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Research, Design and Develop a prototype of Multi-Spindle Drilling Head

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Abstract

In recent years, the study of machine tool technology has got strong attention to expand development in universities, research institute and also in industry. However, there are a few publications/papers related a design and application of the multi-spindle drilling which flexibly adjusts parameters such as the number and the position of holes. In this research, the author will present a new design of a multi-spindle drilling head that uses Cardan universal joint for driving in order to increase productivity, decrease product expenses. To check the principle of working after simulation we developed a prototype of Multi-Spindle drilling head in this research.

Keywords: Tool machine, multi-spindle drilling, drill systems, Cardan universal joint

1. Introduction

Multi-spindle Drilling machines are used in mechanical industry in order to increase the productivity of machining systems. Such machines are equipped with 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. It is not possible neither to fix two or more parts on the table or use two or more tables on the same machine. Thus, in every moment only one part can be present on such a machine.

Throughout the survey in some mechanical factories of the mechanical flange machining which contains many holes arranged in a circle which is able to change the dimension shown in Fig. 1. Most of them have the low productivity because of using only one drill each time. Furthermore, the mechanical flange joint has a variety of dimensions, therefore it is very difficult to create the specialized attachment of each one because of cost. It is required to design the flexible drilling technology system which is able to drill multiple positions in one technological step while adjusting for the different diameters number of holes.

Nowadays, more and more countries in the world are applying the technical achievements to manufacturing practice. This significantly decreases the labor expenses, quickly responds to the demands of society, and competes on price and labor productivity.

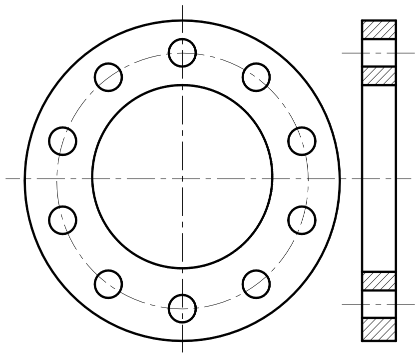

Fig.1. Illustration of the part

Literature has been studied regarding the Multi-spindle drilling operation as follows: [1] Studied on Design & development of multi-spindle drilling head. In this case study, they developed SPM for drilling two holes simultaneously. Fixed Multi-spindle Drilling Head can be of fixed center construction for mass and large batch production and for batch production, adjustable center type design is offered. Planetary gear train type adjustable multi-spindle drilling head is used [2-4]. Twin-spindle drilling machines are used for mass production, a great time saver where many pieces of jobs having two holes are to be drilled [5]. The multi-spindle drilling attachment three spindles is driven simultaneously which carry three dill chunks [6]. A. M. Takale, V. R.Naik [7] studied about design and manufacturing of multi-spindle drilling head and cycle time optimization, the machine used for multi-spindle drilling head is same

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(Radial drilling machine) which presently uses to produce the part, so machine hour rate remains unchanged. Olga Guschinskaya, Alexandre Dolgui, Nikolai Guschinsky, and Genrikh Levin [8] studied about Scheduling for multi-spindle head machines with a mobile table.

Most of previous studies on multi-spindle drill focus on the specific of part production which fixes the position of multi-holes (as shown in Fig. 2 the dimension $\phi_1=\phi_2$=constant). It means that if there is a new part with the different dimension that drill system can't be used, we have to design the new one. To overcome this limitation, in this paper, we will design a new drill system that is able to drill multiple positions in one technological step while flexibly adjusting the different diameters number of holes shown in Fig. 2.

The paper is organized as follows: Section 2 proposes the principle of multi-spindle drill head; Section 3 will present the calculation and software simulation; Section 5 introduces the prototype and results; Section 6 gives conclusions and future work.

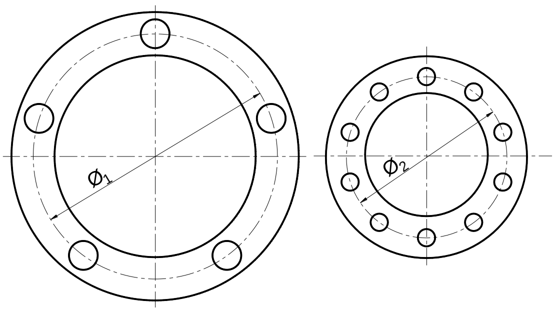

Fig. 2. Flange machining contains many holes

2. Proposed methodology

This section, we will propose the principle of the multi-spindle drilling that can solve mission drill multiple positions in one technological step while flexibly adjusting for the different diameters number of holes. The main new idea follows:

To propose the mechanical project ideas, then calculate, simulate, and optimize the mechanism of the simultaneous multi-position drilling system.

