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Experimental and Numerical Analysis of Vibration Isolation Materials on Vibration Reduction within Plazma Torch

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Abstract: Vibration is generally caused due to the resonance condition. In that case system's natural frequency matches its forcing frequency. There are many reasons for the vibration generation. Plazma torch is used for cutting different types of cutting profile in Roboplazma cutting system. This system contains Fanuc 100 ic robot for giving motion to the cutting torch. Due to the movement of robot, the vibrations transfer to cutting torch and it affects on cutting profile. There are different methods which controls the vibration in a system. In this analysis to minimize the vibration level, isolators or isolation pads are used. This suggests the comparison of different types of isolation material by FFT Analyzer. Numerical analysis is carried out in ANSYS Workbench 16 to validate results. This is the dynamic condition for analysis so that modal analysis gives different modes with natural frequencies. Harmonic vibration analysis gives the deformation of different vibration isolation pads. This analysis suggests the best suitable material for isolation pads.

Keywords: Vibration isolation pads, Plazma torch, FFT Analyser, ANSYS Workbench 16, Deformation

I. Introduction

Vibration is a mechanical phenomenon in which oscillations occur about an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road. Vibratory systems comprise for storing potential energy i.e. spring, for storing kinetic energy i.e. mass or inertia, and by which the energy is gradually lost i.e. damper. The vibration of a system involves the alternating transfer of energy between its potential and kinetic forms. This paper proposes the solution for vibration reduction by incorporating the isolation pads. Provision of isolation materials between source and receiver of vibration it reduces intensity of transmitted forces, so that automatically it affect on phenomenon of vibration generation. Vibration isolation is the process of isolating an object, such as a piece of equipment, from the source of vibration by which the undesirable effects of vibration are reduced. Vibration isolation materials are used for evaluating their effectiveness in minimizing the effect of vibration Active vibration isolation involves sensors and actuators that produce destructive interference that cancels-out incoming vibration. The purpose of vibration isolation is to control unwanted vibration so that its adverse effects are kept within acceptable limits. Vibrations originating from machines or other sources are transmitted to a support structure such as a facility floor, causing a detrimental environment and unwanted levels of vibration. Vibration isolation is used to control vibrations which undesirable to the system. Generally isolator springs are used for this purpose, also isolator pads are appropriate solution. Isolator pads are made up of flexible materials which possesses damping capacity.

II. Experimentation

Experimentation consists of following sections:

A. *Materials for comparative analysis*

The selection of isolation materials is depends on damping properties of material and its stiffness values. The selection of isolation material was chooses on the basis of ease of availability, installation and cost. On the basis of material properties best suitable material for isolation were selected. These material properties are given in table 1.

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TABLE I
MATERIAL PROPERTIES FOR ISOLATION PAD

Sr. No.	Material	Density (kg/m^3)	Young's Modulus	Poisson's ratio
1	Neoprene rubber	1240	0.81546	0.499
2	Cork	180	18.6	0
3	PVC	1400	2480	0.4

TABLE II
DAMPING FACTOR AND STIFFNESS FOR ISOLATION PAD

Sr. No.	Material	Damping factor	Stiffness (N/m)
1	Neoprene rubber	0.05	21.525*10^9
2	Cork	0.06	15.83*10^6
3	PVC	0.081	7.44*10^9

B. Experimental set up

The RoboPlazma cutting system is used for various types of cutting profile. This system mainly consists of robot, torch bracket, Plazma cutting torch, flanges and isolation pad. The welding between cantilever and robot mounting base there is no reason for vibration generation, so that in whole system vibration generation source is in between robot wrist mounting and torch bracket.

