ISSN: 0976-3376

Available Online at http://www.journalajst.com

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol.07, Issue, 03, pp.2600-2605, March, 2016

RESEARCH ARTICLE

DESIGN OF ROD GROOVING MULTISPINDLE DRILLING UNIT

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ARTICLE INFO

Article History:
Received 28th December, 2015
Received in revised form
11th January, 2016
Accepted 26th February, 2016
Published online 31st March, 2016

Key words:

Gear Housing Spindle Housing Von-Mises Stress.

ABSTRACT

Increasing production capacity of manufacturing industry with minimum increase in cost is the challenge faced by the modern production industry. In this regard an attempt was made to design a rod grooving multiple spindle drilling unit to replace existing single spindle unit. Proposed design enabled 6 grooves to be drilled simultaneously and results achieved was reduced cycle time and higher productivity. The parts of this multi spindle unit have to be designed using conventional methods. Finite Element Analysis of spindle housing and gear housing was performed to analyze structural integrity using ANSYS. Results of analysis indicate that these parts are structurally sound. After implementation of the design we found that the production rate increase from 150 components per shift to 425 components per shift. Added benefits include less chance for error, less accumulated tolerance error and less tools change

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INTRODUCTION

Multi spindle drilling machines are used for simultaneous drilling of number of holes. Such machines are equipped by spindle heads that carry multiple tools for performing simultaneous machining operations. This greatly reduces the operation time and also improves the centre distance accuracy. Multi Spindle Drilling Machines technology will boost productivity, assure quality and reduce cost of Drilling operation, and enable us to with stand global competition. 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 less tools changes. The various types of multispindle drilling heads are1) Adjustable multispindle drilling head. These are the gear adjustable centre drilling head, in which drill Spindle is fitted on slotted plate (slotted plate is fixed in position in the gearbox) and the gear is mounted on the drill spindle. By changing the gears as per required pitch, circle diameter the drill spindle is adjusted in the slotted plate. 2) Fixed Multispindle drilling head: In fixed multispindle drilling head, it's not possible to change the centre distance to some range.

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Literature Survey

In Indian manufacturing sector the growth of manufacturing depends largely on its productivity. Drilling machine is used primarily in drilling holes, there are a few other functions that the multiple spindle drilling machine is capable of performing the functions include tapping, spot facing, reaming, countersinking, and counter boring to name a few (Takalwe and Naik, 2012). Multispindle drilling attachment works mainly on planetary gear system arrangement. Multi Spindle drilling attachment main function is more than one drilling operation at a time. It has many advantages like increase the production, decrease the operation time, reducing the labor cost, increase productivity and many more. Also reduce the cycles of operations. This is not possible if carry out the production by using general purpose machines (Bankar *et al*., 2013).

Although these multiple spindle drilling attachment performs basic drilling operations, there are some specific functions that are performed more accurately and conveniently by each of these types (Udgave and Khot; http://technicaljournals.org ISSN: 2249- 6564). 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. This is not possible if we carry out the production by using general purpose machines.

The best way to improve the production rate (productivity) along with quality is by use of special purpose machine (Spicer *et al*., 2005; Bhandari). Usefulness and performance of the existing radial drilling machine will be increased by designing and development of multispindle drilling head attachment (Allen *et al*.,). Until the 1990s, many manufacturing experts believed that CNC multi-spindle automatics would never be very successful, given their high costs, complexity and susceptibility to failure. On the other hand, it could be foreseen that cam-controlled machines had no longer a future. Convincing solutions could only be achieved if multi spindle machines were designed and constructed in a completely new way with a view to CNC technology, that is, if "genuine" CNC machines were created (8).

