Improvement in Design & Development of Multi-Spindle Drilling Head Machine

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***Abstract*—** The main objective of this work is the systematic description of the current research and development of multi-spindle drilling head machine with a focus on improvement in shaft of the machine. Manufacturing plays vital role in any industry for producing the product. With stiff competition and challenges in the present-day market, manufacturers are compelled to be more responsive to the customer's demands regarding not only quality, but scheduled delivery. Enhancing productivity is a key concern for almost all the mass production industries. In case of mass production where variety of jobs is less and quantity to be produced is huge, it is very essential to produce the job at a faster rate. The best way to improve the production rate along with quality is by use of special purpose machine.

Performance and application of the existing radial drilling machine will be increased by designing and manufacturing of multi-spindle drilling head attachment. This paper deals with the conceptual design procedure of multi-spindle drilling head (MSDH) machine with emphasizing on one of its major component i.e. main shaft.

Keywords- *Design, Multi-spindle drilling head machine, ANSYS, Main shaft.*

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I. INTRODUCTION

1.1 Multi-spindle drilling head (MSDH) machine

In the conventional manner, only one job can be worked at a time for various operations such as drilling, tapping, spot facing, reaming, counter sinking, counter boring etc. but 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.

The Multi-spindle drilling attachment is an ideal solution to the above problems where in the conventional drilling machine is used to perform these three operations at a time, so also different operations like drilling, reaming, countersinking or spot facing can be done simultaneously.

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 today's market the customer demands the product of right quality, right quantity, right cost, & at right time. Therefore it is necessary to improve productivity as well as quality. One way to achieve this is by using multi spindle drilling head. On the other hand, in order to meet quality requirements of final product.

The various methods of multi-spindle drilling heads are:-

1 Adjustable multi-spindle drilling head- It can be used in many components, where change the centre distance to some range.

2 Fixed Multi spindle drilling head- It is used where the centre distance cannot change to some range.

Multi-spindle heads can be of fixed centre type construction for mass & large batch production and for batch production, adjustable centre type design is offered.

1.2 Shaft

A shaft of multi spindle machine is a rotating machine element which is used to transmit power from one place to another. The power is delivered to the shaft by some tangential force and resultant torque set up within the shaft permits the power to be transferred to various machines linked up to the shaft. In order to transfer the power from one shaft to another, the various members such as pulleys, gears etc. are mounted on it. These members along with the forces exerted upon them causes the shaft to bending.

Shafts are generally manufactured by hot rolling and finished to size by cold drawing or turning and grinding. The material used for the manufacturing of ordinary shafts is normally carbon steel of grade 40C8. 45C8. 50C4 and 50C12. Generally MSDH machine shafts are made by material 40C8 or 45C8. Depending upon the loads, forces these materials are used. The material used for the shafts should have the following properties-

1. It should have high strength.
2. It should have good mach inability.
3. It should have low notch sensitivity factor.
4. It should have good heat treatment properties.
5. It should have high resistance properties.

TABLE I
MECHANICAL PROPERTIES OF STEELS USED FOR THE SHAFTS

Indian standard designation	Ultimate tensile strength, MPa	Yield strength, MPa
40 C 8	560-670	320
45 C 8	610-700	350
50 C 4	640-760	370
50 C 12	700 Min.	390

There are many possibilities of failure of these shafts when loads are not stationary or due to unbalance forces of the various members of the machine. So in this paper our aim is to improve design of main shaft of the multi-spindle machine by changing its materials of high strength for safe working of the machine.

II. PROBLEM DEFINATION AND DISCUSSION

For our project we visited the JIAN Industries, Rabale, Navi Mumbai where Linear Multi-spindle drilling machine (as shown in figure) is used for drilling three holes at a time linearly along x axis using pneumatic cylinder. It was observed that after drilling some jobs the main shaft of the machine fails during operation. So company sponsoring this project to us and we give them solution to this problem by improving the design of MSDH machine and its shaft.

Fig. 1 Linear Multi-spindle drilling machine

Main Shaft

Fig. 2 Main shaft of Linear Multi-spindle drilling machine

Spindle shaft

Fig. 3 Spindle shaft of Linear Multi-spindle drilling machine

III. METHODOLOGY

For the solution of the problem faced by the company related to the failure of shaft during operation, we go for the re-designing of the shaft and replace its material 40 C 8 by new material 50 C 12 and find out the result.

