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Research Article

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Design and Calculation for Multi Spindle Drilling Head with Adjustable Centre Distance

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Abstract This paper emphasis on designing of adjustable multi spindle drill head and calculation for its adjustable centre distance. Multi-drill finds a major application in almost every mechanical industry. In mass production where the product type is less and quantity to be produce is large thus multi drilling machine is preferred for higher machine efficiency and less production time (by eliminating the time required for tool change). Adjustable multi spindle drill is a type of multi drilling machine which gives the machine an ability to change the centre distance between two drilling bit which helps in increasing the flexibility of drill machine to drill at varying distance which is not possible with fixed spindle multi drill machine.

Keywords DOF, Module, drill bit, sun & planetary gear, pitch, reference diameter

1. Introduction

Drilling is a cutting process that uses drill bit to cut holes of circular cross-section in metallic or non- metallic material by pressing the bit against the work-piece rotated at higher rpm. Almost every component on production line has to go through drilling operation. Many of them are of drilling multiple holes close to each other (Ex: drilling operation in break disc manufacturing) thus it becomes tedious and time consuming to drill hole one by one. The use of multi drill is preferred here as it takes same time to drill multiple holes as that of the time taken to drill single hole. Adjustable multi spindle drilling machine consists of more than one drill bit arranged across central drill through compound or sun & planetary gear arrangement. The central distance for drilling can be adjusted by simply revolving the drilling spindle drive gear to suitable adjustment point [1].

Types of multi spindle drill head

There are two type of multiple drill head available in the market the fixed multi spindle drill head and adjustable multi spindle drill head. We cannot change the centre distance in fixed multi spindle head. While we can change the centre distance to some limit in adjustable multi spindle drill head. These are the gear adjustable drilling head [2].

Problem Definition

In the conventional method drilling of two or more holes close to each other is done by manually adjusting the work piece under the drill bit. Fixed Multi spindle drill finds a way to solve this problem to an extent but due to its fixed spindle position it can only drill holes at a fixed distance [3-4]. This limits its application to mass production industry where same type of pattern drilling is performed.

Solution

All the above stated problems point toward the use of multi drill having provision to adjust centre distance of the drill bit so as to change centre distance according to the pattern which saves the cost of making standard multi drill head for each pattern specially if the new pattern requires only small variation in drilling distance (Say few centimeter) [5].

2. Design

The design and construction of three spindle adjustable drilling head is shown in figure 1. It is consist of central gear or sun gear (spur gear) surrounded by planetary gear.

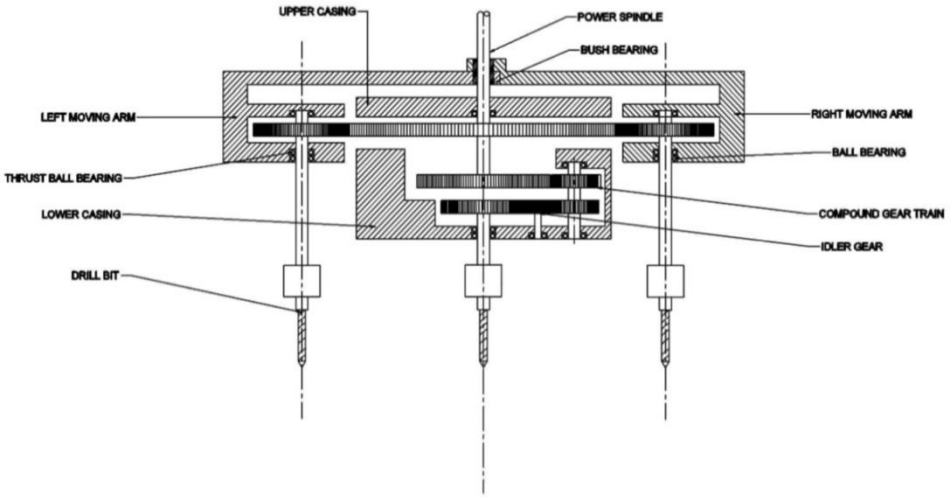


Figure 1: Sectional view of three spindle multi drill machine

The sun gear spindle is directly connected to pulley which is powered by motor through belt drive. Compound gear train is attached with the central gear in order to rotate the central drilling bit in the same direction as that of the direction of drilling bit attached to planetary gear thus each of the three drilling bits rotate in the same direction.

The planetary gear has given two DOF (degree of freedom) one is the rotation about its own axis and other is half circular motion about the central gear axis on a slotted plate fixed with gearbox as shown in figure 2.

