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XYO PROTOTYPE BALANCER AS APPLIED TO TOP AND FRONT-LOADING WASHING MACHINES

Testing Report Summary

CURRENT STATE AND OPPORTUNITY

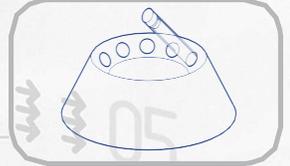
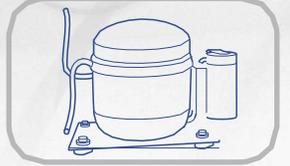
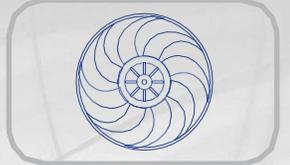
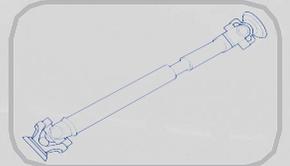
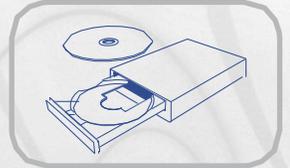
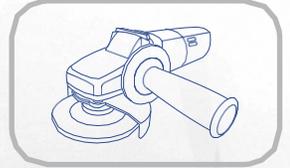
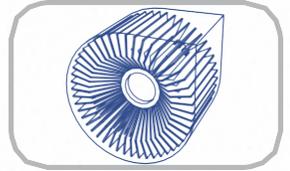
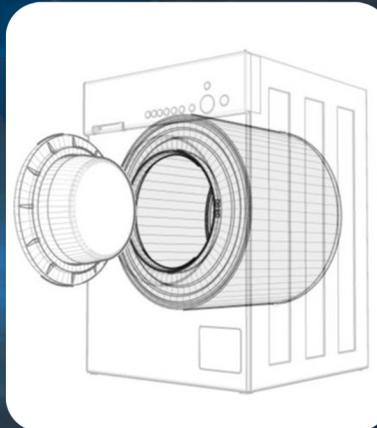
The XYO technology shows significant improvements in washing machine performance during independent studies. Perpetual Industries wants to work with innovative washing machine manufacturers to optimize and implement the XYO balancer in their product.

Contact us to see how your product can beat the competition using XYO



XYO[®]
INSIDE

**TOP & FRONT LOADING
WASHING MACHINE
TEST REPORT**



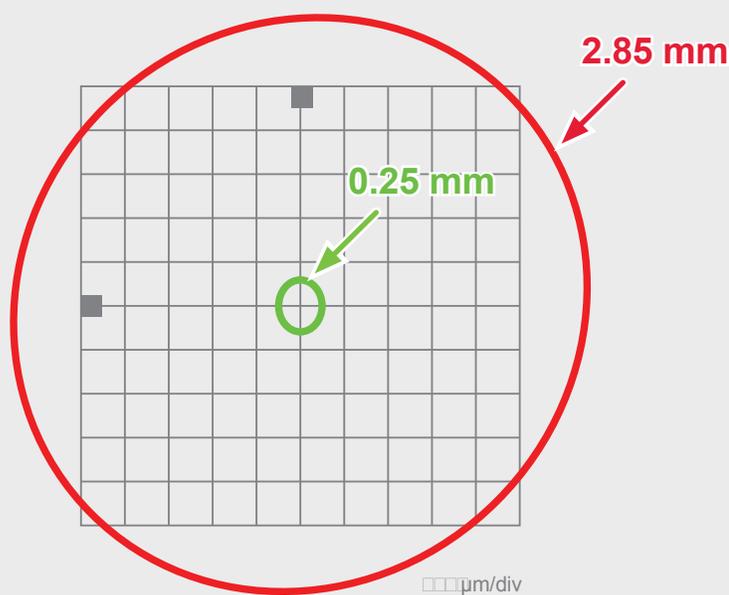
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RESULT HIGHLIGHTS

The XYO mechanical balancer reduces vibration by compensating for variable mass imbalance during the spin cycle of washing machines. Test results with a **prototype XYO balancer** demonstrate a significant impact on the performance of front and top loading washing machines. Additional benefits include:

- ▶ Higher spin speeds
- ▶ Reduced energy consumption
- ▶ Lower noise emissions
- ▶ Less mechanical wear

Top-Loading Washing Machine Vibration Decreased by 91%



Impact of XYO on spin basket orbit of a top-loading washing machine with 1.1 kg of mass imbalance

■ WITHOUT XYO ■ WITH XYO

Note:

- ▶ The results in this report are based on separate tests from the GE washing machine report; however, the improvements with XYO are significant in both reports.
- ▶ These results are based on prototype XYO balancer designs. While the results shown are significantly positive, it is possible to exceed them with further optimization.
- ▶ Tests were conducted with mass imbalance loads ranging from 0.1 kg to 1.5 kg; however, the XYO balancer can be designed to compensate for greater loads if desired.
- ▶ Perpetual Industries is looking for a capable partner that needs the competitive advantage that XYO can provide.

