IDENTIFICATION OF THE POSSIBLE NOISE SOURCES OF THE WASHING MACHINE AND FURTHER STUDIES OVER THE APPLICABLE NOISE REDUCTION METHODS.

Fevzi Menteş (1) and Cüneyt Öztürk (2)

(1)Arçelik A.Ş,Çayırova-41460,İstanbul,Turkey
(2)Arçelik A.Ş,Çayırova-41460,İstanbul ,Turkey

1.INTRODUCTION

This paper describes the part of the studies which are all conducted on the basis of our intent to develop quiter washing machine .The goal of these studies might be summarized briefly as , to identify the the noise sources and to consider and to develop effective methods for the purpose of achieving to present "quiter washing machine" in convenience with the consumer s increasing sensitivity against noise.

The strategy was build on ,first the identification and of the seperate noise sources then the appreciation of how the interaction could occur within the system ,finally the application of the the developed methods over the identified sources and the radiation path.

2.DEFINITION OF THE PROBLEMS AND THE METHODS

2.1.The source of the noise and the possible paths to radiate.

The origin of the radiated noise of washing machine are mainly centered around the fractional horse power drive motor.Vibrations resulting from pulsations ,travelling through the motor housing and the shaft ,excites the large cabinet through the structure of the tub .The excited cabinet might show tendency to act as the acoustic amplifier and might have the modes of vibration around the forcing frequencies of the torque pulsations of the motor.

2.2.The importance of understanding the dynamic behaviour of the mechanical system.

To identify the structural resonances of the mechanical system,Modal testing are considered as an efficient tool to determine the vibrational properties of the structures in terms of its modes of vibration ,from a purely experimental study of the structure.

Modal test which consists of the hitting the seperately hung , tub and the cabinet at each specific point with a force hammer and measuring the response of the mechanical systems by the accelerometer .for each of the force applied points.In this approach,a frequency domain model of the structure was used in conjunction with "Frequency Response Function (FRF) measurements obtained from the structure.These measurements are made with an FFT based spectrum analyzer.Figure-1,illustrates the measurement set up of the Modal test. Modal analysis software have been employed to calculate the natural frequencies and display the behaviour of the system at each frequency. Then it is looked for whether there exists any possibility to coincide with the pulsating frequency and it s harmonics which leads to the increase of amplification .

2.3.The importance of the right identification and the classification of the noise.

In order to to determine the particular frequencies at which the most of the noise radiates ,sound intensity techniques are being applied.The total radiated sound power are measured by using hemisphere method.The repeatability and reliability of the measurements are obtained over the sufficient number of measurements.By the use of sound intensity tecniques ,further advantageous of having information about both the direction and magnitude of the radiated noise ,easy application of contour mapping and 3-D plot techniques are considered.During the source identification measurements,the washing machine is placed almost the center of the semi -anechoic room and kept in operation under controlled conditions .After a period of warm-up and when the steady state conditions are being achieved ,intensity measurements are used.İntensity measurements are made in each of sub area . The use of all these efficient tools lled us the proper identification of the sources at a time.

2.4.Considering over the possible noise control methods.
Noise control are considered ,to be achieved by the use of one of the well known methods of ;treating the noise sources,treating the transmission path,or treating the receiver of the noise source.Since the third mehod could not be considered as practical then special attention is paid to investigate the sources of dominant noise and and the paths which they are transmitted.

2.5.Treatment methods.
Treatment methods are considered to be developed on the basis of the obtained datas and the specific disturbance frequencies.The choose of the proper acoustic absorbers and the vibration dampers might be considered on the basis of efficiency,cost ,conveniency with the standards and adapability to the manufacturing..Treatment methods are all considered around the applicable passive treatment methods.The applicability of the active controls and the use of electronics are not included within the scope of the studies.

2.6.The goal of noise reduction.
The objective of our studies are determined as achieving minumum 3 dBA decrease of the over all radiated sound power of the washing machine which is considered both for the washing cycle (Whites programme,full load) and the spinning cycle (for 800 RPM drum speed).