A multi-spindle automatic can be a horizontal or a vertical lathe designed for series production according to a pre-established program with a fixed sequence of operations. The characteristic feature of these machines is, in accordance with European Standard EN 13788, the spindle drum usually comprising six or eight work spindles arranged in parallel on a pitch circle. For example, a multi spindle drilling unit manufacturer, Auto Drill designs and manufactures Multiple Spindle Drilling units for its customers (Khurmi and Gupta, 2005). Based on the specifications and requirements of the customer, Auto Drill manufactures the Multi- Drill fixture which is capable of drilling all the hinge holes on a door in 3 separate hinge locations simultaneously. Another good example given was a Multi-hole bolt patterns which are commonly used on pipe flange &these are for machine connections and other bolting applications. Drilling these patterns is time consuming and subject to errors. When the volume is reasonably high or the accuracy is critical then it is best for use (Shigley and Mischke, 1989). (11)

Fig. 1. Earlier setup for Rod grooving operation

Design of Gears

Depending on the gear availability and requirement the material chosen is 17MnCr95. By referring to the Design Data Hand Book prescribed by K. Mahadevan & K. Balaveera Reddy and considering requirement for the product the gear was designed according to the following specifications: Tangential Tooth Load Ft = 4387.9N where v=3.059m/s, According to Lewis eqn the velocity factor Cv=0.499. No of Teeth on gear Z=37.

Design of shaft

Selecting the shaft to be a solid shaft (i.e., non-hollow) and which is made up of the material 17Mn1Cr95. Power in S.I units, i.e. P = 7.457 kW, The speed of the shaft is n = 728 rpm (not selecting the rpm as 630 &assuming the greater value i.e. to achieve a safer design). The distance between bearings = 150mm. The results for theoretical Calculations are, Torque transmitted by the shaft = 97821.91 Nm for the radius of 40 mm. Tangential tooth load F_T= 2445.5 N and Radial Tooth load Fr= 890.11 N. The Bending Moment due to $F_r$is M_V = 66757.99 N-mm. The Bending Moment due to F_T is M_H= 183416.25 N-mm. The resultant bending moment is $M=\sqrt{(MV)2+(MH)2}$ = 195187.48 N-mm. The maximum Torsional shear stress, τmax= 197.5 N/mm^2 By considering the values of shock and endurance factors (C_m=2 and C_t=1.5 are the constants for ASME Code). Diameter of the shaft, d= 22.73 mm is calculated Since, this diameter is not a standard size. Thus, by referring to the table 3.5a pg.48 in Data Hand Book, Select a suitable diameter of shaft i.e. of the next size which is available. i.e., the diameter of the shaft should be equal to d = 25 mm.

Selection of bearings

The object of lubrication is to reduce friction wear and heating of machine parts that move relative to each other. A lubricant is any substance when applied between the relatively moving parts will reduce friction and wear and carry away the heat generated. Deep groove ball bearings are the most widely used bearing type. Consequently, they are available from SKF in many designs, variants, series and sizes and Angular contact ball bearings have raceways in the inner and outer rings that are displaced with respect to each other in the direction of the bearing axis.

Bearing Calculation

Minimum load factor for the SKF bearings which are used in the main spindle,

Fr = Minimum radial load = 890.11 N = 0.89 KN
Kr = Minimum Load Factor = 1.4759
Life of bearing is expressed in different ways. For comparison purpose, life is to be converted to L in million revolutions.

Housing Design

Housing plays an important role in the outcome of any assembly. It is because of the simple reason that all other working components are mounted on these housing and their working depends on the distance from other working components which I guided or controlled by the housing. The housing of multi spindle drill head is divided into two halves to support assembly.

Otherwise components cannot be placed in exact locations.
The two halves include.

- Spindle housing
- Gear housing

Spindle housing

Spindle housing has allocations for the placement of the 12 working spindle. The housing is designed as to accommodate 24 bearing. These bearing have to be placed on either side of the housing (12 number on each side).

