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Predictive Maintenance at Automatic Storage Retrieval Machines (ASRS) with Vibration Sensors

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The article describes how vibrations on storage and retrieval machines can be measured. An experimental investigation in the laboratory is shown. Furthermore, measurements in industrial practice are discussed.

Der Artikel beschreibt, wie Schwingungen an Regalbediengeräten gemessen werden können. Es wird eine experimentelle Untersuchung im Labor gezeigt. Weiterhin wird auf Messungen in der industriellen Praxis eingegangen.

[Keywords: Predictive Maintenance, Condition Monitoring, Vibration Analysis, Intralogistik, Automatic Storage Retrieval Machines (ASRS)]

1 Introduction

An intelligent factory needs intelligent maintenance. Research is being conducted worldwide on this topic. For Example [GAM16]; [HHL15].To date, none of these research findings has found its way into practice. Reasons are usually in dealing with investments. In many cases, investments are made in production as a source of value added and not in maintenance as a cause of costs.

In order to make the intelligent factory a reality, investments in maintenance must be made. Because maintenance is an essential part of every factory [Ban14].

Ideally, a system such as ASRS operates 24 hours a day, 365 days a year, without interruption and without breakdown. To achieve this goal, the state of the art is time-based maintenance.

A new approach in Industry 4.0 is predictive maintenance. Wear on the system can be quantified and predicted. On the one hand, machine data (like power consumption, actual speed etc.) are evaluated and, on the other hand, data that is supplied by various sensors is used (see *[Kle08, S. 11])*.

In some areas of industry this procedure is already state of the art (compare Predictive Maintenance, [UW99], [OPO14], [HQW16]; [BSM18]; [BBS16]; [DMG17]; [HJ16]; [PMD16]; [AKH18]; [CBA17]). Only a few prototypes are known for in-plant logistics systems. Especially in the case of ASRS, the traversing movements increase the complexity of the measurements and evaluations, although the highest availability of the devices is demanded by the operators.

2 Experimental Investigations

The aim is, similar to the turbine or ball bearing, to determine the condition of an ASRS by means of vibration monitoring and to predict wear. Vibration analysis have already been used in other industry (for example [Alm16]; [BB18]; [BS16]; [Bou]; [CLD15]; [FZW17]; [GBS17]; [HM16]; [Lab17]; [INM17] and [DIN13, S. 8]. Initial experiments show that certain types of wear, such as e.g. brake plates are detectable. For this purpose, the author team has carried out measurements on ASRS.

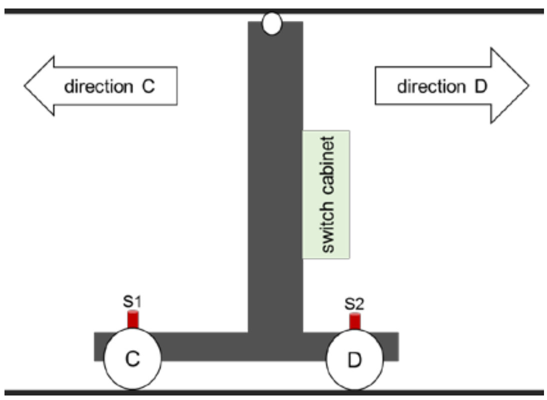

Figure 1.: *Schematic structure of an ASRS and placement of the sensors*

An unevenness on the wheel or the rail creates a shock. This vibrates the entire system. These vibrations can be measured with an acceleration sensor. For vibration monitoring capacitive acceleration sensors have been used. The application of the sensors is shown in Figure 1.

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3 RESULTS OF THE EXPERIMENTS

3.1 TAPE ON WHEEL

To detect an imbalance comparable to brake plates (see [WBD, S. 54]) adhesive tape has been applied to the wheel of an ASRS. Figure 2 shows the data from the sensors on wheels C and D.

