OPTIMIZATION OF HIGH-SPEED MOTORIZED SPINDLE IN MILLING MACHINE

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Abstract: The present prosperous industrial advancement, with the multifarious design of products and reduction of production cycle, high- speed machining technology has been extensively adopted by manufacturers. With the improvement of the science and technology, the high recurrence axles has been occurred of the typical mechanical shafts to an ever increasing extent, and furthermore be utilized of the numerical control machine with extraordinary impacts. The Fundamental ambitions of this proposal are structuring and examine the fast mechanized milling machine spindle. The spindle analyzed with contrasting materials like wise Steel, Aluminum Alloy 6061, 7075 and Carbon Fiber. In this analysis we find stress, Strain and deformation at every mode on these materials. The total analysis is done by using Ansys Software.

***IndexTerms* – Structural analysis, CREO, Aluminum, Steel, Carbon fiber.**

I. INTRODUCTION

Milling is the process of machining flat, curved, or Milling machines are basically classified as vertical or irregular surfaces by feeding the work piece against a rotating horizontal. These machines are also classified as knee-type, cutter containing a number of cutting edges. The milling ram-type, manufacturing or bed type, and planer-type. Most machine consists basically of a motor driven spindle, which milling machines have self-contained electric drive motors, mounts and revolves the milling cutter, and a reciprocating coolant systems, variable spindle speeds, and power-operated adjustable worktable, which mounts and feeds sown in the Fig1. Milling machine is used for machining flat surfaces, contoured surfaces, surfaces of revolution, external and internal threads, and helical surfaces of various cross-sections. The surface obtained by this machine tool is superior in quality and more accurate and precise.

II. LITERATUTE REVIEW

Y.Lu 1, Ying Xue Yao 2, R.H. Hong 3 et al. [1] discussed that, the heat generation developed in the built-in motor and the bearings is calculated. The thermal deformation of spindle is 6.56 µ m, it is too small to affect the precision of the spindle. Jenq-Shyong Chen Wei-Yao Hsu et al. [2] discussed that, the characterizing and modeling of the thermal growth of a motorized high speed spindle is reported. A motorized high speed spindle has more complicated dynamic, non-stationary and speed-dependent thermal characteristics than conventional spindles. Chi-Wei et al. [3] explained the proposed an integrated model with experimental validation and sensitivity analysis for studying various thermo-mechanical-dynamic spindle behaviors at high speeds. DepingLiu, Hang Zhang, et al. [4] presents a method to investigate the characteristics of a high-speed motorized spindle system. The geometric quality of high-precision parts is highly dependent on the dynamic performance of the entire machining system, which is determined by the interrelated dynamics of machine tool mechanical structure and cutting process. Nagaraj Arakere, et al. [5] concludes that the ball bearing stiffness controls the rigid body modes while the spindle-holder interface stiffness controls the two bending modes. The experimental spindle-holder assembly frequency responses are presented as a function of spindle speed and compared to the rotor dynamics model results. Jin Kyung Choi, Dai Gil Lee et al. [6] proposed that High cutting speeds and feeds are essential requirements of a machine tool structure to accomplish its basic function which is to produce a work piece of the required geometric form with an acceptable surface finish at as high a rate of production as is economically possible. From the comparison of the numerical results with the experimental results, it was found that the finite element method predicted well the thermal characteristics of the spindle bearing system. Jenq-Shyong Chen*, Kwan-Wen Chen et al. [7] proposed Angular contact ball bearings are the most popular bearing type used in the high speed spindle for machining centres. Because the bearing load is increased rapidly with the raised spindle speed due to the centrifugal force and temperature raise, proper initial preload and especially operating-induced load control of the angular ball bearing is important to the rigidity, accuracy and life of the spindle. The bearing layout, preload mechanism an on-line load bearing control are discussed in this paper. Mohammed A. Alfares et al. [8] explained that a mathematical model based on five degrees of freedom dynamic system is utilized to study the effects of axial preloading of angular contact ball bearing on the vibration behavior of a grinding machine spindle. The results show that the initial axial preload applied on the bearings plays a significant role to reduce the vibration levels of the grinding machine spindle system and consequently results in better accuracy for the finished surfaces. Bernd Bossmanns, Jay F. Tu et al. [9] proposed that Lack of a more complete understanding of the system characteristics, particularly thermal effects, severely limits the reliability of high speed spindles to support manufacturing. High speed spindles are notorious for their sudden catastrophic failures without alarming signs at high speeds due to thermal problems. In this paper, a finite difference thermal model is developed to characterize the power distribution of a high speed motorized spindle, in particular the characterization of heat transfer and heat sinks. Without loss of generality, this model is built upon and verified by a custom-built high performance motorized milling spindle of 32 KW and maximum speed of 25000 rpm (1.5 million DN. S.Vinoth1, T. Azhagu Murugan2 et al. [10] proposed motorized spindle is one of the core parts of high-speed machine tool to a great extent, its thermal characteristics determine the thermal stress and thermal deformations and therefore the research on thermal characteristics is of great significance to increase the accuracy of high-speed machine tool. The results of temperature rise are used to determine the working speed of the spindle without bearing failure.