It also accommodates 36 oil seals of which 12 have to be placed on the top end while 24 have to be placed on the bottom side. The bottom side has more seals because there is chance of loss due to leakage. Housing also accommodates covers over the bearing as it has screw tappings. On the top side there is accommodation for 4 bearings based on the requirement to support the bearings of idler and input shaft. The spindle housing also has accommodation to guide the assembly. This is required to prevent the rotation of the assembly along the main input shaft. Another function of guide allocations is to guide the assembly into proper position for drilling.

Gear housing

Gear housing covers the gear for lubrication. The gear housing has allocations for mounting of 4 bearings and importantly the gear connector i.e. the connector that connects the existing radial drilling machine to the assembly. The gear housing covers the 16 gears and helps in lubricating by creating closed space.

Fig. Present multiple drilling machine head set up

ANALYSIS OF HOUSINGS

There are two housings in multi spindle drilling unit.

- Spindle housing
- Gear housing

These housings cannot be designed or analyzed by conventional methods. Finite element analysis of these components has been carried out to check the structural integrity.

Calculations

From CMTI data hand book,

Thrust force is given by, T_H= 1.16 KD $(100S)^{0.85}$

=1.16*(1.45) (11.1)*$(100*0.21)^{0.85}$
= 248.33Kgf = 2436.11N

Torque, $T_s = 975\frac{N}{n}$

Where, N= power at spindle

n= speed in rpm
$T_s=975\frac{6.12}{917.65}$
=6.50Kgf-m =64.54N-m

Convergence study

The word convergence is used because the output from the finite element program is converging on a single correct solution. In order to check the convergence of the solution, at least two solutions to the same problem are required. The solution from the finite element program is checked with a solution of increased accuracy. If the more accurate solution is dramatically different from the original solution, then the solution is not converged. However, if the solution does not change much (less than a few percent difference) then the solution is considered converged.

The solution to an analysis is greatly affected by convergence. A solution that has not converged could provide very inaccurate results

Convergence study for Gear housing

The suitable element size was determined by performing convergence study. Initially large element size was considered and the critical stress (maximum principle stress) was found out. Later the element size was decreased and the corresponding critical stress was calculated. The obtained values are given in table 3 and the convergence graph is represented in fig

Table 1. Convergence values for Gear Housing

Element size in mm	number of elements	Max Principal stress(Mpa)	Shear stress(Mpa)
10	31326	9.3728	4.4168
9	36113	9.6234	4.8664
8	41034	9.8648	4.617
7	47464	10.078	4.5234
6	60741	10.641	4.4512
5	85871	10.948	4.6064
4	125703	11.278	4.2515
3	213172	11.933	4.6333
2.5	315306	13.028	5.1081
2.4	365676	13.351	5.322
2.3	381461	13.418	5.8006
2.2	425843	13.52	5.92

From the graph it is clear that the values of critical stress are converging at element size2.4 and the results match with the theoretically calculated value. So the element size 2.4was chosen as suitable value for conducting the analysis. From the graph it is clear that the values of critical stress are converging at element size 3.2 and the results match with the theoretically calculated value. So the element size 3.2 was chosen as suitable value for conducting the analysis.

