# PERPETUAL INDUSTRIES INC.

**Please direct all inquiries to:**

#110, 5 - 8720 Macleod Trail South

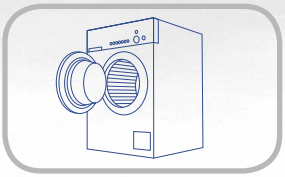
Calgary, Alberta, Canada T2H 0M4

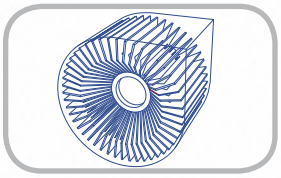
P: 403-214-4321

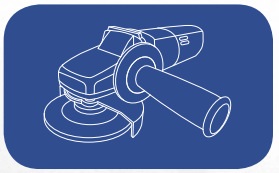
F: 403-770-8122

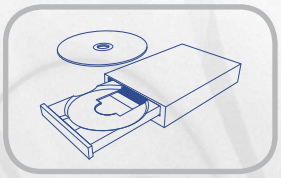
E: info@perpetualindustries.com

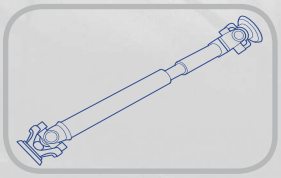
**www.perpetualindustries.com**

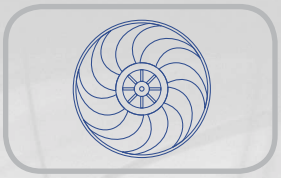



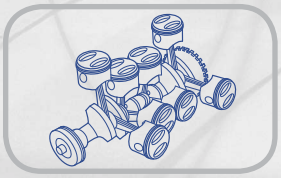












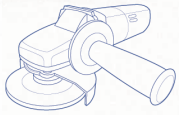
## CURRENT STATE AND OPPORTUNITY

The XYO technology shows significant improvements in angle grinder performance during independent studies. Perpetual Industries wants to work with innovative power tool 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 PROTOTYPE BALANCER AS APPLIED TO ANGLE GRINDERS

