Journal of Engineering and Sustainable Development
Vol. 21, No. 5, september 2017
ISSN 2520-0917
www.jeasd.org

CHARACTERISTIC OF SPECIFIC INDUSTRIAL APPLICATION

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Abstract: The shot peening process used mainly to hardened the surface and increases the fatigue life of the rotating parts . This cold treatment will change the designed natural frequency of the part and change the vibration characteristics . Especially when this parts are driven by a high speed velocities. This research investigates the behavior of the vibrations after a superficial treatment done by shot peening. An experimental test rig was manufactured, and different industrial applications and geometries have been tested and treated by shot peening process. Three important commonly used industrial applications are selected to study and investigate its vibration characteristic after shot peening treatment namely connecting rod, crankshaft, and supercharger shaft for a (3Kv) generator. Vibration parameters such as acceleration velocity and displacement for specific time duration was recorded and analyzed also, the natural frequency and first six mode shape . The fundamental increases after shot peening and the percentage of increasing in natural frequency for crankshaft, connecting rod, and supercharger shaft are (26 %), (32 %), and (20 %) respectively where . For comparison reason a different numerical finite element models for the connecting rod, crankshaft and superchargers shaft are suggested and implemented in ANSYS 15. A good accuracy was achieved between numerical models and experimental measurements.

Keywords: *Shot peening, vibrations, crankshaft ,connecting rod*

خصائص تطبيقات صناعية محددة

الخلاصة: عملية السفع بالكرات تستخدم اساسا لتصليب اسطح الاجزاء الدوارة و زيادة حياة التعب . وهية عملية معالجة على البارد وسوف تقوم بتغير التردد الطبيعي و خصائص الاهتزاز للاجزاء. خصوصا للاجزاء التي تتعرض للدوران بسرعات عالية . هذا البحث هو للتحقق من سلوك الاهتزاز بعد المعالجة السطحية بواسط السفع بالكرات . تم تصنيع جهاز اختباري لهذا الغرض ، وقد تم اختيار ثلاث تطبيقات صناعية مختلفة الاشكال الهندسية لغرض التعامل معها بواسطة السفع بالكرات لدراسة تاثير السفع بالكرات على الاهتزاز وهي (عمود المرفق ، و ذراع التوصيل لمولدة (3kva) مع عمود سوبر جارج). خصائص الاهتزاز مثل التعجيل ، السرعة و الازاحة لفترة زمنية محددة تم تسجيلها وتحليلها ، مع تحليل اول ست انماط للتردد الطبيعي . ان زيادة في التردد الطبيعي لعمود المرفق ، ذراع التوصيل و عمود السوبر جارج هي (26% ، 32% و 20%) على التوالي . ولغرض المقارنة تم اقتراح نماذج عددية باستخدام طريقة العناصر المحددة (FEM) لعمود المرفق ، ذراع التوصيل و عمود السوبر جارج بتوظيف برنامج ANSYS 15 . وتحققت دقة جيدة بين النماذج العددية والقياسات التجريبية.

1. Introduction

In the simplest words, the vibration of engine equipment's is the simple movement of back and forth or wiggles of machines and components. For example, driven system (pumps, compressors), drive motors, and the shafts, bearings, belts, gears, and other

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components that compose mechanical systems. Vibration in all equipment is a sign of worry and a reason for problems. But in sometimes, vibration is a normal part of the running machine and should not cause any concern. In other situations, vibration is a major part of the machine design. For instance, some vibration nearly inescapable in the internal combustion engines, compressors, and reciprocating pumps. Shot peening is a cold working process where a small spherical ball bombarded the surface of a part. Each shot is striking the metal acts as a tiny peening hammer imparting a small indentation or dimple on the surface [1].