As the power transmitted by the main spindle shaft or main shaft of the machine is equivalent to the other spindle shaft, so the force or torque in each shaft is same one. So for re-design of shaft we can consider either main shaft or other spindle shaft. In addition to the shaft we design other components of the machine in design procedure.

IV. DESIGN PROCEDURE

For designing multi-spindle drilling head machine we assume following data & design its different components.

Material = MS Steel
Depth of cut = 50 mm, Max. dia. of hole = 6 mm.
Dia. of motor pulley = dia.of arbor pulley = 50 mm.
Data From Design Data Book-
Kc = Specific Cutting Force For MS = 52500 kg /m^2
Here we are going to drill 3 holes at a time
Total force required for drilling
F = Area of drill x Kc
F = 3.14 X 0.01^2 /4 X 52500 x 9.81
F = 41 N
F = 3 X 41 = 123 N
Torque required for drilling, T = F x D/2 = 12 x 10/2
T = 615 N mm

4.1 Motor Selection

Rpm of drilling = 500 rpm
But standard motor run on 1440 rpm
So reduction in gearing is required.
So reduction ratio = 1440/500 = 2.88:1
We select pinion gear teeth = 30
So number of teeth on big gear = 30x2.88=86.4
= 87 teeth
So torque is going to increase by 2.88
Required torque of motor = 615 x 2.88 =1771 N mm
We know Power, P = 2 Π (1440) 1.7/ 60
P = 256 watt = 0.34 hp
But standard motor available is 0.5 hp so we select 0.5 hp motor for our project.

4.2 Design of Transmission

As we know that N_1 / N2 = D_2 / D_1
As D_1=D_2, so N_1=N_2=1440 rpm.
Speed of arbor = N_2=1440 rpm.

4.2 Design of Shaft

By studying the all the information about shaft of the above linear multi-spindle machine, we found that material used for the manufacturing of the shaft is 40C8.

So first we design shaft by considering the mechanical properties of this material i.e. 40 C 8.
Ultimate tensile strength = 560 N/mm^2
Yield strength = 320 N/mm^2
Following stresses are normally adopted in shaft design
Taking factor of safety = 2.5
Max^m tensile stress = yield strength / FOS
= 320/ 2.5 =128 N/mm^2
Max^m shear stress = 0.5 x ft = 0.5 x 128 = 64 N/mm^2
Shaft design on basis of study
P = 0. 5 hp = 0. 5 x 746 = 373 watt
Power = 2 Π (1440) T/ 60
373 = 2 x 3.14 x 1440 x T / 60
So, Torque T = 2.48 N m = 2480 Nmm
The transmission ratio of gearing is 2.88:1
So actual torque applied on shaft is
Tfinal = 2480 x 2.88 = 7142 N mm
We know, the standard dia. used in machine is 8 mm.
T= 3.14/16 x fs induced x 8^3
7142 = 3.14/16 x fs induced x 8^3
fs induced =71 N/mm^2

By calculation it is observed that induced stress is more than allowable so selected shaft dia is fail under tortional stress. In practical working also this shaft is fail under tortional movement, so we design same dia. shaft with different material composition.

We select new material for the shaft is 50 C 12.
Mechanical property of 50 C 12 for shaft is as below-
Ultimate tensile strength = 700 N/mm^2
Yield strength= 390 N/mm^2
Taking factor of safety = 2.5
Following stresses are normally adopted in shaft design-
Max^m tensile stress = yield strength / FOS
= 390/ 2.5 =156 N/mm^2
Max^m shear stress =0.5 x ft = 0.5 x 156 = 78N/mm^2
As the tensional property of above material is more than 71 N/mm^2, so same dia. of shaft with change in material is safe under above loading.