RESULT HIGHLIGHTS (Continued)

Damper Temperature **Decreased by 68%**

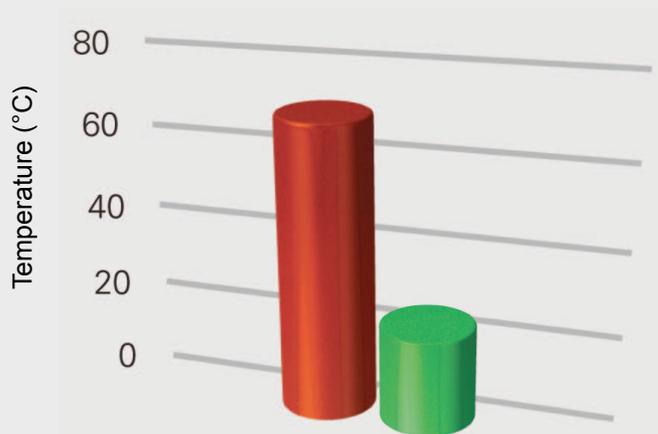


Figure 2. Impact of XYO on damper temperature for front-loading washer

- ▶ Figure 2 shows that damper temperature decreased 44°C using the XYO balancer
- ▶ Dampers will be more reliable because they will remain cool
- ▶ Less energy will need to be dissipated and smaller dampers can be used
- ▶ Fewer warranty claims will occur due to the increased longevity of dampers
- ▶ Less expensive dampers can be utilized to minimize manufacturing costs

■ WITHOUT XYO ■ WITH XYO

Energy Consumption **Decreased by 33%**

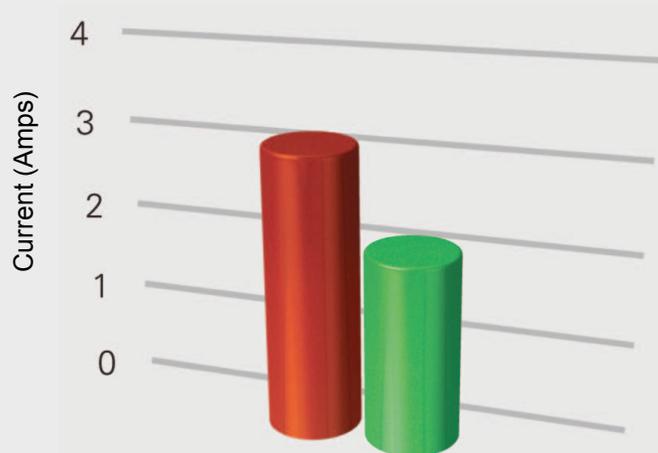


Figure 3. Impact of XYO on energy consumption for front-loading washer

- ▶ Figure 3 shows that current draw decreased 1 Amp with the use of XYO
- ▶ Washing machine manufacturers can achieve better energy ratings with lower power consumption
- ▶ There is greater water extraction using less energy

RESULT HIGHLIGHTS (Continued)

Spin Speed **Increased by 90 RPM**

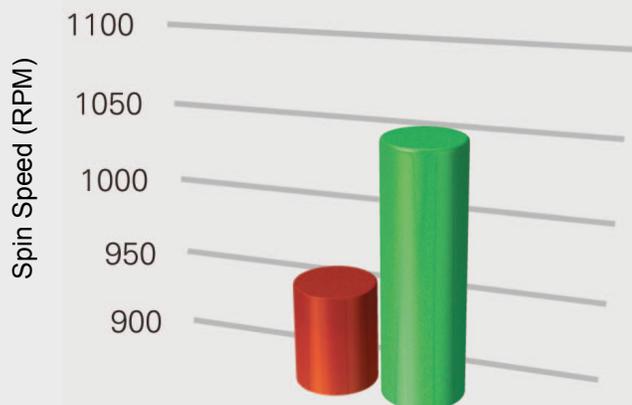


Figure 4. Impact of XYO on spin speed for front-loading washer

- ▶ Figure 4 shows the washing machine spin speed increased from 960 RPM to 1050 RPM with the XYO balancer
- ▶ Higher spin speed results in greater water extraction
- ▶ Greater water extraction leads to shorter spin cycles
- ▶ Power consumption will decrease even further with shorter spin cycles

■ WITHOUT XYO ■ WITH XYO

Noise Emission **Decreased by 10 dB**

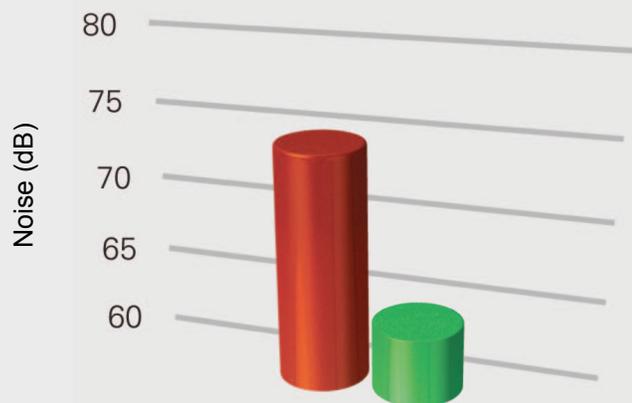


Figure 5. Impact of XYO on noise emission for front-loading washer

- ▶ Figure 5 shows that noise emission decreased from 74 dB to 64 dB with XYO
- ▶ Quieter operation of the washing machine improves its noise rating
- ▶ A smooth and quiet product provides a significant competitive advantage to washing machine manufacturers