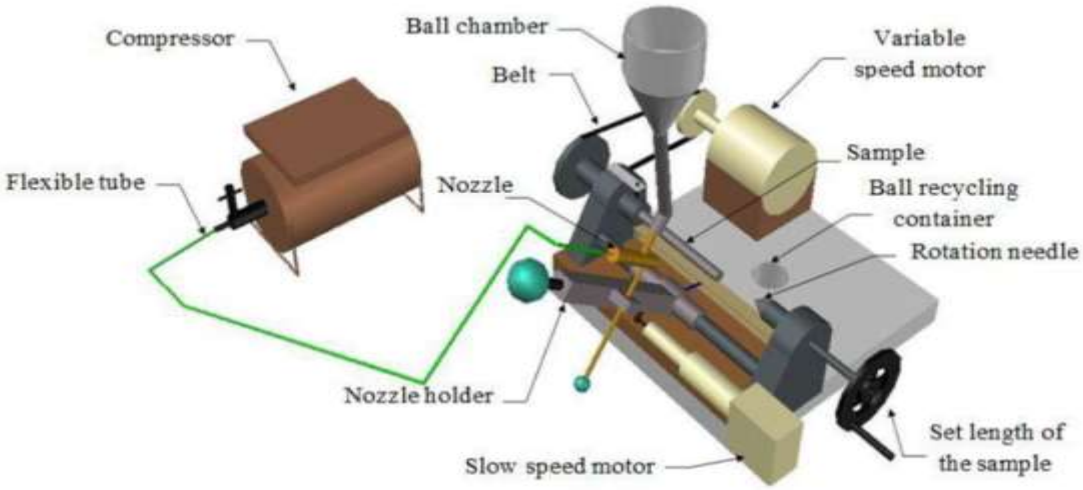
The shot peening machine has evolved into two main types air blast and wheel. The air blast machines pressurized air is used to feed the ball into the air stream with the combination of gravity feed [2]. Speed of media can be changed by regulating the air pressure some reduction in shot effectiveness can occur due to shot rebound when the blast is directed normal to a surface [3]. The crankshaft is a complex geometry in the engine, which converts the reciprocating displacement of the piston to rotary motion and experiences a large number of load cycles fatigue [4]. Connecting rods are wide using in a various engines. The connecting rod connects the piston to the crankshaft, and its main function is to transfer the piston pressure to the crankshaft. The free vibration nonlinear slender rotating shaft with simply support conditions and the effect of shear deformation is negligible because the shaft is slender the nonlinear system was analyzed by the multiple range method analyzed by M. Shahgholi et al. [5] While; M. H. Jalali et al. [6] Investigate the dynamic behavior of the rotating system the dynamic characteristics of a high-speed rotor with certain geometrical and mechanical properties were evaluated at rest and under operating conditions. The modal analysis of the rotor at rest under free–free boundary conditions this is done with the beam finite element model, 3D finite element model test and comparison of the results indicated satisfactory agreement between them and Yasser Fouad et al. [7] .

Evaluated the effect of shot-peening on the high cycle fatigue performance of the age-hardening aircraft alloy Aa2024 at different Almen intensities Using spherically conditioned cut wire (SCCW 14) with a rate of shot size 0.36 mm and at Almen intensities of 0.1, 0.2, and 0.3 mm A with full Shot peening coverage (100 pct.). ŽAGAR Sebastian et al. [8] Dealt with the effect of different shot peening (SP) treatment conditions on the ENAW 7075-T651 aluminum alloy. The obtained maximum value of compressive residual stress ranges between -200 MPa and -300 MPa at a depth between 250 μm and 300 μm. M. M. Rahman [9] Under variable amplitude loading conditions the fatigue life of the AA6061-T6, was studied the effect of shot peening with different surface finish for a two stroke free piston engine at the most critical location The shot peening has produced repeatable results indicating improvement in the fatigue life over the range of loads and geometric configurations.

