MEASUREMENT OF GUIDEWAY ALIGNMENT OF AN ON-SITE GRINDING MACHINE

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ABSTRACT

The largest of the drying cylinders in paper machines are the Yankee cylinders with typical length of 4...6 m and diameter of 3...6 m. The Yankee cylinders are typically used in soft tissue machines. Because of the size and weight of the cylinders it is not always possible to dismantle them for regrinding. The cylinders are heated from inside with pressurized steam. Typical surface temperatures are 100...200 °C. This means that the operating environment during the grinding process is hot and moist. The guideway of the grinder must be aligned with the cylinder surface. Alignment with a thin steel wire is commonly used method for guideway alignment in machine tools. An alignment accuracy of 0.01 mm is easily achieved when combined with optical readers (microscope, optical micrometer, etc.). If an optical micrometer is used, it must be fastened to the carriage moving on the guideway. The measurement direction of the micrometer must be perpendicular to moving direction of the carriage. The alignment error can be seen in the measured displacement of the wire. Typically an optical micrometer has an accuracy of 2 µm. Normally the wire alignment can be used only for horizontal guideways. If the guideway is tilted, then sag of the wire will produce an error in the alignment measurement. The sag of the wire can be calculated with the catenary equation. The sag can be reduced by using thin (light) wires and high tensile force. Also the wire length must be kept at its minimum. This paper discusses some of the aspects of the alignment of the guideway of on-site grinding machines with a thin steel wire.

Index Terms – Roll grinding, on-site, straightness, alignment, optical micrometer

1. INTRODUCTION

The regrinding of large paper machine cylinders is a challenging task. The body length of a drying cylinder in a drying section is typically 5 to 11 m and the diameter is 1 to 2 m. The largest of the drying cylinders is a Yankee cylinder with a typical length of 4 to 6 m and 3 to 6 m diameter. The Yankee cylinders are used in soft tissue machines, in board machines and for MG paper machines [1]. Because of the size and weight of the cylinders it is not always possible to dismantle them for maintenance purposes. This is especially true for the Yankee cylinders. Normal maintenance of the cylinders includes periodical regrinding of the cylinder surface. Together with the coating of the cylinder the regrinding is the most time consuming maintenance action. The down time of the paper machine can be reduced if the grinding can be performed on-site with the cylinder still in the machine. This paper discusses some aspects of the alignment of the guideway of on-site grinding machines and the calculation of the measurement uncertainty. The desired accuracy for the alignment system is ±0.010 mm.

This paper is a part of a larger research project. The aim of the project is to develop an on-site grinding machine for different rolls and different cylinders, but mainly for the Yankee dryer cylinders. The Yankee cylinder is a part of a Yankee dryer (Fig. 1) used for making tissue paper, board or MG paper. The main task is to dry the paper web and for tissue papers it has a doctor blade (also known as crepe blade). The blade is used for creping the paper web. This produces a soft paper needed as toilet or other tissue papers. The drying is done with hot air (< 500 °C) blown from the dryer hood on to the paper web. The cylinder is also heated from inside with pressurized steam. Typical surface temperatures are from 100 to 200 °C. This means that the operating environment in and around the dryer is hot and moist.

2. MATERIALS AND METHODS

The regrinding of the Yankee cylinder is preferable done in the dryer. If the cylinder is also recoated, this is also done in the dryer. Only small sized cylinders can be removed from the machine for the maintenance. If the cylinder is ground in the dryer, the grinder must be installable next to the cylinder. The guideway of the grinder must be aligned precisely with the cylinder surface. This is not necessary if the alignment error is small and can be measured and corrected in the control system of the grinder. In practice both methods are used, because the correction of the alignment error is more efficient if the guideway is well aligned. In the dryer the alignment is hardly ever as good as in a grinder in the workshop.

