Measurement Accuracy and Calibration of the Quantum Neo X-ray System

Cerulean, Milton Keynes, UK

Introduction

Tobacco heating products (THP) constructions are becoming increasingly complex and tools used for quality assurance of these products are not yet readily available.

X-ray systems have been used in laboratory situations to assist in product development but have suffered from the complexity of the systems being used and the high capital outlay. Translating such capability to a routine quality assurance tool that can be sited close to a combiner and form part of the routing quality check of production is a complex engineering challenge.

A system has been devised that can be fitted into an existing physical test station – the Cerulean Quantum Neo – and used to routinely measure segment length and diameters. Part of the challenge to make this a routinely useable system is the necessity to offer a simple method of calibration.

Quantum Neo x-ray shelf

The design of the shelf is fully integrated into the hardware and software of the Quantum Neo product. The system consists of a fully shielded enclosed system with fail safe interlocks that prevent the operator being exposed to any harmful x-rays in use or even when calibrating or servicing.

The shelf – designated Q – deploys a low energy focussed x-ray source and a linear imaging array. The sample under test is scanned between the source and imaging array and a full picture built of the product. The system relates the image so formed to linear dimensions of segments hidden under the wrapper of the product under test.

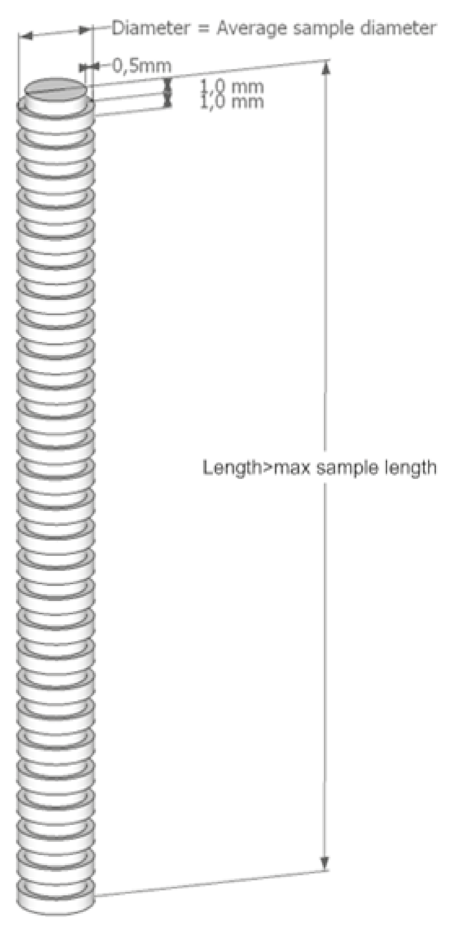
The geometry deployed could be subject to a number of defects such as the product not being scanned at a uniform rate between source and detector, or the source and detector can be misaligned causing image distortion, or the product could be tilted in the pane of the source / detector which would give rise to inconsistency of magnification and so an error in dimensional measurement.

Some of these deficiencies can be corrected in software and some need mechanical adjustment (made during build or after major servicing)., but to do this a standard tool is required to give a reference for the compensation to be applied.

Calibration tool

A calibration check rod has been designed with a series of steps machined into a test rod. Each step is of known diameter and length. The known dimensions allow firstly a calibration of image pixels to linear dimensions in both X and Y directions.

Secondly parallel sides and steps allow distortion to be detected and so compensated. The tool used and types of errors possible are shown in figure 1 and 2. To adjust for sample rotation on the image plane (A) the ROI is expected to be parallel to the image y-axis (yellow rectangle), if not the system computes the rotation angle between y-axis (blue line) and the straight edge interpolated in the ROI (red line).



In the case of sensor rotation on the image plane (B) the sensor line must be parallel to the image x-axis. If not, an image deformation occurs so that orthogonality of the test piece is not preserved. This requires adjustment in the factory set up. Case C where the longitudinal axis of the sample does not lie on the image plane, result in the two ends having different magnification. Using two ROI's (yellow box) and the known dimension of the calibration tool (red arrows) allows software to compensate for small differences in magnification.

Once compensation has been made final calibration can be performed using a series of known points on the calibration master and so the calibration function converts image pixels to measurements in millimetres.

