ISSN 2395-1621

Vibration Reduction in Concrete Breaker for Safety of an Operator

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ABSTRACT

There are several occupational illnesses related with vibration transmission from power hand tools. Hand transmitted vibration (HTV) is one of the most common hazards faced by workers in the construction industry. These hazards are mainly due to the use of concrete breaker on construction site. So to diminish this problem, there is a need of modification in the existing concrete breaker. This study concerns the development of handle design for reduction of vibration. Initially, the existing concrete breaker is studied with ergonomic standards. Analytical model is done in MATLAB, and the readings of vibration for existing concrete breaker were taken by FFT analyzer. Using this data as input, the new geometry of handle is finalized. The new geometry will be validated experimentally.

Keywords— **Biodynamic model, Concrete Breaker DE WALT D25091, FFT analyzer, HAVC**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

The question of human comfort when he met with machine interaction has conquered a lot of attention in the recent past. Principally in a tough work environment like construction, human comfort is directly related to operator's health, work efficiency and work quality. Hand transmitted vibration (HTV) is one of the most common hazards faced by workers in the construction industry. Likewise the regular and prolonged exposure to hand-arm vibration can cause permanent occupational disease. The harmful health effects included damage to blood vessels, sensory nerves, muscles, bones and joints in the hands and arms. In some cases, damage to blood circulation may result in vibration white finger (VWF). All of these symptoms could be painful and influence workers' effectiveness and productivity. A major source of such types of diseases are the hand held impact hammers, such as pneumatically or electro-mechanically driven impact hammers which include rock drills and rotary hammers, pavement breakers i.e. concrete breaker.

According to the national survey (OSHA) [1] it is seen that the Percentage of workers exposed to vibration when they were working with hand held power tools according to the type of exposure and countries are 4.6% of workers in Germany, 5.6% of workers in Spain and 8.3% of workers in Finland. Another survey which is conducted by the UK Medical Research Council in 1997 figured that there were 288,000 HAVS sufferers i.e. 3% of workers in Britain. In 2000, Palmer et al. [1] prepared a large scale survey in Britain and estimated that over 30% workers were periodically exposed to high intensity hand-arm vibration which is mainly due to by concrete breaker during operation. With reference to such kind of problems several no. of researches have published and the results suggested that the Ergonomic factors include repeated and sustained exertions, forceful exertions, stressful postures, contact stress. According to this survey it is seen that concrete breaker imposes 22% Vibration on working area. The immersed vibrations produced transferred into trauma that affected the nervous and vascular systems of the hand (Palmar, et al., 2001). [1-3] with reference to National surveys and studies, many Researchers focused on reduction in vibration of percussion machines. There are several technical solutions had been planned over the years to reduce the vibration exposure levels on Concrete Breaker, but these have generally not been successful. Like, Anti-vibration gloves [6-8], Additional mechanisms are developed inside of the body of concrete breaker have been planned but these have not been shown to be effective for attenuating vibration below 150 Hz.

G. Lundborg, et.al [4]HAV can be caused by hand-held power tools such as hammer drills, concrete breakers, and chainsaws. Though the regular exposure to HAV is known to lead to potentially permanent and debilitating health effects known as hand-arm vibration syndrome (HAVS), such as vibration white finger and carpal tunnel syndrome. HAVS may cause several disorders or injuries like vascular, neural and musculoskeletal disorders. So to study the HAVS the author uses the functional magnetic resonance imaging (fMRI) to assess the somato topic mapping of the hands of workers subjected to occupational vibration. For this he studied six employees, who were suffering from HAVS. Statistical analysis of these six employees indicates significant somatotopic cortical changes following long-term exposure to vibrating hand-held tools. Massimo Bovenzi, et.al [5] the number of exposure years for a possibility of VWF in 10% of a vibration-exposed population. Thus the Author evaluates and measures the vibration exposure by the operator on field. Also investigate the performance of four alternative frequencies weighting so calculate the rate of VWF in a group of forestry and stone cutting workers who are employed by the European Union (EU) and entitled Risks of Occupational Vibration Injuries. As per ISO standard 5349-1, a set of candidate frequency weightings for the evaluation of workplace vibration exposures is currently under consideration in the working group on hand-transmitted vibration.

