

In the conventional manner just a single job can be worked at once for both of the above operations, however with increase in productivity demands a special purpose device or attachment is need which will increase productivity by,

1. Performing operations on more than one job at a time.

2. Performing multiple operations in one cycle.

3. Indexing capability to sequence operations one after another.

1.3 Solution

The multi-spindle drilling attachment is a perfect answer for the above issue. Where the regular drilling machine is utilized to perform three operations at any given moment, so likewise different operations like boring, reaming, countersinking or spot confronting should be possible by using multi spindle drilling attachment.

1.4 Objectives

- Manual design calculations of spindle and shaft.

- Manual design calculations of main gear and compound gear.

- Manual design of drill holder and bush bearing.

- Manual design of Multi Spindle Drilling Head for adjustable centre distance.

- Modeling of all the parts in CATIA.

- Analysis using ANSYS.

- Comparison of results.

1.5. Centre Distance

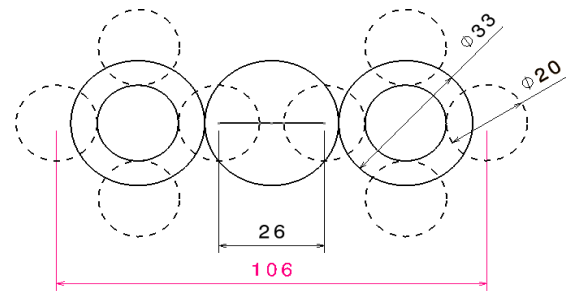Centre distance can vary within the range of 26mm to 106 mm. This is shown in below figure.

Fig -1.2: Range of centre distance

2. DESIGN AND CALCULATIONS

2.1 Selection of Prime Mover

Diameter of hole (d) = 4 mm & 5 mm
Thickness of the plate (t) = 8 mm
Work piece material = Cast Iron
Power = $\{1.25 \times D^2 \times K \times N \times (0.056 + 1.5 \times Fn)\}/10^5$
For ϕ4 mm
Power = $\{1.25 \times 4^2 \times 1.5 \times 720 \times (0.056 + 1.5 \times 0.0635)\}/10^5$
Power = 0.032 kw
For 2 Spindles = 0.032×2 = 0.065 kw
Power = 0.088 HP
For ϕ5 mm
Power = $\{1.25 \times 5^2 \times 1.5 \times 720 \times (0.056 + 1.5 \times 0.0635)\}/10^5$
Power = 0.051 kw
For 2 Spindles = 0.051×2 = 0.1 kw
Power = 0.13 HP
Total power required = 0.13+0.13 = 0.277 HP
Therefore 0.5 HP motor is required.

2.2 Design of Spindle

Consider diameter of spindle = 16 mm
Material of spindle = Mild steel
$P = 2\pi NT/60$
$T = (367.5 \times 60)/(2 \times \pi \times 720)$
T = 4874 N-mm
Consider 25% overload
T = 6092 N-mm
$D = \{(16/\pi \times \tau) \times K_t \times M_t\}^{0.33}$
$16 = \{(16/\pi \times \tau) \times 2 \times 6092\}^{0.33}$
$\tau = 15.14$ N/mm^2

The values of shear stress is 15.14 N/mm^2. This is very less as compare to yield stress of spindle material. (415 N/mm^2) Therefore spindle design is safe.
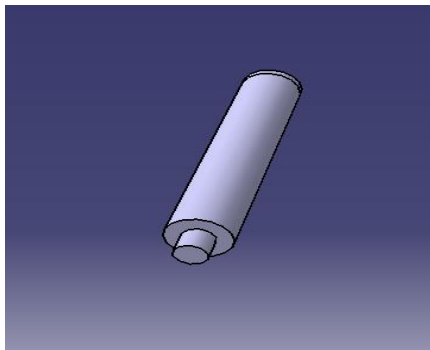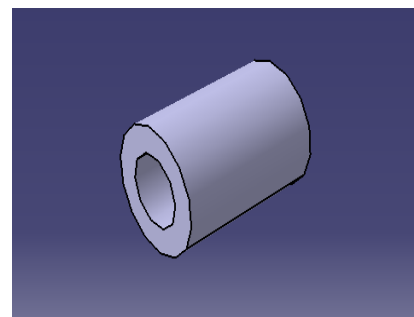
Fig -2.1: CATIA Model of Spindle