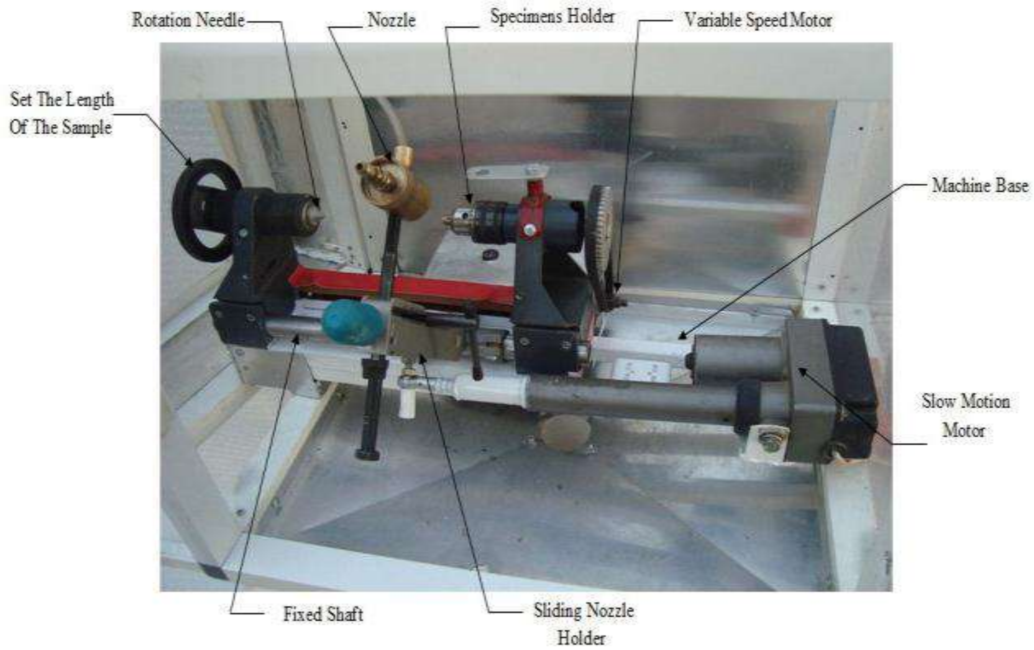
All the above aforementioned studies concentrate on the vibration behavior of rotating shaft and others on increasing the material resistance against corrosion, cracking, and cycling load by using shot peening treatment with different time. Other aspects which form the main idea of this work. This includes design and manufacturing for a machine to be suitable for shot peening treatment. By controlling many parameters such as shoting distance line of shot and ball size. This work are devoted to examine the vibration behavior on natural frequency before and after shot peening with different shot peening process variables.

2. Experimental work

In order to study and control the Shot peening process parameters like shot time (ST), ball size and distance of shot an experimental rig was designed and manufactured. It is consist of 3-axis rotation machine equipped with a variable radius nozzle connected to a flexible hose and air compressor. The air compressor pressure ranges between 1-10 bar as shown in Fig.(1) (a & b).



(a) CAD design.



(b) Experimental rig
Fig.(1) Shot Peening Experimental Rig.

The design allows for 3-axis movement and rotation for the tested specimen as shown in Fig.(2) this movement are controlled by three variable speed motor ranges (50-1300 rpm).

The selected steel balls diameter are (0.6 ,3, 4 mm).

Three commonly used industrial applications are chosen and tested namely connecting rod, crankshaft and supercharger shaft for a kerosene generator(3 Kv) .

The material properties are listed in table (1). The geometric properties are shown in Fig.(3) a ,b and c

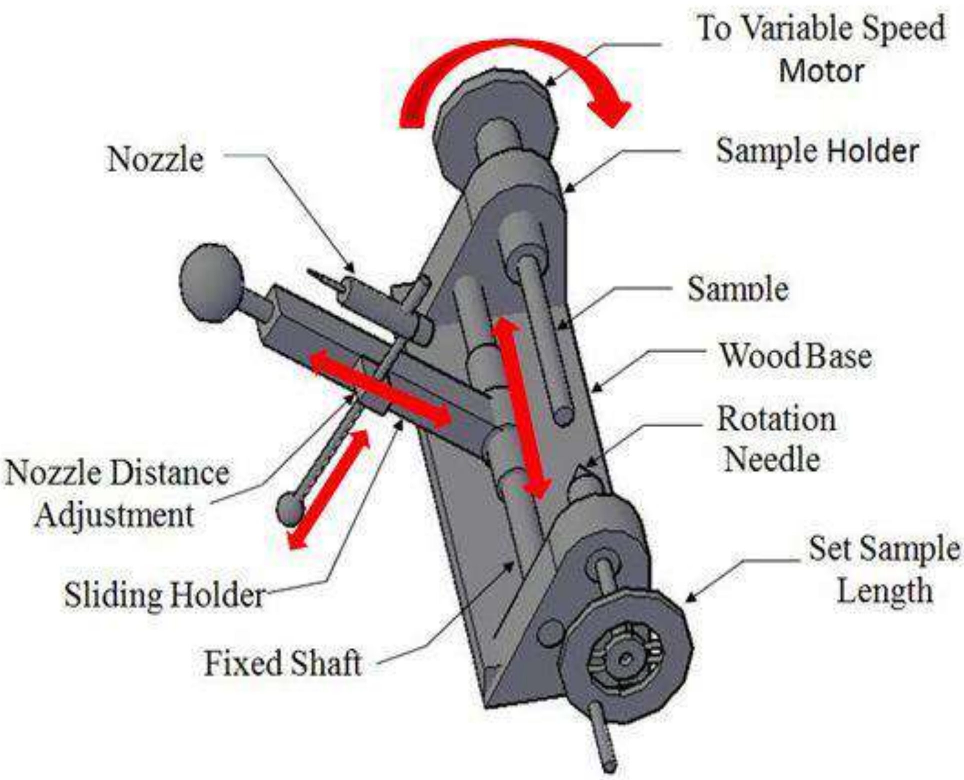
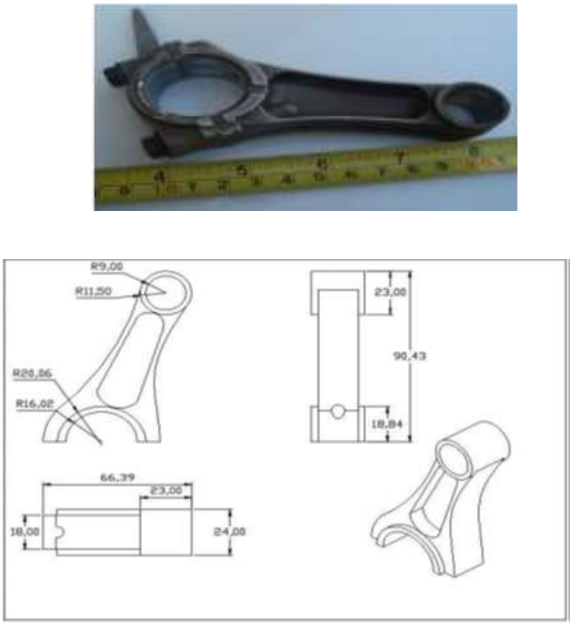