## Rockwell Summary Report

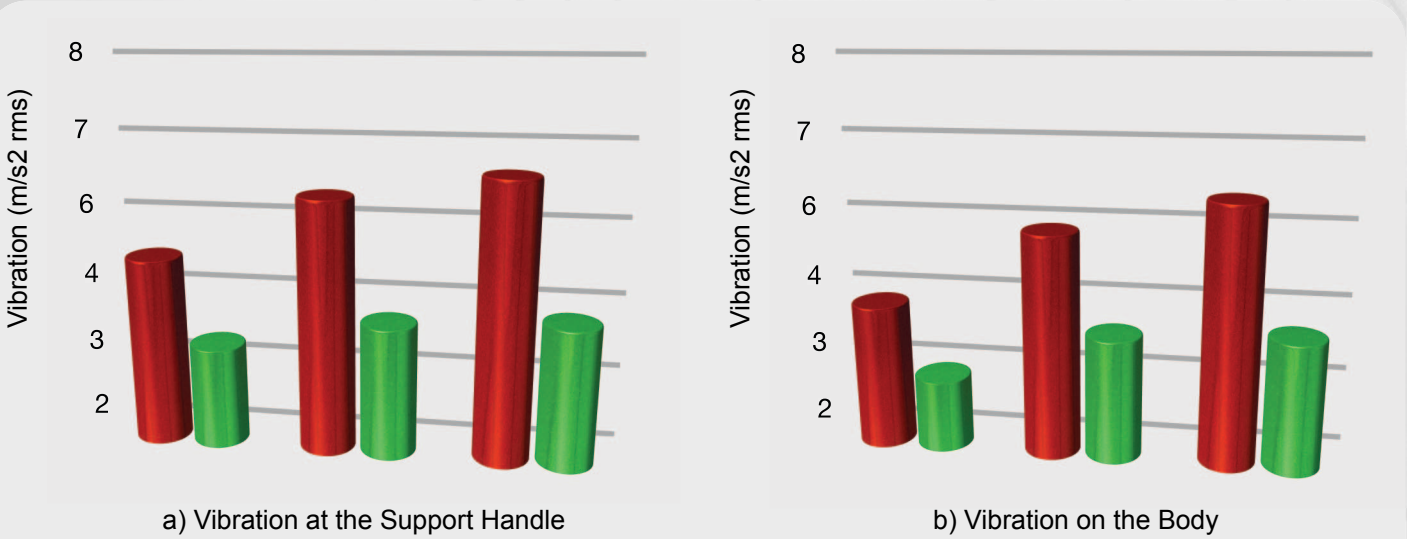


## RESULT HIGHLIGHTS

The XYO balancer reduces vibration by compensating for variable mass imbalance during the operation of an angle grinder. Tests show that the XYO balancer has a significant impact on the performance of an angle grinder. Benefits of reduced vibrations include:

- Preventing vibration-related health issues
- Allowing longer product usage without discomfort
- Better wear life of grinding disks
- Greater warranty life of the product

# Angle Grinder
# Vibration Decreased by 51%




a) Vibration at the Support Handle

b) Vibration on the Body

*Figure 1. Vibration levels for the angle grinder with an optimized disk speed profile*

**WITHOUT XYO** **WITH XYO**

**Note:**

- **Results are based in this report are based on the Rockwell RK4751 angle grinder using a prototype XYO balancer design; another report is available showing results for 2 other angle grinder models.**
- **Tests were conducted in accordance with ISO 8041, ISO 5349-1, and EN 60745.**
- **While the results are significantly positive using the XYO balancer, it is possible to improve the performance of angle grinders with further optimizations.**
- **Perpetual Industries is seeking a capable and innovative angle grinder manufacturer to optimize and implement the XYO balancer in their product.**

## INTRODUCTION

Power tools have been known to induce the risk of vibration-related diseases. An acute disease that is caused by regular exposure to hand-arm vibration (HAV) is known as white finger or Raynaud's disease. There are also other vibration-related diseases such as: permanent and painful numbness and tingling in the hands and arms, painful joints and muscle weakening, damage to bones in the hands and arms.

Vibration issues have been an important topic in the power tool sector ever since the EU guideline 2002/44/EC, where the employer can be held liable for vibration-induced injuries. Depending on the vibration value associated with a power tool the daily usage has limited as shown by Figure 2.

According the EU guidelines, shown in Figure 2, a power tool can be used continuously if the vibration level is at 2.5 $m/s^2$-rms or less, while a power tool with a vibration level of 5.0 $m/s^2$-rms will be limited to 8 hours of usage per day.

Some factors that contribute to angle grinder vibration include:

unbalanced grinding disks

alignment or meshing of gears

straightness of the spindle

rigidity of the housing

abrasive action of the grinding disk on the work piece

The main cause of vibration in an angle grinder is due to the changing mass imbalance of the grinding disk during operation (Figure 3).

Manufacturers have introduced anti-vibration handles and gloves to reduce the exposure to vibration but they do not cure the problem, and most workers do not like the reduced precision that is associated when these methods are employed.

The XYO balancer can compensate for dynamic or static unbalanced forces during operation. As a result, the XYO balancer-equipped angle grinder will continue to provide consistent performance even when the mass imbalance varies as the grinding disk wears during use.