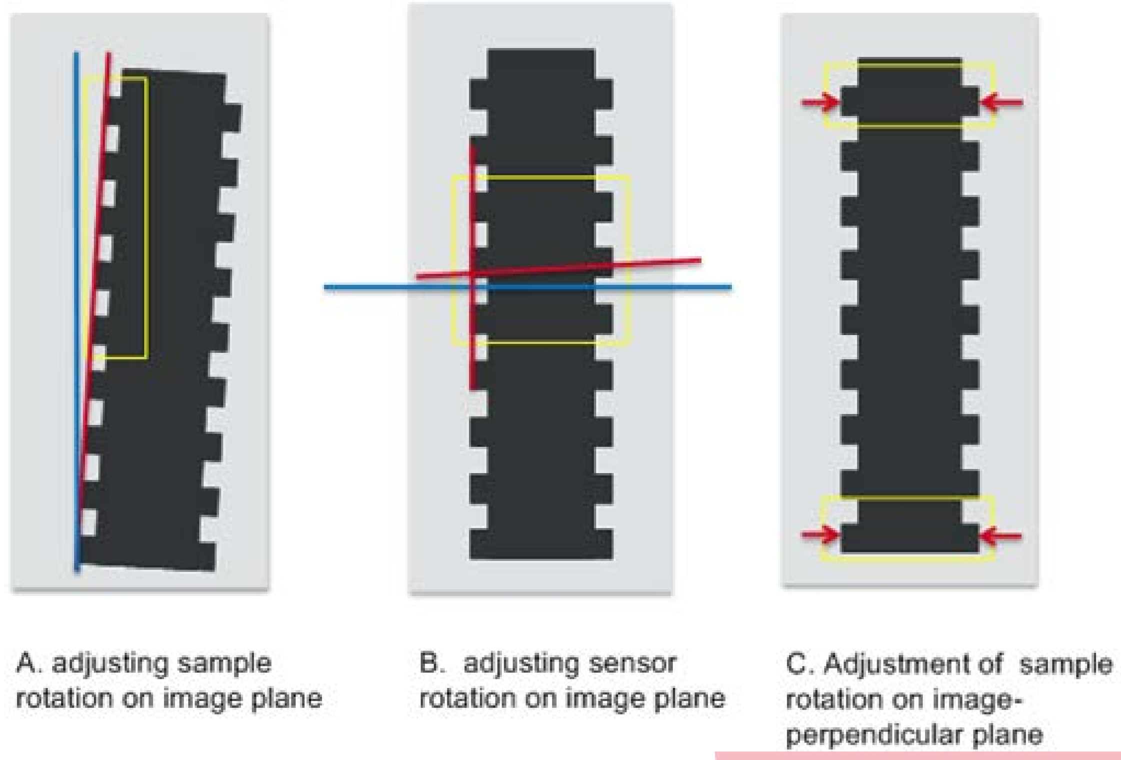


Figure 2: Compensation conditions corrected through use of Quantum Neo x-ray calibration standard

Experimental

After calibration a set of 10 THP products from a commercial source were measured 10 times by the Quantum Neo "Q" shelf. No physical damage was observed to the rods by this repeated measurement. Figure 3 shows representative images of the samples being tested as formed by the x-ray shelf, the tobacco segment, hollow acetate tube, polylactic acid and monoacetate segments all being clearly defined.

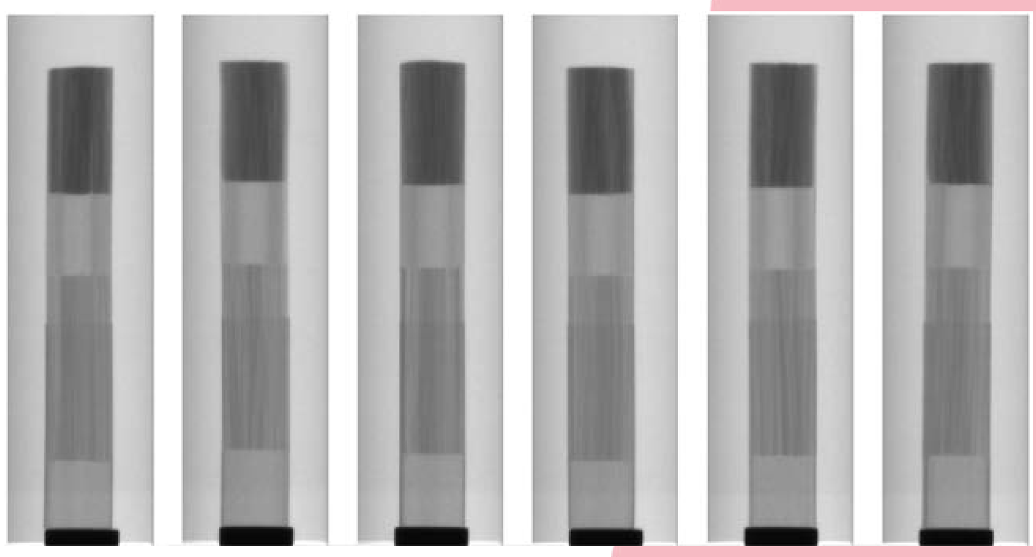


Figure 3: Six representative images of samples under test (raw images unprocessed)