Fig.(2) 3-axis movement and rotation.

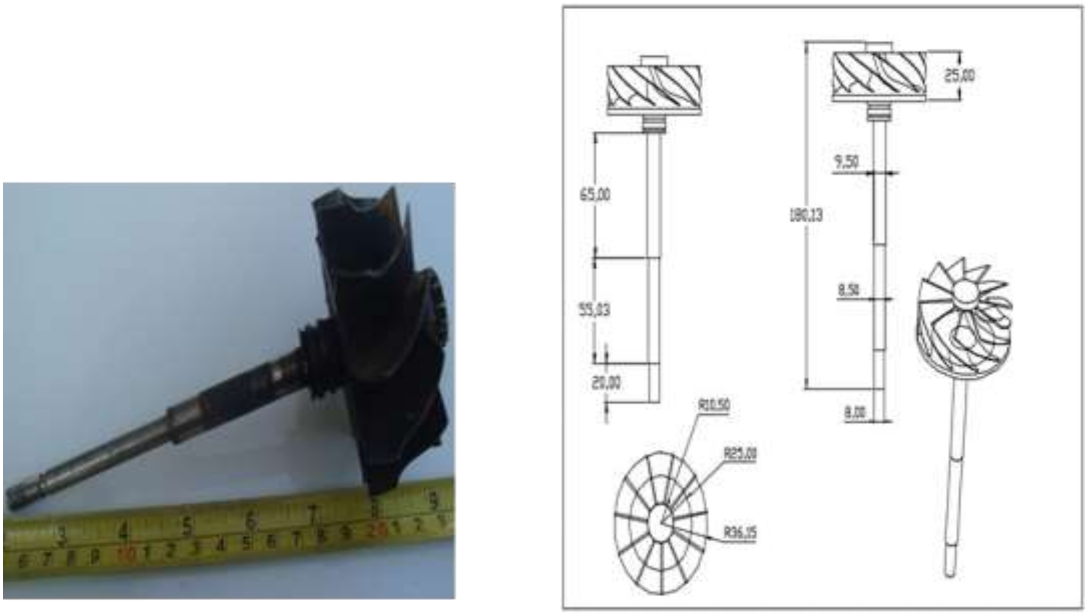
Table (1): Material specification.

