Technical Report

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Hardness Measurement

on

Cigarettes and Cigarette Filter Rods

Sub-Group Physical Test Methods
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1. Introduction

There are many parameters that can influence the perception of the quality of tobacco products by consumers: the taste, the packaging, the draw resistance or the hardness for example. A too soft or too hard filter or a tobacco rod will not be experienced positively.

Hardness measurement is not specific to the tobacco product industry. It can be found in areas as diverse as engineering, ergonomics or fruit and vegetable farming. In addition, the way in which the consumer judges the quality of this parameter varies greatly from one individual to another. It is well known [1] that the requirement for manual assessment of hardness or firmness depends on the product and the assessors. Thus, the applied force between the fingers is greater when the product is firmer and women generally apply a lower force than men for a given product. It would thus be utopian to think of designing a universal assessment capable of reproducing this tactile sensation. Generally, the various methods used (as those discussed within this report) call on the same principle: the application of a set force over a given period and the observation on the resulting crushing. Thus, in order to evaluate hardness, it is necessary to apply a force and to measure a displacement. In this case, hardness is measured by crushing. Many devices, based on this principle, have been developed for the food-processing and tobacco industry [2,3,4,5,6]. For a given physical principle, the force, the contact points and the crushing time can differ greatly from one device to another.

In the tobacco industry, hardness is a Quality Indicator. The measurement of this characterizing parameter allows the user:

- To qualify making machines
- To characterize materials (tow, blend)
    - e.g. for cost optimisation
        - To get the right amount of materials
- To detect potential errors of production like
        - Plasticizer application
        - Wrong blend, or tobacco weight
- To keep under control a parameter that is experienced by the consumer
        - Stability of the product
            - Tactile perception
            - Combustion/Taste changes
            - Loss by the ends

Consequently, hardness is an important parameter contributing to the knowledge and the control of the products. Hardness measurement is mostly used by the tobacco companies to control their production but also sometimes to control their purchases.

Currently, there are three main suppliers of hardness measurement equipment: Borgwaldt, Cerulean and Sodim. Two other suppliers propose equipment as well: Burghart and Toshi.

Whatever the supplier, the methodology is globally the same even if the vocabulary is different.

With Borgwaldt's equipment, the diameter of the cigarette or filter rod (DR) is initially measured with a diameter measuring device. Then a crushing load is applied and the remaining diameter (DL) is measured after a given time. The hardness is calculated as: %H = (DL/DR) x 100

With the Cerulean device, a preload is applied and the point of contact diameter (DP) is measured. A higher load is then applied and the depressed diameter (DL) is measured after a given time or once a slope threshold is reached. The hardness is calculated as: %H = (DL/DP) x 100

With the Sodim system, a preload is applied and the diameter is measured (DP). A load is then applied and the diameter is measured after a given time or once a rate of change is reached. The hardness can be calculated using different formulas: H = (DP-DL); %H = 100 x (DP-DL)/DP; H = (DR - DL) or %H = 100 x (DR - DL)/ DR x 100

With DR: rod diameter
DP: point of contact rod diameter under preload
DL: point of contact rod diameter under load

<u>Note:</u> the diameter measurements under preload (DP) or load (DL) mentioned above is more exactly a measurement of width. This is not comparable with the diameter measurement as per ISO 2971.

2. Equipment

2.1. Preload, load ranges and loading time

The table below shows the ranges of parameters that can be applied for each supplier's equipment