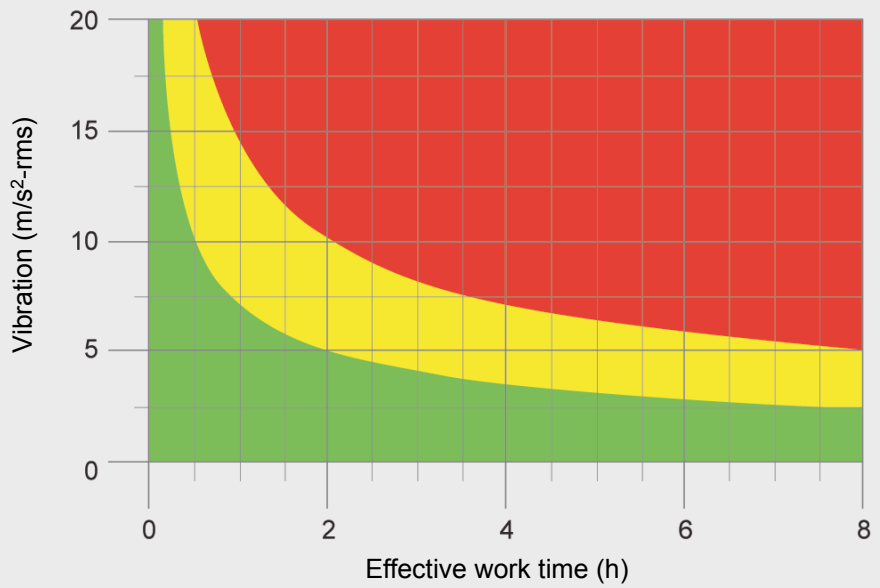



*Figure 2. Effective work time versus vibration*

**SAFE EXPOSURE**

**APPROACHING EXPOSURE LIMITS**

**ABOVE EXPOSURE LIMITS**

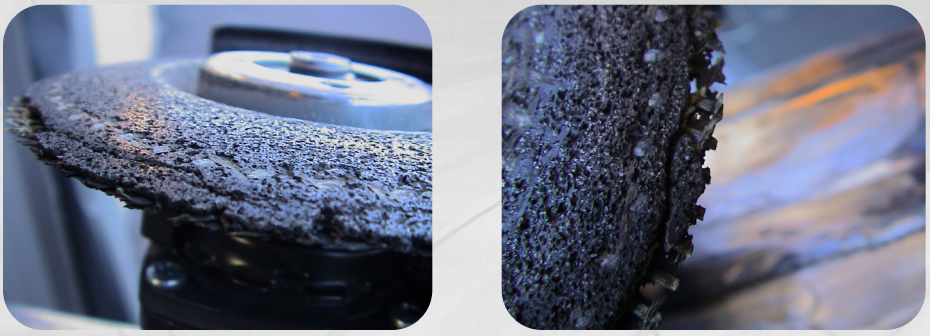


*Figure 3. Mass imbalance of grinding disk*

## TEST OBJECTIVE

The objective of the testing was to quantify the advantages of using the XYO balancer with angle grinders, like the one shown in Figure 4. The capabilities and limitations of angle grinders were also to be tested to determine the minimum achievable vibration for the Rockwell angle grinder being tested.

## TEST OVERVIEW

Testing was performed on the Rockwell RK4751 model using 125mm (5”) diameter disks, shown in Figure 5. Three disks with different mass imbalances, and compliant with ISO standards, were used:

- 58 g.mm
- 76 g.mm
- 90 g.mm

The prototype XYO balancer was installed on the spindle, replacing the backing flange (Figure 6).

Vibration levels were measured with and without a prototype XYO balancer installed. Triaxial accelerometers placed on the support hand and body of the angle grinder (Figure 7) were used to record data.

Different acceleration levels were applied to the disk spin speed in order to optimize performance of the angle grinders.

110 mm, 115 mm and 125 mm disk with no mass imbalance were also tested without the XYO balancer to determine the gyroscopic effects of the rotating disk; this provides a true baseline for calculating the vibration reduction with XYO.

See the “Appendix” for additional details of the testing procedures.