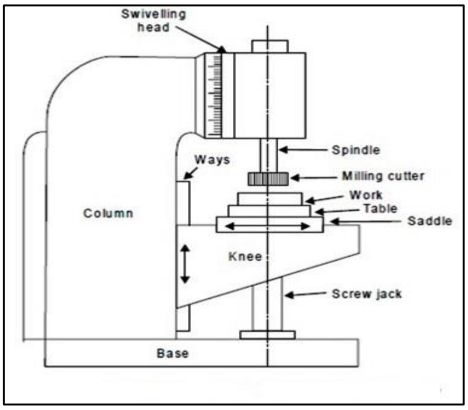

Figure1. Line diagram of milling machine

2 ANALYSIS OF SPINDLE

2.1 Speed Analysis of Aluminum Alloy 7075 and 6061 at 10000rpm 1Deformation Stress and strain

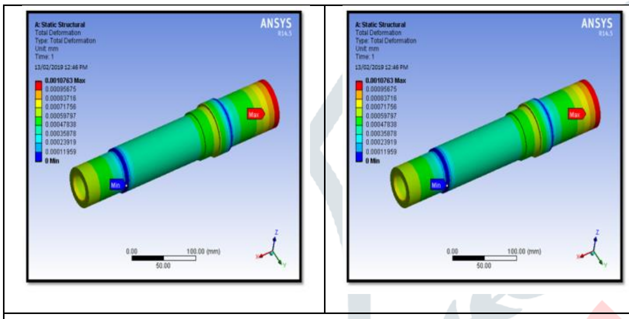

Fig: 2.1Deformation for Aluminum Alloy 7075 and 6061

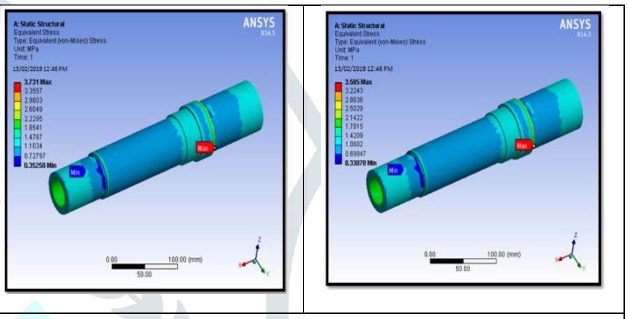

Fig: 2.2 Stress for Aluminum Alloy 7075 and 6061

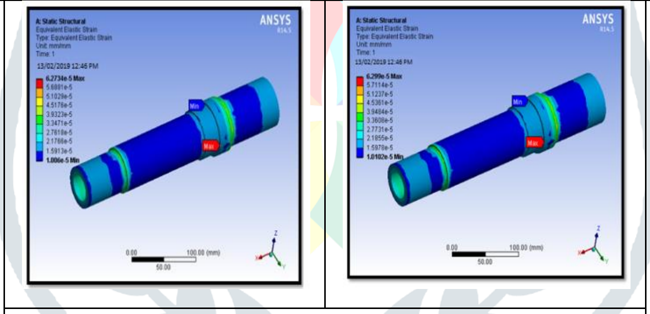

Fig: 2.3 strain for Aluminum Alloy 7075 and 6061

2.2. Material- Steel and Composite Fiber

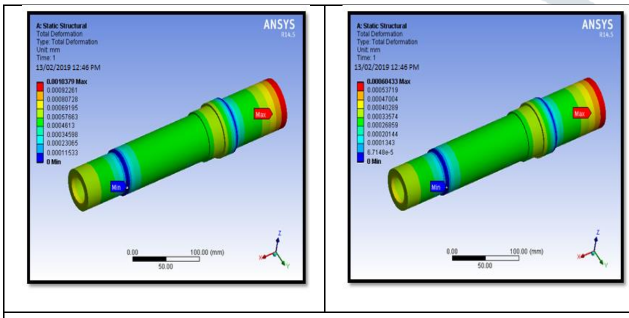

Fig: 2.2.1 Deformation for Steel and composite fiber

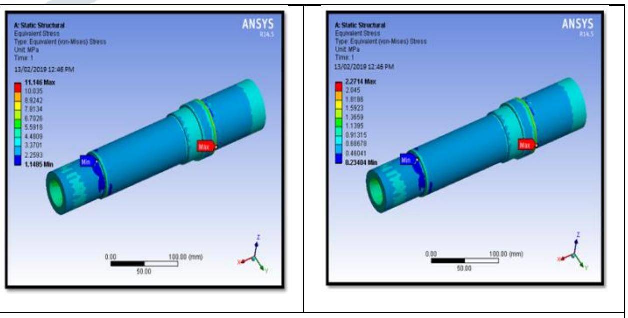

Fig:2.2.2 Stress for Steel and composite fiber

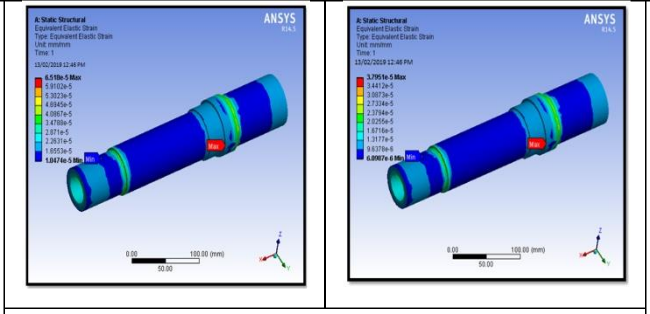

Fig: 2.2.3 Strain for Steel and composite fiber

2.3. Analysis of Spindle Speed at 13000rpm Material- Aluminum Alloy 7075 Aluminum Alloy 6061

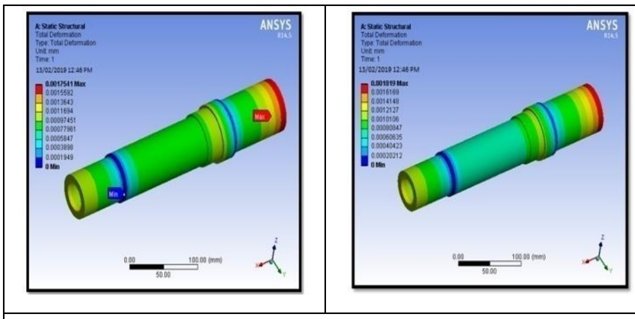

Fig: 2.3.1 Deformation for Aluminum Alloy 7075 and 6061

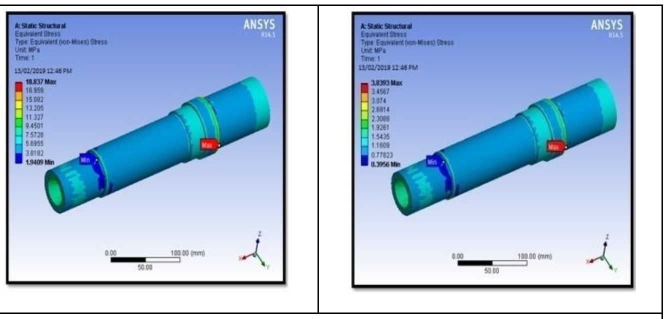

Fig: 2.3.2 Stress for Aluminum Alloy 7075 and 6061

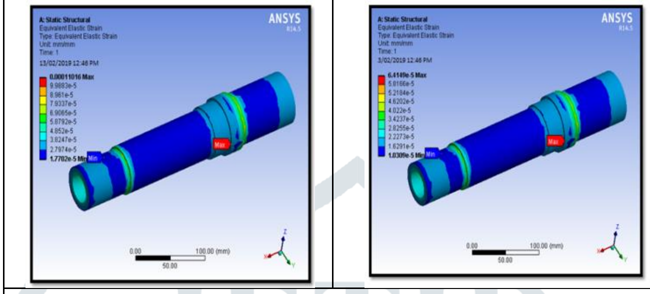

Fig:2.3.3 Strain for Aluminum Alloy 7075 and 6061