E. Roland Andersson [6] developed a principle for a vibration damping handle that can be used for problem machines and to test its vibration attenuating effectiveness. The findings confirm that a handle designed according to the principles proposed in the study can combine effective damping properties with adequate control of the working process and the machine. By maximizing the distance, between the rubber element and the hand grip, which gives the best result, the result which is indicated is possible to extend the daily exposure at reduced risk for occupational injuries using such a handle. The principle is used in author's study is not suitable where the handgrip and the rubber element cannot be separated with enough distance to provide an effective damping all along the hand grip. R. Oddo, et.al, [7] developed the suspended handle to provide attenuation of the vibration and shocks being generated at the tool blow frequency, which occurs between 35 and 45 Hz on most types of pneumatic drills. For the hand-arm system author represented a four-degree-of-freedom lumped parameter model, with reference to these two different types of suspended handles are developed, one incorporating helicoidal springs, the other viscoelastic mounts. These combined hand-arm-suspended handle models. The evaluation of experiment gives the attenuation that could be achieved for both low-frequency suspended handles would be on the order of 30% at 35 Hz and 50% at 45 Hz, versus 0% and 50%, respectively for the free handle. The use of helicoidal springs offers the advantage of behaving more linearly and being less sensitive to environmental parameters such as temperature or oil than viscoelastic mounts.

In recent research authors mainly attracted towards various type of concrete breaker like pneumatic due to its high vibration. This study is paying attention on electromechanical type of concrete breaker. Thus relevant studies are reviewed to form an important background and knowledge on proper methods and the design issues. The electro-mechanical breaker, which is piston-operated vibrating tools and it, is extensively used in various areas of industry and construction, so due to the extensive use of such type of breaker it was analyzed in the present study.

Representation of the electro-mechanical breaker is shown in Fig. 1. They require an electric motor that drives the exciting piston by means of the crank and connecting rod. These motor were run by an external power source, but do not require a compressor. There by reciprocating piston setting the striker in motion. The striker hits the intermediate spindle that in turn hits the pick which then hits the ground surface. The worker has to press the machine against the ground surface by applying a permanent force.

Fig.1.Representation of the electro-mechanical breaker

There are several no. of methods existing for protecting the worker from hand-transmitted vibration. Though, the first method involves reduction of the vibratory effects forced by the machine upon the Worker by reducing the intensity of the sources of harmful vibration through the proper design of the machine.[8].

The second method of vibration reduction is dynamic absorption of vibration. The operating frequency of a typical hand-held breaker is constant. Therefore, it is possible to effectively reduce the vibration by engaging a dynamic absorber tuned to the driving frequency and attached to the machine. Though, a passive dynamic absorber is effective only in a narrow frequency range and causes an undesirable increase in weight of the tool.

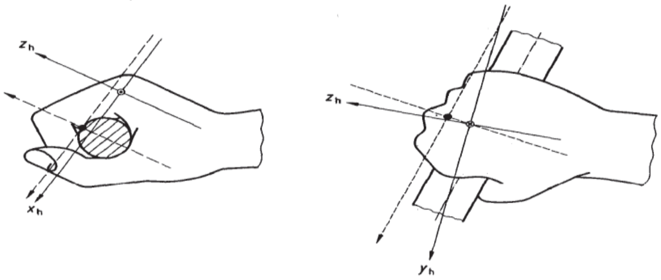
The third and the well-known method of vibration protection is vibration isolation. This is mainly achieved by using two methods: isolation of the tool handles from the vibrating source and isolation of the hand from the vibrating handle this is achieved by using gloves, energy flow dividers, operator substitution by a guided machine or a robot, remote control, etc. Active vibration isolation systems can be designed in order to meet these criteria, but such system is more complicated and in most cases the cost increase.

The principle in which the vibration isolator introduced into the handle of breaker can be used in the design of a vibration isolation system for hand-held concrete breaker, where the isolator is attached to a handle of the casing of machine. Unfortunately, such idea was not developed. Also experiments or practical design engaging this principle have not been reported. So the current study involved in these principal and with these references, one proposed designed handle is developed.

II. HTV & VIBRATION EXPOSURE

Owing to the engrained relationships between the HTV exposure and various health disorders, there is significant efforts have been made towards measurements and valuation of HTV. The ISO has defined standardized methods for measurements, evaluations and risk assessments of HTV. The standard, ISO 5349-1 (2001) [9], The ISO 5349-2 (2001) [10] describes the practical regulations for measurements at the workplace such as the Location and orientation of transducers, Mounting of transducers, measurement procedure and the measurement ambiguity.