3.APPLICATION METHODOLOGY

3.1.İdentify the modal parameters of the mechanic system.
The illustrations of the modal shapes of the cabinet ,tub&drum and the motor protecting plate are given in figure,2,3 and 4 respectively.
These models are not intended to present the physical structures but could be considered to serve as iinstruments to understand the behaviour of structures by describing the dynamic properties of the structures.
Hence by the help of the modal parameters (Modal frequency,Modal damping,Mode shape)all the modes ,it could be represented the dynamic properties of a free structures for each of the modes of vibration seperately,within the frequency range of interest .(1)

3.2.Identification and classification of the objectionable noise sources.
The acoustical measurements and the analysis revealed the followings:
*A significant amount of the sound power which was emitted ,mainly from around the lower periphery of the back and side panels.A large percent of the high frequency noise was also emitted from the same region.
*Most of the sound power of the washing cycle was around low frequency and directly relevant with the pulsating frequency of the motor.

FIGURE -1 SETUP FOR MODAL TESTING

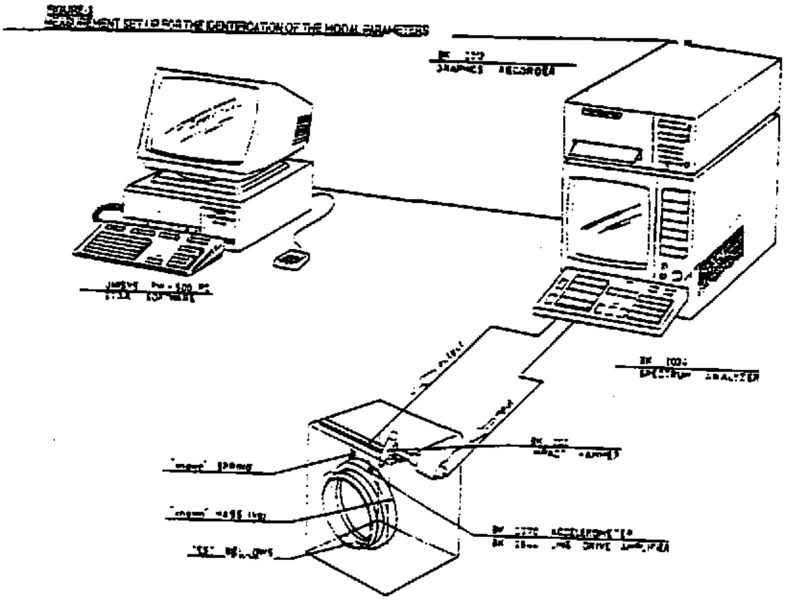


FIGURE -2 MODAL SHAPE OF THE CABINET

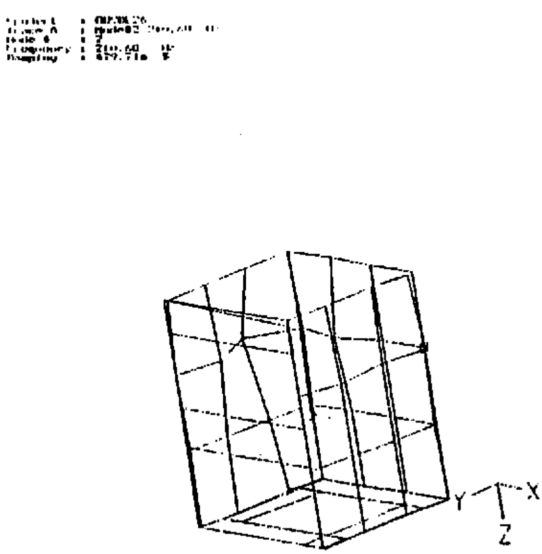


FIGURE -3 MODAL SHAPE OF THE TUB & DRUM

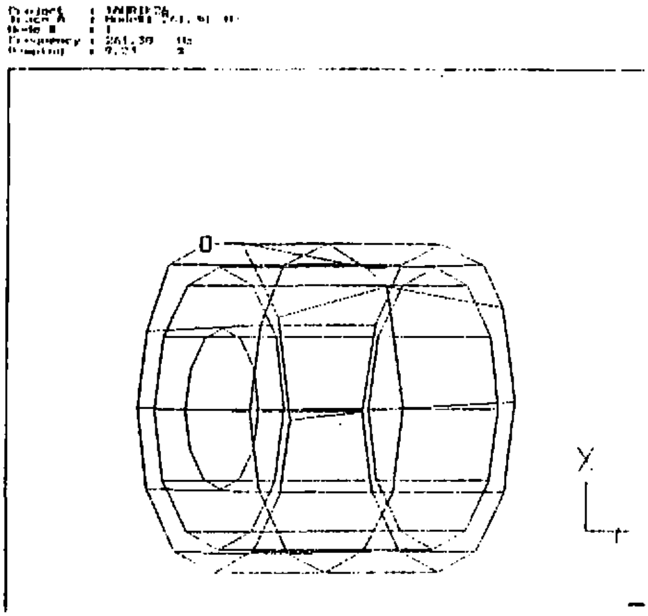
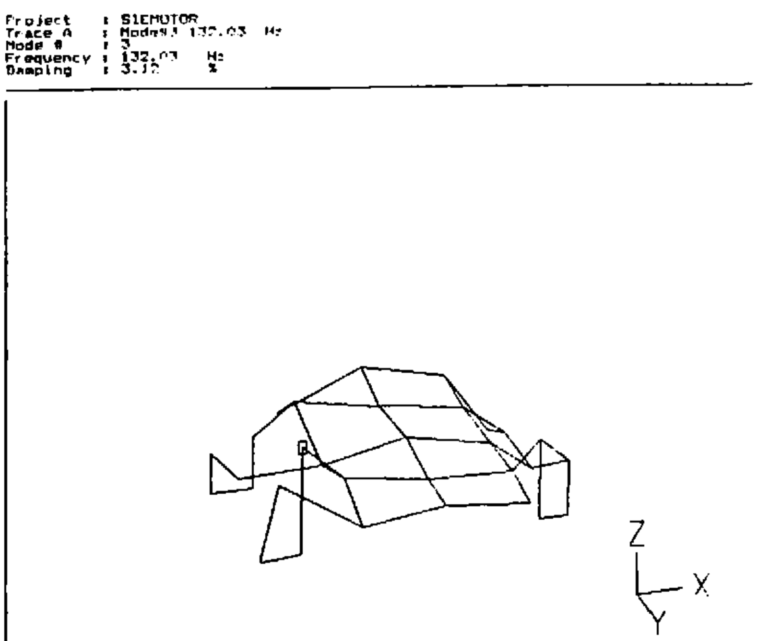


FIGURE -4 MODAL SHAPE OF THE MOTOR PROTECTING PLATE



*The sound power of the spinning cycle were distributed to all over frequency range of 200 Hz. to 10 Khz. but the dominancy of the lower frequencies could not be so noticeable.
After carefull study of the results ,the identification of the various sources and the transmission paths were completed.
First ,The reason of the high sound power around the lower periphery of the back and side panels are the gap of the chassis.Airborne noise might be able to find out it s own way to escape through the openinngs and the gap between the floor and the cabinet which reduce the barrier properties .