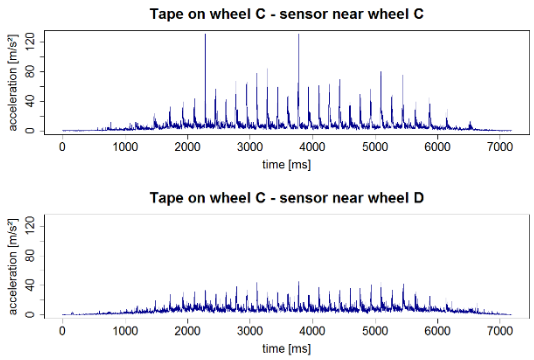

Figure 2.: *Sensor Data tape on wheel a) wheel C b) wheel D*

The extreme amplitudes in the acceleration (peaks) result from the imbalance caused by a 0.3 mm thick and 19 mm wide adhesive tape. The adhesive tape has been applied in these measurements across the direction of travel of the wheel (see Figure 3).

Figure 3.: *Photography wheel with tape on wheel C*

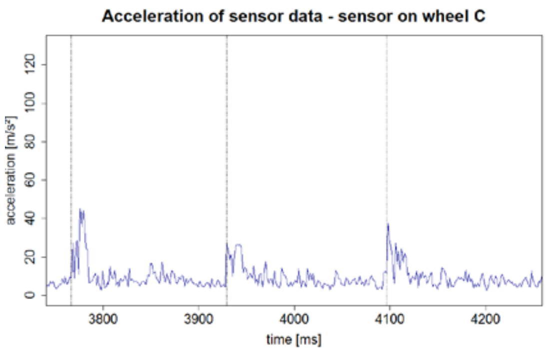

Figure 4.: *Acceleration of sensor data over 3 wheel rotations Sensor on wheel C*

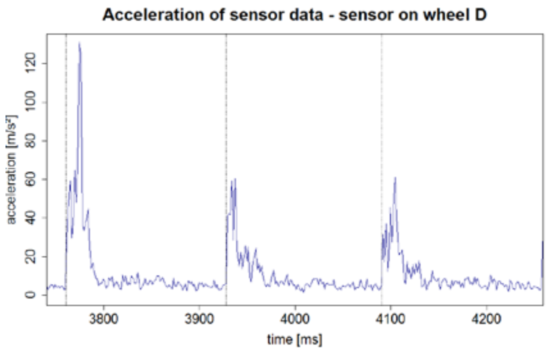

Figure 5.: *Acceleration of the sensor data over 3 wheel rotations Sensor on the wheel D*

In Figure 4 and Figure 5, a period of t = 184 ms can be read between the high amplitudes. Given a wheel diameter of d = 200 mm and a speed of v = 3.4 m/s, the period duration can be confirmed with Formula 1.

$$t = \frac{s}{v} = \frac{\pi \cdot d}{v} \quad (1)$$

Formula 1: Duration of a wheel revolution

The theoretical value is t = 184.7 ms. By contrast, no high amplitudes could be measured during a homing run without applied adhesive tape. This indicates the suitability of the sensors for measuring imbalances.

The amplitudes are in the range between a = 30 m/s² and a = 130 m/s². The shocks between the high amplitudes are 1/8 of this size. This is the normal vibration caused by the dynamic movement.

The shock transmitted damped by the chassis. The reason for this is the attenuation of the ASRS. Therefore, the peaks in Figure 2 b are smaller than in Figure 2 a.

3.2 UNEVENNESS ON RAIL

In another experiment, the tape has been applied at three locations on the ASRS rail. The distance between the stripes is purely random.

Figure 6 shows a journey towards direction D. Wheel D (Figure 6 b) passes over an adhesive strip first and then the wheel C (Figure 6 a) rolls over the adhesive strip.

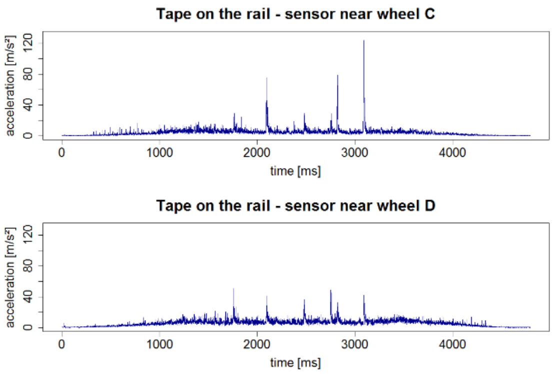

Figure 6.: *Sensor data tape on rail a) Wheel C b) Wheel D*

Driving over the adhesive tape causes a shock to the ASRS. These oscillations thus generated are transferred to the overall system of the ASRS and are measurable. The first high amplitude is a = 50 m/s², measured on the wheel D. Almost at the same time, a high amplitude can be seen on the wheel C at a = 30 m/s².