Properties	Crankshaft	Connecting rod	Supercharger shaft
Young's modulus	165 MPa	71.7 GPa	210 GPa
Density	7100 kg/m3	2.81 g/cm3	7.85 g/cm3
Poisson's ratio	0.275	0.33	0.27
Tensile stress	414-827 MPa	572 MPa	655 MPa
Yield stress	330 MPa	372 MPa	415 MPa

(a)



(b)



(c)

Fig.(3) Three different applications (all dimensions are in mm)

3. Results and discussions

The shot peening distance (SD) and ball size are an important shooting process variable. The hardness of Six aluminum shafts with 100 mm length have been tested after shot peening . The hardness are measured with INNOVA test Fig.(4-a) and when the ball trace are tiny will measured with micro hardness device Fig.(4-b) . Where the distance between nozzle and sample is an important factor tested and analyzed. Different ball distances are examined as shown in table (2).

(a) INNOVA test device model VERZUS 700 (b) Microhrdness device

Fig. (4)

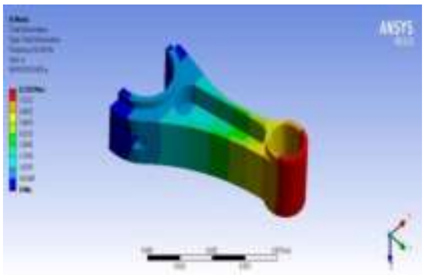
No	Length	HRC before shot	HRC after shot	Ball Size	Distance from nozzle
1	100 mm	51.34	66.75	4 mm	50 mm
2	100 mm	47.47	74.46	4 mm	40 mm
3	100 mm	48.7	26.69	4 mm	25 mm
4	100 mm	47.98	92.58	3 mm	40 mm
5	100 mm	50.72	65.2	3 mm	25 mm
6	100 mm	48.2	31.6	3 mm	10 mm

To get the natural frequency of the generator connecting rod, generator crankshaft and supercharge shaft the excitation method have been used. An experimental vibration apparatus are constructed to measure the natural frequency based on frequency response function(FRF). consist of Accelerometer type KISTLER (4371 sensitivity 9.8 mV/g) ,Condition amplifier type 7749.

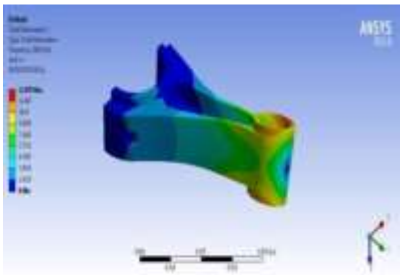
Oscilloscope model GDS-810S with (100 MHZ) as maximum frequency and (FFT spectrum analysis with two input channel) , special Testing hammer ,Computer to drive the system of oscilloscope using serial connection and Rig for fixing the sample during the test. As shown in Fig.(5).

Fig.(5).Experimental vibration measurement setup.

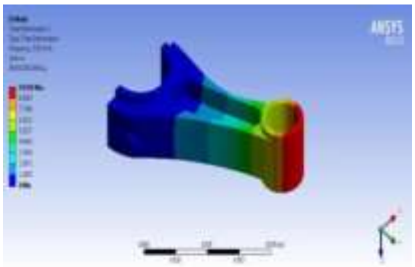
The numerical results of the natural frequency of the connecting rod, crankshaft, and supercharge shaft is obtained by employing the ANSYS MODAL 15. The simulation results of natural frequency that has been obtained from ANSYS program as shown in Figures (6, 7, 8) was used for comparing with experimental frequency .