2.4. Analysis of Spindle Speed at 13000rpm Material Steel and Composite Fiber

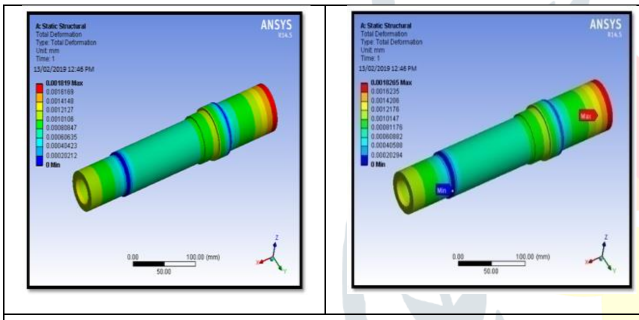

Fig:2.4.1 Deformation for Steel and composite fiber

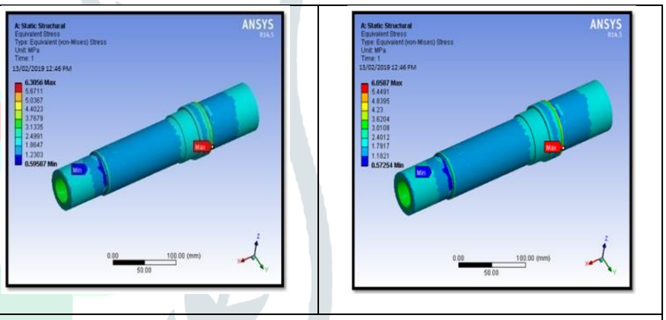

Fig:2.4.2 Stress for Steel and composite fiber

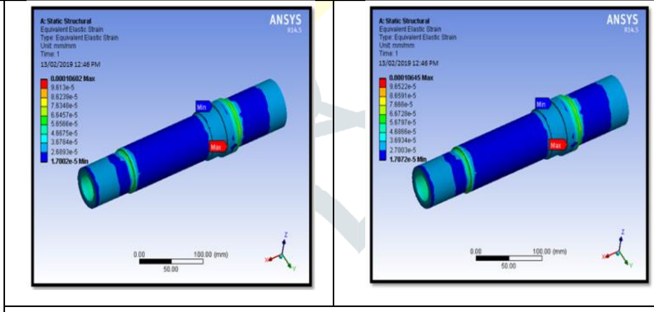

Fig:2.4.3 Strain for Steel and composite fiber

2.5. Analysis of Spindle Speed at 13000rpm Material- Aluminum Alloy 7075 Aluminum Alloy 6061

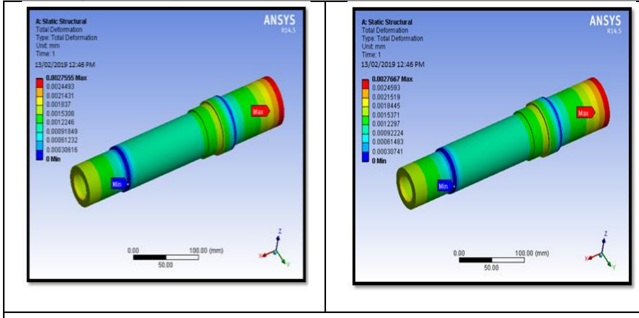

Fig: 2.5.1 Deformation for Aluminum Alloy 7075 and 6061

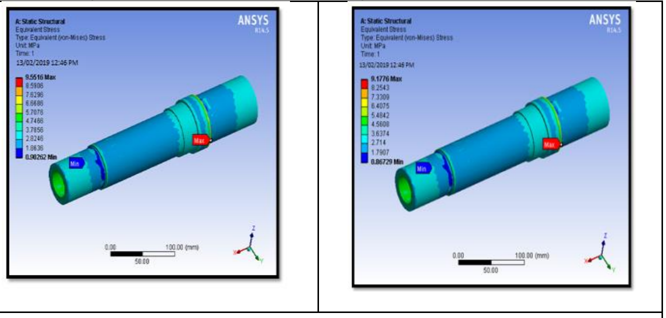

Fig: 2.5.2 Stress for Aluminum Alloy 7075 and 6061

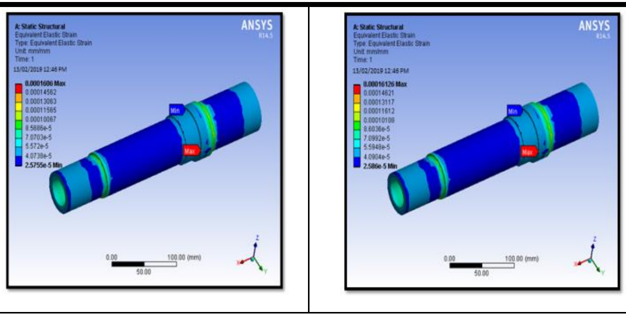

Fig:2. 5.3 Strain for Aluminum Alloy 7075 and 6061

2.6. Analysis of Spindle Speed at 16000rpm Material- Steel and composite fiber deformation

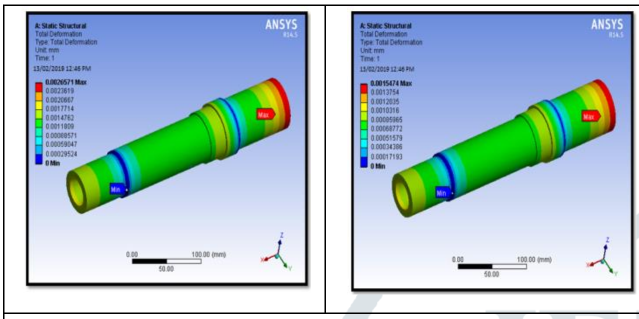

Fig:2.6.1 Deformation for Steel and composite fiber

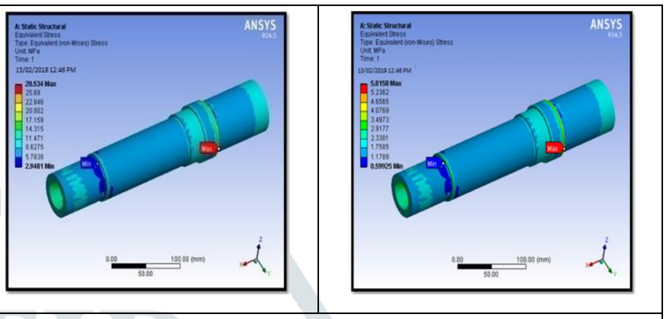

Fig:2.6.2 Stress for Steel and composite fiber

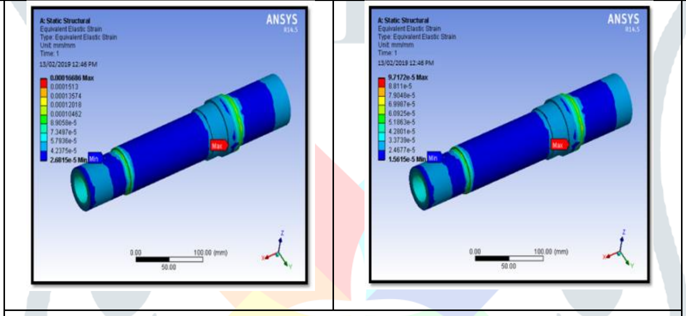

Fig:2.6.3 Strain for Steel and composite fiber

3.1 Modal Analysis Material- Aluminum Alloy 6061 Aluminum Alloy 7075