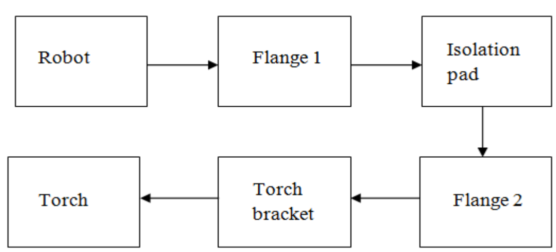

Fig. 1. Block diagram of experimental set up

Isolation pads are mounted in between robot wrist mounting and torch bracket. Accelerometer is mounted on flange so that it captures the vibration signal spectrum of plazma torch because vibration generation due to robot motion and torch motion. Flanges are mounted for provision of isolation pad.

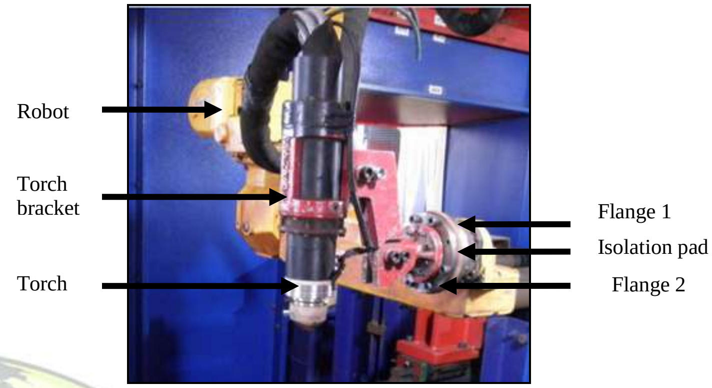

Fig. 2. Experimental set up

C. Experimental data

Experimental testing is carried out at cutting speed of 26 mm/sec, 100 mm/sec and 500 mm/sec. Table III shows velocity, acceleration and deformation for different materials at cutting speed of 26 mm/sec.

TABLE III
VELOCITY, ACCELERATION AND DEFORMATION FOR NEOPRENE RUBBER, CORK AND PVC AT CUTTING SPEED OF 26 MM/SEC

Sr. No.	Material	Velocity (mm/sec)	Acceleration (g)	Deformation (mm)
1	Neoprene rubber	0.888	0.020	0.0009939
2	Cork	0.914	0.020	0.0009939
3	PVC	0.453	0.012	0.0005963

Table IV shows velocity, acceleration and deformation for different materials at cutting speed of 100 mm/sec.

TABLE IV
VELOCITY, ACCELERATION AND DEFORMATION FOR NEOPRENE RUBBER, CORK AND PVC AT CUTTING SPEED OF 100 MM/SEC

Sr. No.	Material	Velocity (mm/sec)	Acceleration (g)	Deformation (mm)
1	Neoprene rubber	0.902	0.032	0.0007068
2	Cork	0.839	0.066	0.001457
3	PVC	0.903	0.028	0.0006184

Table V shows velocity, acceleration and deformation for different materials at cutting speed of 500 mm/sec.

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TABLE V
VELOCITY, ACCELERATION AND DEFORMATION FOR NEOPRENE RUBBER, CORK AND PVC AT CUTTING SPEED OF 500 MM/SEC

Sr. No.	Material	Velocity (mm/sec)	Acceleration (g)	Deformation (mm)
1	Neoprene rubber	1.58	0.092	0.001143
2	Cork	1.71	0.088	0.001093
3	PVC	1.27	0.057	0.000708

III. FINITE ELEMENT ANALYSIS

Finite element analysis of Plazma torch is performed using ANSYS Workbench 16. Spending a sufficient time on studying imported geometry and performing auto mesh for initial trials the fine meshing is done. To avoid the complexity in analysis only assembly of the robot mounting flange, isolation pad and torch mounting flange is considered. It having solid elements; the tetrahedral meshing is used for FEA analysis.