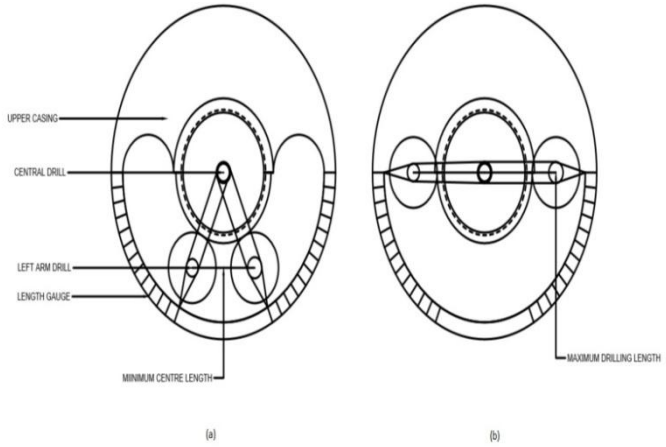


Figure 2: (a) minimum drilling length position, (b) maximum drilling length position

Thus the adjustment of central distance can be easily done by rotating the planetary gear about the sun gear. Two casing (upper casing & lower casing) of cast iron is provided to act as a support on which the gear train is mounted. Trust ball bearing is provided at the end of each drill bit shaft to protect it against the axial thrust and damage.

3. Calculation

The calculation done here is to find the effect of planetary gear rotation about the sun gear on the drilling distance. Below are some governing parameters which will be used in calculating the distance between adjustable drilling bits.

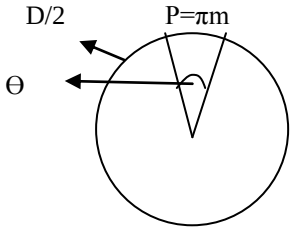
a) Θ be the angle subtended by pitch arc on the centre

Therefore,

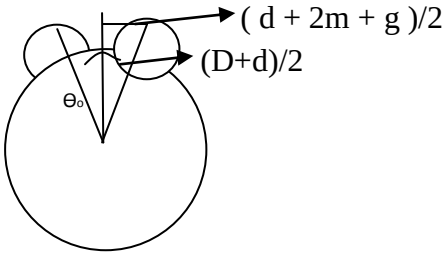
$\Theta = \pi m / D/2$

$\Theta = 2\pi m/D$

where, D = pitch diameter of sun gear
m = module of gear



b) Let Θo be the minimum angle between rotating spindle arm and central line for minimum central distance.



Both planetary gear is rotating in the same direction so the meshing of both gear is not possible (i.e; minimum centre distance has to be more than d).

So, minimum centre distance = d + 2m + g

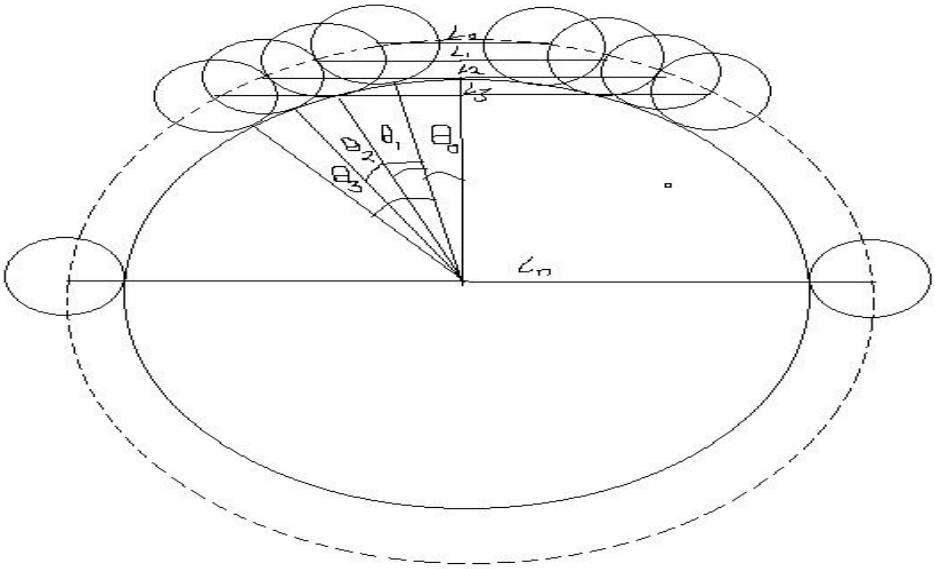
where, g = safe gap between top land of the Planetary gear

Therefore, $\Theta o/2 = \text{Sin}^{-1} [(d + 2m + g) / (D + d)]$

$\Theta o = 2\ \text{Sin}^{-1} [(d + 2m + g) / (D + d)]$

Note:-From above equation we can say that Θo will be minimum if module of the gear is minimum.

c) Let, L=central distance between planet gears.