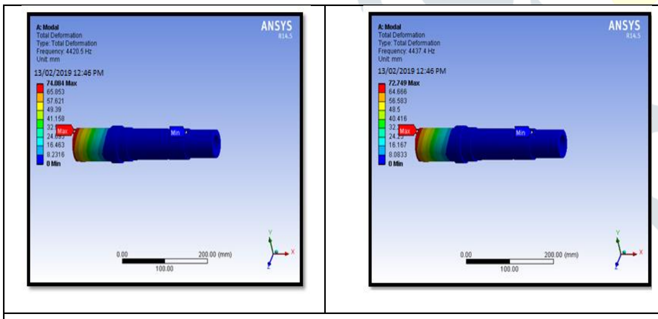

Fig: 3.1.1Deformation for Aluminum Alloy 7075 and 6061

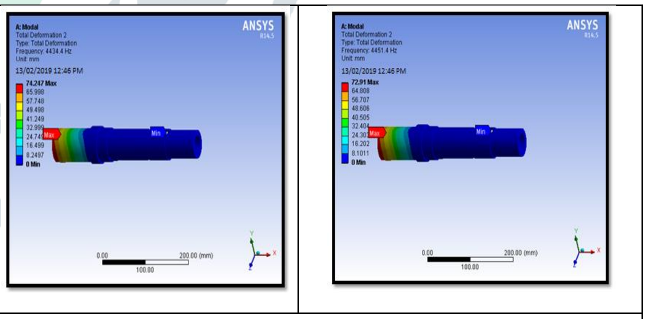

Fig:3.1.2 Stress for Aluminum Alloy 7075 and 6061

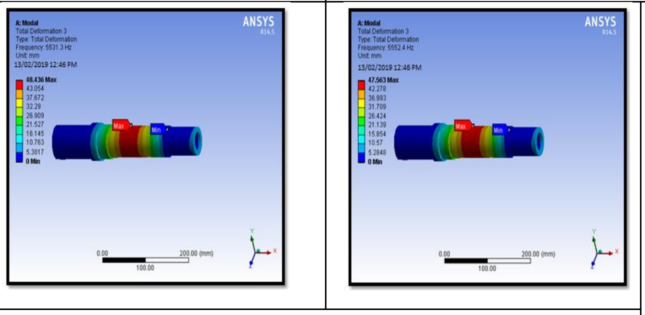

Fig:3.1.3 Strain for Aluminum Alloy 7075 and 6061

3.2. Modal Analysis Material- Steel and Carbon fiber deformation

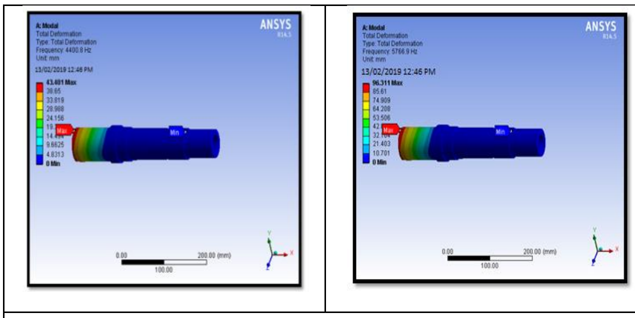

Fig:3.2.1 Deformation for Steel and composite fiber

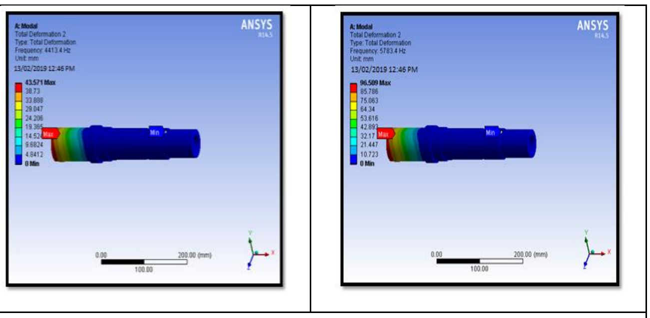

Fig: 3.2.2 Stress for Steel and composite fiber

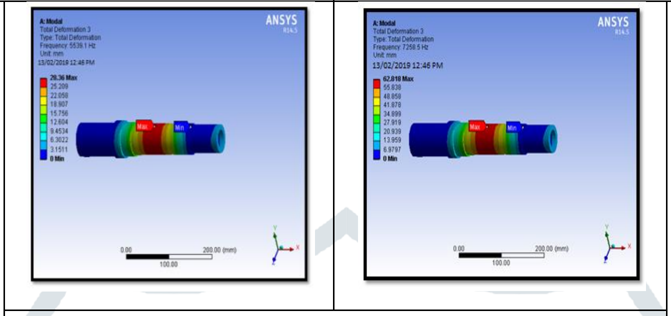

Fig:3.2.3 Strain for Steel and composite fiber

4. TRANSIENT ANALYSIS– at 1000 RPM

4.1. MATERIAL- ALUMINUM ALLOY 7075 at 10, 20 sec and 30 sec

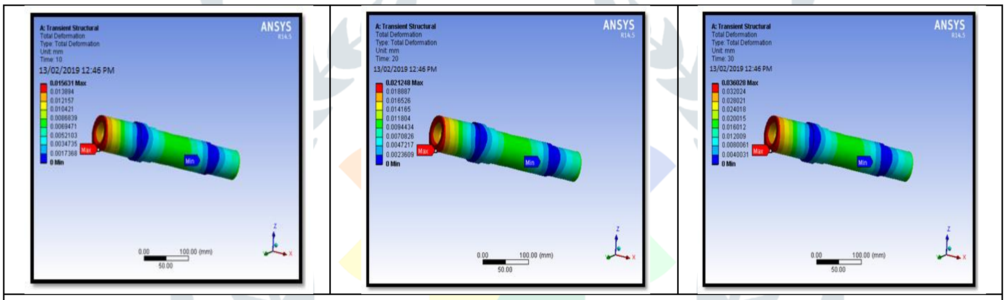

Fig: 4.1.1Deformation for Aluminum alloy7075 at 10 sec 20 sec and 30 sec

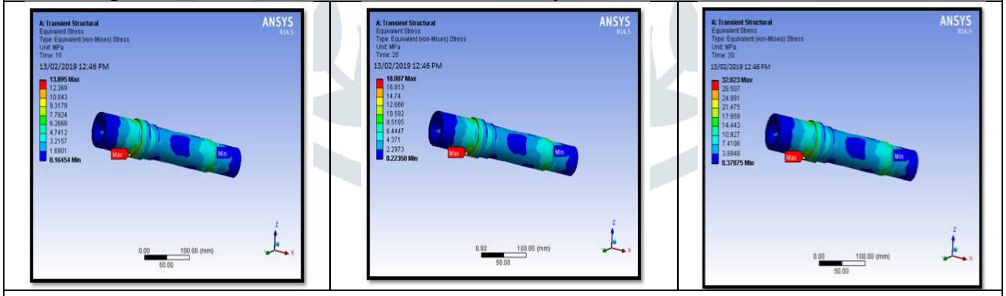

Fig: 4.1.2 Stress for Aluminum alloy7075 at 10 sec 20 sec and 30 sec

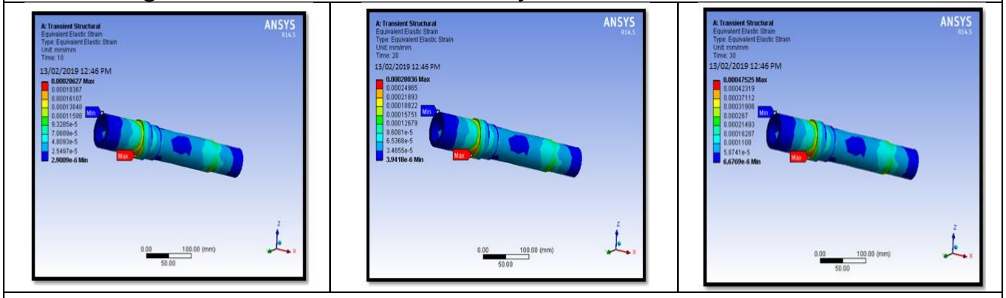

Fig:4.1.3 Strain for Aluminum alloy7075 at 10 sec 20 sec and 30 sec

4.2. MATERIAL- ALUMINUM ALLOY 6061 at 10, 20 sec and 30 sec

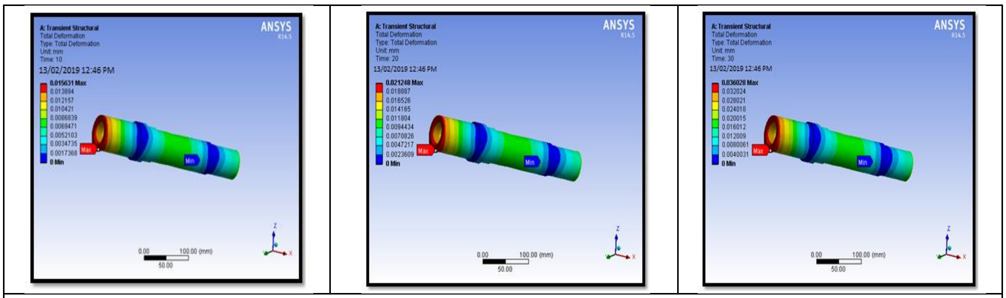