*Figure 4. Example of an angle grinder*

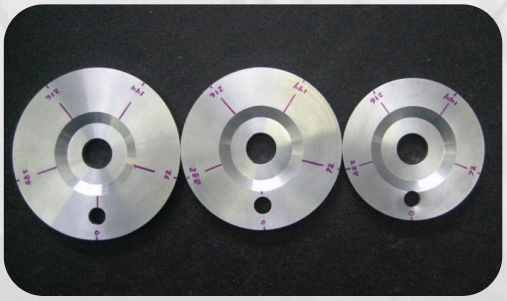
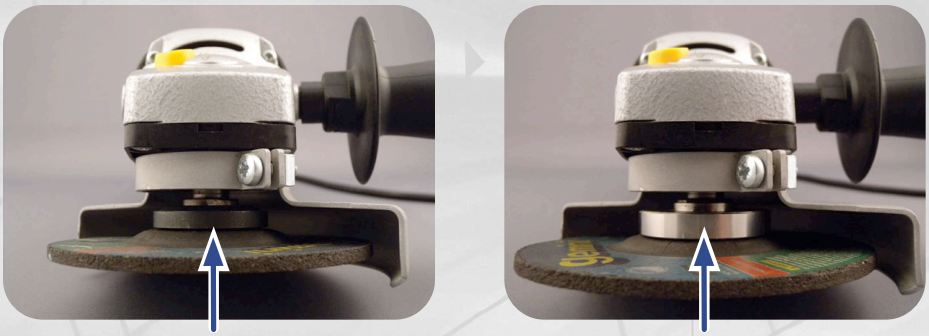


*Figure 5. ISO test disks used during testing*



**Regular backing flange** **XYO backing flange**

*Figure 6. Angle grinder with original backing flange (left) and XYO balancer replacing the backing flange (right)*

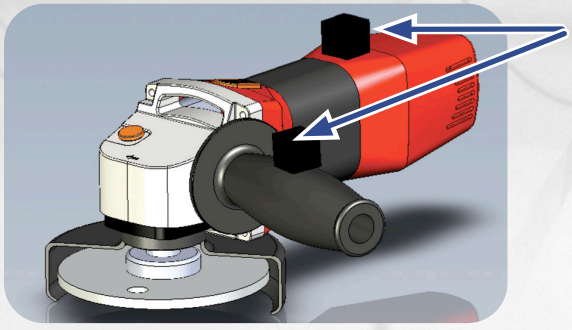



*Figure 7. Location of accelerometers for testing*

# TEST RESULTS

## Baseline Vibration

The rotational motion of the grinding disk can effect vibration of the angle grinder. Slight misalignment at the spindle and slack in the gearing can amplify **gyroscopic effects** further and make it challenging to reduce vibrations. The following **disks with no mass imbalance** were tested on the RK4751 angle grinder to measure gyroscopic effects on vibration:

- No disk on the spindle
- A 110mm balanced disk
- A 115mm balanced disk
- A 125mm balanced disk

Figure 8 shows the **minimum achievable vibration (baseline)** with no mass imbalance of the disk. Vibration levels start at 1.11 m/s$^2$-rms with no disk applied to the angle grinder, and increased up to 2.12 m/s$^2$-rms with a 125mm balanced disk. The data shows a **direct correlation between** the **vibration intensity** and **diameter of the disk** being tested. The increasing trend in the vibration level with the disk diameter is attributed to:

- Gyroscopic motion of the rotating disk
- Spindle misalignment
- Slack in the gear meshing