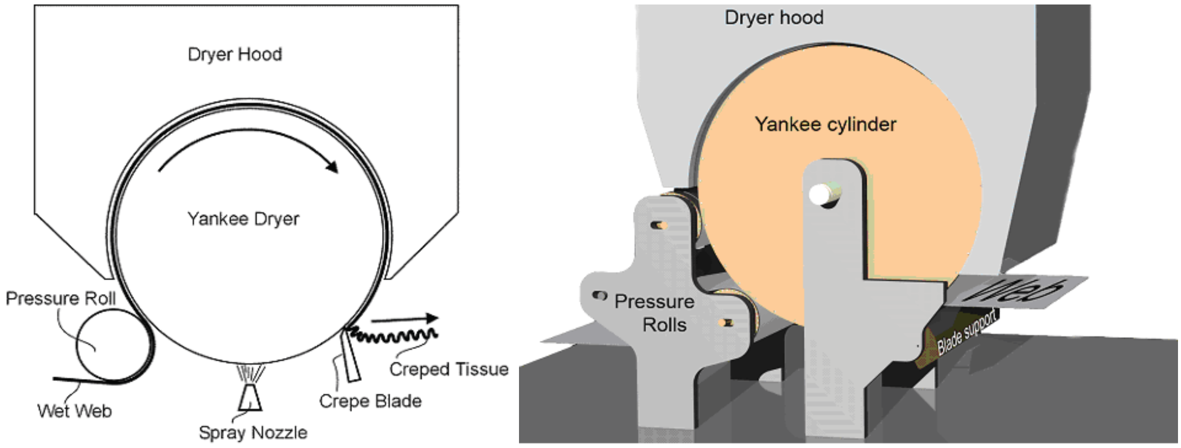

Fig. 1. Yankee cylinder arrangements. Left side: one pressure roll [2], right side: two pressure rolls.

Because of the dryer hood, the surface of the Yankee cylinder is in the most cases accessible only from below (Fig. 1). There are two choices to how to place the on-site grinder. First is from the pressure roll side. This normally requires the removal of the pressure roll or rolls. The support of the rolls can be used as the support of the grinder. The second location is the crepe blade side. Here the blade support can be used as the grinder support. In both cases the grinding is performed from below the roll (Fig. 2.).

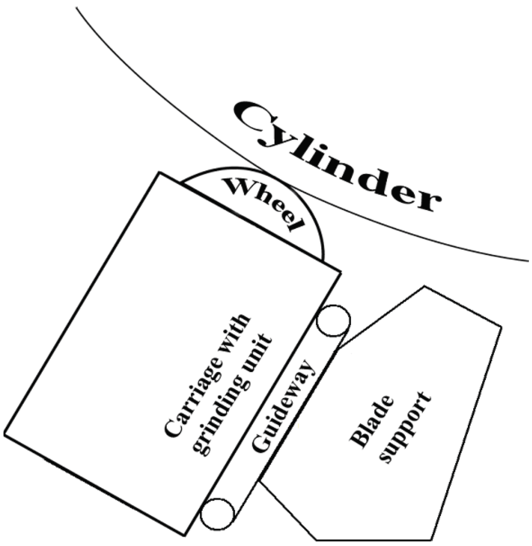

Fig. 2. Arrangement for the on-site grinding.

To choose a suitable alignment system for the grinder guideway several possibilities were studied. One possibility for the alignment system was laser alignment which is based on straightness of reference laser beam.

These laser equipments have been used for guideway alignment for a long time and there are several commercial devices available on the market. In this case the diffraction of the laser beam caused by the hot and moist air in the operating environment produced a random error in the alignment measurement. Usually the maintenance of the cylinder must be done quickly so that the cylinder has no time to cool off. Also in discussions with the representatives of the manufacturers of laser alignment devices it became clear that this type laser devices are not usable in the operating environment of the dryer. After testing, the wire alignment system was chosen mainly because its insensitivity to the harsh environment.

2.1. Wire alignment

The wire alignment is a commonly used alignment method, where the alignment of the guideway is compared with a thin steel wire. The method is used for the guideway alignment in machine tools. It can be a high accurate method when combined with optical readers (microscope, optical micrometer, etc.). An alignment accuracy of 0.01 mm is easily achieved. If an optical micrometer is used, it must be fastened to the carriage moving on the guideway. The measurement direction of the micrometer must be perpendicular to moving direction of the carriage. The alignment error can be seen in the measured displacement of the wire. Typically, an optical micrometer (Fig. 3) has an accuracy of ±2 μm [3].

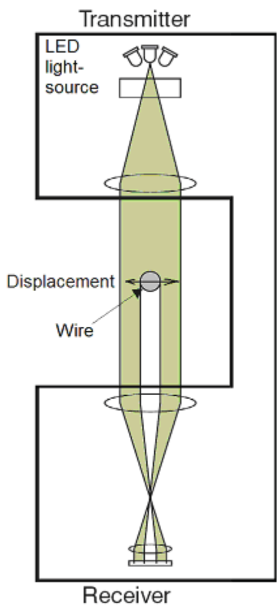

Fig. 3. The working principle of the optical micrometer [3].