The huge majority of hand-held power tools transmit vibration along multi-axes. The standard ISO 5349-1 (2001) defines two coordinate systems, basicentric and biodynamic, which provide guidance for mounting of transducers and measurements for handgrip and flat palm postures, respectively. Figure 2 shows the proposed handgrip position coordinate systems.



a) -----Biodynamic coordinate system;b) —— Basicentric coordinate system

Fig 2.Coordinate systems for the human hand-arm (ISO 5349-1, 2001)

The HTV is measured along each orthogonal axis concurrently, while the defined frequency weighting and band-limiting filters are used to obtain HTV exposure in terms of frequency-weighted root-mean-square (r.m.s.) acceleration or eight-hour 8 equivalent energy for assessing the exposure risk (ISO 5349-2 2001).

A. Measured Vibration (Vector Sum)

Vector Sum $a_{hv} = \sqrt{a^2{}_{hwx} + a^2{}_{hwy} + a^2{}_{hwz}}$ [1]

The 'vector sum' or 'vibration total value' are the same common terms which is more accurately called as the 'root-sum-of-squares'.

B. Daily Personal Vibration Exposure

Daily vibration exposure is derived from the magnitude of the vibration (vibration total value) and the daily exposure duration.

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}} \quad [2]$$

Where,

T is the total daily duration of exposure to the vibration a_{hv}

To is the reference duration of 8h (28800 s).

C. Exposure Action and Limit Values

Exposure Action Value 2.5 m/s²

Exposure Limit Value 5 m/s²

As per Standard a vector sum vibration of 5 m/s² A (8) should not be considered a safe level. The symptoms of the hand-arm vibration syndrome are rare in persons exposed with an 8 hour energy-equivalent vibration total value A(8) at a surface in contact with the hand of less than 2 m/s², and unreported for A(8) values of less than 1 m/s².

III. BIODYNAMIC HAND-ARM MODELS

Human hand-arm system (HAS) plays an essential role in the dynamics of integrated hand-tool-work piece system. The most fundamental property of an oscillating system is Natural frequency which constitutes the free oscillation frequency of a system after having been disturbed. Every real system has several natural frequencies, and each of these has a given pattern of movement. When a system is subjected to an external driving force whose frequency is equal to a natural frequency in the system, resonance occurs and the magnitude of the vibration increases.

Resonant frequency values for different parts of the human body have been determined statistically based on Standards (ISO 10068: 1998.2001). Though, these frequencies are only an approximation, meanwhile they depend on an individual's physical characteristics [11-12]. The model of the human body shown in Figure 3 specifies resonant frequency values for different body parts.

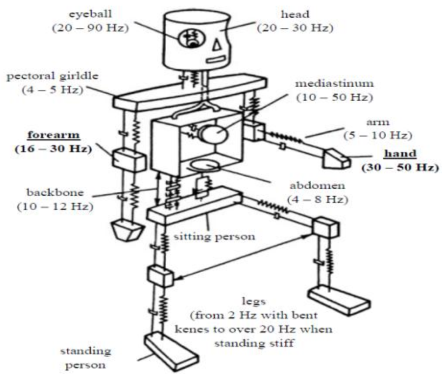


Fig 3. A model of the human body which shows Resonant Frequency

This model suggests that frequency is a serious factor considering the energy input into the dynamic structure of a mechanical-biological system. Due to significant absorption of the transmitted vibration in the HAS, it is essential to evaluate a tool design in the presence of coupling with a HAS model. Hence, the application of a valid biodynamic hand-arm model is critical and it can better understanding of the vibration transmission characteristics of the HAS under different excitations, vibration energy distributions, the developments in mechanical-equivalent simulators or test-rigs to estimate the dynamic performances of different vibrating tools, and evaluations of potential vibration reduction mechanisms. (D.D. Reynolds; R.H. Keith).

IV. MATHEMATICAL MODEL

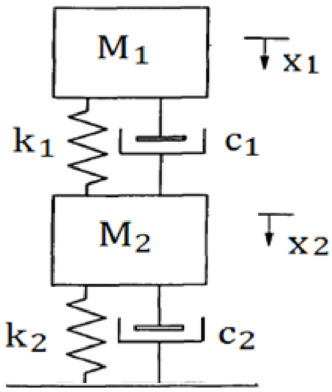


Fig.4. 2 DOF Mathematical model of Concrete Breaker

A. Analytical study

The study of existing machine is very important aspects of this research .for the vibration exposure of existing breaker analytical model were done in MATLAB and the practical condition values were also taken by FFT analyzer.

In the current study, Figure 4 shows the 2 DOF model is considered as a hand-handle and lower body of machine system.