Fig:4.2.1 Deformation for Aluminum alloy 6061 at 10 sec 20 sec and 30 sec

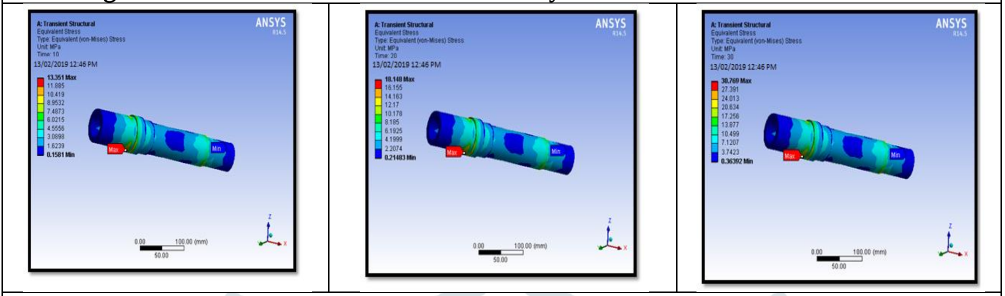

Fig: 4.2.2.Stress for Aluminum alloy 6061 at 10 sec 20 sec and 30 sec

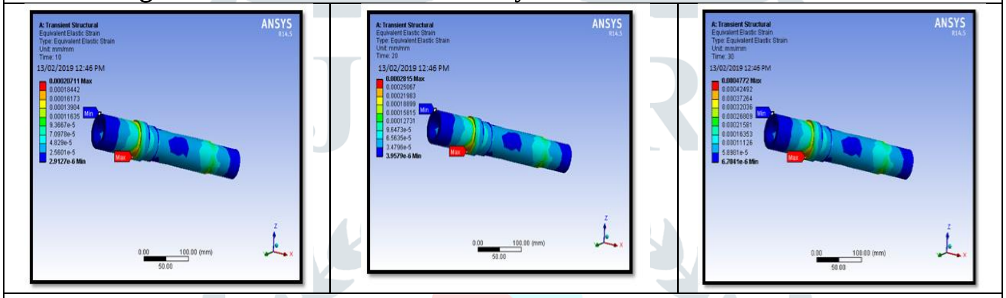

Fig: 4.3.3 Strain for Aluminum alloy 6061 at 10 sec 20 sec and 30 sec

4.3. MATERIAL- STEEL at 10, 20 sec and 30 sec

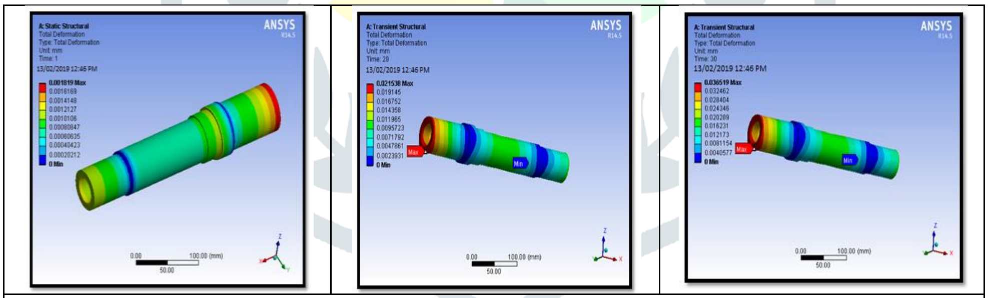

Fig:4.3.1 Deformation for Steel at 10 sec 20 sec and 30 sec

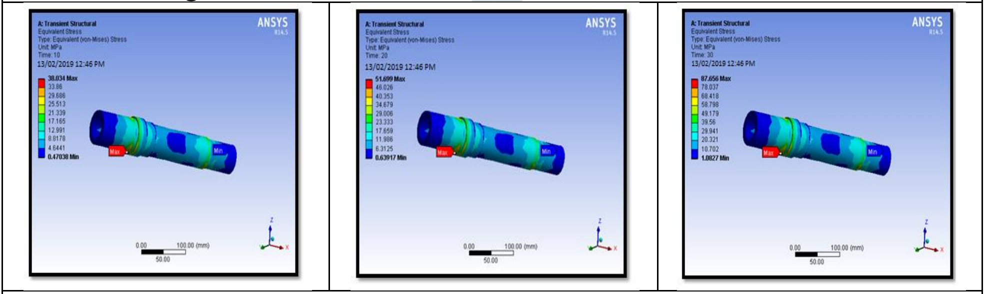

Fig: 4.3.2Stress for Steel 6061 at 10 sec 20 sec and 30 sec

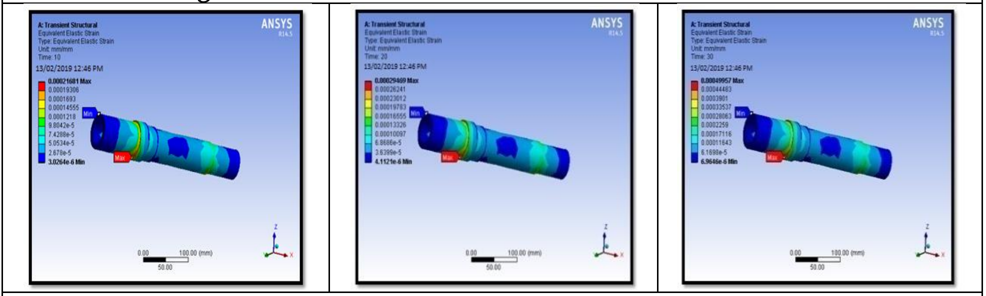

Fig:4.3.3 Strain for Steel at 10 sec 20 sec and 30 sec

4.4. MATERIAL- CARBON FIBER

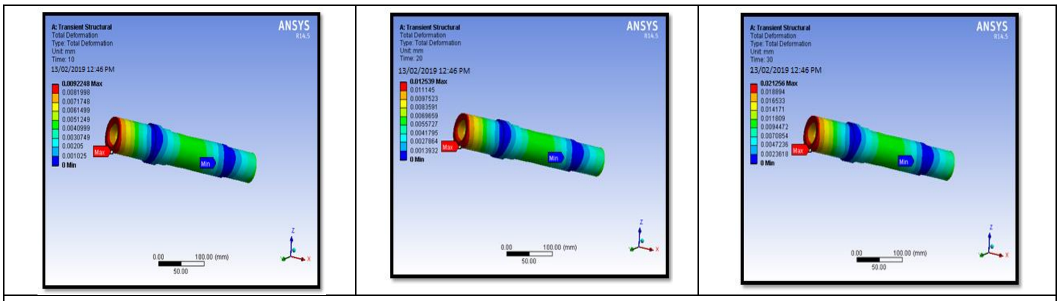

Fig: 4.4.1 Deformation for Carbon Fiber at 10 sec 20 sec and 30 sec

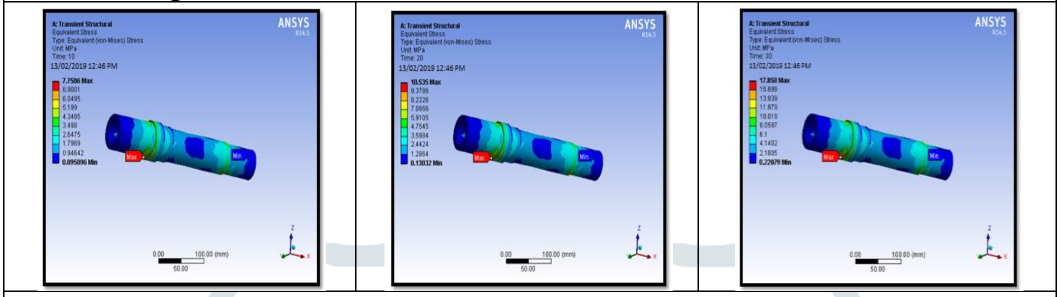

Fig:4.4.2 Stress for Carbon Fiber at 10 sec 20 sec and 30 sec

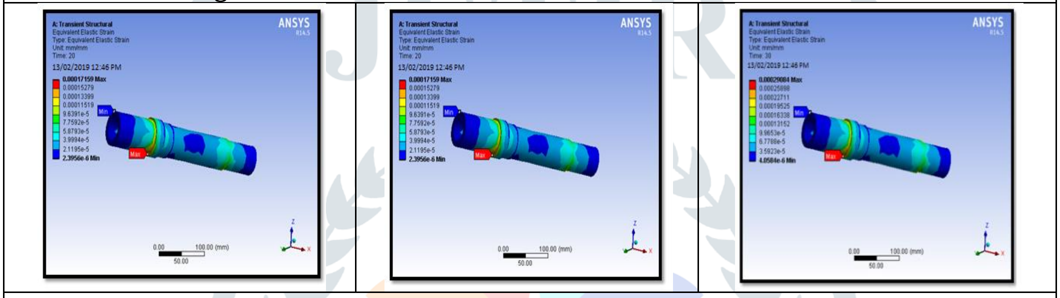

Fig: 4.4.3 Strain for Carbon Fiber at 10 sec 20 sec and 30 sec

5. RESULTS AND DISCUSSION

Table 5.1 Static Analysis Result

Speed (rpm)	**material**	**Deformation(mm)**	**Stress(M Pa)**	**Strain**