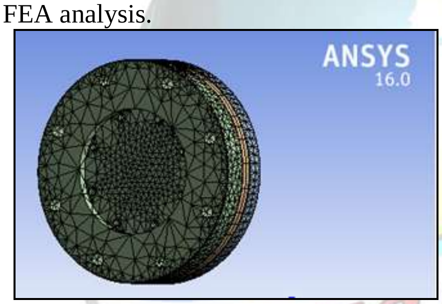

Fig. 3. Meshing

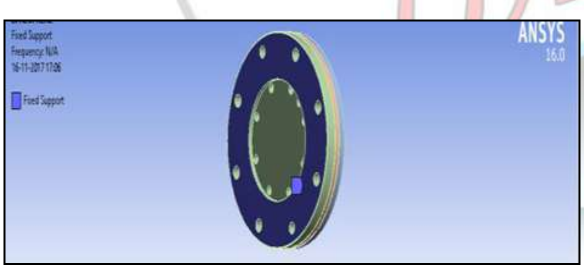

Fig. 4. Fixed support

A. Modal analysis

Modal analysis is used to determine the inherent dynamic characteristics of a system in forms of natural frequencies and mode shapes. These parameters are important in the design of a system for dynamic loading conditions. Conventionally, modal analysis is performed with specific commercial tools. On the other hand, modern FEA softwares have good potential to perform modal analysis studies. Modes are combination of deformed shapes of a structure. Modes are inherent properties mainly depend on material properties and stiffness. Any changes in these will result in change of mode shape. Each structure has multiple modes which occur at particular frequency called natural frequency. It is pre-requisite for Harmonic analysis. Aim is to determine mode shapes and their corresponding frequencies. Here, only up to 6 modes are considered. Table VI, VII and VIII gives the numerical results which consist of natural frequencies and deformation corresponding to its modes of neoprene rubber, cork and PVC respectively.

TABLE VI
NATURAL FREQUENCY AND DEFORMATION FOR NEOPRENE RUBBER

Sr. No.	Mode no.	Natural frequency (Hz)	Deformation (mm)
1	1	33.536	33.327
2	2	33.571	33.384
3	3	36.284	50.686
4	4	164.25	235.44
5	5	165.29	236.02
6	6	193.14	329.35

TABLE VII
NATURAL FREQUENCY AND DEFORMATION FOR CORK

Sr. No.	Mode no.	Natural frequency (Hz)	Deformation (mm)
1	1	713.81	36.199
2	2	714.18	36.191
3	3	925.84	51.665
4	4	946.38	43.946
5	5	1391.7	70.278
6	6	1392.4	70.385

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TABLE VIII
NATURAL FREQUENCY AND DEFORMATION FOR PVC

Sr. No.	Mode no.	Natural frequency (Hz)	Deformation (mm)
1	1	673.07	36.716
2	2	673.55	36.703
3	3	819.27	55.039
4	4	914.43	42.695
5	5	1239.1	66.483
6	6	1240.6	67.155

B. HARMONIC ANALYSIS

In a structural system, any sustained cyclic load will produce a sustained harmonic response. Harmonic analysis results are used to determine the steady-state response of a linear structure to loads that vary sinusoidally harmonically with time, thus enabling to verify whether or not designs will successfully overcome resonance, fatigue, and other harmful effects of forced vibrations. In the harmonic response analysis based on response spectrum, the machine vibration frequency varies as 100 Hz, 150 Hz and 200 Hz. Table IX shows numerical results using harmonic analysis for the neoprene rubber, cork and PVC.

TABLE IX
DEFORMATION FOR NEOPRENE RUBBER, CORK AND PVC

Sr. No.	Cutting speed (mm/sec)	Frequency (Hz)	Material	Deformation (mm)
1	26	100	Neoprene rubber	0.00091304
2	100	150		0.00069902
3	500	200		0.0011305
4	26	100	Cork	0.00094172
5	100	150		0.0013726
6	500	200		0.0010272
7	26	100	PVC	0.0005898
8	100	150		0.00056709
9	500	200		0.00064382

IV. RESULTS AND DISCUSSION

The comparison of different isolation material at cutting speed of 26 mm/sec for 6 mm thickness is shown in fig.5.

