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Enhancing the behavior of automatic washing machine using Tuned Liquid Damper "TLD"

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Abstract

Background: In the vertical automatic washing machine, the laundry works as a mass inside the cylinder (basket), which causes vibration problems during the washing and spinning process, and the vibration appears more during the spinning process, as the fan rotates during the washing process and the basket rotates at high speed during the spinning process.

The main objective of this study is to reduce the vibrations of domestic Automatic Washing Machines through the use of Tuned Liquid Dampers (TLDs).

In this paper, the focus is on studying “TLD” through the use of the balance ring “BR” in the basket, which has been modified by a change in the properties of the liquid inside “BR” by alternating viscosity by adding detergent in different proportions or by making some changes in the internal body of the “BR”, and these changes are reviewed in the experimental part. The results were drawn by conducting experiments on the balance ring and introducing some additions to the ring from the inside. ten points were identified on the body of the washing machine and the resulting vibrations were measured. About the process of washing and spinning with and without a load, such as the unbalanced mass that represents the laundry.

Conclusions: The primary objective of this research was to show the effective use of Tuned Liquid Damper (TLDs) in local automatic vertical washing machines with a change in liquid density with several experiments where by the liquid density of the Balance Ring BR is changed by adding detergent for BR in different proportions and measuring the vibrations of the washing machine in the washing and spinning process with a load and without load and comparing those results with the optimal state of the liquid density of the ring The results showed that the best result of vibrations was that the balance ring liquid density values were adjusted.

Keywords: washing machines, vibration, Tuned Liquid Damper, Balance Ring, washing, spinning.

1. Introduction

Automatic washing machines are an important category of household appliances used to automate manual tasks, which have been helping people for many years.

In vertical automatic washing machines, the unbalanced laundry mass inside the rotating drum (Spin basket) may lead to many problems resulting from excessive vibrations. Therefore, one of the necessary challenges within the local and foreign markets scenario to increase competitiveness is to reduce vibrations and noise in such high-speed devices.

The main objective of this study is to reduce the vibrations of domestic Automatic Washing Machines through the use of Tuned Liquid Dampers (TLDs).

- This project aims to study the effectiveness of Tuned Liquid Dampers (TLD) in reducing the seismic vibration of a Vertical Washing Machine when it is

subjected to horizontal sinusoidal excitation during the Washing and Spinning processes. TLD is a water confined container, or simply a water tank, which uses the sloshing energy of water to reduce the dynamic response of a structure when it is subjected to excitation. In this study the balance ring is used in the automatic washing machine to damper vibrations as it is filled with a solution

(water + chloride calcium), Experiments are conducted to change the properties of the solution and changes to the balance ring to reach the best results through which the desired goal can be achieved

"Enhancing the behavior of automatic washing machine using TLD ".

2. Literature review

Numerous researchers have delved into the realm of reducing vibrations through various damping methods in civil and mechanical applications. Among these studies, a substantial focus has been placed on mitigating vibrations in automatic washing machines, employing techniques such as dampers and Tuned Liquid Dampers (TLDs). Notable research works include:

V.J. Modi, S.R. Munshi (1998): Explored enhancing energy dissipation in a liquid damper by introducing a two-dimensional obstacle, leading to a 60% increase in energy dissipation during vibrations.

Pradipta Banerji (2000): Investigated the effectiveness of a rectangular TLD in controlling structures' responses to earthquake ground motions, outlining design parameters such as tuning ratio, depth ratio, and mass ratio for efficient earthquake response control.

Churnika N. Narkhede (2009): Conducted experiments and analyses on the suspension system of the cylinder in vertical automatic washing machines, indicating that vibrations could be reduced by adjusting spring stiffness and damping coefficients, with a potential 32% reduction through analytical calculations.

Bharadwaj Nanda (2010): Highlighted the effectiveness of TLDs in managing vibrations in structures like high-rise buildings, particularly when properly tuned to the structure's natural frequency and placed on upper floors.

Yongjian Chang (2015): Explored parameters like frequency ratio, mass ratio, damping ratio, and activation conditions of MTLD structures compared to traditional TLD structures, proposing a preliminary MTLD design for engineers.