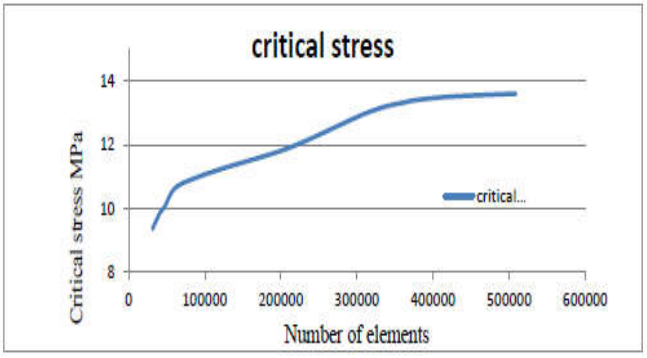


Fig. Graph of Critical Stresses v/s number of elements

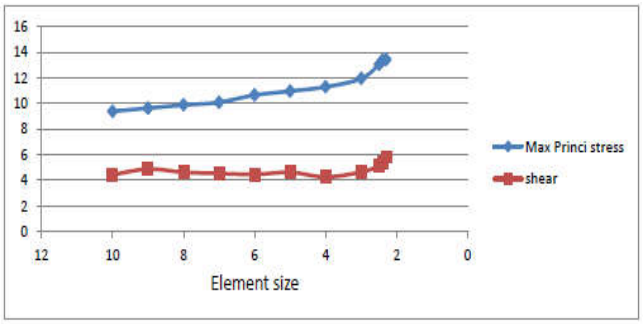


Fig. Graph of maximum Principal Stress and shear stress v/s element size

Convergence study for Spindle housing

Table 2. Convergence values for spindle housing

Element size in mm	Max Principal stress(Mpa)	Shear stress(Mpa)
10	7.7527	2.27
9	8.6866	2.253
8	8.625	2.2753
7	8.16	2.4
6	10.316	2.3685
5	10.533	2.3893
4	10.714	2.427
3.5	11.044	2.4576
3.2	11.939	2.471
3	12.027	2.442
2.8	12.193	2.461

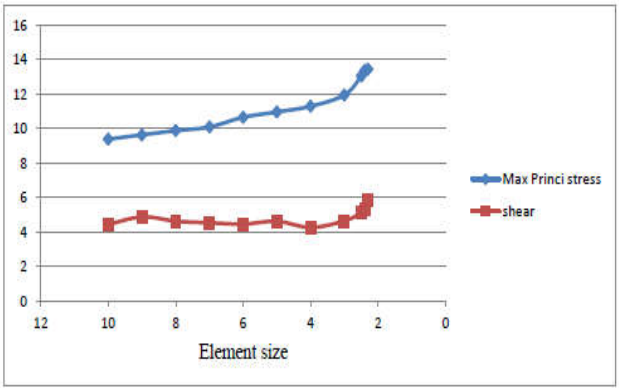


Fig. Graph of Max principal stress and shear stress v/s element size

From the graph it is clear that the values of critical stress are converging at element size 3.2 and the results match with the theoretically calculated value. So the element size 3.2 was chosen as suitable value for conducting the analysis.

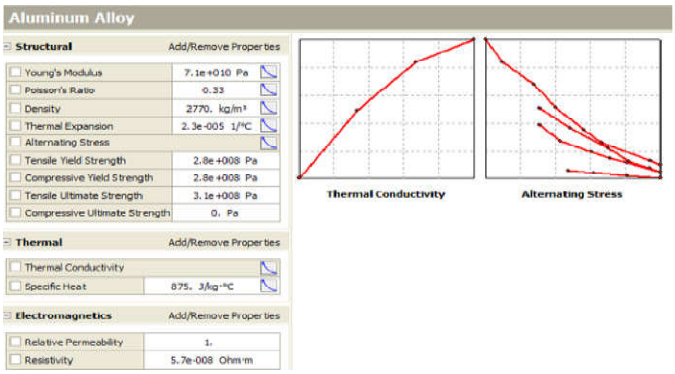
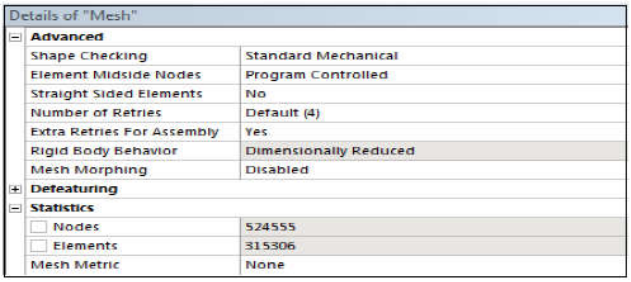