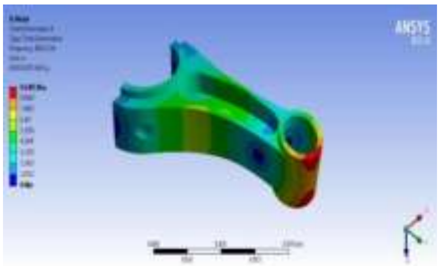
(a) $f_1 = 811.96\ Hz$



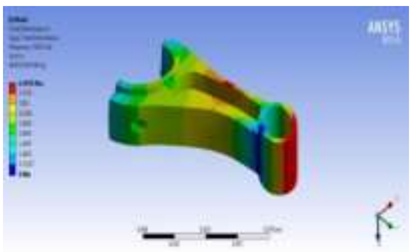
(b) $f_2 = 2802.9\ Hz$



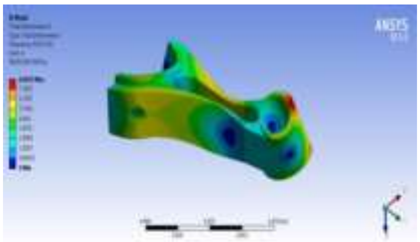
(c)$f_3 = 3151.5\ Hz$



(d) $f_4 = 4928\ Hz$

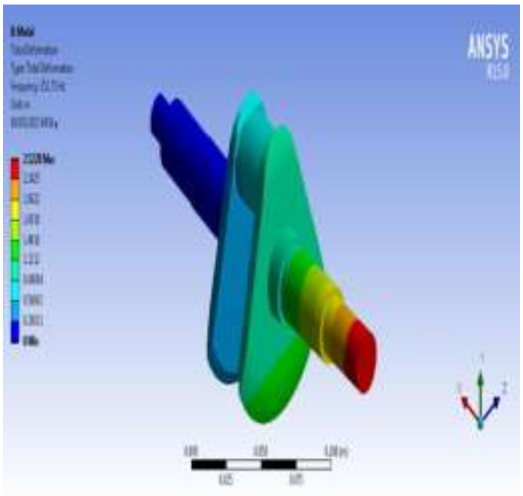


(e) $f_5 = 7020\ Hz$

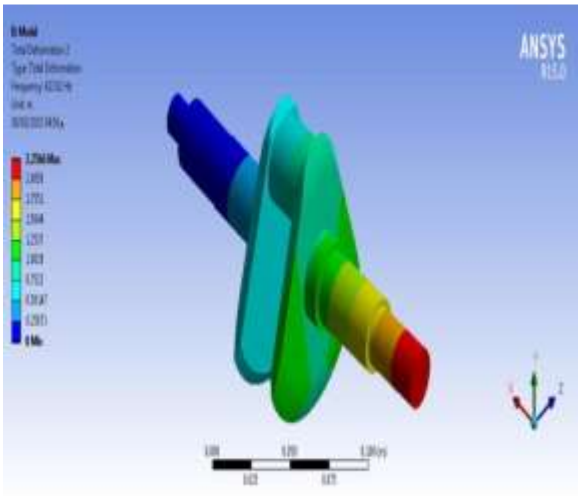


(f) $f_6 = 9176.2\ Hz$

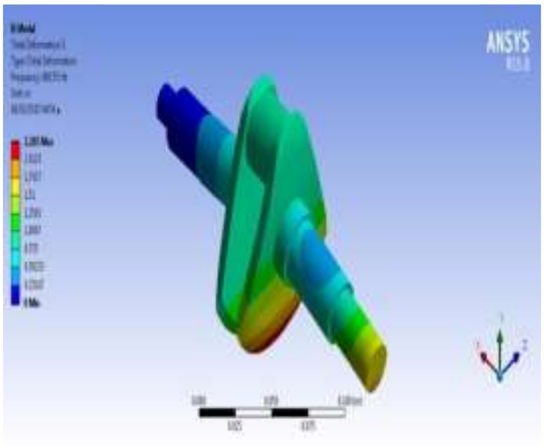
Fig.(6) First Six natural frequency and mode shapes for connecting rod



