Innovative Vibration Dissipation Technology for Enhanced Stability in Hot Strip Mills

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INTRODUCTION

In the quest to improve process stability and productivity in hot strip mills and ESP plants in the presence of unwanted vibrations, Primetals Technologies has developed a groundbreaking Vibration Dissipator. This advanced system effectively reduces and eliminates resonance vibrations, stabilizing individual finishing mill stands and enhancing overall process stability.

The Vibration Dissipator leverages two combined physical effects: the classical absorber, which "swallows" resonance vibrations, and an energy dissipating element that broadens the suppressing frequency range. This innovative solution incorporates specially designed hydraulic elements, including a combination of hydraulic capacitive, resistive, and inductive effects, and can be configured as a passive or semi-active energy dissipating hydraulic system. A focus lies as well on an easy retrofittable solution, minimum maintenance requirements and robustness in a harsh industrial environment.

Making allowance for the fact that typical vibration phenomena occurring on a specific stand in hot strip mills vary (e.g. 80Hz – 120Hz), a current enhancement is the development of a semi-active concept with adaptable hydraulic capacity, allowing for real-time adjustment of the Vibration Dissipator's frequency to match changing production conditions. The system includes a sophisticated frequency identification mechanism, utilizing accelerometers and advanced algorithms to detect and adjust to the actual vibration frequency in real-time.

Let us explore the concept and challenges of this technology. Discover how Primetals Technologies is setting new standards in vibration control and process stability and learn how the Vibration Dissipator can transform your rolling mill operations.,

KEYWORDS: VIBRATION DISSIPATOR – resonance vibrations – HOT ROLLING – Suppress vibrations – passive system – Hydraulics

UNDERSTANDING THE CHALLENGE - UNWANTED VIBRATIONS

Unwanted vibrations, particularly when combined with resonance, can occur in various mechanical systems and structures, occasionally with damaging consequences. While not as catastrophic as historical examples like the Tacoma Narrows Bridge collapse (Figure 1), vibrations in rolling mills can still lead to equipment damage, reduced component lifespan, and compromised product quality.

Figure 1 - historic failure of the Tacoma Narrows bridge due to resonance

These vibrations may be externally or self-excited. While externally excited vibrations can often be traced and mitigated, self-excited or parameter-excited vibrations - such as resonance - are inherent to the system and difficult to predict. Many mill operators are familiar with the challenge of "living with" these vibrations.

High rolling speeds and significant thickness reductions are common triggers. For example, stand number 2 or 3 in hot rolling mills may experience resonance vibrations around 100 Hz. These can imprint chatter marks on the work rolls, degrading surface quality and disqualifying the strip from high-value applications like cold strip substitution. Additionally, vibrations increase mechanical stress, reducing equipment lifespan.

To address these issues, Primetals Technologies developed the **Vibration Dissipator**, a device capable of suppressing or eliminating resonance vibrations -improving product quality, throughput, process stability, and equipment longevity.

THE CONCEPT

A Dissipator That "Swallows" the Vibration Energy

The Vibration Dissipator is based on two synergistic effects:

1. A **classical absorber** that introduces a secondary vibratory system to counteract the primary resonance.
2. An **energy-dissipating element** that broadens the effective damping frequency range.

The concept is similar to a **mass-tuned damper**, where a secondary system is added to shift and suppress resonance peaks (see Figure 2). This naturally creates a second frequency, but both frequencies are apart from the original resonance frequency. If you add damping to the system, both peaks come down and you get a good suppression of the resonances in a broader frequency range (orange curve in Figure 2).

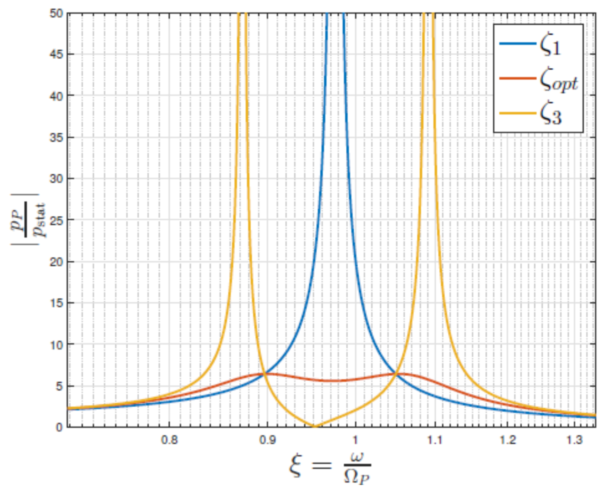

Figure 2 – Vibration Dissipator with optimized damping (red)

Traditionally realized with mechanical springs and masses, this principle is replicated here using hydraulic analogs (Figure 3) - compact and effective in the 50 – 250 Hz range.