Fig. Material properties of Aluminum alloy

Mesh details

Element type: Tetrahedron

Element size: 2.4mm



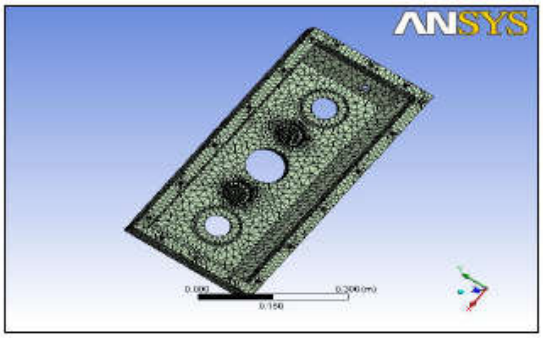


Fig : Meshed Gear housing

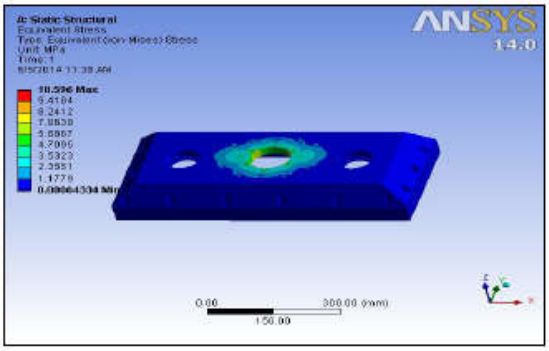
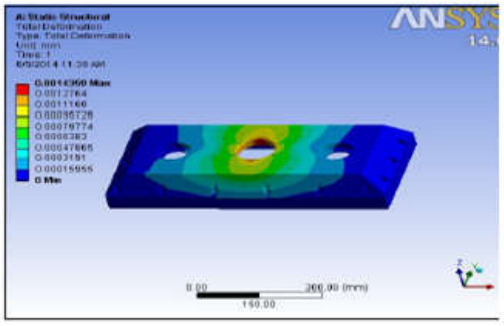


Fig: Von-Mises stress in Gear housing

Total Deformation



Maximum Principal Stress

ndle housing
Mesh Details
Element type: Tetrahedron
Element size: 3.2mm

Details of "Mesh"	
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	0.572590 mm
Inflation	
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Defeaturing	
Statistics	
Nodes	782583
Elements	468062
Mesh Metric	None