To export the design drawings, manufacturer, plans to prepare for the process of manufacture and test.

To transfer technology to the local mechanical factories.

To serve teaching and research for the mechanical engineering student.

There are some ways to drill multiple locations at once, for example, use gear systems multiple drills at the same time or the cardan joints (Universal Joint) systems. Cardan joints are common devices for transmitting motion between misaligned intersecting axes. Their capability of easy mounting, resisting high loads, and commercial availability makes them an attractive problem [9-15].

This research, we use Cardan joints (Universal Joint) systems shown in Fig. 3 combine with gear systems to design the Multi-Spindle drilling head. The Fig. 4 shows how we can drill multiple locations at once and flexibly adjust for the different diameters.

The double cardan joint: The double cardan joint includes two objects: the cardan joint K_1 and K_2 shown in Fig. 4. We will compute kinematics of the double cardan joint.

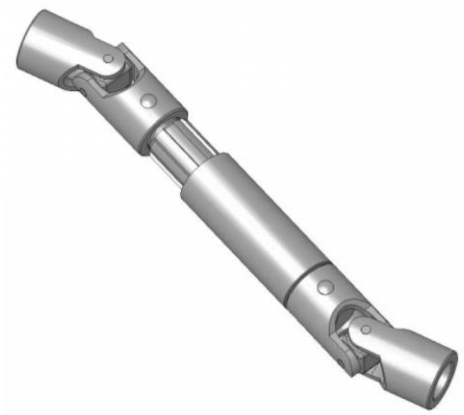

Fig. 3. Cardan shaft (Universal Joint)

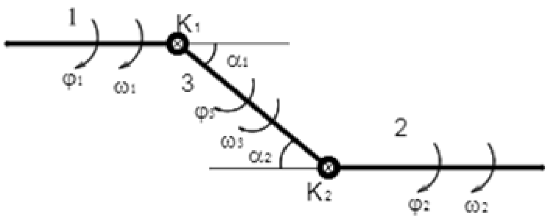

Fig. 4. double cardan joint.

The cardan joint K_1:

$$\tan(\phi_1) = \tan(\phi_3).\cos(\alpha_1) \tag{1}$$

The cardan joint K_2:

$$\tan\left(\phi_3 + \frac{\pi}{2}\right) = \tan\left(\phi_3 + \frac{\pi}{2}\right).\cos(\phi_1) \tag{2}$$

$$\Rightarrow \tan(\phi_2) = \tan(\phi_3).\cos(\alpha_2) \tag{3}$$

$$\Rightarrow \tan(\phi_1) = \tan(\phi_2).\frac{\cos\alpha_a}{\cos\alpha_2} \tag{4}$$

In this case, the rotational speed of Cardan shaft is constant.

3. Simulation and Calculation

3.1. Design and simulate the mechanism of the simultaneous multi-position drilling system

We use Inventor software to build a simulation of Multi-Spindle drill systems shown in Fig. 5 and Fig. 6.

In the Fig. 5, the spindle position can be adjusted to center or far from the center of the main gear. The Fig. 6 shows the connection between gear systems and cardan joints for the principle of working. The overall of multi-spindle drill head was presented in Fig. 7.