Galal Ali Hassaan (2015): Investigated the impact of various parameters on horizontal washing machine vibrations, including insulation stiffness, damping coefficient, and drum mass relative to laundry capacity.

Guang-qing Lu (2016): Suggested that dampers significantly influence vibratory and acoustic responses in washing machines, with improved damper designs effectively reducing noise during washing and spinning processes.

Ibtisam Mahdi Shihab (2017): Analyzed the effects of insulator rigidity, damping coefficient, and cylinder mass on washing machine vibration, successfully reducing vibrations by studying various factors and optimizing insulation efficiency.

Mr. Aakash Bikram (2018): Evaluated the efficacy of Tuned Liquid Dampers (TLDs) in decreasing building vibrations due to seismic activity, proposing design procedures and modeling methods to understand TLD parameters' impact on building vibrations.

3. Experimental Work

The tested fully automatic washing machine, vibration tested for 10 points on washing machine body. The test procedures are described here. The experiments were conducted, under permission, in Quality Assurance laboratory, El-Araby company for engineering industry, Quesna, Menoufia, Egypt. The measurement instruments and its calibrations are discussed also. The test results obtained here involve measuring of Power Spectrum.

3. 1 The Tested Apparatus

The layout of the sketch on which experimental program was conducted is shown schematically in Fig. 3.١ It consists of a Washing Machine, Samples of Balance ring Assy, and experimental instrumentation.

Fig. (3.1) Explanation of the Test section layout

3. 2. Fully automatic Washing Machine

A vertical fully automatic washing machine consists mainly of 4 components: Tub assembly, Spin Basket assembly, Suspension system (dampers), and Body. Where, The Tub Assy is the major body of motions in the washing machine, which consists of motor is the power source, Gear box. Fig. 3. 2 shown the schematic diagram for a Vertical Washing machine

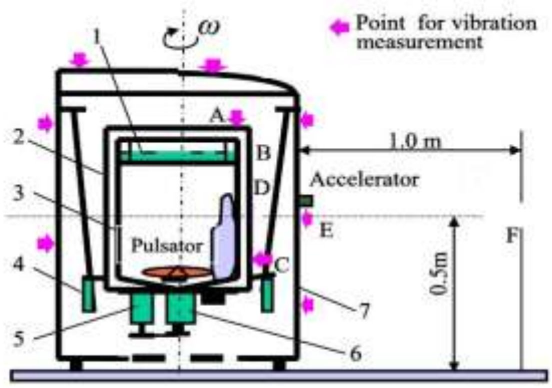

Fig. (3. 2) The figure shows an outline description of the schematic diagram of a vertical automatic washing machine:
1- Balance Ring, 2- Tub, 3- Spin Basket,
4- Spring (damper), 5-Motor, 6- Gear box,
7- Body, 8- Pulsator

3. 3. The Balance Ring

The balance ring it consists of two parts as shown in fig below (3.3.1) & (3.3.2) balance ring 1,2 They are welded on a welding machine by friction, after filling the ring with calcium chloride solution

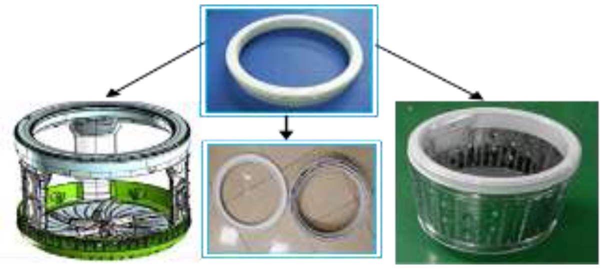

Fig. (3. 3 .1) Spin Basket Assy

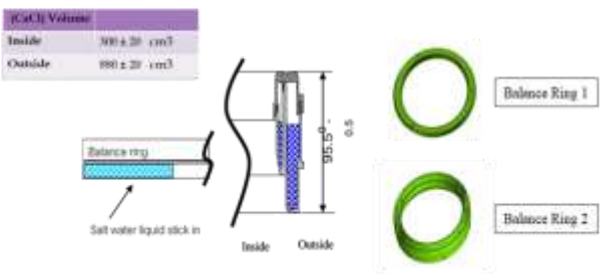

Fig. (3. 3 .2) Balance Ring BR Cross section

3. 4 The test device

The SA-02M/ SA-02A4 signal analyzers are devices that allow for the analysis of signals. They have the capability to perform multi-channel FFT (Fast Fourier Transform) analysis, as well as analysis in various frequency bands such as octave bands, 1/3 octave bands, and 1/12 octave bands. These analyzers consist of two main components: the hardware, which includes the input section and signal processing section, and optional dedicated software that can be installed on a computer, the device is a shown in fig. 3.4.