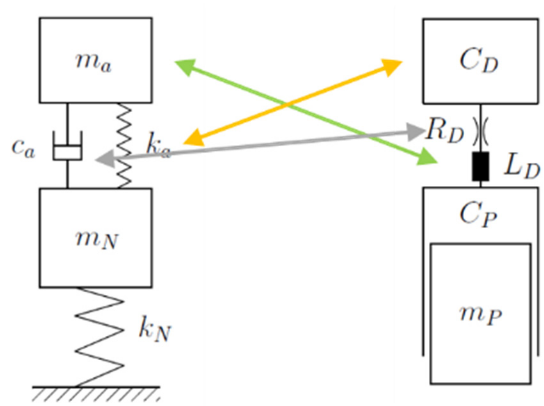

Figure 3 - Equivalence of mechanical and hydraulic elements

The system is integrated directly into the hydraulic gap control (HGC) cylinder, where roll vibrations cause piston oscillations. The resulting pressure fluctuations are absorbed by the Vibration Dissipator, reducing roll stack oscillations.

As indicated above the solution consists of specially designed hydraulic elements, such as a combination of

- Hydraulic capacitance (CD) – a defined fluid volume
- Hydraulic resistance (RD) – an adjustable throttle valve
- Hydraulic inductance (LD) – a pipe segment

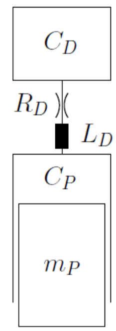

Figure 4 - Basic concept of the Vibration Dissipator

Its name "vibration dissipator" derives from the physical interpretation of the effect. If the frequency meets the designed frequency of the dissipator, the volume takes over the pressure oscillations of the HGC - it "swallows" them while the mass stops vibrating.

ADVANCED DEVELOPMENT

Adjustable Hydraulic Volume
With the varying parameters of a mill stand, the resonance can vary significantly over the time. Below you find the evaluation of the occurring resonance during the period of several weeks (see Figure 5).

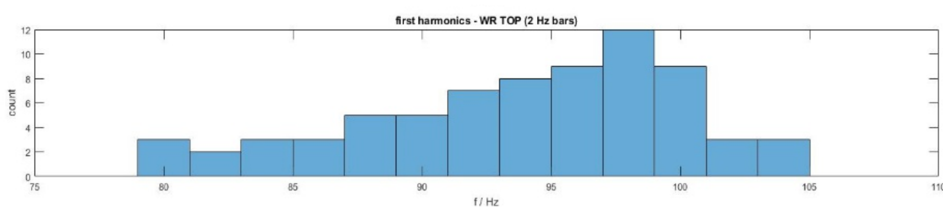

Figure 5 - Frequency distribution of the resonances of the stand of an ESP line during several weeks

Because resonance frequencies vary over time, the next-generation Vibration Dissipator features an **adjustable hydraulic volume** (see Figure 7). This allows the system to dynamically tune its frequency response (**Error! Reference source not found.**-6).

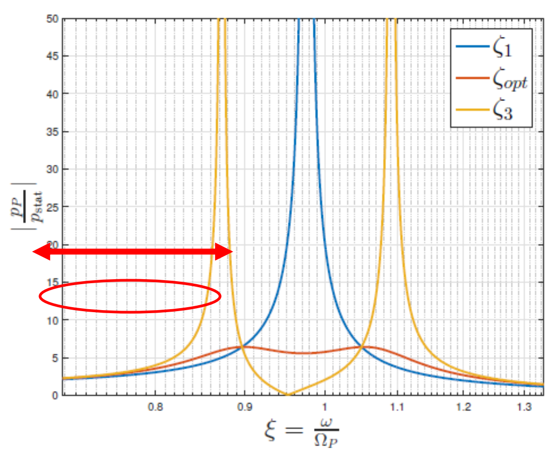

Figure 6 - Adjustable frequency

A movable piston adjusts the internal volume. A spring-loaded wedge mechanism clamps the piston in place; when adjustment is needed, hydraulic pressure releases the clamp, allowing the piston to move and set a new volume. This enables **fast, precise tuning** to match current vibration conditions.