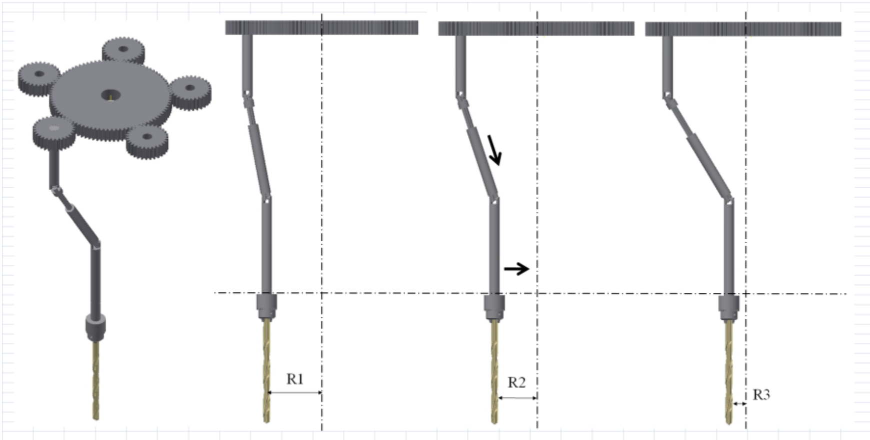

Fig. 5. The principle of multi-position drilling

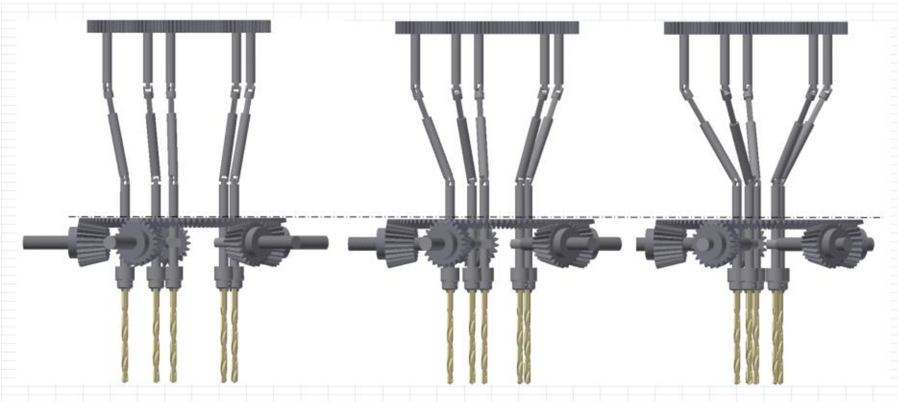

Fig. 6. Simulation of multi-position drilling

Fig. 7. Modal of multi-position drilling

3.2. Compute the durability and power of the drilling system

We will check the durability for cardan shaft [15]. The parameters of our proposed Cardan joint (see Fig. 8) are given values in Table 1.

Input dynamic parameters: cutting drill hole with the diameter D=11 mm, material carbon steel C45 (HB = 170), feed rate: S = 0.12-0.20 mm/Rev [16].

From [16], we cutting speed for mild steel (workpiece material) 20-23 m/min.

$$\text{Cutting Speed: } v = \frac{\pi * D * n}{1000} \quad (5)$$

$$n = 655.557 \approx 650 \quad (rpm)$$

Feed Rate=0.2(mm/rev)*650(rev/min)=130(mm/min)

Power at one spindle (kW)

$$P = \frac{1.25 * D^2 * k * n(0.056 + 1.55)}{10^5} = 0.43(kW) \quad (6)$$

Where Material Factor (K=1.22) with material carbon steel C45 (HB = 170).

Power for 5 Spindles *P=5*0.43=2.13 (kW)≈2.42 (hp)*

- ✓ Assumed efficiency for gear drive and cacdarn shaft 90%, thus power available at gear shaft will be 2.69 (hp)
- ✓ Assumed efficiency for Belt drive 70% thus the power available at belt drive will be 4.76 (hp)

Tormomem on each cardan joint [16]:

$$M_x = 10 * C_M * D * q * S * y \quad (7)$$

Where: $C_M = 0.0345; y = 0.8; q = 2$

$M_x = 10*0.0345*152*0.31*0.8 = 30,41$ *(N.m)*

Table 1. The main components value

Parameter	Value
D	11 mm
d_1	12 mm
L_2	56 mm
C	13 mm
B	50 mm
X	128 mm
d_2	12 mm
D_1	25 mm
L_{min}/L_{max}	290/350

Durability under torque: Twisted bending stress of cardan shaft is calculated [15]

The proposed cardan shaft is firstly theory based evaluated using the standard twisted bending stress of maximum allowed $[\tau] = 172$ (MN/m^2) [16].

$$\tau = \frac{M_{2\max}}{W_x} = \frac{M_{e\max}.i_{hi}.i_{p1}}{W_x.\cos\alpha} \le [\tau] \quad (8)$$

Where: M_{emax} the maximum torque on cardan shaft, i_{h1} maximum transmission ratio.

$$\mathrm{i_{h1}} = \frac{\mathrm{n_{max}}}{\mathrm{n_{dc}}}.\mathrm{i_{brht}} \quad (9)$$

i_{p1} minimum transmission ratio.