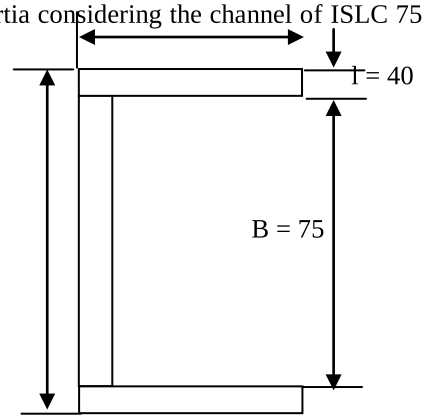
4.3 Design of Gearing arrangement

Selecting the module of pinion gear from design data hand book -
m = 2.5 mm
For m = 2.5 mm we take following data from design data hand book.
Pressure angle Φ = 20^0
Addendum = m = 2.5 mm
Dedendum = 1.25 m = 3.125 mm
Working depth = 2 x 2.5 = 5 mm
Min depth = 2.25 x 2.5 = 5.625 mm
Thickness of tooth = 1.5708 x 2.5 = 3.927 mm
Fillet radius = 0.04 m = 40 mm
Min no of teeth of pinion for intermittent service & in hand operated operation is 28 as per requirement.
Selecting no. of teeth on pinion gear Np = 30 teeth
Allowable stress for pinion made of semi steel
=126N/ mm^2
Checking beam strength of pinion using LEWIS equation for gear teeth
Wt = fw.b.3.14.m.y
Where, Wt = beam strength of pinion tooth
b = width of gear = 25mm
fw = working stress = 210 N / mm^2
m = module of gear = 2.5
y= tooth form factor
y = 0.154 – 0.912/Np = 0.154 – 0.912/30
y = 0.12
Wt = 210 x 25 x 3.14 x 2.5 x 0.12
Wt = 4945.5N
Induced load coming on gear teeth is
T = F X D/2
2480 = F X 40/2
F = 124 N
As applied load on gear teeth is less than beam strength of gear so selection of gear is safe.

4.4 Design of C-Section

The vertical column channel is subjected to bending stress given by => $M/I = f_b / y$

In above equation first we will find the moment of inertia about x and y axis and take the minimum moment of inertia considering the channel of ISLC 75 x 40 size.



We know the channel is subject to axial compressive load.

In column section the maximum bending moment occurs at channel of section

$$M = Ra \times L/2$$

$$M = 750 \times 100/2 = 562500 \text{ N-mm}$$

We know $f_b = M/Z$

$$Z = t\,(l \times b + (b^2/6))$$

$$Z = 5\,(40 \times 65 + (65^2/6)) = 3304 \text{ mm}^3$$

Now check bending stress induced in C section

f_b induced = M/Z

f_b induced = 562500 /3304 = 170.25 N / mm^2

As induced stress value is less than allowable stress value so design is safe.

f_b = Permissible bending stress = 320 N / mm²

f_b induced < f_b allowable. Hence our design is safe.

4.5 Design of welded joint of Channel

The welded joint is subjected to pure bending moment, so it should be design for bending stress. We know minimum area of weld or throat area

A = 0.707 x s x l Where s = size of weld

l = length of weld A=0.707 x 5 x (75 + 40 + 35 + 58 +35)

A= 0.707 x 5 x 243A = 859 mm^2

Bending strength of parallel fillet weld

P = A x fb , fb = 80 N / mm^2

As load applied at the end of lever is 250 N. So moment generated at the welded joint is

M =P x L = 250x 450 =112500 N– mm

We know fb = M /Z

$$Z = \frac{BH^3 - bh^3}{6H} = \frac{40 \times 75^3 - 35 \times 58^3}{6 \times 75} = 209824$$

Calculating induce stress developed in welded joint

f_b induced = 112500 / 209824 = 0.536 N /mm ^{2}

As induce stress is less then allowable stress the design is safe.

4.6 Design of Welded joint

Checking the strength of the welded joints for safety, the transverse fillet weld welds the side plate and the edge stiffness plates. The maximum load which the plate can carry for transverse fillet weld is

P = 0.707 x S x L x ft

Where, S = size of weld, L = contact length = 75mm

The load of shear along with the friction is

50 kg = 500N

Hence, 500 = 0.707 x 3.4 x 75 x ft

Hence let us find the safe value of 'ft'

So f_t = 500 / 0.707 x 3.4 x 75 = 3 N/mm^2.

Since the calculated value of the tensile load is very smaller than the permissible value as ft=56 N/mm^2.

Hence welded joint is safe.

V. RESULT

From design procedure we find that shear stress induced is less than allowable or maximum shear stress for material 50C12 than previous material i.e. 40C8.