Second,,Low frequency noise which occurs at the pulsating frequency (line frequency) and the second harmonics are directly relavant with the torque pulsations of the motor .It was the result of the amplification over the cabinet panels .Panels respond as a sound board to the mechanical excitation ,transmitted over the specified path of radiation.Coinciding of the natural frequencyof the structure and the second harmonic of the excitation frequency are also considered to lead increase of the amplification.
It was also considered that the splash of the water might effect the high sound power at lower frequencies.
Third,The reson of the noticeable tendency of shifting to the high frequency disturbances at the spin cycles are directly relevant with the increase of the noise born from the brushes of the series FHP(Fractional Horse Power) drive motor .Noise could be effective between the range of 6-8 Khz. in proportion with the number of lamels of the commutator and the RPM.
Once the acoustical identification of the sources completed.Further studies are focused around the seperate evaluation of the potential sources and variability of the possible reason s which might effect the noise.
The details of the studies are obtained after the years of experience and within the content of our study ,considered only with the effects of FHP series drive motor, Discharge pump and the tranmission belt.
*Motor:The faced problems are all considered within the well known classification of"mechanical" and " magnetic" noises according to how they arise ?Specific disturbance frequencies of the noisy and normal motors are illustrated over the figures of 5&6 respectively.
We have determined that the electormagnetic excitation forces play an important role in the production of the noise(2).The magnetic forces acting on the stator and rotor of our FHP series drive motor may produce excesive vibrations and noise specially around the frequencies of 50 Hz,100 Hz.,600 Hz.,3 Khz.The first two of these frequencies are mainly critical since there exists possibility of coinciding the natural frequencies of the members of the machine concerned.
The rest of the motor disturbances and the corresponding frequencies are;
-Torque pulsations (Supply frequency or 2*supply frequency.),
-Rotor eccentricity and changes of the air gap.(1*rotational frequency or 2*rotational frequency),