ADDITIONAL BENEFITS INCLUDE:

- ▶ **Lower shipping costs** by eliminating the use of heavy counterweights used to stabilize the tub during operation.
- ▶ **Reduced manufacturing costs** because mechanical items such as hydraulic dampers and springs can be removed, or replaced with smaller, lighter and cheaper components.
- ▶ **Fewer warranty claims** will result from the increased product life of the washing machine; excessive vibration will be avoided using the XYO balancer to reduce mechanical wear
- ▶ **Longer warranty periods** can be offered to customers for a competitive advantage.

INTRODUCTION

During the spin cycle of all washing machines and extractors the mass imbalance caused by wet clothes can lead to violent vibration. Since excessive vibration can have negative impacts (e.g., increased energy consumption, noise emissions and mechanical wear) manufacturers have tried several techniques to reduce or eliminate vibration. Some examples of these techniques include: adding counterweights to reduce movement, implementing fuzzy logic systems to redistribute the load, using elaborate suspension systems. None of these techniques solve the vibration problem at its source. In fact, they increase the manufacturing and shipping costs of the product.

TEST OBJECTIVE

To determine the impact and benefits of implementing XYO technology in household washing machines, comparative testing was performed. The testing consisted of quantifying the performance of a stock machine to that of a system equipped with XYO. A sample XYO system for a top loading washing machine appears in Figure 7.

TEST OVERVIEW

The main vibration concern in washing machines is the motion of the spin basket. Reducing the displacement of the spin basket leads to many advantages. The measurements presented here concentrate on quantifying the vibration of the spin basket and real world concerns such as noise and energy consumption. Values such as orbits, acceleration, energy consumption and noise were quantified on a stock machine and compared to a machine with the XYO balancer installed.



Figure 6. Examples of front loading (left) and top loading (right) washing machines used in the study

Example XYO balancers



Figure 7. Example of an installed XYO balancer on a spin-basket

Rubber mass imbalance



Figure 8. A piece of rubber simulating mass imbalance from wet clothes

Mass Imbalance was applied to both types of machines by securing rubber weights of varying mass.

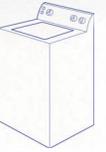
Orbits for the top loading washer presented were generated using a Bentley Nevada ADRE 3 measurement analysis system. The orbits were obtained by integrating the signal from a set of velocity transducers. The orbits for the front loading washer were obtained by mechanical trace.

Acceleration of the spin basket for both machines were recorded using a 50g (100mV/g) accelerometer.

Noise emissions were measured using a type 2 BEHA 93-20 Sound level meter inside a sound chamber.

Current was measured with a digital clamp multi-meter.

Rotational speed was measured by placing a piece of reflective tape on the rotor and rotation was detected by an optical pickup.



TEST RESULTS

Top-Loading Washing Machine

Vibration displacement is displayed in Figure 9 using orbit plots and the results are further summarized in Figure 10. Vibration was significantly reduced (**96%**) when a prototype XYO balancer was fitted to the machine.

Orbit Plots

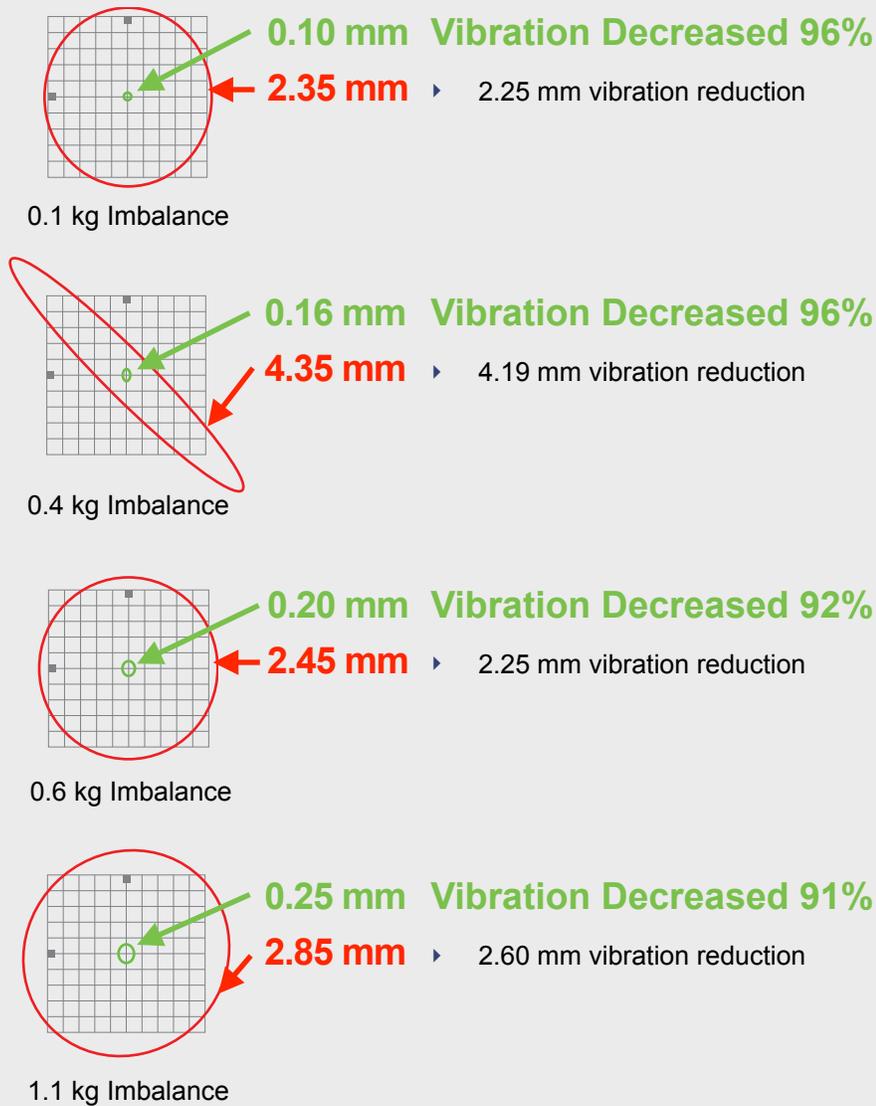
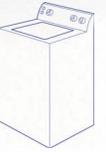