10000	Aluminum alloy7075	0.0010763	3.731	6.2734e-5
	Aluminum alloy 6061	0.0010807	3.585	6.299e-5
	steel	0.0010379	11.146	6.518e-5
	Carbon fiber	0.00060433	2.2714	3.7951e-5
130000	Aluminum alloy 7075	0.001819	6.3056	0.00010602
	Aluminum alloy6061	0.0018265	6.0587	0.00010645
	steel	0.0017541	18.837	0.00011016
	Carbon fiber	0.0010215	3.8393	6.4149e-5
160000	Aluminum alloy 7075	0.002755	9.5516	0.0001606
	Aluminum alloy 6061	0.0027667	9.1776	0.00016126
	steel	0.0026571	28.534	0.00016686
	Carbon fiber	0.001547	5.8158	9.712e-5

Table 5.2 Modal analysis of result table

Material	Modes	Deformation (mm)	Frequency (Hz)
Aluminum 7075	1	72.749	4437.4
	2	72.91	4451.4
	3	47.563	5552.4
Aluminum 6061	1	74.084	4420.5
	2	74.247	4434.4
	3	48.436	5531.3
Steel	1	43.481	4400.8
	2	43.571	4413.4
	3	28.36	5539
Carbon fiber	1	96.31	5766.9
	2	96.509	5783.4
	3	62.818	7258.8

5.3Transient analysis results table

Table 5.3.1 Transient analysis results at speed 10000 rpm

Material	Time (sec)	Deformation (mm)	Stress (MPa)	Strain
Aluminum 7075	10	0.015631	13.895	0.00020627
	20	0.021248	18.887	0.00028036
	30	0.036028	32.0.23	0.00047525
Aluminum 6061	10	0.15695	13.351	0.0002071
	20	0.021335	18.148	0.0002815