FIGURE -5 VIBRATION SPECTRUM OF THE NOISY MOTOR

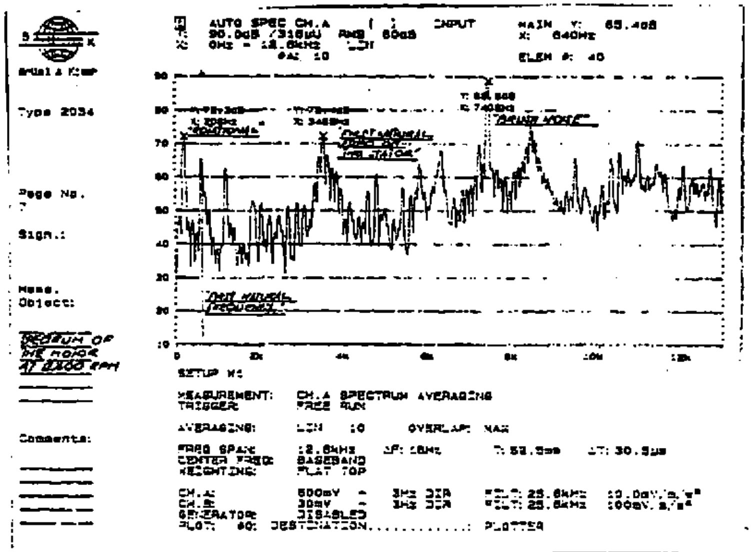
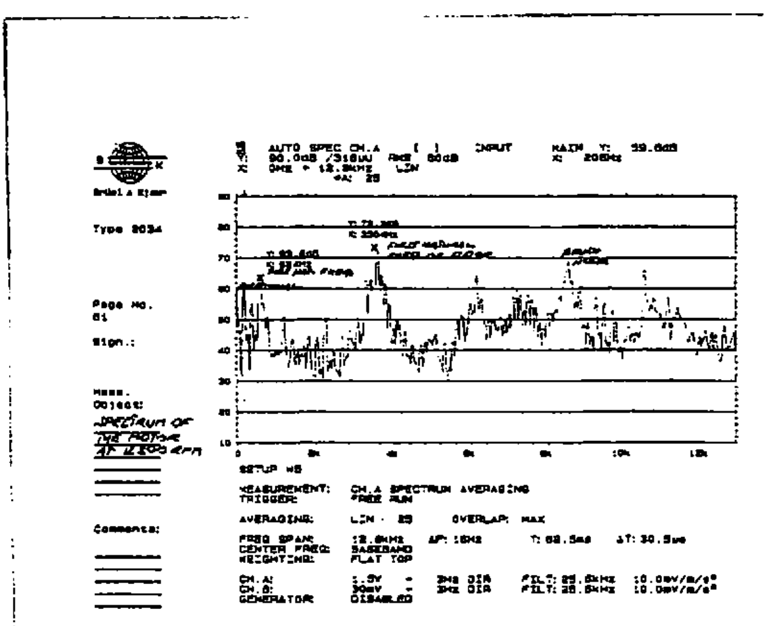