Figure 9. Orbit plots for top-loading washing machine (200 $\mu\text{m}/\text{div}$)

■ WITHOUT XYO ■ WITH XYO



Top-Loading Washing Machine (Continued)

Figure 10 shows the performance of a prototype XYO balancer with a representative range of imbalances.

Note: the XYO balancer can compensate for greater mass imbalances if desired.

Vibration vs. Mass Imbalance with and without XYO

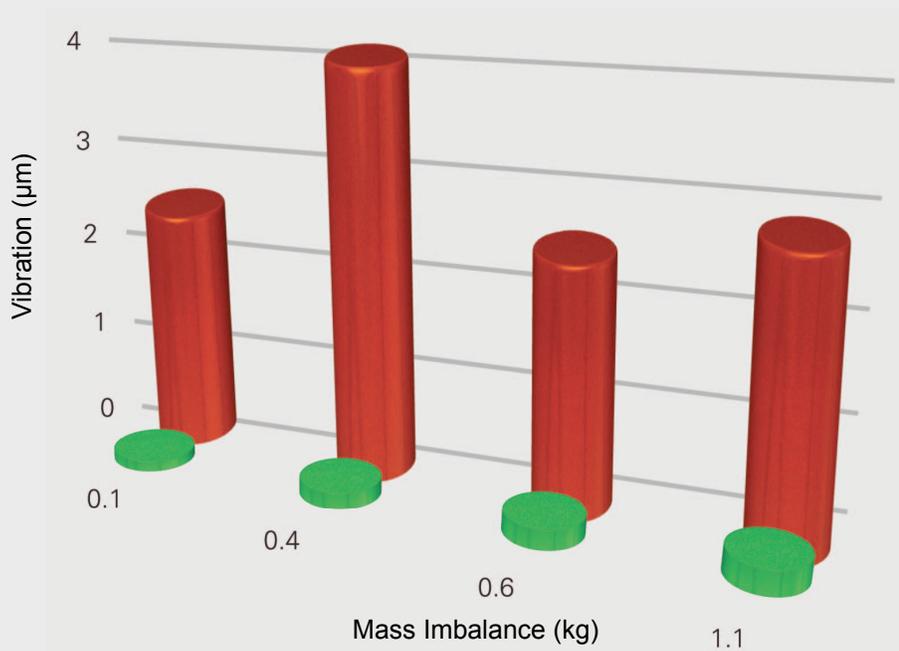
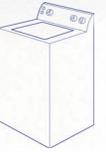


Figure 10. Vibration of top-loading washing machine for various mass imbalance

■ WITHOUT XYO ■ WITH XYO



Top-Loading Washing Machine (Continued)

The acceleration test results for the spin basket of a top loading washer appear in Figure 11. Two 50g accelerometers were placed on the main bearing of the spin basket. XYO reduced the vibration by **93%** in the X-axis for a mass imbalance of 1.5kg.