	30	0.036175	30.769	0.0004772
Steel	10	0.015844	38.034	0.0002168
	20	0.021538	51.699	0.0002946
	30	0.036519	87.656	0.0004995
Carbon fiber	10	0.0092248	7.7506	0.0001264
	20	0.012539	10.535	0.00017159
	30	0.021256	17.858	0.00029084

Table 5.3.2 Transient analysis results at speed 13000 rpm

Material	Time (sec)	Deformation (mm)	Stress (MPa)	Strain
Aluminum 7075	10	0.021016	18.681	0.0002773
	20	0.039758	35.338	0.00052443
	30	0.060937	54.159	0.00080351
Aluminum 6061	10	0.02402	17.95	0.00027843
	20	0.0399	33.955	0.00052657
	30	0.061187	52.039	0.00080679
Steel	10	0.021303	51.135	0.00029148
	20	0.04301	96.731	0.00055126

	30	0.06177	148.25	0.00084464
Carbon fiber	10	0.012402	10.42	0.0001697
	20	0.023456	19.706	0.0003209
	30	0.035941	30.194	0.00049165

Table 5.3.3 Transient analysis results at speed 16000 rpm

Material	Time (sec)	Deformation (mm)	Stress (MPa)	Strain
Aluminum 7075	10	0.026618	23.66	0.00035118
	20	0.022894	38.125	0.0005657
	30	0.092406	82.116	0.0012178
Aluminum 6061	10	0.026727	22.734	0.00035262
	20	0.043069	36.633	0.0005680
	30	0.092784	78.902	0.0012228
steel	10	0.026981	64.765	0.0003691
	20	0.04348	104.36	0.0005947
	30	0.093669	224.78	0.0012802
Carbon fiber	10	0.015706	13.196	0.0002149
	20	0.025305	21.259	0.00034622
	30	0.054477	45.762	0.000745

CONCLUSION

The following conclusion has been drawn from the experimentation

We have analyzed Milling machine spindle speed with different materials like Aluminum 7075, Aluminum 6061, Steel and Carbon fiber by Structural, Modal, Dynamic and transient analyses by using Ansys software.

1. By observing the Static analysis the deformation, stress and strain are observed at different spindle speeds increased gradually like 10000 rpm,130000 rpm and 160000 rpm the obtaining stresses are low at carbon fiber when compare with Al 7075, Al6061 and steel.
2. By observing the Modal analysis the deformation and frequency has increased at three different nodes for Carbon fiber when compare to Al 7075, Al 6061 and steel.
3. By the observation for transient analysis the deformation and frequency has low for Carbon fiber at three different times when compare to Al 7075, Al 6061 and steel.
4. Hence from all above cases we conclude the suitable material for high speed motorized spindle is carbon fiber.

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