FIGURE -6 VIBRATION SPECTRUM OF THE NORMAL MOTOR



-İmbalance (Rotational frequency),
-Misalignment and the bent shaft (2*Rotational frequency),
-Motor mechanics (End shields,loose bolts etc.),
-Bearings(At specific frequencies),
-Brushes(at the coinciding frequency of # of lamels* rotational frequency)
*Discharge pump:The air borne noise might also be generated by the discharge pump and the transmission.The noise might vary in proportion with the load and denotes tendency to increase while working with unloaded.İmproper mounting of the pump which could make the pump nearer to the chassis might cause the magnetic vibration of the chassis plate . The improper design of the fan blade and impeller all might cause specific noises which needs to be eliminated.
*Transmission belt:The main resons of the noise born from the transmiission of power and the transmission belts are;
-Whistling noise due to the reason of slipping,
-Tapping noise ,caused by the improper changes of thickness of the ribs.(Overlapping),
-Improper tensioning,
-Lose of paralelilsm,
-"Misalignment" and unsuitable interaction with the motor noise, which could noticeably disturbing noise at ech specific frequency.

3.3.Working over the possible remedies.
Since all the acoustical measurements and analysises indicated that the main sorurce of the mechanical vibrations is the FHP series motor.Then specific studies are performed to identify the reasons of the noise and to develop the treatment methods which can be applicable over the sources.
These measurements are enabled us to determine the specific disturbance frequencies and to evaluate the balanca quality of the motors and to lead the shift of disturbance frequency studies.
Shifting of the disturbance frequencies are considered on the basis of the possibility of coinciding with the resonance frequency of the system.The high resonance frequency can reinforce the resonance while passing through the specific frequency. It is specially identified,over the motors which have imbalance problems at high spin speeds.
Further treatment methods are applied in cooperation with the motor manufacturer to reduce the epidemic brush noise problems of the FHP series motors and around 2-4 dBA drops are obtained when we considered it within the content of all the treatment methods .

3.4.Development of the possible treatment methods.
3.4.1.For the purpose of reducing the transmisability of the motor vibratiion over the motor housing,the hardness of rubbers which are fixed within the housing is reduced from 80 shore-A to the 55 shore-A..The soft rubbers provided the optimum performance and lead to 2 dB drop of the transmitted vibration.It is considered that the change of the rubbers might be effective specially around the lower frequencies.

3.4.2.Using soft rubbers between the bearing housing and the back plate of tub,lead noticeable drop of the measured vibratiion and caused 1 dBA drop of the overal l raditated sound power.
Use of these vibration dampers also are found effective within the range of lower frequencies.
3.4.3.The bottom pad acoustic absorber which covers up the whole gap of the chassis is developed from the acoustic intensity studies.It is found that although it might be effective against the mid to high frequency range disturbances ,Since the sound absorption depends on the flow resistivity of the material and the wavelength of the noise.It could not be considered for the low frequency noises which have large wave llengthEfficiency cold not be justified since ;
-It is not effective against the pulsating frequencies and nothing to do with the acoustic amplifications of the cabinets,
-The noise is absorbed by the fiberglass blanket and be dissipated into heat,causes the additional heating problem within the motor windings,
-Lead no noticeable changes of sound power , but compulse to the change of existing mechanic construction,
3.4.4.Cabinet acoustic absorbers :Again the similar problems of the case 3.4.3 are faced.
3.4.5.Vibration dampers over the back plate of the tub and the sida panels of the cabinet.
İt is determined that the full coverage of the back plate of the tub might be very effective way to damp the vibrations .But in terms of the cost it could not be reasonable to apply because of the cost of new investements and the required changes of the mechanic design.
Furthermore ,use of mastic dampers are also efficent way to apply agains t the low frequency noises .In this case ,first the hot spots are determined by the use of accelerometers then vibration dampers are fixed over the specified points and noticeable reductions which reaches to the 3 dB drop of the transmitted vibrations are achieved.
It is considered that all the methods might be effective in different ways and in different range of frequency,but in our case the most effective methods to apply are the first two methods which provides us noticeable drops of the over all radiated sound power both for washing,spinning cycles.Our aimed values of 3dBA drops of the sound power are being achieved by the use of these methods and with no noticeable cost increment and no changes of the mechanical design.Figure-7&8 illustrates the comparison of the treatment methods and the difference between the untreated and the treated machines which reaches almot 4 BA for washing and 3 dBA for spinning cycle when considered within the scope of all the treatment methods.

