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Modal Analysis Of High Speed Milling Spindle By Experimental Approach

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Abstract: *In this paper we determine the natural frequency of highest speed milling spindle for length 335.4mm and 16000 rpm speed based on modal analysis. This paper taking the high speed milling spimdle of M.S. bar which is derived and presented by using finite element model in ansys software.This model takes into account bearing support contact interface , which is established by spring damper element COMBIN 14 for giving cushioning effect to spindle.Furthermore, the modal analysis has done by means of Ansys commercial software. After that this result is compaired with experimental result provided by FFT analyzer.The results show that the natural resonance region speed is far greater than the designed milling spindle.*

Keywords: *Milling Spindle, Finite Element analysis, FFT analyzer,ANSYS.*

I. Introduction

In today's prosperous industrial development, with the multifarious design of products and reduction of production cycle, high speed machining technology has been widely adopted by manufacturers [1].The great development of the science and technology, the high frequency spindles has been taken place of the normal mechanical spindles more and more, and also be used for the numerical control machine with great effects. The need of productivity increased so the higher speed machining requirements increases, this led to the development of new bearings, power electronics and inverter systems. Today, the overwhelming majority of machine tools are equipped with motorized spindles. Unlike externally driven spindles, the motorized spindles do not require mechanical transmission elements like gears and couplings [2].

High-speed motorized spindle is an important component of the high-speed machine tools its performance decides the level of the whole machine tools development to some extent. Especially for high speed machine tools with high accuracy, the influence of vibration is even more serious. The safety and reliability due to imperfect dynamic performance have become the primary problem of structural design and machine operation. Therefore, the dynamic performance research of the high-speed motorized spindle has an important theoretical and practical significance [3]. As the FEM (finite element method) has become an essential solution technique in many areas of engineering concerned static and dynamic process, the FEM is utilized in the design of motorized spindle bearing system [4].

The main aim of this paper is to develop a finite element model of the high speed motorized spindle. The modal simulation is conducted by using ANSYS commercial software. This result is analyzes and verified by experimental approach.

II. Modal Analysis By FEA

Milling motorized spindle vibration is inevitable during milling, which not only changes the relative position of work pieces and milling cutters to influence the machining accuracy, but also accelerates the wears of milling cutter, further influencing the machining accuracy. Research shows that the processing quality largely depends on the vibration produced by machine [14]. The influence of vibration is more serious in specially for high speed machine tools with high accuracy.

First create the spindle model by using FEA with considering following elements.

1) **Beam 3 (2D-Elastic) Element description :-**BEAM 3 is suitable for analyzing slender to moderately line 2D structures. This element consist of 8 elements (9 nodes) of different c/s area. Shear deformation effects are also considered.
2) **Combin 14 Spring Damper :-** Combin 14 element which can be applied to simulate springs and dampers is provided in ANSYS commerical software[14]. This element has torsional or longitudinal capability in one, two, or three dimensional applications. The purely rotational element is in torsional spring- damper option, which gives three degree of freedom at each node i.e roatations about the nodal x, y, and z axes without considering bending or axial loads.

Specifications

- Young's modulus – 2.1e5 N/mm^2
- Poisson's ratio – 0.27
- Density – 7.8 e-6 kg/mm^3
- Front bearings diameter - ϕ*65 x* 100 x 18 (Triplet)
- Rear bearingdiameter - ϕ*55 x* 90 x 18 (Duplex)
- Total Length of spindle – 335.4 mm

Table .1 Element wise c/s area and moment of inertia of spindle.

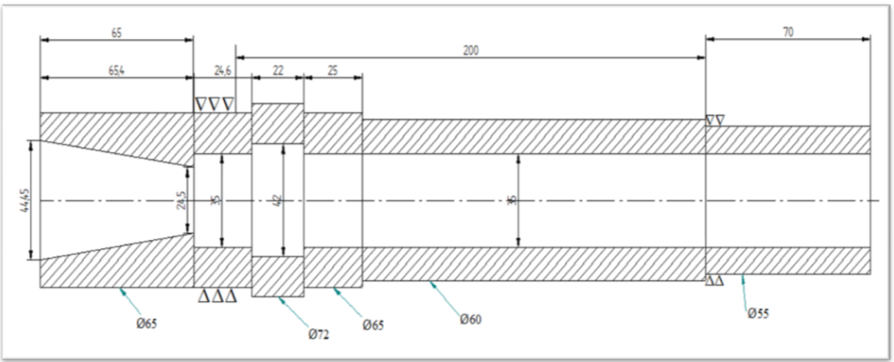
Element Sr. No.	Diameter in mm d_o	d_i	Area in mm^2 $(\pi/4)*(d_o^2-d_i^2)$	Moment of inertia mm^4 $(\pi/64)*(d_o^2-d_i^2)$	Height In mm
1	65	34.475	2.384*e3	806.9*e3	65
2	65	35	2.356*e3	802.58*e3	65
3	65	35	2.356*e3	802.58*e3	65
4	72	35	3.109*e3	1245.5*e3	72
5	72	35	2.356*e3	802.58*e3	65
6	60	35	1.865*e3	562.5*e3	60
7	55	35	1.413*e3	375.5*e3	55
8	55	35	1.413*e3	375.5*e3	55

By cosidering the table.1. data and given specification of material create the FEA modal (2D).