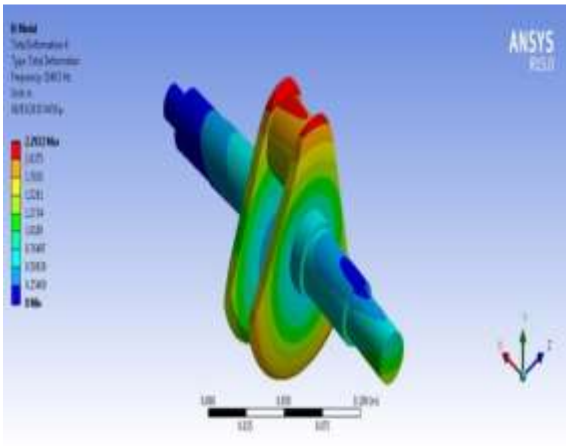
(a) $f_1 = 352.751\ Hz$



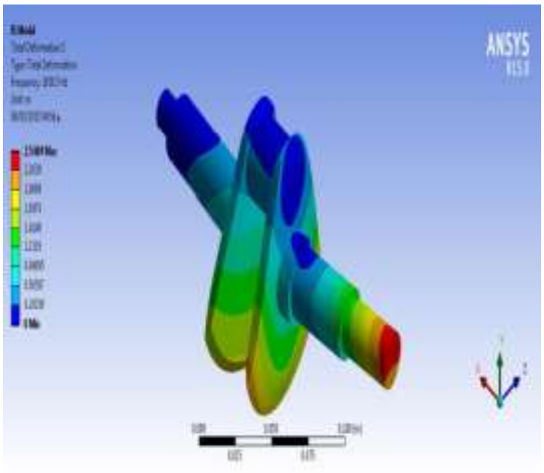
(b) $f_2 = 423.82\ Hz$



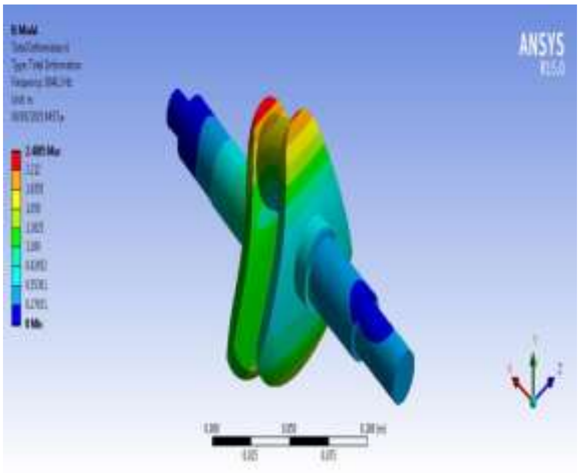
(c) $f_3 = 988.55\ Hz$



(d) $f_4 = 1540.5Hz$

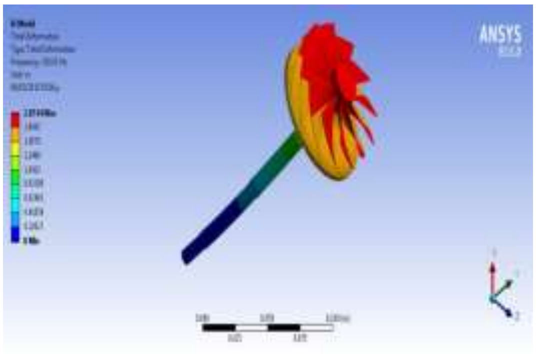


(e) $f_5 = 1650.5\ Hz$

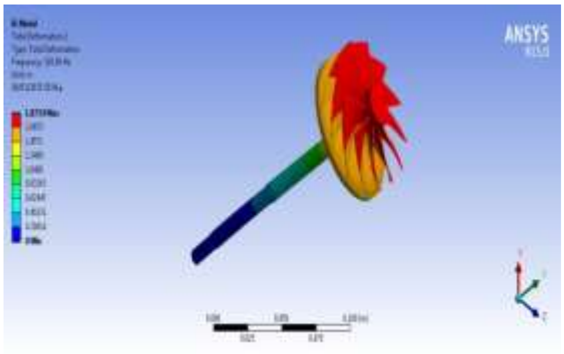


(f) $f_6 = 3046.3\ Hz$

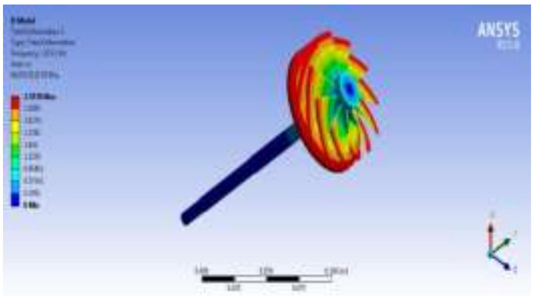
Fig.(7) First Six natural frequency and mode shapes for crankshaft