In this paper we try to develop the Multi-spindle machine by improving the shaft material which can be also proved by modeling and analyzing the shaft for both the material in ANSYS 15.0 software as follows-

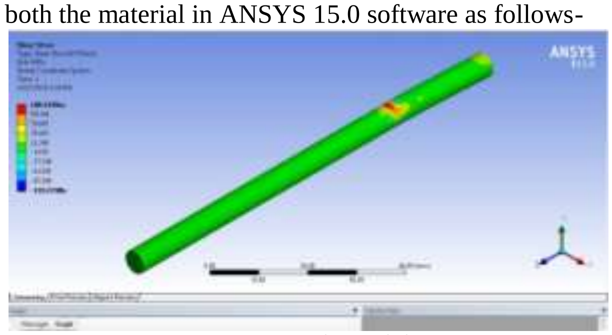


Fig. 4 Maximum Shear Stress for Shaft for 40C8 Material

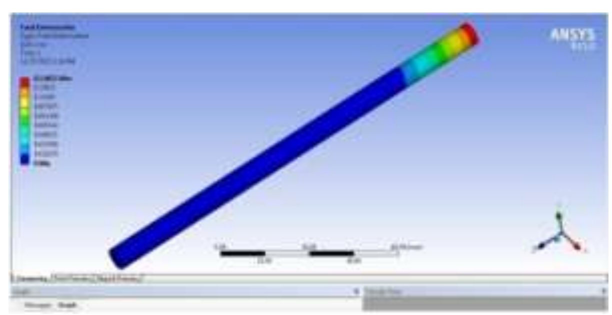


Fig. 5 Maximum Shear Stress for Shaft for 50C12 Material

TABLE II
ANALYSIS RESULT USING ANSYS 15.0

Material	Induced Shear Stress Value	Max Shear Stress Value
40C8	71 N/mm^2	54.22 N/mm^2
50C12		74.53 N/mm^2

So, for the above SPM, from above result, 50C12 is the best material for the shaft for safe working and the better performance of the machine.

VI. CONCLUSION

The Multi-spindle drilling machine is redesign and developed satisfactorily commissioned. Any saving done due to use of advanced manufacturing technique directly contributes to the net profit of the product. The following satisfactory conclusion is drawn after completion design and development of the SPM and which is achieved by replacing the shaft material.

1. Smooth and continuous operation of the machine due to improvement in shaft.
2. Reduction in breakdown and cycle time of the machine.
3. Developed Multi spindle drilling head machine produces numbers of holes drilled on same work piece with required accuracy and tolerances to be maintained, which is difficult to obtain by using radial drill machine. Also rate of production justify the additional cost involved in multi drilling machine. Also it has improved the repeatability, accuracy and less rejection, due to accurate automation
4. Due to reduction in breakdown of the machine, production rate increases which lead the reduced production cost, and reduced labour cost which minimizes the production cost.

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REFERENCES

[1] A. M. Takale, V. R. Naik; January-April 2012, "Design & manufacturing of multi spindle drilling head (msdh) for its cycle time optimization", International journal of Mechanical Engineering applications research, Vol –03 ISSN: 2249- 6564.
[2] Prof. P.R. Sawant, Mr. R. A.Barawade January-March, 2012, "Design and development of SPM - A case study in multi drilling and tapping machine," IJAERS, Vol. I, E-ISSN2249–8974.
[3] M. Narasimha1, R. Reji Kumar 2, R. Srinivasa Moorthy "Design of adjustable multi-spindle attachment, International journal of Industrial Engineering Research and Development (IJIERD), ISSN 0976 –6979 (Print) Volume 4, Issue 2, May - August (2013), © IAEME.
[4] Bajirao H. Nangare Patil, Prof. P. R. Sawant "Design And Development of Gearbox for MultiSpindle Drillig Machine (SPM) International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 5, May -2013 ISSN: 2278 0181
[5] V B Bhandari , "Design of machine elements" Tata McGraw Hill Publishing company limited"
[6] R. S. Khurmi and J. K. Gupta, A Textbook of Machine Design, Eurasia Publishing House, New Delhi, India, 2002.
[7] R.S. Khurmi and J. K. Gupta, Theory of Machines, New Delhi, India, 2003.
[8] P.S.G. Data book.
[9] ASME Codes & Standards

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