Fig : Total deformation of Gear housing

Meshed spindle housing

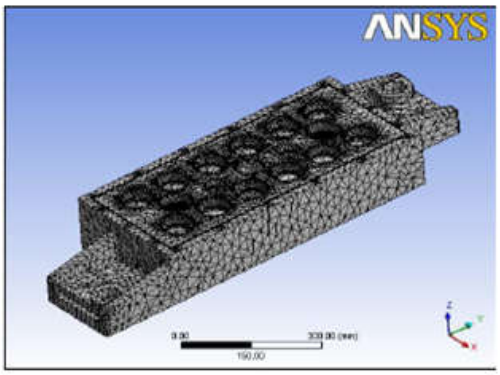


Fig. Meshed spindle housing

Bearing load

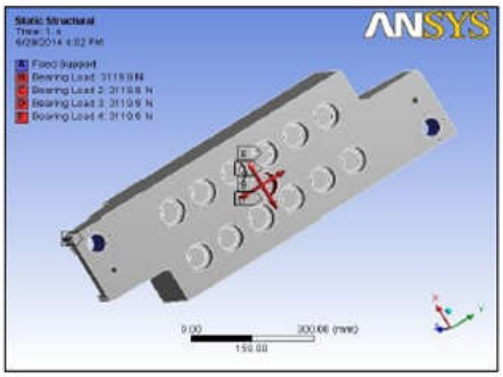


Fig : Bearing load on spindle housing

Equivalent Stress

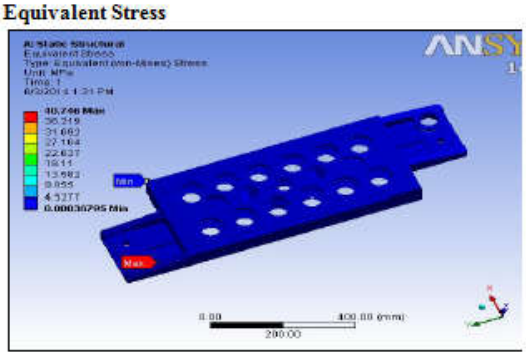


Fig : Von-Mises stress in Spindle housing

Total Deformation

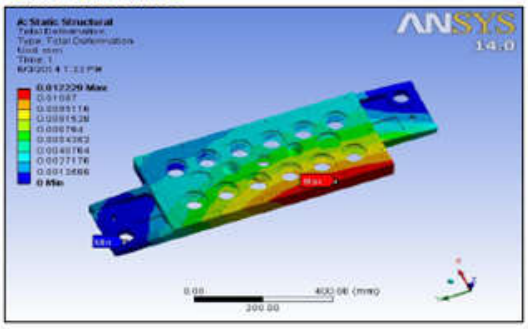


Fig : Total deformation of Spindle housin

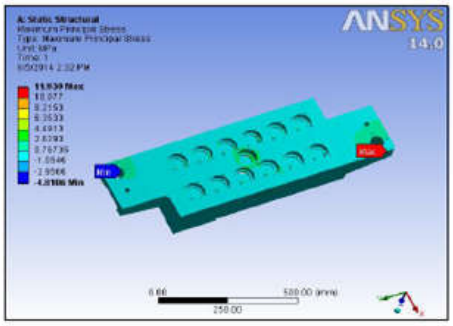


Fig : Max principal stress in Spindle housing

The design was made perfect by trial and error method; this was actually done by keeping a masterpiece, i.e. with a finished component with exact dimensions and comparing the dimensions of the finished part which is machined by the new multi spindle unit, with the dimensions which are specified and the aim for us to see to it that the tolerance limit was achieved as specified. This was carried further by giving trial runs and comparing the output of the multi spindle drilling machine.

Since the machine designed is a 12 spindle machine, and we are machining tie rods of 2 companies in the same machine. The required specifications were achieved by altering the spindle unit, as the pitch achieved was slightly more than required, hence by grinding the unit to a precise amount and after re-assembly the pitch was reworked and later it was made accurate and with in the tolerable zone. The requirements of pitch were different for 2 different customers and the trials report was carried out using the vernier calipers. Since, the company produces parts with high precision and to international standard, it was essential that the required precision wasachieved.2 tables have been made to analyze the quality of products produced after the fine turning the machine, and the trials were taken for a simple size of 5 components checked for different characteristic specifications as required by the company. The table consists of the descriptions, tolerance limits and the reports tabulated into asingle sheet, to check for the optimal working. As the spindle unit was almost ready to be used for production purpose after testing it ok. The trials and results report has been included in the following pages.

Conclusion

Proposed Multi-spindle Drilling Attachment, increases productivity at low cost and in less time. Cycles of operations are reduced with the help of our equipment. Although these multiple spindle drilling attachment performs basic drilling operations, there are some specific functions that are performed more accurately and conveniently by each of these types. Possibility of hole missing is eliminated, because six holes are drilled at a time. By using multispindle drilling head, productivity will increase. Because with the present process one hole produced at a time requires 6.3 minutes for each component. i.e. 150 components are produced per shift. But by using multispindle drilling head, cycle time is reduced to approximately 73 seconds. i.e. 425 components are produced per shift.

Analysis of Housing has been carried out with the use of ANSYS14 Workbench. The stress levels are low and which does not cause the failure of material. Hence these parts are safe.

Scope for future improvement

- By applying the same design concept we can have different number of spindles according to the requirement.
- For enhancement and fast production, an indexable drill jig can be mounted on the drill machine table.
- Automaton of machine can further enhance the accuracy.
- Same drilling setup can be used for different work piece by developing fixtures.

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