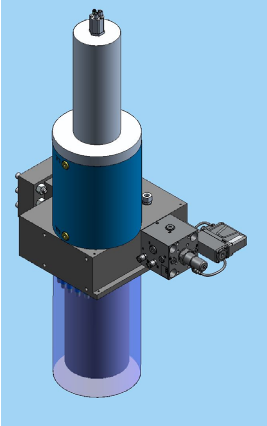

Figure 7 - Dissipator with adjustable volume

An integrated **frequency identification system**—already proven in other Primetals Technologies' solutions—uses accelerometers and algorithms to detect the current vibration frequency and guide system adjustment.

TECHNICAL REALIZATION

The First Industrial Prototype

The initial prototype, though lacking automatic adjustment, incorporated all core hydraulic elements in a compact valve block easily mounted to an HGC cylinder (Figure 8). The hydraulic resistance is adjustable, allowing fine-tuning of the damping effect.

Laboratory tests and a pilot installation on an Arvedi ESP line confirmed the system's effectiveness.

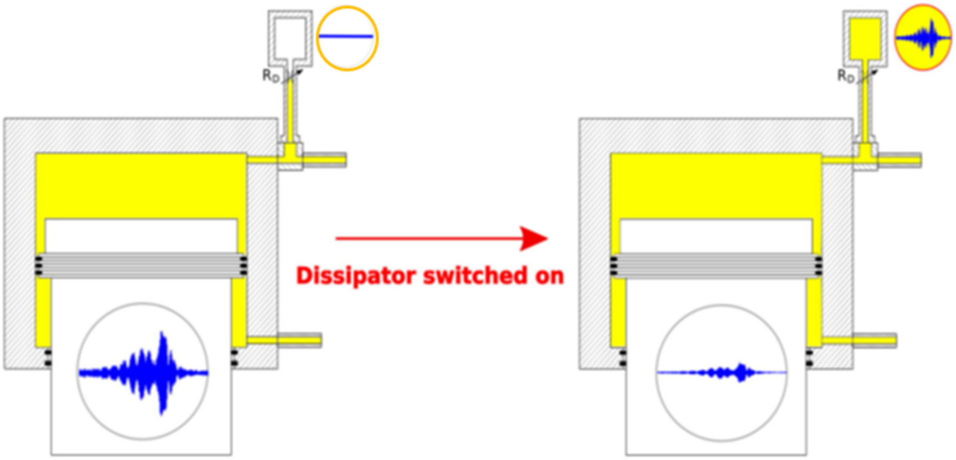

Figure 8 - Technical concept

The dissipator operates independently of the gauge control system, which functions at significantly lower frequencies, ensuring no interference with strip thickness control.

The system can also be easily **deactivated** by closing the hydraulic resistance valve, offering operational flexibility.

Laboratory Tests

A scaled prototype was first tested at Johannes Kepler University in Linz, simulating piston oscillations. Encouraged by the results, a full-scale prototype was built.

With the perspective to even use it in a test installation in a mill (having a resonance frequency of around 95 Hz) the prototype was designed to suppress vibrations around this center frequency.

For the next stage of tests, we mounted the Vibration Dissipator onto a normal test cylinder. This test cylinder had a defined diameter, position of the piston and a defined mass, which was additionally attached to the piston, to achieve a resonance frequency of approx. 95 Hz. With an external valve, we excited this resonance frequency and tried to suppress the occurring vibration with the Vibration Dissipator.

For clear results, a test setup was chosen, where a sine wave frequency sweep signal was sent to the external valve, (from 60 Hz to 140 Hz).

In Figure 9, the red plot shows the pressure in the cylinder piston, with a deactivated Vibration Dissipator. It is clearly visible that the system has its first resonance frequency at around 95 Hz. The green plot shows the pressure in the cylinder piston, where the Vibration Dissipator is active. Around the desired design frequency of the Vibration Dissipator, the resonance amplitudes are excellently. Moreover, there is a significant reduction of the amplitudes over the whole frequency range.