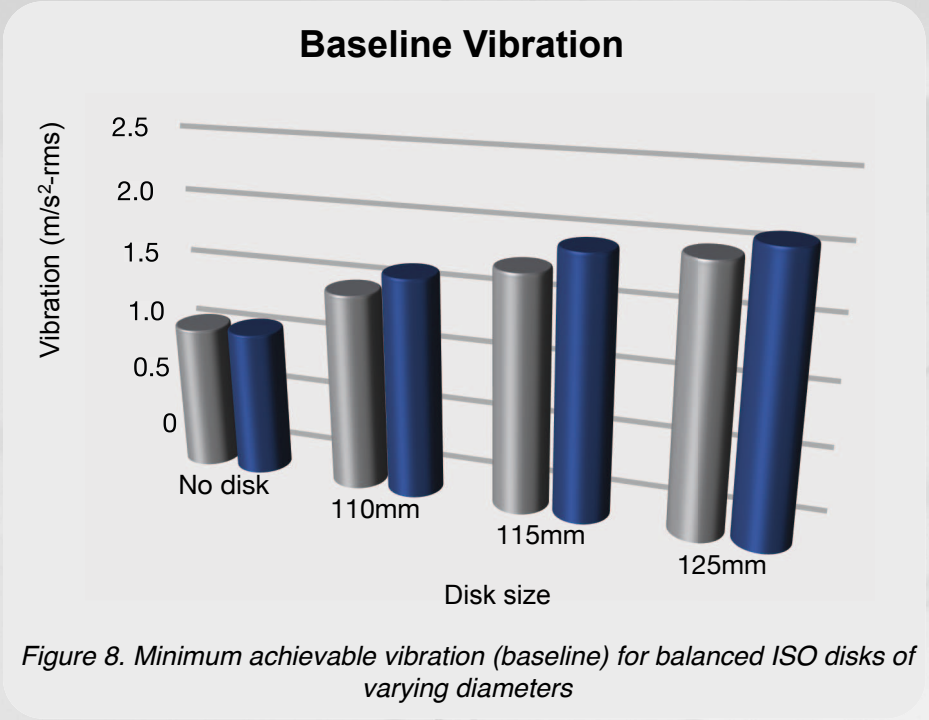



*Figure 8. Minimum achievable vibration (baseline) for balanced ISO disks of varying diameters*

**Note:** The balanced disks used for this test were similar to the ISO disks shown in Figure 5, except they did not have a hole to create a mass imbalance.

## TEST RESULTS (Continued)

### Performance with XYO Balancer

An angle grinder running with prototype XYO balancer was tested against a stock model. The results are shown in Figures 9 and summarized in Table 1.

The prototype XYO balancer facilitates up to a **36%** reduction at the support handle, and a **39%** reduction along the angle grinder body.