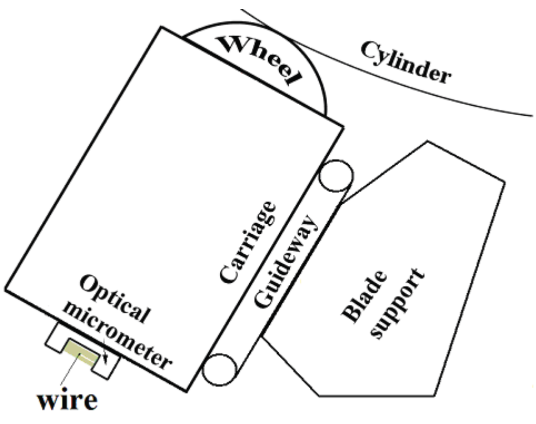

Fig. 4. The measurement of the wire displacement for the guideway alignment with an optical micrometer.

Normally the wire alignment is used only for horizontal guideways. If the guideway is tilted like, in Fig. 2 and Fig. 4, then the sag of the wire will produce an error in the alignment measurement. The sag (Fig. 5) can be reduced by using thin wires (lightweight) and high tensile force. Also the wire length should be kept at its minimum to reduce the undesired sag. Under gravity, small sag will always be present. The error produced by the sag in the alignment measurement can be compensated if the magnitude of the sag is known. Also the tilt angle and the position of the carriage in CD direction (longitudinal direction of cylinder), must be measurable.

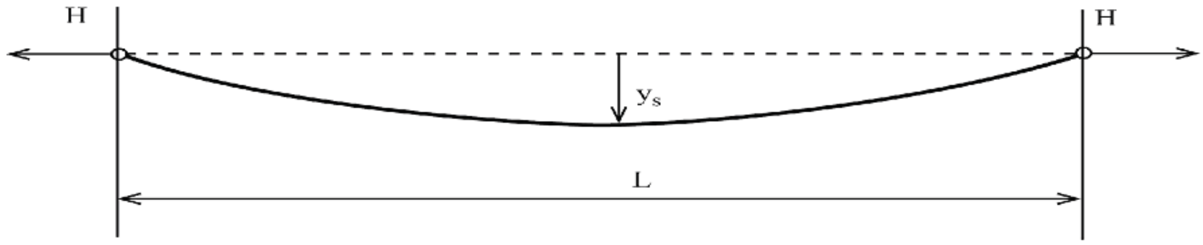

Fig. 5. The sag of the span is denoted with y_s.

The sag of the wire can be calculated with the catenary equation:

$$y(z) = -\frac{H}{mg}\left[\cosh\left(\frac{mgL}{2H}\right) - \cosh\frac{mg}{H}\left(\frac{L}{2} - z\right)\right], \tag{1}$$

Or, if the span of the wire is not large, as an approximation:

$$y(z) = \frac{mg(Lz - z^2)}{2H}, \tag{2}$$

Where m is mass of the wire per meter (kg/m),
g is gravitational acceleration,
L is the length of the wire between supports,
z is the position along the wire,
H is the tensile force and
y is the sag.

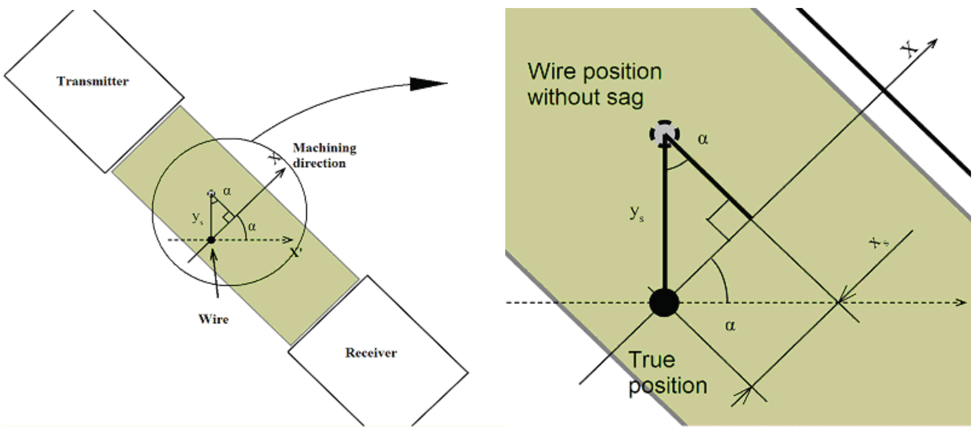

Fig. 6. α is the tilt angle of the guideway and y_s is the sag.