The SA-02M&SA-02A4 have the capability to analyze signals in different frequency bands, including:

1. Octave Bands: Octave band analysis divides the frequency spectrum into octave intervals. Each octave band represents a doubling of frequency. For example, if the base frequency is 100 Hz, the octave bands would cover 100-200 Hz, 200-400 Hz, 400-800 Hz, and so on.
2. 1/3 Octave Bands: 1/3 octave band analysis further divides the frequency spectrum into smaller intervals. Each 1/3 octave band represents a frequency range one-third the width of the corresponding octave band. This allows for more detailed frequency analysis.
3. 1/12 Octave Bands: 1/12 octave band analysis provides even finer frequency resolution by dividing the spectrum into smaller intervals. Each 1/12 octave band represents a frequency range one-twelfth the width of the corresponding octave band.

Fig. (3. 4) Multi-Channel signal Analyzer SA-02M

Signal Analyzer SA-02M Base software as shown in fig (3.5), It contains three main analysis modes as follows:

- FFT analysis mode.
- 1/N octave band analysis mode.
- 1/N & FFT octave band analysis mode.

Fig. (3. 5) software of Signal Analyzer SA-02M

4. Results and Discussion

The obtained experimental data explain the effect of using a Balance Ring BR that has different properties on the result of vibrations if the washing machine in running on the washing and spinning mode.

The parameters studied are; add detergent in both BR section (2champer), add detergent in outer BR section (outer chamber), add detergent in inner BR section (inner chamber), add detergent in both BR section (2champer) and added foam, add detergent in both BR section (2champer) and added foam and orifice, add detergent in both BR section (2champer) and added foam and orifice and added friction, add detergent in both BR section (2champer) and added foam and orifice and added friction. To compare performance analysis of vibration for each experimental in case Washing and Spinning. The graphs are obtained from device SA-02M multi-channel signal analyzer explained in this chapter and results table as shown later.

4. 1 measuring vibration in washing mode

In this experiment, the Balance Ring is injected with a solution with adding a Detergent in different proportion at 0%, 7%, 10%, 13%, 20% of the weight of the solution on each side of the BR and the vibrations resulting from the mode of washing processes are measured without and with a load. As shown in fig. (4.1.1) and (4.1.2)

Table 4. 1 and Figure (4. 1. 1.a), (4. 1. 1.b) & Table 4. 2 and Figure (4. 1. 2) indicates measuring of vibration in washing without load and with load respectively. Whereas W1 (Washing without load), W2 (Washing with load).

Nomenclature:

N-W1: Washing normally without load without detergent

N-W2: Washing normally with load without detergent

N-S1: Normal Spinning without load without detergent

N-S2: Normal Spinning with load without detergent

TLD: Tuned Liquid Damper

BR: Balance Ring

W1: Washing without load

W2: Washing with load

B-7D-W1: 7% Detergent in Both BR

B-13D-W1: 13% Detergent in Both BR

B-10D-W1: 10% Detergent in Both BR

B-20D-W1: 20% Detergent in Both BR

S1: Spinning without load

S2: Spinning without load

Table (4.1): Results for group1 of Experimental at washing mode without load

W1	1	2	3	4	5	6	7	8	9	10
N-W1	25.6	22.43	12.5	30	33.8	10.89	11.3	26.8	41.1	28.29
B-7D-W1	19.9	37.75	16.7	49.4	65.2	4.01	3.97	14.9	56.2	5.12
B-10D-W1	33.4	40.27	22.5	44.9	60.3	7.91	5.23	34	84.6	9.13
B-13D-W1	20.6	38.27	16.8	53.2	54.7	4.4	4.91	14.4	59.2	5.79
B-20D-W1	49.5	52.9	26.8	48.7	61.7	14.3	7.6	49.7	100	18.4