Vibration of Spin Basket with and without XYO

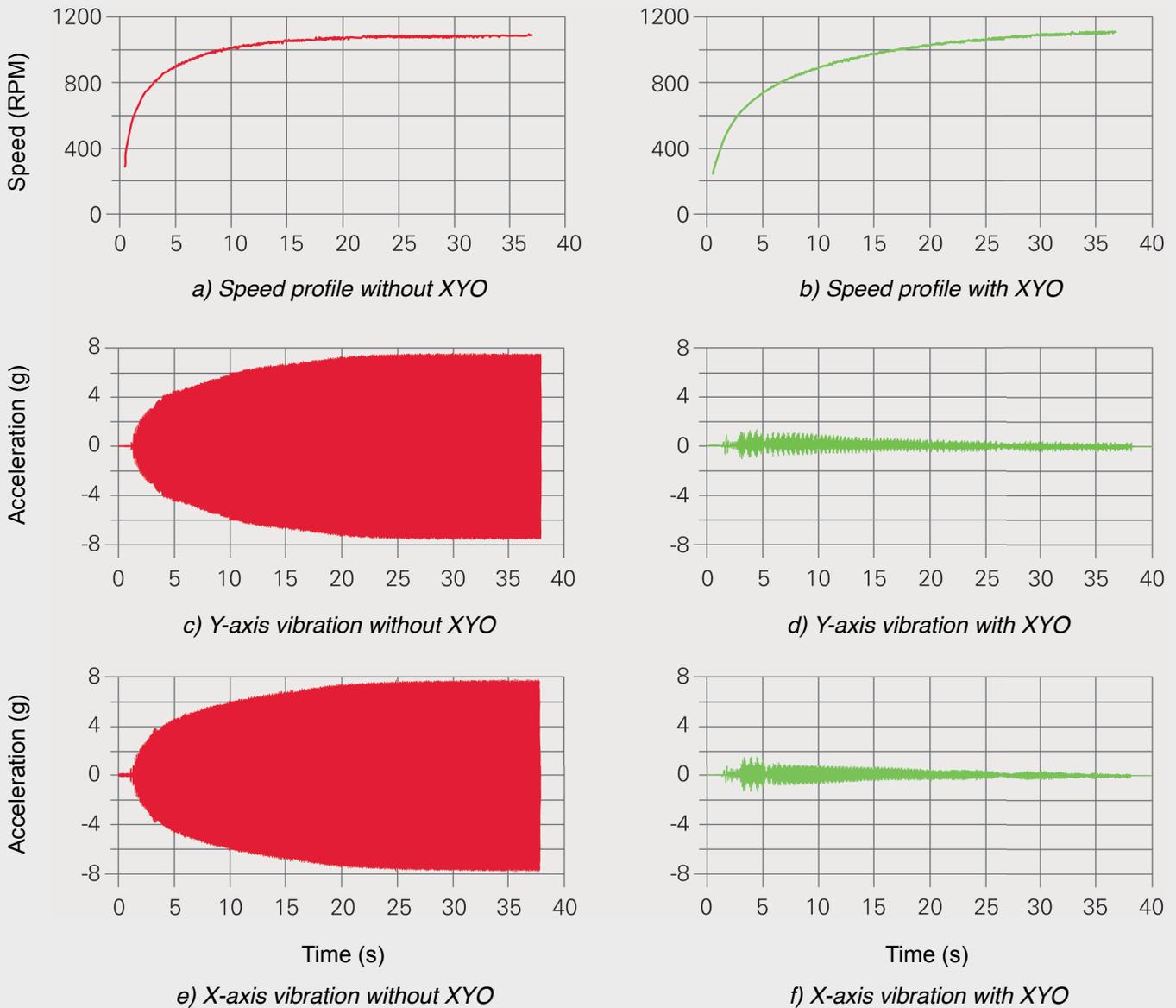


Figure 11. Vibration of spin basket of a top-loading washer with and without XYO for a mass imbalance of 1.5 kg

■ WITHOUT XYO ■ WITH XYO



Top-Loading Washing Machine (Continued)

Using XYO on a top-loading washing machine resulted in significant vibration reduction. The additional benefits are highlighted in Figures 12 to 15 and Tables 1 to 2 below. It should be noted that **the 5kg counterweight was removed** while testing with the prototype XYO balancer; it was no longer necessary for stabilizing the washing machine because of the capabilities of XYO. The weight reduction of the washing machine is an additional benefit of XYO that can lower manufacturing and shipping costs.

Damper Temperature Decreased by 53%



Figure 12. Impact of XYO on damper temperature

- ▶ Figure 2 shows that damper temperature decreased 44°C using the XYO balancer
- ▶ Dampers will be more reliable because they will remain cool
- ▶ Less energy will need to be dissipated and smaller dampers can be used
- ▶ Fewer warranty claims will occur due to the increased longevity of dampers
- ▶ Less expensive dampers can be utilized to minimize manufacturing costs

■ WITHOUT XYO ■ WITH XYO

Energy Consumption Decreased by 11%

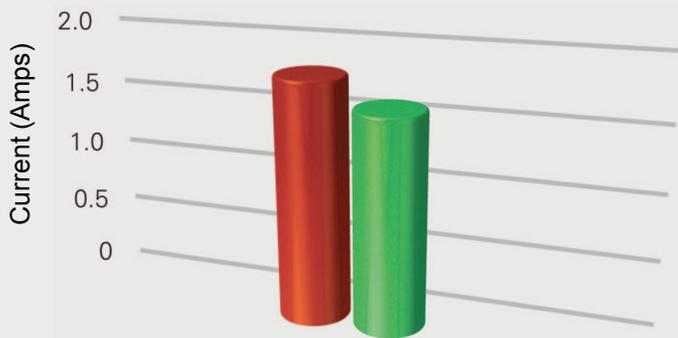
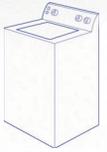