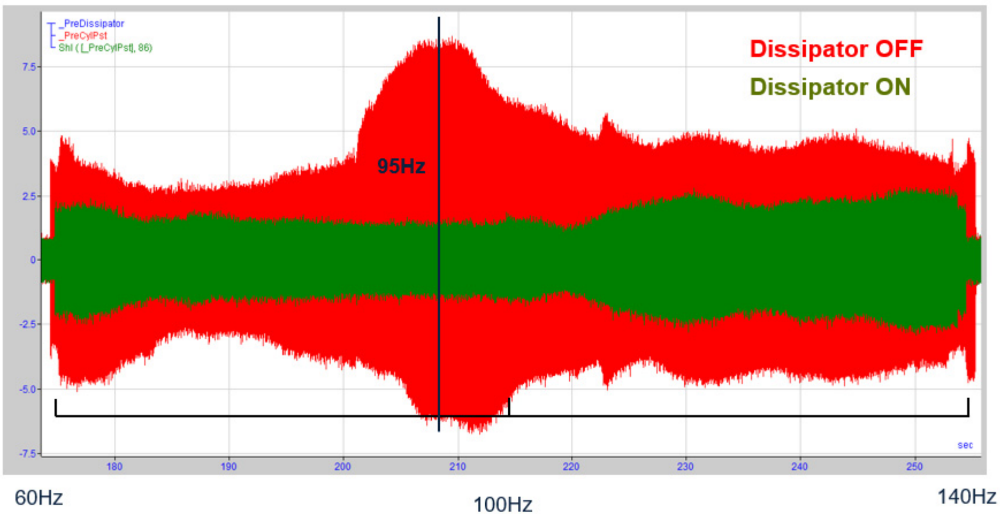

Figure 9 - Successful lab tests of the prototype

Test Installation on a Mill Stand

Figure 10 - Test installation on a mill stand

The third stage of tests comprised the test installation on an industrial rolling mill stand (Figure 10). After activation of the Vibration Dissipator the effect was clearly recognizable, because of major reduction of vibrations were well audible.

The following figure (Figure 11) shows that the reduction of the resonance vibrations is visible in the force signal of the roll force cylinder too. The blue signal displays if the Vibration Dissipator was activated (high level) or deactivated (low level). Right after activation, the amplitude of the roll force fluctuation (red) signal drops immediately. Several times of activating and deactivating the Vibration Dissipator shows a reproducible effect of suppressing the roll force fluctuation.

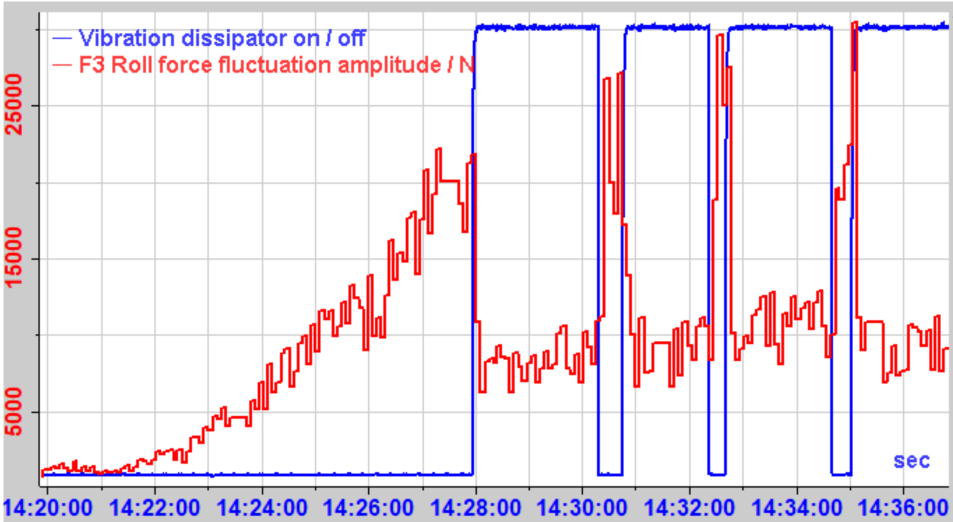

Figure 11 - Reduction of vibration level in roll force
(red line: roll force fluctuation level
blue line: dissipator active/deactivated)

CONCLUSION AND OUTLOOK

The Vibration Dissipator has proven to be an effective solution for both new and existing hot rolling mills. It can be installed during standard maintenance intervals with minimal modifications. Its independence from existing control systems ensures compatibility, and its modular design allows for tailored integration.

The next-generation Dissipator includes:

- Adjustable hydraulic volume
- Automatic frequency identification and tuning
- Compact automation unit with integrated algorithms and HMI

This innovation sets a new benchmark in vibration control—enhancing product quality, equipment longevity, and process stability in hot rolling operations.