Therefore, $L/2=(D+d)/2\{\sin[(2p/D)n*180/\pi + \Theta o/2]\}$

Where, $(2p/D)n*180/\pi = \Theta n$

So, we can also write above equation as,

$L/2=(D+d)/2 \sin\{(\Theta n + \Theta o/2)\}$

Following are some solved examples in order to understand the theory.

Table 1: Calculation of adjustable centre distance Ln for planetary gear reference diameter = 36mm, sun gear reference diameter = 76mm and the gear module = 1& g=4mm.

n	Θo/2	Z	Ln/2	Ln
0	22 ℃	76	21	42
1	22 ℃	76	25	50
2	22 ℃	76	29.25	59
3	22 ℃	76	33	66
4	22 ℃	76	36.7	73.5
5	22 ℃	76	40	80
6	22 ℃	76	43	86
7	22 ℃	76	46	92
8	22 ℃	76	48.5	97
9	22 ℃	76	50.6	101
10	22 ℃	76	52.4	105
11	22 ℃	76	54	108
12	22 ℃	76	55	110
13	22 ℃	76	55.5	111
14	22 ℃	76	56	112

Table 2: Calculation of adjustable centre distance Ln for planetary gear reference diameter = 36mm, sun gear reference diameter = 76mm, gear module = 2 & g=4mm.

n	Θo/2	Z	Ln/2	Ln
0	23.13 ℃	76	22	44
1	23.13 ℃	76	30	60
2	23.13 ℃	76	37.5	75
3	23.13 ℃	76	44	88
4	23.13 ℃	76	49	98
5	23.13 ℃	76	53	106
6	23.13 ℃	76	55	110
7	23.13 ℃	76	56	112

Table 3: Calculation of adjustable centre distance Ln for planetary gear reference diameter = 36mm, sun gear reference diameter = 76mm, gear module = 3 & g=4mm

n	Θo/2	Z	Ln/2	Ln
0	24.25	76	23	46
1	24.25	76	35	70
2	24.25	76	44.5	89
3	24.25	76	51.5	103
4	24.25	76	55.3	110.6

4. Conclusion

From the above calculation it is concluded that lower the gear module used for designing drill head higher will be the precision level in adjusting centre distance point for drilling operations.

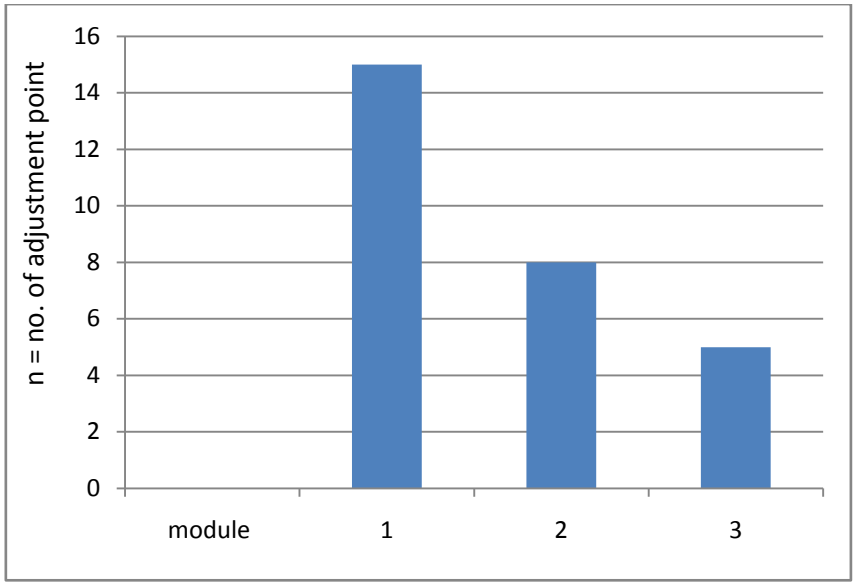


Figure 3: Variation of adjustment point v/s module of gear used in multi-drill head

Also it seems from the above calculation that the number of adjustable central drill point increases:-

- With Increase in sun gear dia.
- With Decrease in planet gear dia.

5. Application

- For drilling many pattern as required in metal joining plate manufacturing.
- For drilling holes in coupling for fastening purpose.
- In brackets manufacturing company.

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