Figure 13. Impact of XYO on energy consumption

- ▶ Figure 13 shows that energy consumption decreased 0.2 Amp with XYO
- ▶ The XYO balancer can improve energy ratings for washing machines
- ▶ There is greater water extraction using less energy
- ▶ The energy efficiency can be increased through optimization with a capable washing machine manufacturing partner

Table 1. Summary of results for top-loading washing machine

| | WITHOUT XYO | WITH XYO | IMPROVEMENT |
|--------------------|-------------|----------|-------------|
| Damper Temperature | 47 °C | 22 °C | 25 °C (53%) |
| Energy Consumption | 1.8 A | 1.6 A | 0.2 A (11%) |



Top-Loading Washing Machine (Continued)

Spin Speed Increased by 70 RPM

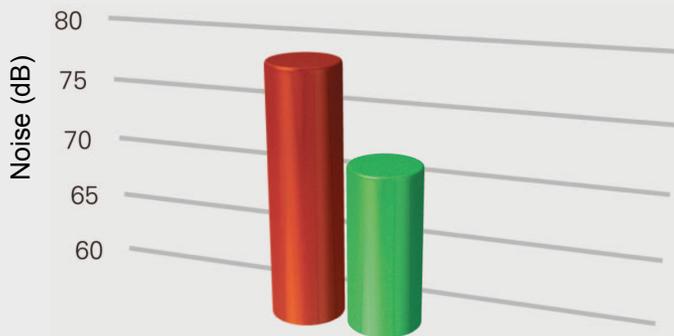


- ▶ Figure 14 shows that top-loading washing machine spin speed from 1060 RPM to 1130 RPM
- ▶ Higher spin speed results in greater water extraction
- ▶ Greater water extraction leads to shorter spin cycles
- ▶ Power consumption will decrease even further with shorter spin cycles

Figure 14. Impact of XYO on spin speed

■ WITHOUT XYO ■ WITH XYO

Noise Emission Decreased by 7 dB



- ▶ Figure 15 shows that noise emission from 79 dB to 72 dB
- ▶ A quieter machine improves the product's noise rating
- ▶ A smooth and quiet product provides a significant competitive advantage to washing machine manufacturers

Figure 15. Impact of XYO on noise emission

Table 2. Summary of results for top-loading washing machine

| | WITHOUT XYO | WITH XYO | IMPROVEMENT |
|----------------|-------------|-----------|-------------|
| Spin Speed | 1,060 RPM | 1,130 RPM | 70 RPM (7%) |
| Noise Emission | 79 dB | 72 dB | 7 dB (9%) |

Note:

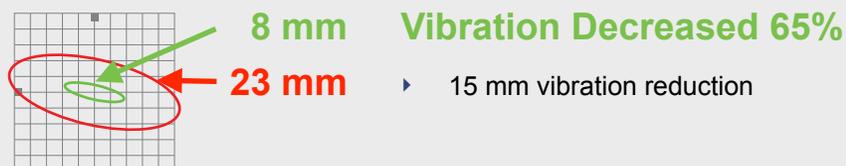
Noise transmission through a wooden floor was reduced by 90% with the XYO balancer; this significantly impacts noise emissions in residential living spaces.



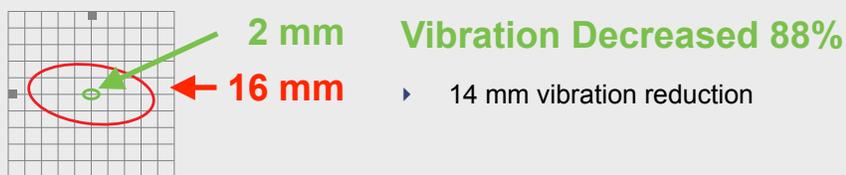
Front-Loading Washing Machine

Vibration displacement was recorded with orbit plots (Figure 16). Vibration was significantly reduced (**93%**) when the XYO balancer was fitted to the machine.

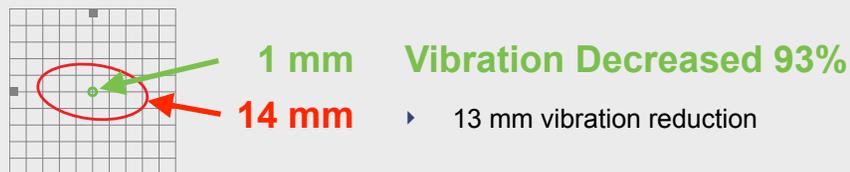
Orbit Plots



0-850 RPM



820 RPM



965 RPM

Figure 16. Orbit plots for front-loading washing machine for a mass imbalance of 1.1 kg

■ WITHOUT XYO ■ WITH XYO



Front-Loading Washing Machine (Continued)

The acceleration test results for the spin basket with 0.5 kg of mass imbalance is presented in Figure 17. Two 50g accelerometers were placed on the front and rear of the spin basket. XYO reduced the vibration by **81%** at the front of the spin basket.