2.3 Design of Big Gear

Material of gear = EN 24
Consider diameter of gear (d) = 33 mm
Consider Module = 1 mm
No. of teeth = 33
From Lewis equation,
$\sigma = \{F_t/(C_v \times b \times Y \times m)\}$
$\sigma = \{370/(0.7102 \times 8 \times 0.3967 \times 1)\}$
$\sigma = 164.16 \ N/mm^2$

The induced stress value is 164.16 N/mm^2. This value of stress is very less as compared to yield stress of gear material. (680 N/mm^2) Therefore designed gear is safe.
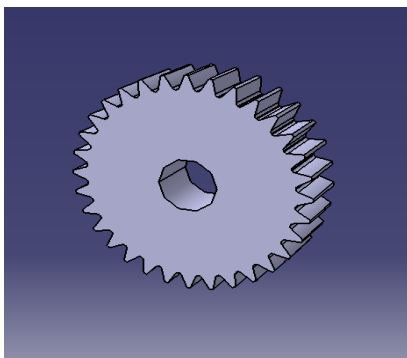

Fig -2.2: CATIA Model of Big Gear

2.4 Design of Small Gear

Material of gear = EN 24
Consider diameter of gear (d) = 20 mm
Consider Module = 1 mm
No. of teeth = 20
$\sigma = 279.29 \ N/mm^2$

The induced stress value is 279.29 N/mm^2. This value of stress is very less as compared to yield stress of gear material. (680 N/mm^2) Therefore designed gear is safe.

2.5 Design of Shaft

Material of Shaft = Mild Steel
Outer diameter of shaft = 14 mm
Inner diameter of shaft = 8 mm
Torque transferred to the shaft = 6092 N-mm
For Shear Stress,
$D_0 = \{(16/\pi \times \tau \times (1-K^4)) \times K_t \times M_t\}^{0.33}$
$14 = \{(16/\pi \times \tau \times (1-0.571^4)) \times 2 \times 6092\}^{0.33}$
$\tau = 25.31 \ N/mm^2$

The induced shear stress value is 25.31 N/mm^2. This value of shear stress is very less as compared to yield stress of shaft material. (415 N/mm^2) Therefore designed shaft is safe.

Fig -2.3: CATIA Model of Spindle

2.6 Design of Drill Holder

Material of Drill Holder = Mild Steel
Diameter of Drill Holder = 8 mm
For shear stress,
$D = \{(16/\pi \times \tau) \times K_t \times M_t\}^{0.33}$
$D = \{(16/\pi \times \tau) \times 2 \times 6092\}^{0.33}$
$D = 121.19 \ N/mm^2$

The value of shear stress is 121.19 N/mm^2. This is very less as compare to yield stress of drill holder material. (415 N/mm^2) Therefore designed drill holder is safe.
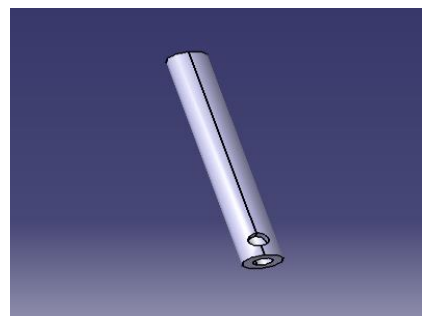