The error caused by the sag in the alignment measurement is shown in Fig. 6. The magnitude of the error depends on the tilt angle and the measurement position along the wire and its formula is:

$$a_{err}(\alpha, z) = y(z)\cdot\sin(\alpha) = \frac{mg(Lz - z^2)}{2H}\cdot\sin(\alpha), \tag{3}$$

Where α is the tilt angle of the guideway. From the formula can be seen that the effect of the sag increases with the tilt angle as expected.

2.2. Expanded uncertainty of the measurement system

All the uncertainties are calculated according to the Guide to the expression of uncertainty in measurement GUM. The principle is originally presented in GUM:1995. The Joint Committee for Guidance in Metrology later published a revised version [4]. Evaluation of standard uncertainty requires a classification of input estimates to either Type A or Type B method of evaluation. The Type A evaluation is the method of evaluating the uncertainty by the statistical analysis of a series of observations. Type B uncertainty, which is typically received from a calibration certificate, a manufacturer's specification or a handbook, states the expanded uncertainty of measurement U. The uncertainties presented in the results are of Type B and the coverage factor k is 2. This gives a coverage probability of 95 %. The expanded uncertainties were calculated with GUM Workbench software [5].

3. RESULTS

The calculated expanded uncertainty of the derived sag compensation formula 3 is shown and discussed here. Also the individual components of the formula are discussed here: magnitude of the tensile force (H), the position along the wire (z), the tilt angle (α) of the guideway, the mass of the wire per length (m) and the length of the wire (L). The expanded uncertainty values are calculated for a typical Yankee cylinder size. The wire length is 6 m, the wire thickness is 0.3 mm and the tensile force is 75 N (corresponds to a weight of ~7.5 kg). The tilt angle of the guideway is set to 60° which is considered to be an average tilt angle. Uncertainty values are calculated for the middle of the wire (z = 3.0 m) and for the end areas of the wire (z = 0.1 m).

Table 1. Minimum accuracy requirement, (*L*=6 m, *α*=60°, *H*=75 N) if 0.010 mm accuracy is needed.

Component	Measurement accuracy
Tensile force (H)	1.0 N (~0.1 kg)
Position error in direction of the movement (z)	1.0 mm
Tilt angle (α)	1.0°
Mass of the wire/m (m)	0.010 g
Length of the wire (L)	50 mm
Expanded uncertainty (U) in the end, z = 0.1 m	±0.6 µm
Expanded uncertainty (U) in the middle, z = 3.0 m	±9.7 µm

Table 1 shows the minimum requirements for the accuracy of the individual components. None of these values are difficult to achieve. If the tilt angle decreases, then the sensitivity of the uncertainty to angle errors increases, but the total uncertainty decreases and vice versa. The maximum uncertainty is at α = 90° (U = ±11 µm) and the minimum is at α = 0° (U = ±6.6 µm) in the middle of the wire. Compared with these values the uncertainties in the end areas of the wire are negligible. Table 2 shows the sensitivity of the uncertainty to individual components, tilt angle (α) and position along the wire (z).

Table 2. Different accuracy ranges and the sensitivity of the expanded uncertainty to the individual components.

Component / accuracy range	α = 0°		α = 60°		α = 90°	
	z = 0.1 m	z = 3.0 m	z = 0.1 m	z = 3,0 m	z = 0,1 m	z = 3,0 m
Tensile force (H)	0.0 %	0.0 %	22.9 %	20.1 %	26.3 %	22.7 %
Position error (z)	0.0 %	0.0 %	12.4 %	0.0 %	14.3 %	0.0 %
Tilt angle (α)	100.0 %	100.0 %	13.1 %	11.5 %	0.0 %	0.0 %
Mass of the wire/m	0.0 %	0.0 %	41.8 %	36.6 %	48.1 %	41.4 %
Length of the wire (L)	0.0 %	0.0 %	9.2 %	31.4 %	10.6 %	35.4 %
Expanded uncertainty (U)	0.4 µm	6.6 µm	0.6 µm	9.7 µm	0.6 µm	11 µm

4. CONCLUSIONS

The tensile force and mass of the wire are the only true uncertainty sources in the formula as Table 2 shows. The values in the Table 1 and Table 2 show also that the calculation of the correction for the wire alignment is insensitive to measurement errors during operation, i.e. to position and angle measurement errors. This means that if the alignment measurement value can be calibrated, then the accuracy of the actual measurement can be maintained if the wire and the tensile force are not changed. The results show that the compensation of the sag of the wire is possible and a guideway alignment accuracy of ±0.010 mm can be achieved at almost any tilting angle of the guideway, if the accuracy of the optical micrometer is ±2 μm or better.

5. REFERENCES

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