Where,

M1 = Handle of Breaker

M2 = lower part of breaker

K1, K2 = Stiffness of spring 1&2

C1, C2 = Damper 1 & 2

The coupling between the operator and the machine was simulated as a two-degree-of-freedom mass–spring–damper system between the handle of the machine and the rigid attachment. A simplified model of the operator’s hand was chosen as a two degree of freedom system with the following

Parameters: M1= 0.98 kg, M2=9 kg, K1=$6.8 \times 10^4\ N/m$, K2 = $6.8 \times 10^4\ N/m$, C1= $2.03 \times 10^2\ Ns/m$, C2= $5.91 \times 10^2\ Ns/m$ (values were obtained from experiment, Research papers the details of which are not discussed in the present paper).

2 Equation of motion were considered are as follows.

$$M_1\ddot{x}_1 + C_1\dot{x}_1 - C_1\dot{x}_2 + K_1x_1 - K_1x_2 = F$$
[3]

$$M_2\ddot{x}_2 + (C_1 + C_2)\dot{x}_2 - C_1\dot{x}_1 + (K_1 + K_2)x_2 - K_1x_1 = 0$$
[4]

With the help of this eq. of motion, Matlab program is done for finding the vibration value and natural frequencies of system.by analytical analysis it is seen that the vibration exposure value is obtained 2.8 m/s² .(these value is depends on the grip force and push force) and were the natural frequency is obtained 48.7Hz. The aim of this research is to overcome these vibration exposure value and resonant frequency by developing the new handle.

B. FFT.

After completing analytical model, the physical readings on breaker were taken on B & K make FFT analyzer, see Figure 5.

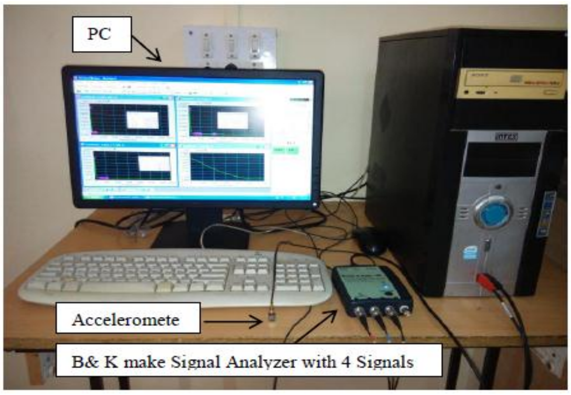


Fig.5: B&K make Accelerometer and Cables

For measuring the vibration ISO 5349-2 standard gives some measurement location which were followed during the analysis. The measuring location is exposed in figure 6.

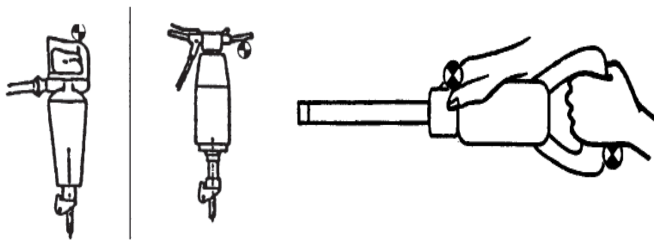


Fig. 6: Practical measurement locations for concrete breaker tool.

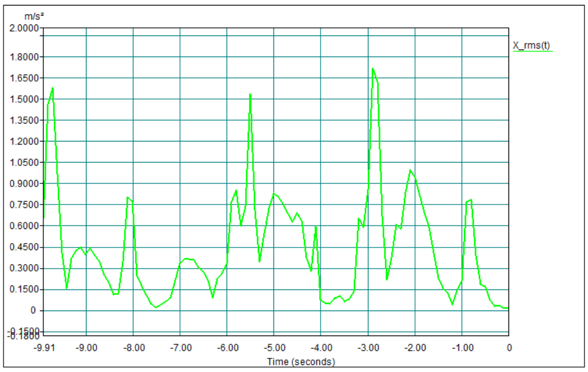
◉ Measurement location (ISO 5349-2, 2001)

The measurement locations specified in ISO 5349-2, 2001 which specify laboratory methods for measuring the vibration at the handles. In the current study one operator were considered during the analysis. He is 25 years old, and weight is 50 kg., were operator operating the breaker for 2 hours for the construction work. As per ISO standard, during operation accelerometer is mount at the handle. Figure 7 represent the accelerometer mounting.

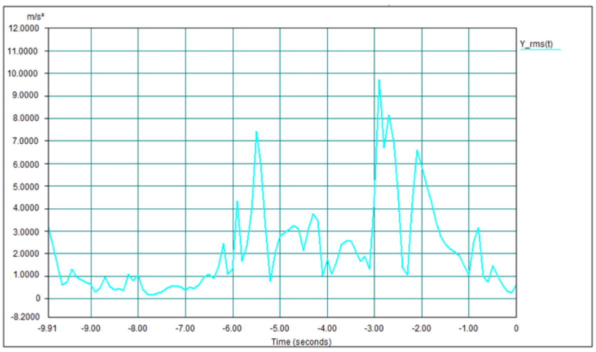
Fig. 7: Accelerometer mounting on Handle.