Fig -2.4: CATIA Model of Drill Holder

3. ANALYSIS

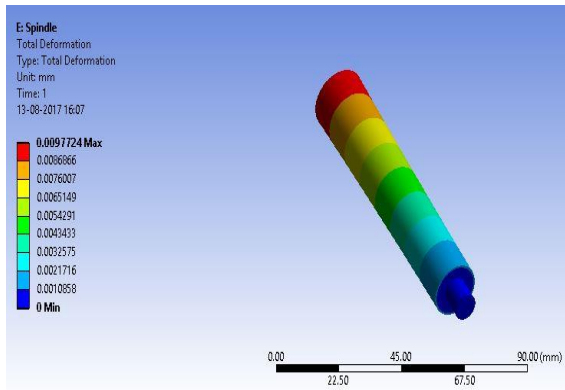## 3.1 Spindle Analysis

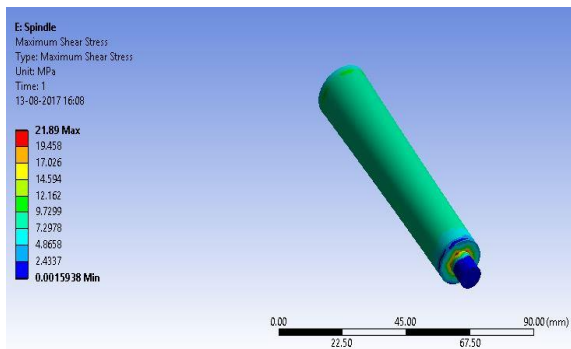**Fig -3.1**: Total Deformation in Spindle

Fig -3.2: Maximum Shear Stress in spindle

Torque of 6092 N-mm is applied to spindle and obtained shear stress value is 21.89 MPa which is very less compared to yield stress of material (415 N/mm^2). So it is safe under shear stress condition. The total deformation observed in the spindle is 0.0097 mm.
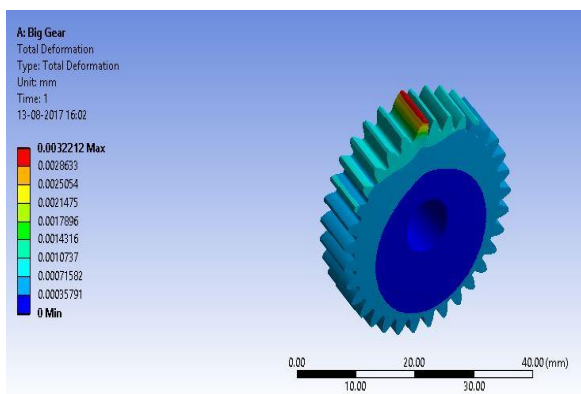
3.2 Big Gear Analysis

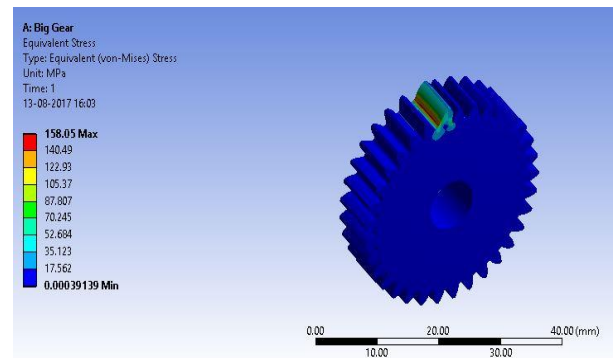**Fig -3.3**: Total Deformation in Big Gear

Fig -3.4: Equivalent Stress in Big Gear

Force of 370 N applied on gear tooth as shown in figure 5.16 above. Induced equivalent stress is 158.05MPa this value is below yield stress (680MPa) of material therefore gear design is safe. The total deformation observed in the big gear is 0.0032 mm.
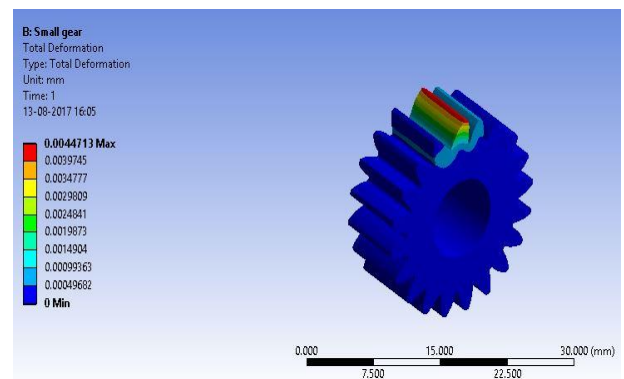
3.3 Small Gear Analysis
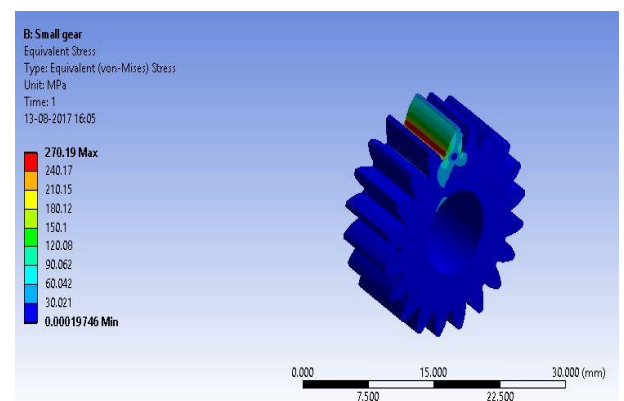