W_x : torque moment resistance $Wx = \dfrac{\pi D^2 \delta}{2}$ (10)

And $\cos\alpha = \dfrac{L_{\min}}{L_{\max}} = \dfrac{290}{350} = 0.83$ (11)

With parameters given on Table 1, using the following equation 1 to equation 11 [16], the twisted bending stress can be calculated as τ=22 (MN/m^2).

Finally, we have $\tau < [\tau]$ *therefor it is satisfied durability under torque.*

Check the twist angle of cardan joint: The proposed cardan shaft is secondly theory based evaluated using the standard twist angle of cardan joint condition of the maximum allowed $[\theta] = 3^0$ [16].

$$\theta = \frac{180}{\pi}.\frac{M_{e\max}.i_{h1}.i_{p1}.l}{G.J_x.\cos\alpha} \quad (12)$$

Where: J_x - moment of inertia of cross section, G modulus of elasticity when twisted $G=8.5*10^4$ *(MN/m^2)*

And $J_x = \dfrac{\pi}{32}\left(D^4 - d^4\right)$ (13)

$$\theta = \frac{180}{\pi}.\frac{M_{e\max}.i_{h1}.i_{p1}.l}{G.J_x.\cos\alpha} \quad (14)$$

With parameters given in Table 1, using the following equation (12) to equation (14) [ref (16)], the twist angle of cardan joint allowed can be calculated as $\theta=0.38^0$.

Finally, we have $\theta < [\theta]$ *it satisfied the twist angle of cardan joint condition.*

4. Prototype and Result

The prototype was produced and shown as in the Fig. 9, Fig. 10.

The Bottom view of Prototype shown in Fig. 9, the cardan joint is adjusted to change the position of drill spindle.

The Overall view of multi-spindle drill head shown in Fig. 10, we use 5 spindles in this prototype.

- To check the principle of the driving system we used DC motor 24v/30w to drive main gear, it showed that the drive system worked as the simulation on software.
- The Multi-Spindle drill system can drill 5 holes ϕ5 on the wood sheet 5 mm thin.
- The system worked smoothly without vibration.

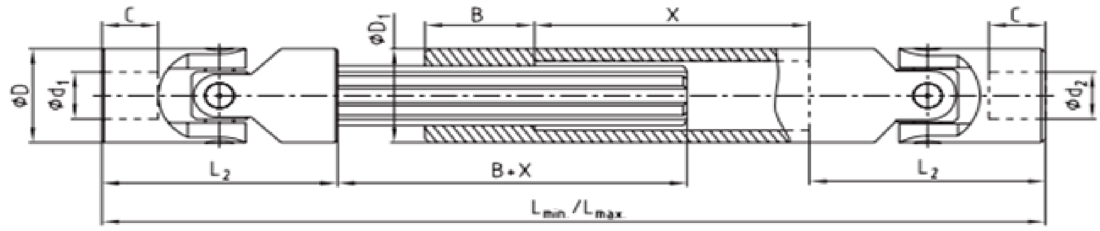

Fig. 8. Parameters of Cardan joint

5. Conclusion

The obtained main results as follows:

A new system of the multi-Spindle drill which uses Cardan universal joint and gear system for driving was designed. With the new drill system, we can drill multi-hole in one step for saving time, In addition, we can also flexibly adjust the position of the spindle to work a variety of different machine part.

The system was simulated by inventor software and calculated durable.

The demo prototype was produced to check the principle of new drill system. The experiment shown that the new system works stability.

The next step, author plan transfers this research to the real application and extend to factories in order to directly compete with the international commodities. It is also an incentive, a driving force for the individuals, organization and companies to continuously cooperate in technical innovation and in the manufacturing process to create favorable conditions for maintaining and developing the domestic production stable in the period of international integration such as ASEAN, WTO, and so on.

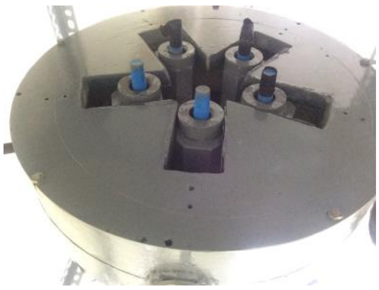

Fig. 9. Bottom view of Prototype

Fig. 10. Overall view of multi-spindle drill head

Acknowledgments

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