Results

Figure 5 shows a graph of the standard deviations of each rod parameter for the 10 rods tested where the Mean Within SD represents the mean of the repeatability of standard deviations for each rod, between SD the standard deviation of the rod means and the between/within SD the overall SD which equals the square root of the sum of the square of the mean within SD and Between SD. The data shows that the total variation is dominated for segment length by inter-rod variation and for diameter measurement by intra-rod variation. The overall repeatability on length is dependant upon the segment interface type varying from 20 to 55 microns , the higher value where there is internal structure of segments. Diameter repeatability lies between 80 and 160 microns with the softer segments showing greater variability. Note only a single cross section measurement is made with this technique.

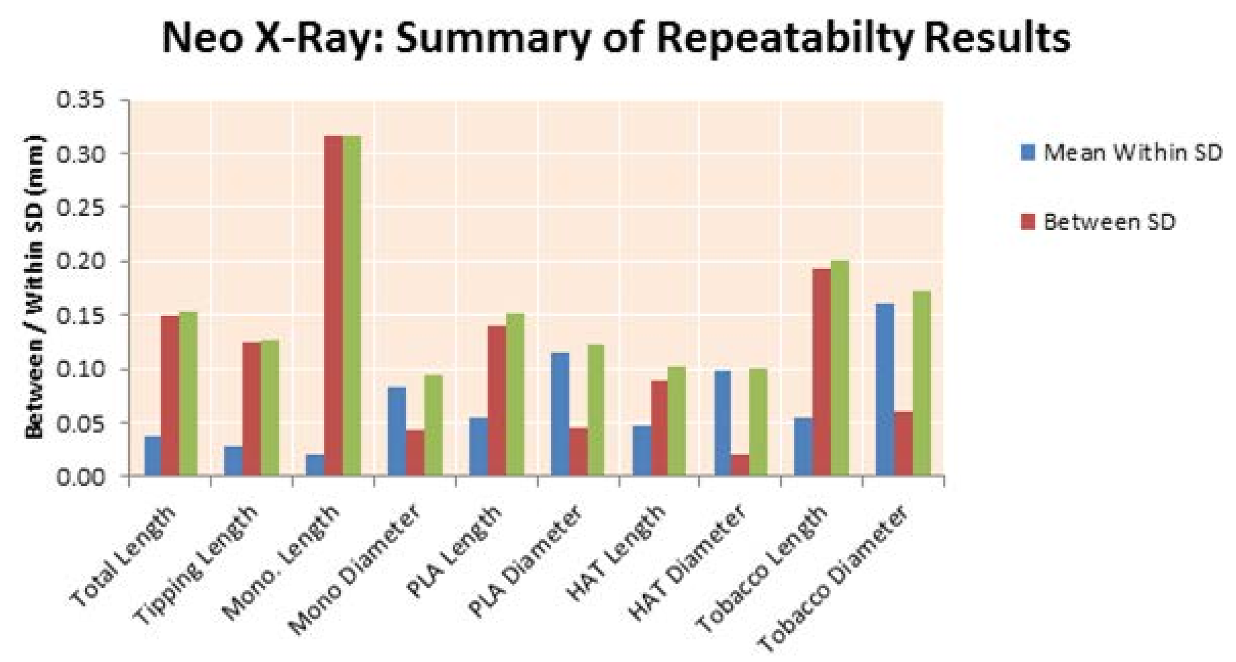


Figure 4: Summary plot of within, between, and between/within standard deviations

Conclusions

The use of a specialist calibration standard alongside compensatory software allows the Quantum Neo x-ray system to achieve repeatability in segment length on real samples of better than 20microns and in diameter better than 100microns. The lower repeatability for diameter measurements are related to taking only a single diameter measurements rather than the 100 typically taken with a conventional laser shelf that rotates the sample. In addition taking samples from a pack rather than directly from a manufacturing line may have resulted in some distortion of the product.

About Cerulean

Based in Milton Keynes, UK, Cerulean manufacture quality assurance test equipment for the tobacco industry.