Fig -3.5: Total Deformation in Small Gear

Fig -3.6: Equivalent Stress in Small Gear

Force of 610 N applied on gear tooth as shown in figure above. Induced equivalent stress is 270.19MPa this value is below yield stress (680MPa) of material therefore gear

design is safe. The total deformation observed in the big gear is 0.0044 mm.
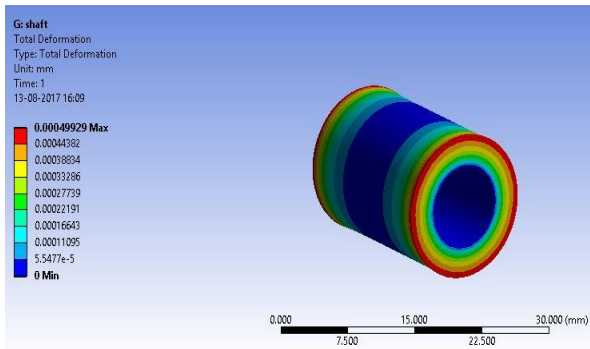
3.4 Shaft Analysis

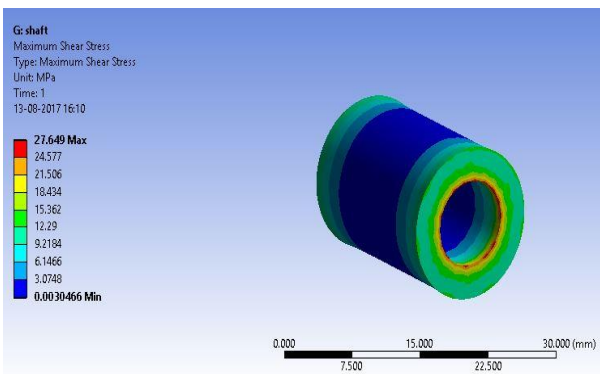**Fig -3.7**: Total Deformation in Shaft

Fig -3.8: Maximum Shear Stress in Shaft

Torque of 6092 N-mm is applied to shaft and obtained shear stress value is 27.64MPa which is very less compared to yield stress of material (680 N/mm^2) so it is safe under shear stress condition. The total deformation observed in the shaft is 0.00049 mm.
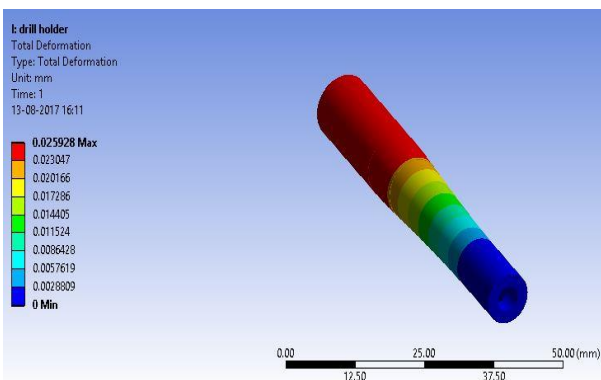
3.5 Drill Holder Analysis