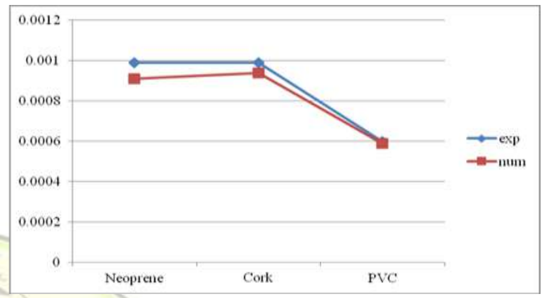

Fig.5 Effect of deformation of different isolation material for 6 mm thickness at cutting speed of 26 mm/sec

Neoprene rubber gives variation in deformation about 8.85% between experimental and numerical results. Cork gives variation in deformation about 5.54% between experimental and simulation results. PVC gives variation in deformation about 1.10% between experimental and numerical results.

The comparison of different isolation material at cutting speed of 100 mm/sec for 6 mm thickness is shown in fig.6.

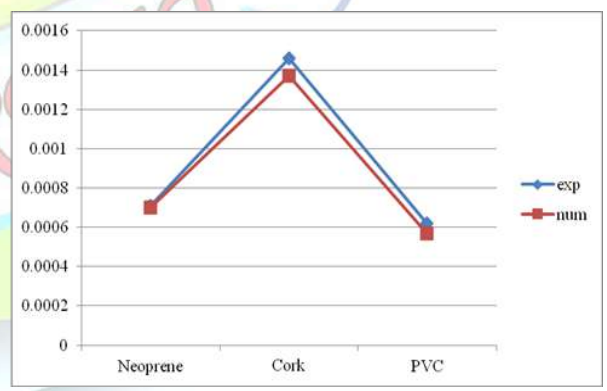

Fig. 6 Effect of deformation of different isolation material for 6 mm thickness at cutting speed of 100 mm/sec

Neoprene rubber gives variation in deformation about 1.11% between experimental and numerical results. Cork gives variation in deformation about 6.14% between experimental and numerical results. PVC gives variation in deformation about 9% between experimental and numerical results.

The comparison of different isolation material at cutting speed of 500 mm/sec for 6 mm thickness is shown in fig.7.

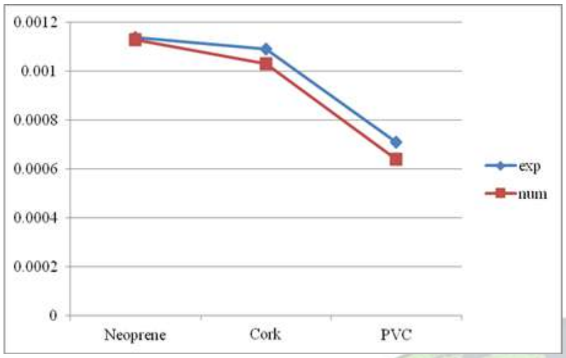

Fig. 7 Effect of deformation of different isolation material for 6 mm thickness at cutting speed of 500 mm/sec

Neoprene rubber gives variation in deformation about 1.10% between experimental and numerical results. Cork gives variation in deformation about 6.40% between experimental and numerical results. PVC gives variation in deformation about 9.96% between experimental and numerical results. Minimum velocity and deformation gives vibration reduction.

V. CONCLUSION

The main objective of this work was to select the suitable isolation material to reduce the vibration effects. Experimental testing was done with the help of FFT analyser; it measures the velocity, acceleration and deformation by varying the cutting speed of robot controller at 26 mm/sec, 100 mm/sec and 500 mm/sec. At the cutting speed of 26 mm/sec; PVC material gives vibration reduction about 40% over neoprene rubber and cork. At the cutting speed of 100 mm/sec; PVC material gives vibration reduction 12.50% and 57.55% over neoprene rubber and cork respectively. At the cutting speed of 500 mm/sec; PVC material gives vibration reduction 38.05% and 35.22% over neoprene rubber and cork respectively. This study suggests that the PVC has better isolation capacity to reduce the vibration compared to neoprene rubber and cork.

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