Vibration of Spin Basket with and without XYO

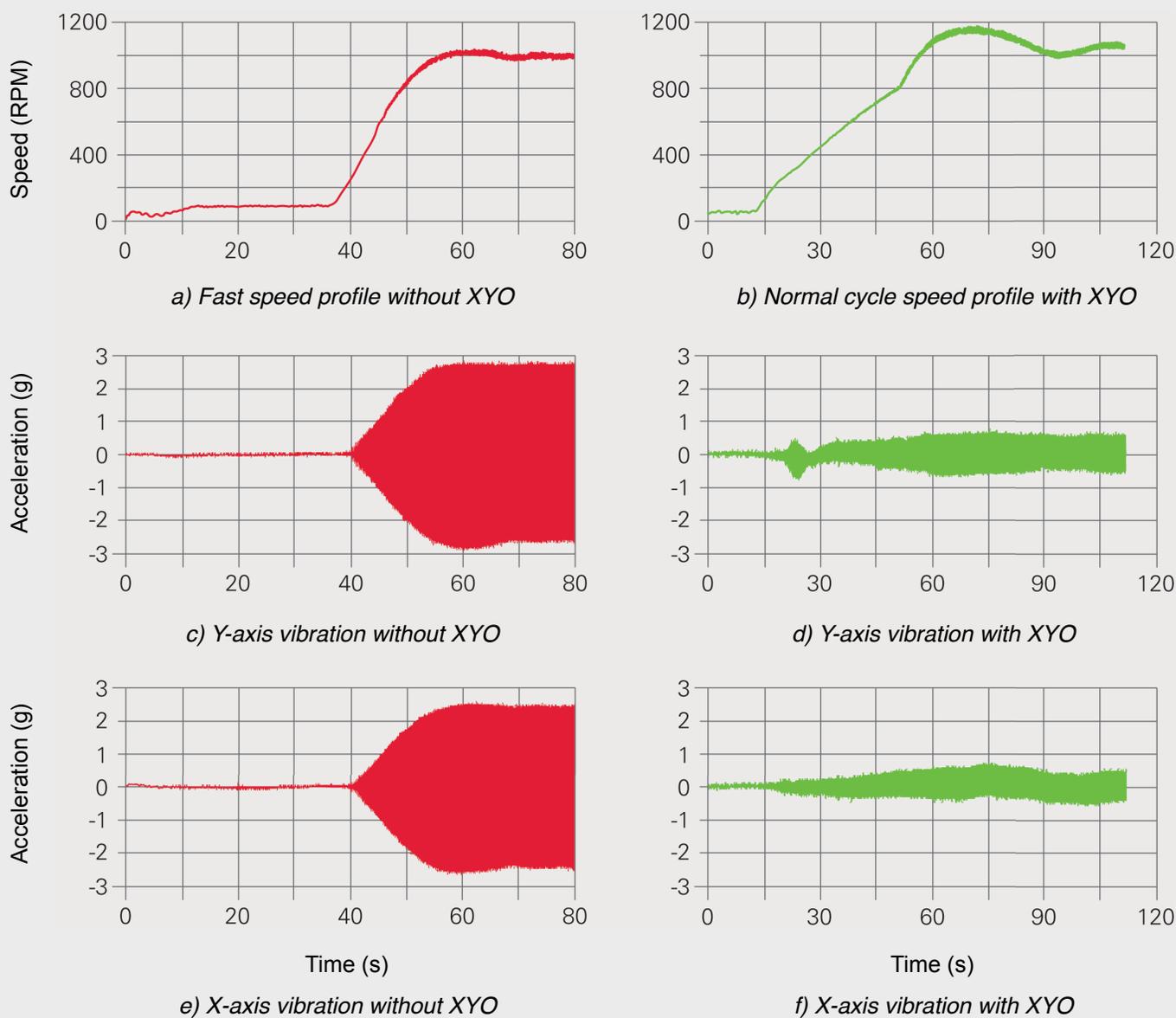


Figure 17. Vibration of spin basket of a front-loading washer with and without XYO with a mass imbalance of 0.5 kg

■ WITHOUT XYO ■ WITH XYO



Front-Loading Washing Machine (Continued)

Using XYO on a front-loading washing machine resulted in significant vibration reduction. The additional benefits are highlighted in Figures 18 to 21 and Tables 3 to 4 below. It should be noted that **the 16kg counterweight was removed** while testing with the XYO balancer; it was no longer necessary for stabilizing the washing machine because of the capabilities of the XYO balancer. The weight reduction of the washing machine is an additional benefit of XYO that can lower manufacturing and shipping costs.