FIGURE -7 COMPARISON OF THE TREATED AND UNTREATED WASHING MACHINES

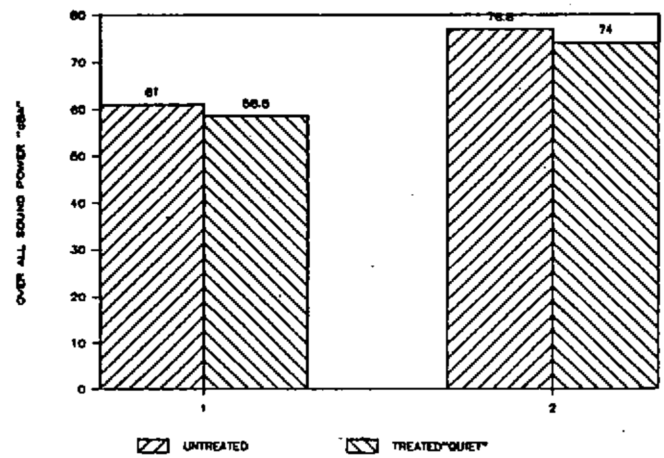
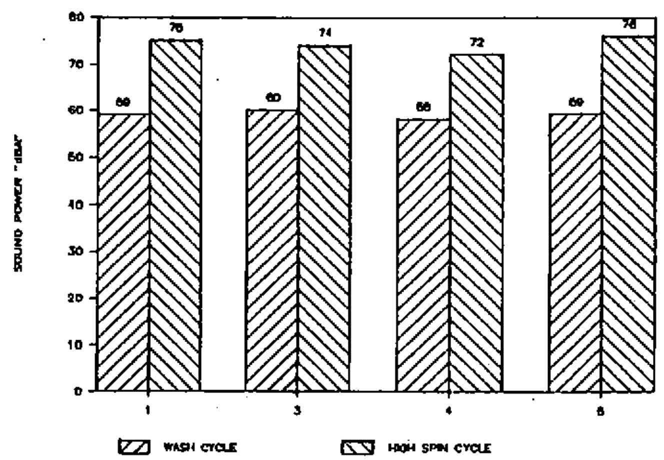


FIGURE -8 COMPARISON OF THE METHODS



4.CONCLUSIONS

The use of the efficient tools of the sound intensity and the modal analysis have led us to the easy identification and the classification of the noise sources.
On the basis of the evolved methodology it might be very effective to initiate studies by determining the resonance frequencies of the system.Resonance frequencies can be determined by using the experimental modal analysis techniques.
Then,when the dominant noise sources and the radiation paths are identified,treatment methods might be developed to eliminate and to reduce the noise.All these treatment methods can let us to have reduced operating noise level for all the cycles and enhanced the sound quality of the washing machine without the loss of performance and product safety.
It can be adviseable to consider the factors of ;
-Conveniency with the manufacturing and the assembly processes,
-Meeting the regulations and the standard requirements of product safety,
-Cost effectiveness,
-Functioning in a variety operating conditions ,
which all might effect the studies.

5.ACKNOWLEDGEMENT

The authors would like to express their gratitude to Mr.Ahmet Olpak ,Dr.A.Kemal Tuğcu and Mr.Mustafa Tüzüngüç for their valuable helps and the supports.

6.REFERENCES

(1)"Structural testing,analysis &reporting system ,oparator s reference manual" SMS,Part no:0400-5010(April-1988)
(2)Vibration diagnostics for industrial electric motor drives-B&K ,Application notes.