Fig -3.9: Total Deformation in Drill Holder

Fig -3.10: Maximum Shear Stress in Drill Holder
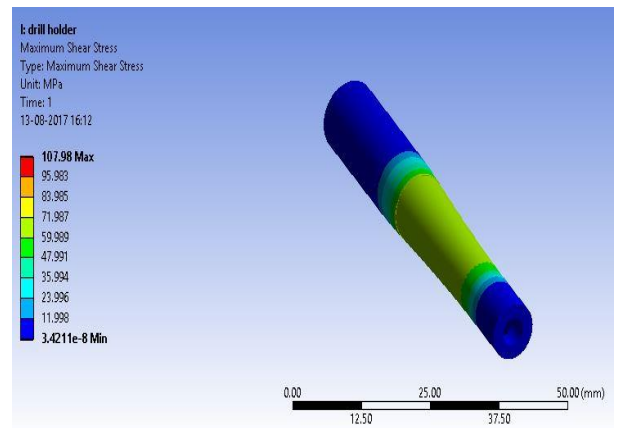
Torque of 6092 N-mm is applied and obtained shear stress value is 107.98MPa which is very less compared to yield stress (415MPa) of material so it is safe under shear stress condition. The total deformation observed in the drill holder is 0.025 mm.
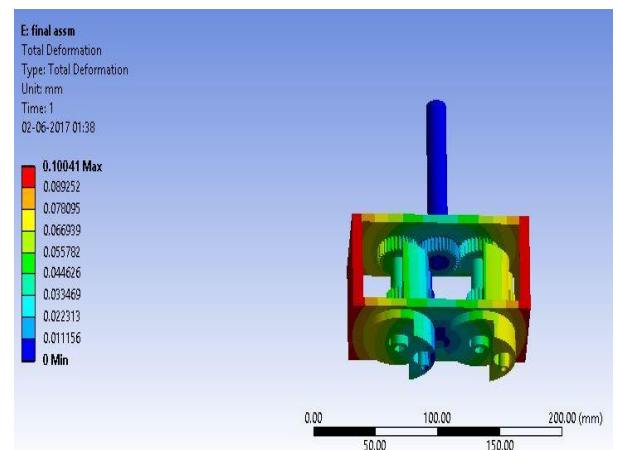
3.6 Assembly Analysis
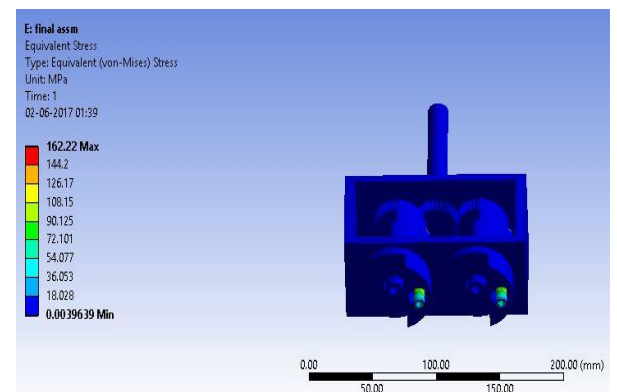

Fig -3.11: Total Deformation in Assembly

Fig -3.12: Equivalent Stress in Assembly

All the values of stresses are below yield stress of the material (415MPa) so assembly is safe under all the loading conditions. . The total deformation observed in the assembly is 0.100 mm.

4. Comparison of Results

In this project various parts of multi spindle drilling head attachment have been analyzed as above. The static analysis is done to study the deformation and stresses induced in the parts. Analytical design calculations is also done by using various design formulas. Comparison of static analysis results with analytical results is done which is given below.

Table 4.1: Comparison of Results

Part Name	ANALYTICAL		ANSYS		
	Shear Stress, MPa	Equivalent Stress, MPa	Shear Stress, MPa	Equivalent Stress, MPa	Deformation, mm
Spindle	15.14	-	21.6	-	0.0097
Big Gear	-	164.16	-	158.05	0.0032
Small Gear	-	279.29	-	270.19	0.0044
Shaft	25.31	-	27.64	-	0.00049
Drill Holder	121.19	-	107.98	-	0.025

5. CONCLUSION

The results obtained through analytical design calculations of the various parts of multi spindle drilling attachment are compared with the yield stress of that material for safe design. And static analysis is done which is compared with analytical results. Results shows the values of deformation, shear stress and equivalent stress and these values are below yield stress of the material. Therefore all the parts are safe under all the loading condition. In comparison of analytical and ANSYS results both results are close to each other. Hence by looking into this results stresses and deformation are within the limit therefore multi spindle drilling head attachment design is safe.

With the help of this attachment, one can drill two holes at a time with provision of varying centre distance between two drilling spindle. Using multi spindle drilling attachment increase productivity at low cost and in less time, cycle time is also reduced. With the help of this design and analysis it is possible to develop three or four spindle drilling machine attachment.

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