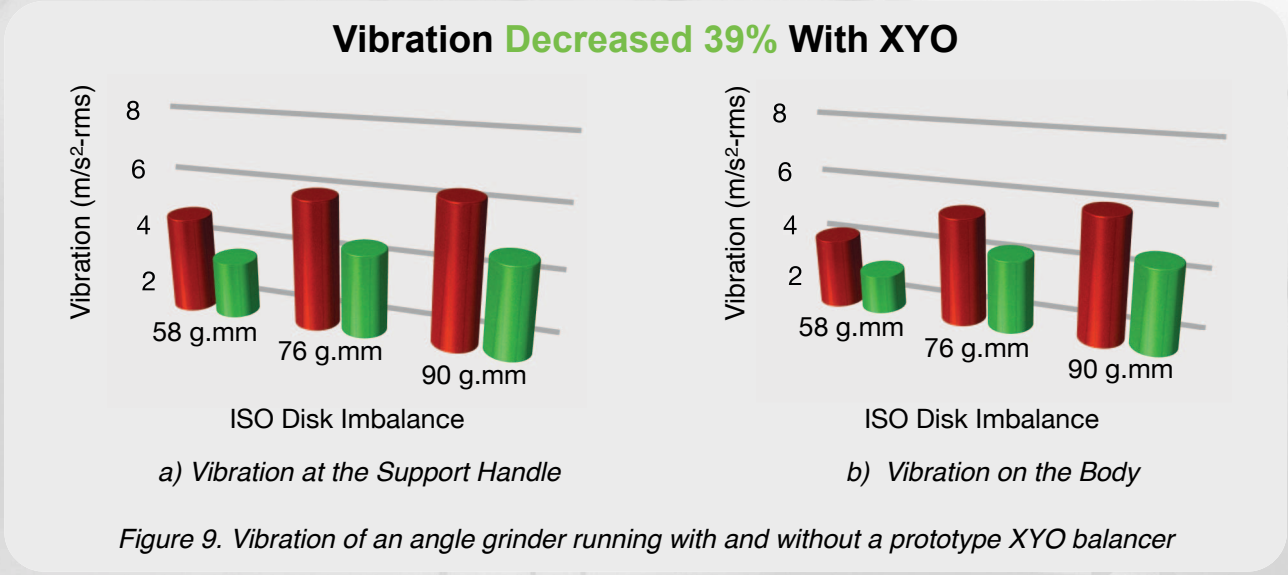



*Figure 9. Vibration of an angle grinder running with and without a prototype XYO balancer*

**Table 1**. Vibration reduction with a prototype XYO balancer; results are compared to the baseline vibration

| LOCATION | VIBRATION (m/s²-rms) | | IMPROVEMENT |
|---|---|---|---|
| | WITHOUT XYO | WITH XYO | |
| Support handle 58 g-mm disk | 4.98 | 3.74 | 36% |
| Support handle 76 g-mm disk | 6.00 | 4.55 | 34% |
| Support handle 90 g-mm disk | 6.37 | 4.8 | 36% |
| Body 58 g-mm disk | 4.28 | 3.26 | 39% |
| Body 76 g-mm disk | 5.51 | 4.36 | 33% |
| Body 90 g-mm disk | 6.05 | 4.7 | 34% |

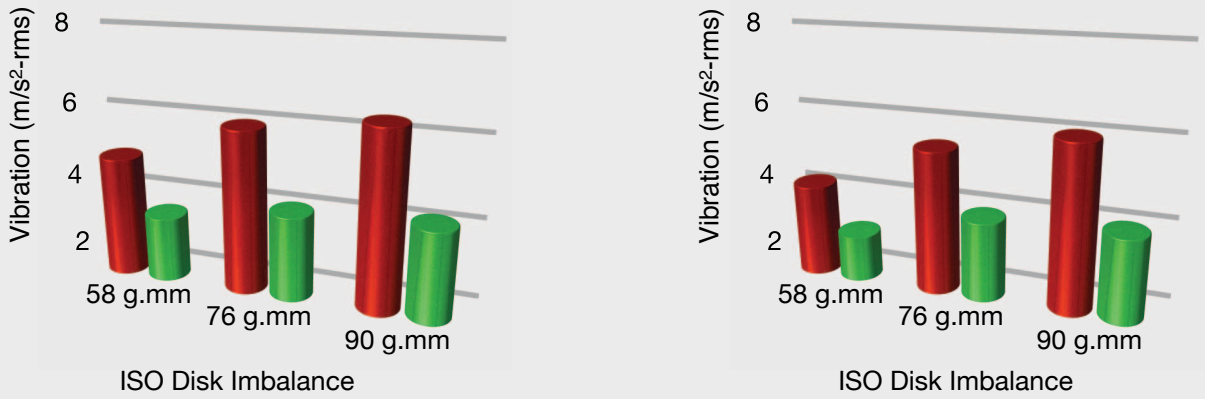
## TEST RESULTS (Continued)

### Performance with an Optimized Disk Speed Profile

Initial testing with the XYO balancer showed improvement in the vibration; however, we wanted to produce a greater reduction to get closer to the baseline values. An optimized speed profile was developed to adjust the disk acceleration. Further testing demonstrated the benefits as shown in Figures 10, and summarized in Table 2.

There is a remarkable improvement in the angle grinder performance with an optimized speed profile; a **49%** reduction was observed at the support handle and a **51%** reduction on the body with the prototype XYO balancer.