Damper Temperature Decreased by 68%



Figure 18. Impact of XYO on damper temperature

- ▶ Figure 18 shows that damper temperature decreased 44°C using the XYO balancer
- ▶ Dampers will be more reliable because they will remain cool
- ▶ Less energy will need to be dissipated and smaller dampers can be used
- ▶ Fewer warranty claims will occur due to the increased longevity of dampers
- ▶ Less expensive dampers can be utilized to minimize manufacturing costs

■ WITHOUT XYO ■ WITH XYO

Energy Consumption Decreased by 33%

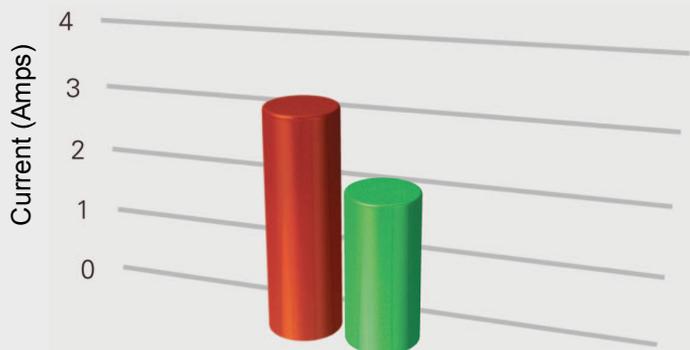


Figure 19. Impact of XYO on energy consumption

- ▶ Figure 19 shows that current draw decreased 1 Amp with the use of XYO
- ▶ Lower energy consumption will increase the washing machine's energy rating
- ▶ There is greater water extraction using less energy

Table 3. Summary of results for front-loading washing machine

| | WITHOUT XYO | WITH XYO | IMPROVEMENT |
|--------------------|-------------|----------|-------------|
| Damper Temperature | 65 °C | 21 °C | 44 °C (68%) |
| Energy Consumption | 3 A | 2 A | 1 A (33%) |



Front-Loading Washing Machine (Continued)

Spin Speed **Increased by 90 RPM**



Figure 20. Impact of XYO on spin speed

- ▶ Figure 4 shows the washing machine spin speed increased from 960 RPM to 1050 RPM with the XYO balancer
- ▶ Higher spin speed results in greater water extraction
- ▶ Greater water extraction leads to shorter spin cycles
- ▶ Power consumption will decrease even further with shorter spin cycles

■ WITHOUT XYO ■ WITH XYO

Noise Emission **Decreased by 10 dB**

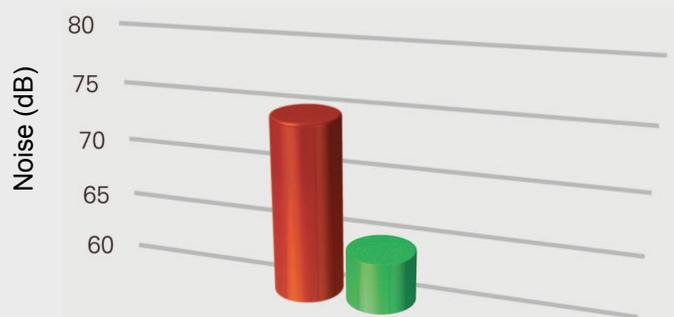


Figure 21. Impact of XYO on noise emission

- ▶ Figure 5 shows that noise emission decreased from 74 dB to 64 dB with XYO
- ▶ Quieter operation of the washing machine improves its noise rating
- ▶ A smooth and quiet product provides a significant competitive advantage to washing machine manufacturers

Table 4. Summary of results for top-loading washing machine

| | WITHOUT XYO | WITH XYO | IMPROVEMENT |
|----------------|----------------|------------------|--------------------|
| Spin Speed | 960 RPM | 1,050 RPM | 90 RPM (9%) |
| Noise Emission | 74 dB | 64 dB | 10 dB (14%) |

FINDINGS AND CONCLUSIONS

Implementing the XYO technology in washing machines can provide manufacturers a significant competitive advantage. Some of the benefits of XYO include:

- ▶ Washing machine manufacturers can offer longer warranty periods due to lower mechanical wear with XYO
- ▶ Since vibration is reduced there will be less wear and tear on mechanical components and therefore less warranty claims should be experienced
- ▶ By using XYO the manufacturer solves the vibration problem at the source. Thus, the manufacturer should be able to use cheaper components and avoid costly methods that were previously used to deal with problems arising from vibration caused by imbalanced loads.
- ▶ The washer will spin faster because of reduced vibration and will result in greater water extraction and reduced spin cycle times. This will also result in further energy savings due to shorter drying times.
- ▶ The reduction in spin cycle time and direct reduction of energy consumed by the motor will translate into a substantial improvement in energy rating of the washing machine.
- ▶ The reduced noise emission of a washing machines equipped with XYO will provide a competitive advantage in the marketplace.
- ▶ The manufacturing and shipping costs of the machine can be reduced by removing the large heavy counterweights.
- ▶ Complicated and expensive electronic imbalance detection systems are no longer required. By implementing XYO, expensive sensors and programming can be eliminated.

The XYO technology has been implemented very successfully in top-loading and front-loading washing machines, as well as industrial washer extractors. The results presented here are based on a prototype XYO balancer design and they can be improved further.

Perpetual Industries wants to work with a capable and innovative washing machine manufacturer to optimize and implement the XYO technology and provide a strong competitive advantage in the market.

Impact of XYO:

- ▶ **Spin basket vibration reduction 96%**
- ▶ **Increase in spin speed 90 RPM**
- ▶ **Noise reduction 10 dB**
- ▶ **Decrease in current drawn 33%**
- ▶ **Damper temperature decrease 68%**

