Price impact on acoustic comfort of a washing machine

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Abstract. The article is focused on price impact on acoustic comfort of a washing machine. In the article is comparison of various washing machines price maximum rpm and acoustic power. Next article is focused on experiments how unbalance in a washing machine tub affect maximum rpm and how maximum rpm affect overall noise of various washing machines.

1. Introduction
Producers and customers are watching whole range of technical specs, when comparing appliances. Some of the technical specs are on energy label. This article is focused on price impact on the washing machine parameters like maximum rpm, noise during spin cycle. A comparison created in this paper is useful for producers to choose price range of their products and customers to decide, if they are willing to pay for more premium products. For comparison was chosen parameters that are most obvious for washing machines, and customers are mostly interested in it (price, maximum rpm, noise). Maximum rpm of spin cycle is relatively important spec, because with higher rpm more water from laundry is drained in shorter time. With shorter spin cycle, less amount of energy is used. Another important spec is a washing machine acoustic power. The washing machine acoustic power depends on maximum rpm. With raising rpm raises acoustic power also. However, washing machines which are able to achieve high rpm with reduced noise, are improving acoustic comfort for customer. Those washing machines have some price-increasing technological solutions. Customer is searching for price-quality compromise constantly [3].

2. Price impact on acoustic comfort of a washing machine
Washing machines can be divided into two biggest categories: top loader and front loader type washing machines. In this comparison was used 28 washing machines from 21 producers in each category. In the comparison was used washing machines with capacity between 4 and 9 kg. For reference was used average market price of washing machines.
Figure 1. Front loader washing machines.

In the figure 1 is 3D graph of front loader washing machines. The graph is showing dependence between price, maximum rpm and spin cycle noise. The most expensive washing machines are achieving the highest rpm and the lowest amount of noise. In the figure 1, we can see that washing machine in the price range around 400 € are also achieving good results with acoustic power less than 75 dB(A). Washing machines in the price range around 800 € are achieving acoustic power less by 1.5 dB(A).

Optimal ratio between noise, price and maximum rpm was chosen from acoustic power median of front loader washing machines used in comparison (75,5 dB(A)). Optimal ratio is marked with red line in the 3D graph. With using this optimum ratio is possible to choose appliance requirements like price and other specs (in this case acoustic power).

Such as comparisons are very important for producers, because they can determine if they are competitive with an appliance in its price category.

Figure 2. Top loader washing machines.
In the figure 2 is 3D graph of top loader washing machines. Again, the graph is showing comparison between price, noise and maximum rpm. In this case, situation differs little bit than with front loader washing machines. Price difference is significantly bigger. Median of the acoustic power during spin cycle is 76 dB(A). Optimal ratio is in range between 300 and 400 €. The best washing machines in the optimal range are able to achieve 1300 rpm. In this case the most expensive washing machine is able to achieve 1600 rpm. Undoubtedly, the most expensive washing machine is achieving the best parameters. The noisiest washing machine is able to achieve 1400 rpm which is good figure in the 350 € range. For customers that silent washing machine is not a must, this washing machine could be good choice.

Optimal range of the front loader washing machine has got wider choice than the top loader optimal range. However, optimal range of the top loader washing machine is in lower price range.

3. Maximum rpm during spin cycle
Maximum rpm during spin cycle has got big impact on noise increase. After wash cycle, in some occasions washing machine won't be able to achieve maximum rpm because of unbalance in the washing machine tub. It depends on quality of a washing machine, how it can handle unbalance. Premium washing machines attempt to balance the tub at first. If the attempt is not successful, they reduce maximum rpm during spin cycle. Cheaper washing machines does not try to balance the tub; they just reduce maximum rpm. Detection of unbalance is very important, if washing machines would not reduce maximum rpm, noise increase and damage may occur. During experiment with the washing machines, a different spin cycles were recorded which consisted of multiple phases. The laundry distribution in the tub is random and different unbalance values occur at each stop and re-spin.

Table 1. Unbalance vs maximum rpm comparison.

| Load      | Maximum rpm | 0 kg  | 3 kg  | 6 kg  |
|-----------|-------------|-------|-------|-------|
| Unbalance 0 kg | 1360         | 1362  | 1360  |
| Unbalance 0.3 kg | 1360       | 1362  | 1364  |
| Unbalance 0.5 kg | 1050        | 1050  | 1364  |
| Unbalance 0.8 kg | 820         | 820   | 1050  |
| Unbalance 1 kg | 0           | 0     | 820   |

Tab 1 shows how is unbalance affecting the maximum spinning speed of a particular washing machine. Unbalance was created with rubber ballast of different mass. An unbalance of up to 0.3 kg has a minimal effect on maximum speed because this unbalance is low compared to the gross weight of the washing machine tub and does not alter the spin cycle. The difference appears from an unbalanced weight of about 0.5 kg, in which the washing machine attempts to distribute laundry in the tub. If the attempt is not successful, reduction of rpm occurs. The washing machine was able to trigger spin cycle up to an unbalance of 1 kg, when the tub was unbalanced completely and did not start the spin cycle because of safety reasons. With an evenly loaded drum weighing 6 kg, the machine began to reduce the speed up to 0.5 kg. when the drum weighed 6 kg, unbalance of 1 kg had a smaller effect on the speed reduction, the machine was able to start spinning up to 820 rpm.

4. Unbalance impact on noise
With increasing unbalance is raising noise also. Unbalance in the tub is created with uneven position of laundry during washing cycles. The biggest impact of the unbalance is achieved during final spin cycle. In this cycle Washing machines must deal with unbalance in the tub. Depending on the price range, washing machines have different capability to handle unbalance in the tub. Regardless to its ability to handle unbalance, usually it’s not possible to complete elimination of noise increase with increased unbalance.
Figure 3. Unbalance impact on overall noise.

In figure 3 is graph, which shows how unbalance in the tub influences acoustic power. Results were achieved with experiments performed on 9 different models of washing machines. As figure shows, with increasing unbalance is increasing acoustic noise. However, some of the experiments unexpectedly resulted in different way (with increase unbalance was noise reduced). Potential reason could be, that position of the unbalance creating ballast located in the tub could change vibration frequency. Statistically, most common location of unbalance is on a front side of the tub. If unbalance location (ballast during experiments) is in the middle or rear side of the tub, it can change results and acoustic power can be lower.

5. Conclusion
Price of washing machines has significant impact on their acoustic comfort. However, some of the average priced washing machines can achieve decent noise reduction, but they are usually missing other functions or equipment in comparison with premium models.

In comparison of washing machines was determined that with unbalance above 0.3 kg reduction of maximum rpm during spin cycle may occur. With reduction of maximum rpm, noise and load is also reduced. Even different models from same producer have got different unbalance detection if different electric motor is used.

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References
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[2] Ciesielka W Golaś 2006 An adaptive, active noise reduction system in closed space Archives of Acoustics 31 0137-5075
[3] STN EN 60704-1 2010: Acoustic. Electric appliances for home and similar usage. Skúšobný predpis na stanovenie hluku prenášaného vzduchem. Part 1: General requirements