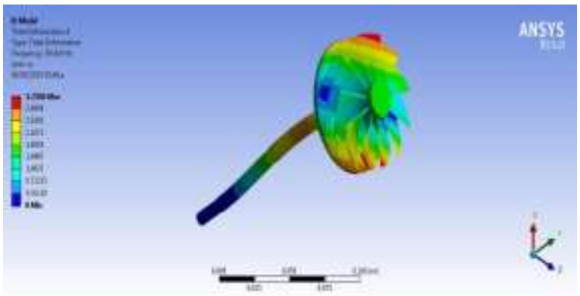
$f_1 = 320.82\ Hz$



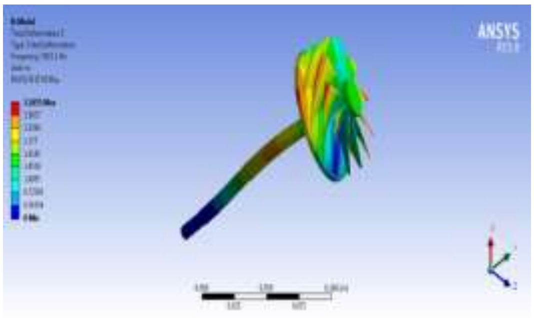
$f_2 = 320.88.751\ Hz$



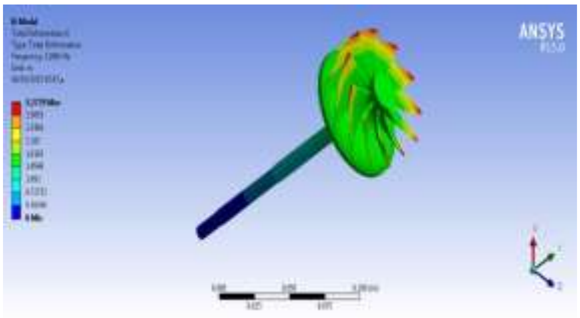
$f_3 = 1176.3\ Hz$



$f_4 = 3814.8\ Hz$



$f_5 = 3815.1\ Hz$



$f_6 = 11906\ Hz$

Fig.(8) First Six natural frequency and mode shapes for supercharger shaft

Table (3) explain that;

(A) natural frequency will increase by 32%, 26.08% and 20.0% for connecting rod ,crankshaft and supercharger shaft respectively and it is obvious the increasing in natural frequency of connecting rod with percentage (32 %) for experimental Nf before and after shot peening.

(B) The frequencies of generator crankshaft after and before the shot peening with ball size (3 mm) with numerical Nf.

(C) The increasing in natural frequency of crankshaft with percentage (26 %) for experimental Nf before and after shot peening.

(D) The frequencies of supercharger shaft after and before the shot peening with ball size (3 mm) with numerical Nf, and obviously the increasing in natural frequency of supercharger shaft with percentage (20 %) for experimental Nf before and after shot peening. To best test the parts that treated with shot peening have been examined its response to vibration in their real position while working, and the vibration is measured by using (Accelerometer device), this device has been explained in the previous section.

Table (3) Measurements of Natural frequency values.

Part name	*Natural frequency (Hz)*				*Ball size mm*	*Shot distance(SD) or shot time(ST)*
	Experimental Before shot peening	Numerical Ansys15	Experimental after shot peening	Deviation %		
Connecting rod	849.25	811.96	1249	32.0	0.6	15 min
Crankshaft	365.5	352.75	494.5	26.08	3	40 mm
Supercharger shaft	344	320.82	430	20.0	3	40 mm

Table (4) explains the vibration behavior of the super charger shaft before and after shot peening process, where the vibration is decreasing after shot peening.

The table (4) clarifies the vibration behavior of the crankshaft and connecting rod for generator without load before and after shot peening. The decreasing percent in maximum FFT is (9.12 %). The table (4) clarifies the vibration behavior of the crankshaft and connecting rod for generator with load before and after shot peening. The decreasing percent in maximum FFT is (28.75 %).

Table (4) Measurements of Natural frequency values.

Part name	*Case*	*Acceleration amplitude (mm/s2)*		
		Max	Min	FFT max
Connecting rod	Before SP	55.89	-55.78	15.81
	After SP	48	-46.22	11.74
	% Deviation (Before SP-After SP/Before SP)	14.1	17.1	25.7
crankshaft	Before SP	66.92	-69.18	30.46
	After SP	60.51	-61.63	27.68
	% Deviation	9.57	10.9	9.12
Supercharger shaft	Before SP	73.5	-62.6	29.56
	After SP	55.43	-45.77	21.06
	% Deviation	24.5	.26.8	28.7

4. Conclusions

The natural frequency will increase with shot peening process. This is very important

1- The Nf after SP will be increased with (32 %, 26.08 %, and 20%) for connecting rod, crankshaft about, and for supercharger shaft respectively.

2- The vibration decreasing of maximum FFT acceleration for connecting rod during work after shot peening with (25.74 %), for crankshaft after shot peening during work without load with (9.12 %), and for supercharger shaft after shot peening during work with load (28.75 %).

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