Fig. (4.1.1.a) Effect of vibration on W/M at 0%, 7%, 10%, 13%, 20% W1

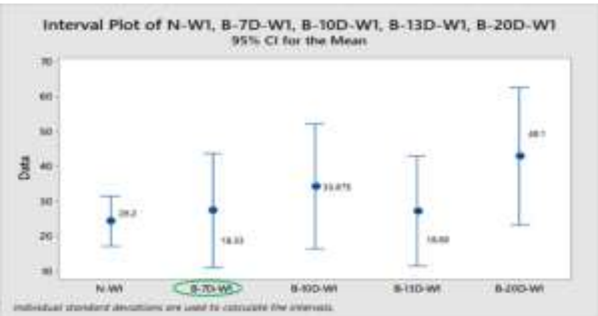

Fig. (4.1.1.b) Effect of vibration on W/M at 0%, 7%, 10%, 13%, 20% W1

Table (4.2): Results for group1 of Experimental at washing mode with load

W2	1	2	3	4	5	6	7	8	9	10
N-W2	66	58.8	37.1	28.8	25.34	15.06	16.89	65.97	84.23	47.61
B-7D-W2	64.7	148	47.43	197	177.9	25.99	27.17	43.64	231.5	38.77
B-10D-W2	39	71.7	27.52	102	114.4	18.84	17.27	38.69	133.6	43.22
B-13D-W2	98.6	201	49.64	149	498	28.38	29.73	46.8	140	40.21
B-20D-W2	43.9	80.9	25.6	96.8	96.7	20.3	17.5	41.06	125.5	71.8

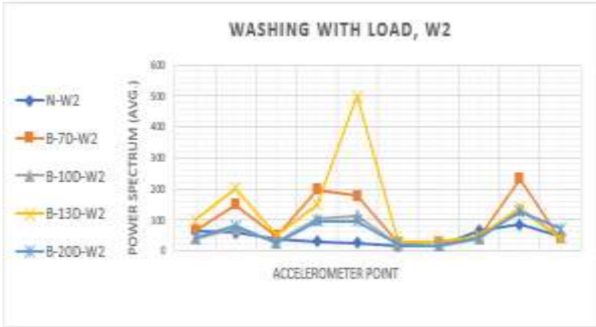

Fig. (4.1.2.a) Effect of vibration on W/M at 0%, 7%, 10%, 13%, 20% W2

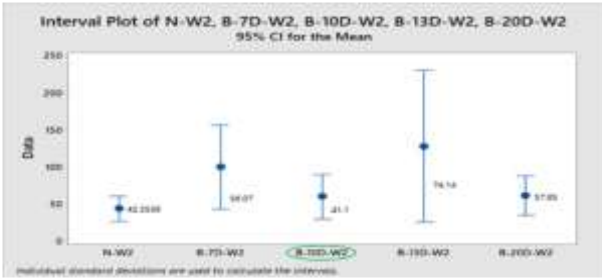

Fig. (4.1.2.b) Effect of vibration on W/M at 0%, 7%, 10%, 13%, 20% W2

4. 2 measuring vibration in Spinning mode

In this experiment, the Balance Ring is injected with a solution with adding a Detergent in different proportion at 0%, 7%, 10%, 13%, 20% of the weight of the solution on each side of the BR and the vibrations resulting from the mode of Spinning processes are measured without and with a load.

Table 4. 3 and Figure (4. 2. 1) & Table 4. 4 and Figure (4. 2. 2) indicates measuring of vibration in spinning without load and with load respectively. Whereas S1 (Spinning without load), S2 (Spinning with load).

Table (4.3): Results for group2 of Experimental at spinning mode without load

S1	1	2	3	4	5	6	7	8	9	10
N-S1	161.9	136.6	83.38	217.9	196.3	22.33	30.95	161.7	138.6	101.23
B-7D-S1	332.1	271.4	172.8	569.2	548.3	70.71	117	339.4	591.4	95.29
B-10D-S1	133.7	121.2	58	78.04	90.12	27.21	19.62	143.5	192.7	19.65
B-13D-S1	283.4	251.8	142.4	494.2	481.6	53.66	91.59	262.6	757.8	76.07
B-20D-S1	192.7	164.7	83.3	96.4	106.9	49.8	32.7	219.5	302.6	40.4