Specimen preparation

The test specimen geometry is as shown in Fig. 1. One testing specimen is prepared as per standard specifications with following or given dimensions. Manufacture the spindle using Mild Steel as a material on lathe machine.

Fig. 1. Schematic representation(drawing) ofM.S. Spindle specimen for production.



Experimentation

The modal analysis test of spindle was performed on FFT Analyzer machine. The detailed results are shown in fig. 2 , fig. 3 and table. 3.For conducting experiment we use the following instruments.

1] Accelerometer2] Impact hammer
3] DAQ- FFT (Fast Fourier Transform)   4] Industrial PC (with FPM software)

Applications

1] Modal testing   2] Order tracking   3] Spectrum analysis
4] Waveform recording   5] Real time octave analysis   6] Sound quality

Fig. 2.shows the real manufactured specimen as per specification of given drawing. After that this specimen kept on FFT machine to free vibration analysis or modal analysis. Free modal analysis result gives on monitor in the form of Waveform i.e frequency v/s db (decibel). From that table consider only frequencies.

Fig. 2. Testing spindle specimen as per drawing

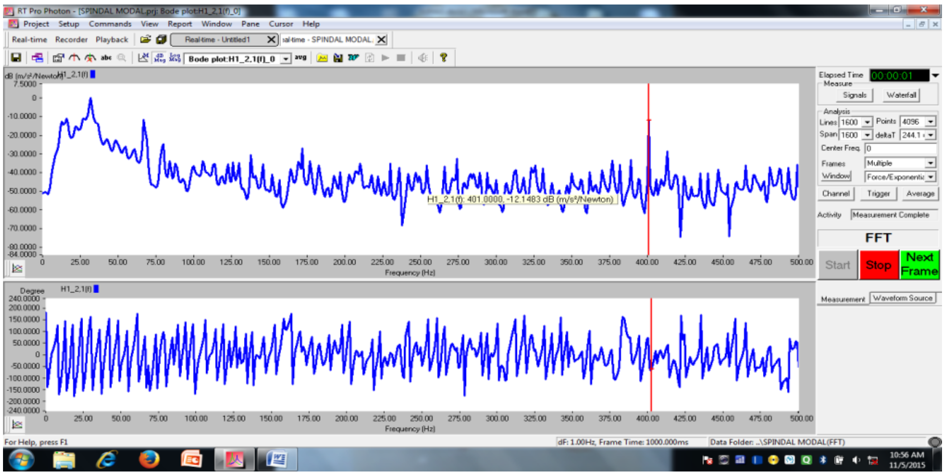


Fig. 3. Modal Analysis results on FFT Analyzer

III. Results

The manufactured specimen as per drawing Kept on FFT analyzer machine and after conducting experiment we got the modal analysis results which are recorded in fig.3 . and Table.3 .

The table.3.shows the different frequencies in which at one frequency the given specimen resonates.In the range 67 Hz to 401 Hz.From fig.3.select a node from the graph, where it gives peak vibration those are listed in table 3.

The fig.4 . shows the modal analysis result by FEA which gives different sets of frequencies for given specifications.

Now compair or match the both results it is seen that frequencies 422 Hz by FEA and 401 Hz by experimental are nearer so that it is observed that 422 Hz frequency is the resonate limit or its natural frequency.

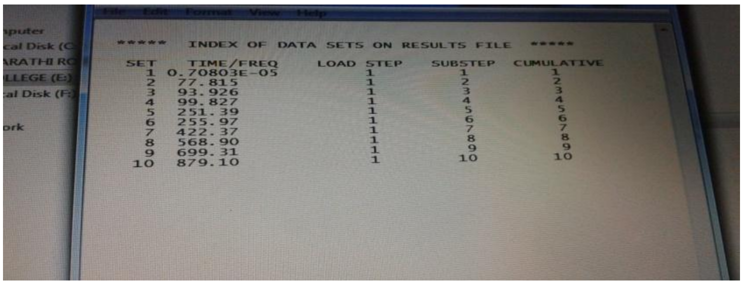


Fig. 4 . Modal analysis result of given specification spindle by FEA

Details of Set of frequencies given by FEAmethod tabulated in the below table.