**Vibration Decreased 51% with an Optimized Speed Profile**



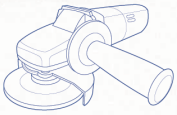

*a) Vibration at the Support Handle* *b) Vibration on the Body*

*Figure 10. Vibration of an angle grinder with an optimized speed profile, running with and without a prototype XYO balancer*

**WITHOUT XYO** **WITH XYO**

**Table 1.** Vibration reduction with a prototype XYO balancer and an optimized disk speed profile; results are compared to the baseline vibration

| LOCATION | VIBRATION (m/s²-rms) | | IMPROVEMENT |
|---|---|---|---|
| | WITHOUT XYO | WITH XYO | |
| Support handle 58 g-mm disk | 4.98 | 3.61 | 39% |
| Support handle 76 g-mm disk | 6.00 | 4.09 | 45% |
| Support handle 90 g-mm disk | 6.37 | 4.22 | 49% |
| Body 58 g-mm disk | 4.28 | 3.14 | 44% |
| Body 76 g-mm disk | 5.51 | 3.95 | 44% |
| Body 90 g-mm disk | 6.05 | 4.05 | 51% |



## FINDINGS AND CONCLUSIONS

The XYO balancer can have a significant impact on vibration of angle grinders. A prototype XYO balancer was tested with the RK4751 angle grinder.

The XYO balancer produced the highest vibration reduction using an optimized speed profile, up to **51%**. This is a significant achievement in the advancement of angle grinder technology; however, analysis of the various tests indicate that the XYO balancer can reduce vibrations much further with the following design enhancements:

- Use an optimized speed profile to increase the XYO balancer performance.
- Improve the spindle alignment with self-aligning bearings.
- Implement an additional XYO balancer for the armature to reduce its vibration as well.
- Incorporate specialized vibration damping materials into the handle and body.

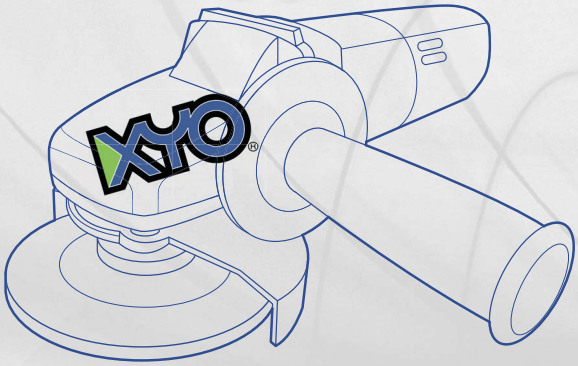
We are confident that the outlined changes coupled with the XYO balancer can have a lasting impact on the future of angle grinder designs. The XYO balancer can provide the following benefits:

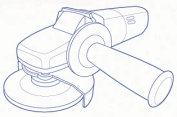
- Reduced risk of vibration-related diseases and ailments.
- Limiting vibration exposure increases the angle grinder's continuous usage periods without causing discomfort to the tool operator.
- Wear life of grinding disks is increased.
- Wear and tear will be mitigated and warranty periods can be extended.
- Smoother operation provides better precision during grinding.

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

### Impact of XYO:

- **Vibration reduced by 51%**
- **Reduce risk of vibration-related diseases**
- **Increased angle grinder usage without causing discomfort**
- **Extended life of angle grinder & disks**