C. FFT Result

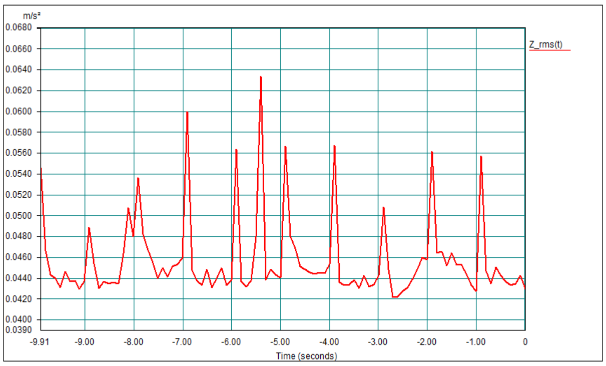
From FFT Analysis high peak r.m.s. values were obtained. By using these values we obtained vibration exposure. Graph 1 shows the high peak r.m.s values.



Graph 1: r.m.s. values in X direction



Graph 2 : r.m.s. values inY direction



Graph 3 : r.m.s. values in Z direction

With reference to these graphs high peak r.m.s. value in X, Y, Z direction are as follows.

X = 1.7142 m/s², Y = 9.4352 m/s², Z = 0.0633 m/s²

By using these r.m.s. values as per ISO standard vibration exposure found 4.79 m/s² which is reference value for current study so the vibration exposure value of new developed designed handle should be less as compared to existing value.

V. Proposed Design of Handle

After the completion of Analytical model analysis and FFT results, the new design of handle of breaker is proposed. The proposed design of handle is modelled in CATIA software. New design of handle is separated in two section i.e. upper part and lower part. See figure 8, 9. In between these two sections there is halve for inserting the vibration isolator. Here passive types of vibration isolators are to be inserted. Theselection of isolator is depends upon the nature of operation which is in these study is very high impact operation.

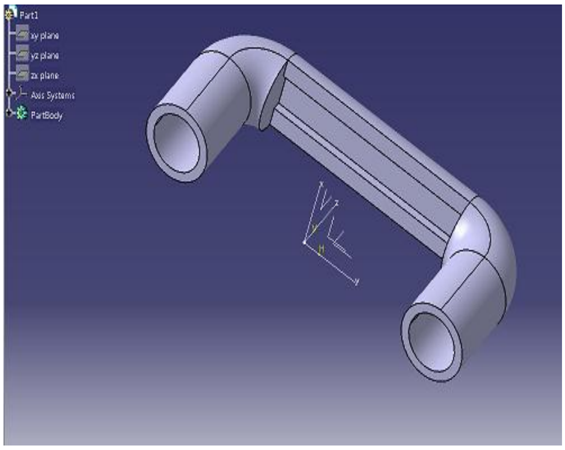


Figure 8: Upper Section of Handle

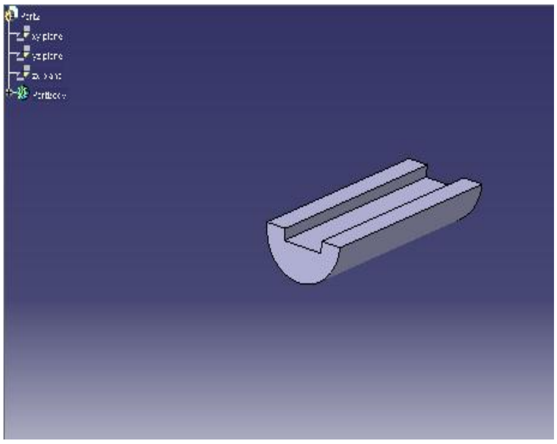


Figure 9: Bottom section of Handle

VI. Conclusions

The current study concentrates on the development of anti-vibration handle. Development of the new handle is one of the main focuses of the study. Details of the development process including helpful, mathematical modeling were described and evaluated. Also FFT analysis is done.

The Vibration Exposure value, and Natural Frequency were obtained i.e. 4.79 m/s² and 48.7 Hz respectively, are the reference or limit values for new proposed handle.

Acknowledgment

I would like to thanks and express my sincere deep felt appreciation to our Principal Dr. A. M. Fulumbarkar, Head of Department Dr. S.S. Lakade. For their valuable guidance in developing the study work.

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