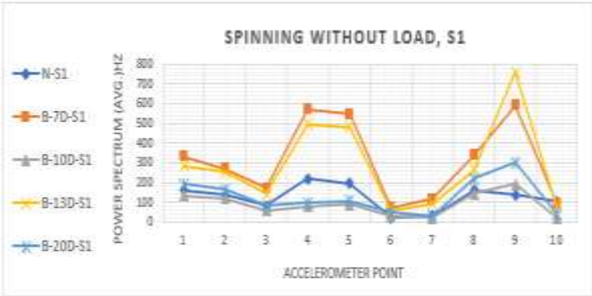

Fig. (4.2.1.a) Effect of vibration on W/M at 0%, 7%, 10%, 13%, 20% S1

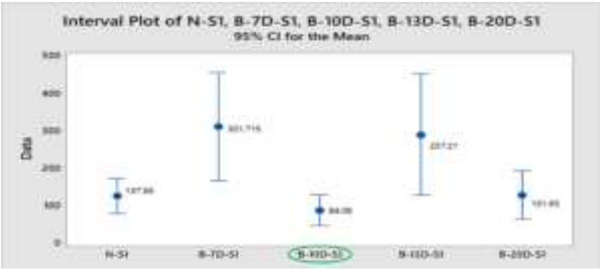

Fig. (4.2.1.b) Effect of vibration on W/M at 0%, 7%, 10%, 13%, 20% S1

Table (4.4): Results for group2 of Experimental at spinning mode with load

S2	1	2	3	4	5	6	7	8	9	10
N-S2	218	188.3	109.2	127.2	132.7	24.45	37.61	225.4	285.8	161.22
B-7D-S2	621.3	517.9	332.1	1150	1360	155.4	170.1	1150	1603	177.3
B-10D-S2	650.5	565.3	390.3	921.7	1210	69.44	109.1	910.9	1620	113.19
B-13D-S2	484.2	349.2	252	1000	1100	126.4	137.8	645.2	5810	169.17
B-20D-S2	672.2	542.1	368.7	925.1	1180	108.3	144.9	908.3	1520	163.99

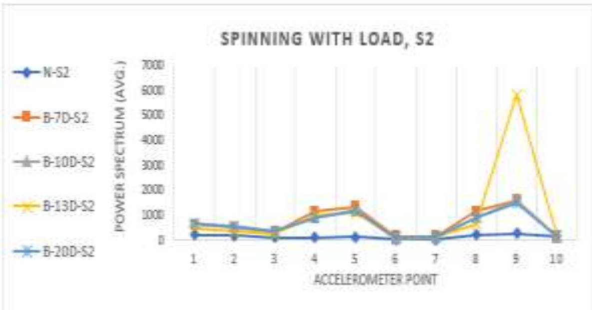

Fig. (4.2.2.a) Effect of vibration on W/M at 0%, 7%, 10%, 13%, 20% S1

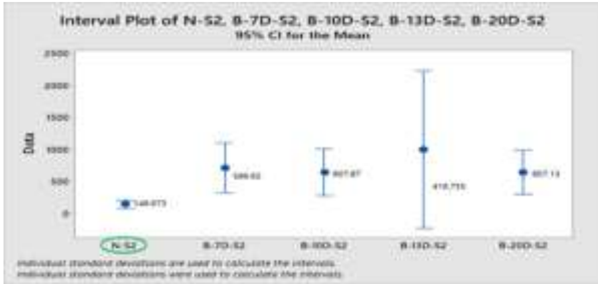

Fig. (4.2.2.b) Effect of vibration on W/M at 0%, 7%, 10%, 13%, 20% S2

4. 3 measuring vibration in All Experimental (Washing and Spinning mode)