At the second high amplitude, the wheel C passes over the tape, it is a shock of a = 75 m/s² measured. At wheel D an impact of a = 40 m/s² is detected at the same time. The comparison of the two sensor data shows that the shocks are also registered by the other sensor.

No statement can be made about the exact heights of the amplitudes at the moment. For this further investigations are necessary.

4 MEASUREMENT IN THE INDUSTRIAL PRACTICE

The typical maintenance work on storage and retrieval machines include

- changing the wheels and
- grinding of the rails

at specified times by the manufacturers. The aim of this recommended maintenance job is to make sure the equipment runs smoothly. In most cases, the rails are subject of higher loads at the points of entry and removal due to the more frequent braking and acceleration processes and are therefore subject to greater wear.

In several experiments, different devices were equipped with the acceleration sensors and measurements were taken directly before and after one of the above-mentioned maintenance work. The measurements were carried out on ASRS with steel wheels for the transport of pallets as well as on small load carriers with plastic wheels. (The measured values have been recorded during reference runs.) The positions of the vibration sensors are identical to those of the laboratory tests.

The measurement results with the acceleration sensors in practice are shown in Figure 7. Measurements before maintenance show regular irregularities (see Figure 7 a).

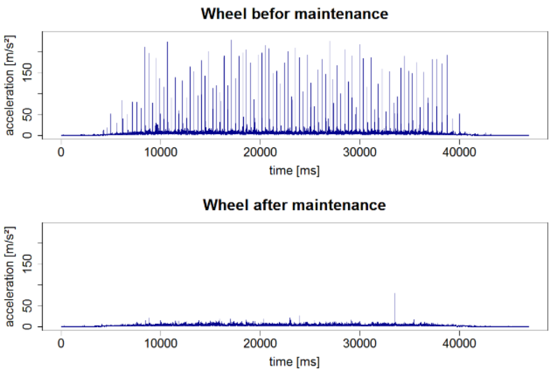

Figure 7.: *Reference run of an ASRS a) before maintenance b) after maintenance*

The distances of the peaks correspond, taking into account the speed, one-wheel revolution (see also formula 1).

The peaks are no longer measurable after the wheel change. On average, the amplitudes of the vibrations have become lower over the test drive. So the mean value for the duration (Duration over 6 runs) of one wheel rotation before the wheel change is a = 4.94 m/s² and after the wheel change is a = 2.91 m/s².

Figure 8 shows the drive of a small load carrier ASRS with plastic wheels. This has many unregularly high amplitudes. The detailed evaluation of the ride shows that the amplitudes show a repeating pattern. Looking at the replaced wheels, several brake plates have been tracked on the wheel. Even with these measurements, the amplitudes of the vibrations have become smaller on average after the wheel change. The mean values have dropped from a = 1.98 m/s² to a = 1.73 m/s².

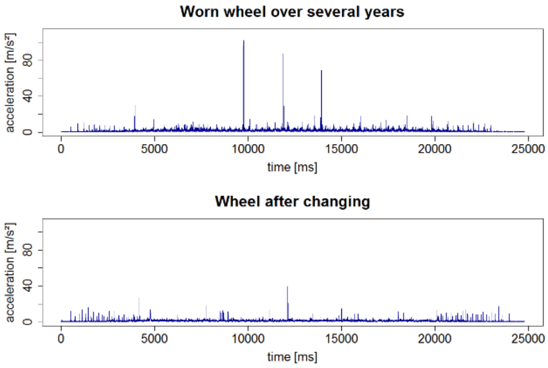

Figure 8.: *Homing ASRS a) before maintenance b) after maintenance*

5 Conclusion

The results from the laboratory and practical examinations show that imbalance or damage to rails and wheels can be measured. This provides the basis for further research. Currently, further measurements with different wear scenarios and further evaluations are carried out by means of mathematical statistical methods. The goal is to predict the timing of required maintenance as accurately as possible. In the context of Industry 4.0, in the future, conveyors should be able to independently indicate that their wear limits have been exceeded or to request appropriate maintenance measures.

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