# APPENDIX

## Test Procedure

- The angle grinder was fitted with Kistler accelerometers affixed to the handle and grip as specified in EN 60745. The accelerometers met ISO 5349-1 specifications and were connected to a NI4472 Data Acquisition Card. Proprietary software was used to capture a vibration reading for 10 seconds at 12,500 Hz as per ISO 8041.
- The ISO specified test disks were prepared for use in the testing. These were manufactured with imbalances of 58, 76, and 90 g.mm.
- The imbalance holes in the disks were used as an orientation mark. The imbalance hole was aligned with the orientation mark on the arbour. Each disk was locked to the angle grinder using the stock locking ring.
- A 2 pole bandpass butterworth filter was used as per ISO 8041, and the hand-arm weighting filter was implemented in NI “Sound and Vibration Measurement Suite 6.0”, in compliance with ISO 5349-1.
- The angle grinder was attached to a harness as specified in EN 60745 which was weighted to produce a simulated feed force of 40 newtons.
- Each disk was tested as follows:
  - 3 test runs with the orientation hole in the 0° position relative to the arbour.
  - 3 test runs with the orientation hole in the 72° position relative to the arbour.
  - 3 test runs with the orientation hole in the 144° position relative to the arbour.
  - 3 test runs with the orientation hole in the 216° position relative to the arbour.
  - 3 test runs with the orientation hole in the 288° position relative to the arbour.
- The above testing procedure was performed on each of three ISO test disk.
- Tests were performed using balanced 110, 115 and 125 mm disks running on the angle grinder without the XYO balancer.

## APPENDIX (continued)

### Test harness

- In accordance with ISO 60745, a test harness was constructed to provide 40 Newtons of simulated feed force on the angle grinder during testing.
- The harness consisted of a wire attachment fixed to the angle grinder above the grinding wheel (Figure 10), a cable looped through two pullers, and a free weight that was selected to equal the mass of the grinder, plus sufficient weight to simulate the required feed force.

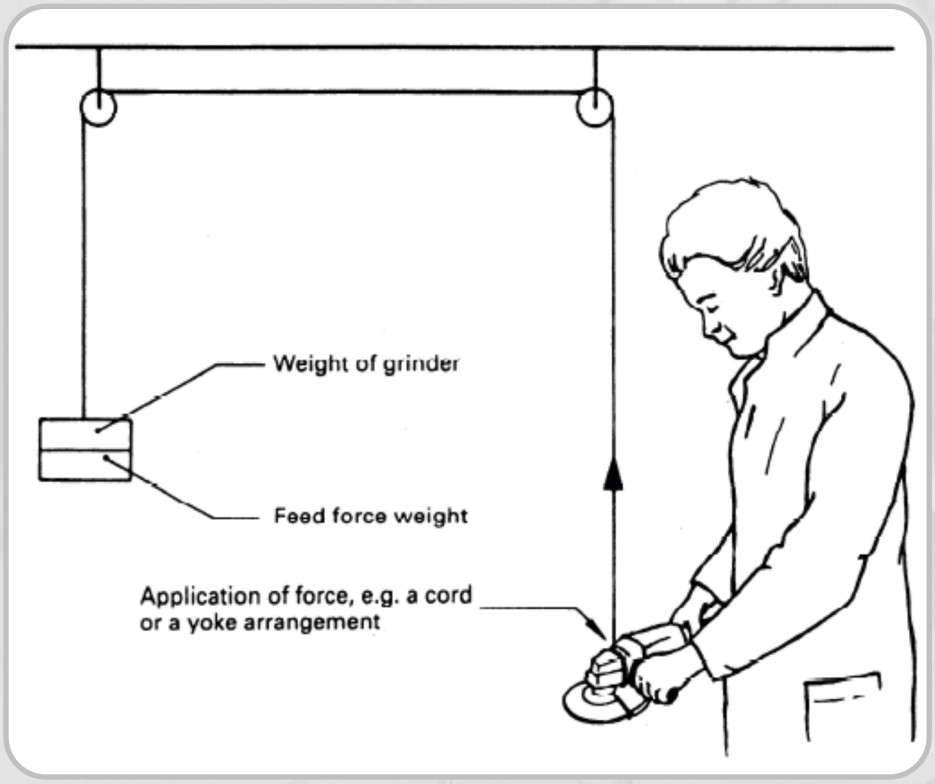



*Figure 10. ISO 60745 test harness schematic*