Table. 2. List of Frequencies by FEA from modal analysis result

SET	1	2	3	4	5	6	7	8	9	10
FREQ[Y]	70.80	77.81	93.926	99.82	251.39	255.97	422.37	568.90	699.31	879.10

Table.3 . Experimental Modal analysis result fore by FFTAnalyzer.

Sr. No.	Frequency (HZ)	Db(decibel)
1	32	-0.939
2	61	-11.59
3	138	-30.74
4	172	-26.94
5	401	-12.14

IV. Conclusions

It is observed that by seeing the both results we determine the natural frequency at which it starts to vibrate at maximum peak level. So based on above results final conclusions are as follows.

1. The modal analysis shows that no resonance occurs in predicted results & it is verified with experimental results.
2. The modal analysis result compare with experimental result then we got nearer422 Hz natural frequency so at this frequency its critical rotating speed is 25320 rpm, which is away from the 16000 rpm of designed spindle.

References

[1] Z.C. Lin, and J.S. Chang, "The building of spindle thermaldisplacement model of high speed machine center", Int. J. Adv.Manuf. Technol., vol. 34, pp. 556-566, Sept. 2007

[2] E. Abele, Y. Altintas, and C. Brecher, "Machine tool spindleunits", CIRP Annals – Manuf. Technol., vol. 59, pp. 781-802, 2010.

[3] C. Li, Y. Ding, and B. Lu, "Development and Key Technology inHigh Speed Cutting", J. Qingdao Technol. Univ., vol. 30, pp. 7-16,Feb. 2009.

[4] W. Li, H. Pu, Q. Liu, G. Chen, and S. Zhang, "ANSYS-Baseddynamic analysis of high-speed motorized spindle", Int. Conf.Comput. Eng. Technol., 2009, pp. 336-340

[5] J. K. Choi, and D. G. Lee, "Characteristics of a spindle bearingsystem with a gear located on the bearing span". Int. J. Mech. T ool.Manuf. Pergamon, vol. 37, pp. 171-173, Aug. 1997.

[6] J. K. Choi, and D. G. Lee, "Thermal characteristics of the spindlebearing system with a gear located on the bearing span", I nt. J.Mech. Tool. Manufact. Pergamon, vol. 38, pp. 1017-1030, Sept.1998.

[7] J.-S. Chen, and Y.-W. Hwang, "Centrifugal force induceddynamics of a motorized high-speed spindle", Int. J. Adv. Manuf.Technol., vol. 30, pp. 10-19, Aug. 2006.

[8] A. G. Rehorn, "Spindle Dynamics: Identification, Modeling andEffects", M. S. thesis, University of Western Ontario, Ont ario,Canada, 2001

[9] E. V. Bordatchev, and R. Henriksen, "State space modeling ofmachine tool spindle units using subspace identificat ion",Proceedings of the 2nd IASTED International Conference onControl and Application, 1999, pp. 120-123.

[10] E. V. Bordatchev, "Modeling and parameter identification of theimpulse response matrix of mechanical systems", Proceeding s of SPIE - The International Society for Optical Engineering, 1998, pp.106-117.

[11] A. G. Rehorn, J. Jiang, P. E. Orban, and E. Bordatchev, "Modelling and experimental investigation of spindle and cutter dynam ics for a high-precision machining center", Int. J. Adv. Manuf.Technol., vol. 24, pp. 806-815, Dec. 2004.

[12] W. Xie, "The FEM Analysis of Dynamic and Static Characteristicof High Speed Motorized Spindle", M. S. thesis, Harbin Institut e of Technology, Harbin, PRC, 2001.

[13] R. A. Burton, and H. E. Staph, "Thermally Activated Seizure ofAngular Contact Bearings". A.S.L.E.Transactions, vol. 10, pp . 408-417, Oct. 1967

[14] Deping Liu, Hang Zhangny Su, Tao& Yufeny Su, " Finite element analysis of high speed motorized spindle based on Ansys", The open mechanical engineering journal 2011,volume 5,1-10.

[15] Joaquim de Ciurana, Guillem Quintanaand Francisco Javier Campa, "Machinetoolsforhighperformancemachining",Machine tool spindles, 2009,75-127, DOI:10.1007/978-1-84800- 380-4_3.

[16] Dr.Sinan Badrawy, "Dynamic modellingand analysis of motorized milling spindlesforoptimizing thespindle cutting erformance", Engineering Manager Moore Nanotechnology Systems, LLC

[17] Osamu Maeda, Yuzhong Cao, YusufAltintas, "Expert spindle design system"International Journal of Machine Tools &Man ufacture 45 (2005) Pages537–548.