Insulation impact on appliance acoustic characteristics

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Abstract. The paper is aimed on types of insulation actually used in washing machines and raising requirements on its characteristics. Next part is design of unconventional insulations, which will be applied directly on appliance. Then, series of tests will pass (according to regulations), so it will be possible to determine acoustic power. After that, we will use simulation to determine impact of insulation rigidity on washing machine shell (with identification of acoustic benefit). Relatively important factor is rigidity of washing machine shell and forces affecting the shell. Force affecting on the shell depends on inner and outer tub weight (and all equipment attached), load, unbalance in a drum and revolutions during spin cycle. Usually more rigid washing machine shell produces less noise than weaker shell. That’s why is relatively important to stiffen shell. Doing this by changing type of insulation is advantageous because it is possible to do without any significant side effects.

1. Introduction

This article is concerned with impact of insulation rigidity on washing machine acoustic characteristics. Washing machine body is affected by forces during washing cycles which originate from mass of water and laundry. The forces also originate from an unbalance inside the washing machine tub. The unbalance is changing after every inner tub stoppage during a spin cycle. Unbalance inside the washing machine tub is big acoustic issue, not only for increased noise, but also for increased load of components.

Nowadays, comfort requirements are raising so premium washing machines are equipped with noise reduction elements such as insulations and other damping items. Also, rigidity of the washing machine body has big impact on overall noise. Rigid washing machine bodies does not deform in excessive way. If there is no excessive relative movement of panels and other components there is no excessive noise also [1].

2. Strength analysis of the washing machine body

Washing machine body is usually well designed in terms of deformation resistance. Panels are equipped with many extrusions which improves their rigidity. Panels of different producers differ in thickness also. Thickness of panels has also big impact on the washing machine rigidity. In ideal conditions, washing machine body should be as robust as possible, to prevent deformations. If producers want to achieve higher level of a robustness, they have to invest into production of the washing machine body. But there is an issue of increased production costs. Efficient way is to use current panels in production and improve their rigidity without big intervention into its structure. The solution is to use noise insulation as a panel stiffener. Production costs increase would be significantly smaller than production of the thicker panels. Nowadays, washing machines have got installed noise...
insulation on the panels, but the insulation has not got any measurable impact on the panel rigidity. It is because sealing tape, which is used to secure insulation on panels is not strong enough to transfer forces from panel to insulation. New solution relies on a new way of gluing insulation on the panels. To secure solid connection between an insulation and a panel, the insulation is equipped with a crosshatch. The crosshatch, made of glass-fabric, is part of the insulation (located between insulation and panel). Adhesive foil on the crosshatch secures solid connection between panel and insulation and allows to transfer forces from panel to insulation, so the insulation can serve as the stiffener. For determination of the insulation impact on the panel stiffness, 3D models of the panels were made. For this simulation only panels without washing machine body was used in simulation. The main reason for this was, that we did not want to affect simulation with other variables such as washing machine body stiffness. With this type of simulation, we determined the sole effect of the insulation stiffness on panels only. In real life conditions, with panels mounted on washing machine, deformation of panels would be smaller and it would be harder to investigate insulation stiffness effect on panels. The 3D models were exposed to strength analysis in the FEM software Ansys.

To determine amount of forces used in simulation, we applied one of our internal tests used multiple times in the past with washing machine experiments. Test consists of full load of wet laundry in the washing machine, plus 50 kg ballast located on the top of the washing machine. During this test, side panels are affected by the downward force of 255 N.

The biggest impact on a rigidity of panels was achieved on the side panels, which on a top loader washing machine transfer the most of the forces [2], [3].

![Figure 1. Side panel with OEM insulation.](image)

In the figure 1 is side panel of the top loader washing machine. The panel is equipped with OEM insulation and is loaded with downward force. The biggest deformation was achieved in the upper corner (because of ballast location). Deformation amount is 15 mm.
In the figure 2 is the same panel loaded with same force but in this case, the panel is equipped with upgraded sticking of the insulation. In this case, smoother deformation was achieved with amount of 0.16 mm. Deformation is evenly distributed on the whole panel surface. In comparison with OEM insulation, deformation was present only in upper part of the panel. The reason is the upgraded insulation sticking transfers forces to insulation, which can serve as the stiffener [4].

In the figure 3 is front panel equipped with upgraded sticking of the insulation. This panel achieved 5 times better deformation resistance than panel with OEM insulation. Front panel is affected by smaller amount of forces than side panels. Because front panel is naturally stiffer than side panels (because of curved shape), we decided to use same amount of forces than on the side panels, to highlight insulation stiffness benefit [5].

3. Insulation impact on overall noise
To make final decision, if upgraded insulation has impact on overall acoustic power, a real scale washing machine equipped with OEM and upgraded insulation was exposed to noise tests. With upgraded insulation was achieved improvement of overall noise. We measured acoustic power, which
was slightly reduced [6]. Experiments were performed at maximum rpm (1200 rpm) and 600rpm. The reason, that we have chosen 600 rpm, this model of the washing machine during its washing cycle mostly works at or around 600 rpm.

![1200 rpm graph](image)

**Figure 4.** Acoustic power at 1200 rpm.

In the figure 4 and 5 is graph of 1/3 octave spectrum, measured on washing machines equipped with OEM and upgraded insulation.

![600 rpm graph](image)

**Figure 5.** Acoustic power at 600 rpm.
4. Conclusion
The upgraded insulation has significant impact on overall rigidity and noise of the washing machine. The biggest benefit of upgraded insulation was on side panels of a top loader washing machine, because those panels are usually more affected by the forces occurred during washing cycle. Front panel achieved minor benefit only. It is because of its curved shape, so the front panel achieved better results than side panel even without any insulation installed. Rear panel was not tested, because on this particular washing machine was not possible to install such a type of insulation. We expect that rear panel would not achieve such an improvement as side panels, because rear panel on top loader washing machines is affected only by minor forces.

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