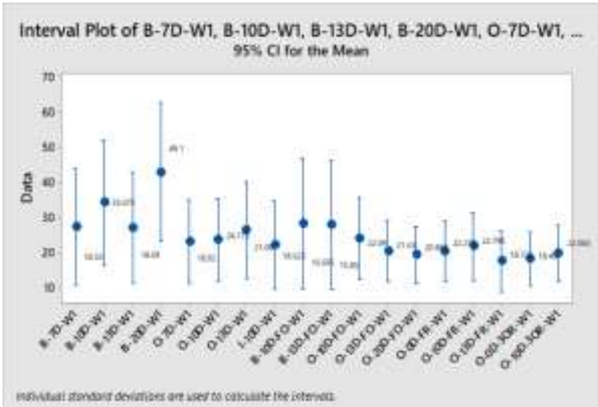

Fig. (4. 3. a) Effect of vibration on W/M at all Experimental W1

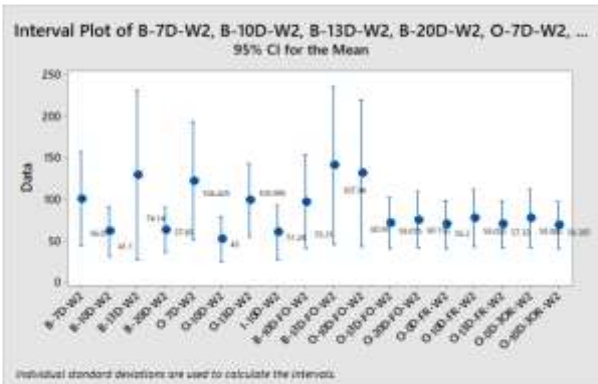

Fig. (4. 3. b) Effect of vibration on W/M at all Experimental W2

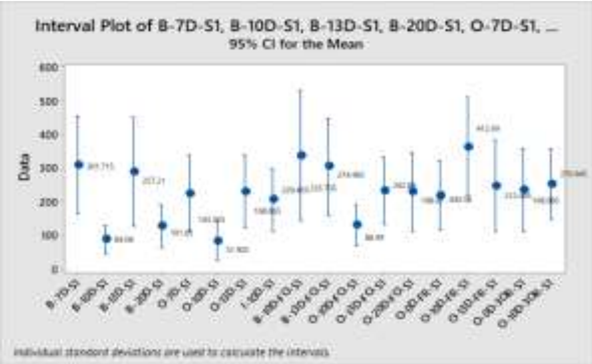

Fig. (4. 3. c) Effect of vibration on W/M at all Experimental S1

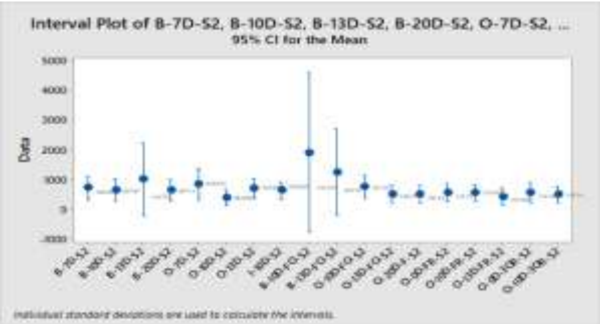

Fig. (4. 3. d) Effect of vibration on W/M at all Experimental S2

5. Conclusion

The application of a Tuned liquid Damper Which is used to reduce vibrations resulting from the washing and spinning process in automatic washing machines by using the balancing ring BR. A large experimental program was conducted to verify the effectiveness of using the balance ring representing TLD framework systems.

This research paper aims to test the effectiveness of using the TLD method in reducing vibrations in automatic washing machines.

The experimental works for measure vibrations on the washing machine body (10 Points) to verify the effectiveness of the balance ring BR, which represents TLD in reducing the Vibrations in vertical automatic washing machines, especially violent vibrations during the spinning process.

TLD in reducing the Vibrations in vertical automatic washing machines, especially violent vibrations during

Below is a summary of the conclusions from this study:

1- It has been absorbed that used of the balance ring BR, which contains a calcium chloride solution it increases the structure's effective damping when the Body of washing machine is subjected to lateral forces caused by vibrations during washing and spinning process.

2- The amount of solution present inside the balance ring, which was determined by the designer, which is calcium chloride in proportions of 300 cm۳ for the inner part of the BR and 880 cm3 for the outer part of the BR, works to significantly decrease in displacement level.

3- Adding detergent to the liquid in the balance ring in different proportions, 7%, 10%, 13%, 20% by weight of the solution, led to a change in the displacement values resulting from vibrations.

4- All experimental results were recorded and make charts for results and make interval plot on Minitab program.

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