Setting parameters	Borgwaldt	Cerulean	Sodim
Preload	N/A	10 to 50 g (Standard: 10 g)	0 to 600 g
Load	100 or 150 g per contact point (20)	100 to 650 g (Standard: 300 g)	0 to 600 g
Loading time	1 to 99 s	0 to 99.999 s or Slope threshold: 0 to 99.999 mm/s	1 to 99 s or Slope threshold: 1 - 99 µm/s
Resolution	0.01 mm	0.004 mm	0.01 mm 0.001 mm in control mode
Speed of crushing	19 mm/s	0.5 - 1 - 1.43 - 2 mm/s	Regulated
Other specific points	The speed of crushing being constant, the load increases gradually but quickly (≈0.05 s) once the jaws in contact with the sample. Measurement on 10 cigarette or filter rods simultaneously.	The speed of crushing being constant, the load increases gradually once the jaws in contact with the sample. Possibility to determine the relaxed diameter measurement and resilience.	The speed of crushing is regulated in order to apply the full load rapidly (<0.3 s). Possibility to make moisture effect correction.

Table 1 – Range of parameter applied for each supplier's equipment

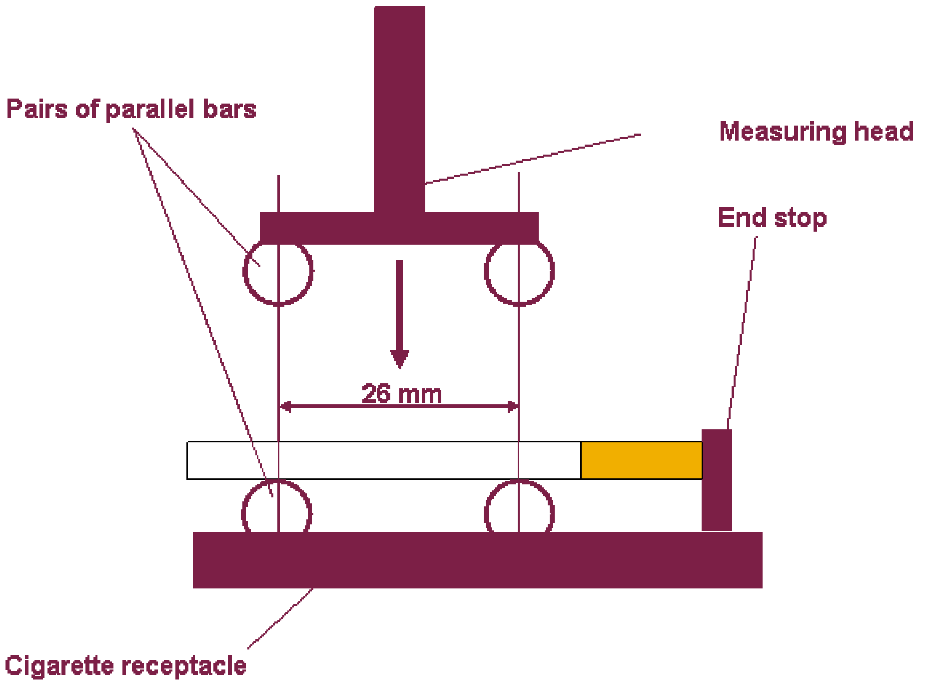
2.2. Shape of the jaws

In the following comparisons, please note:

1. even if the jaws look similar there can be detail differences in size and shape
2. different suppliers use different terminology for the same parts (jaws, foot, anvil, bars).

2.2.1. Borgwaldt

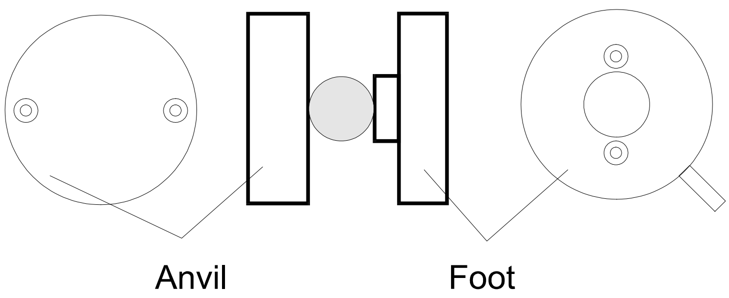
One style of jaw comprises 2 parallel cylindrical bars, 10 mm of diameter and a length of 160 mm.



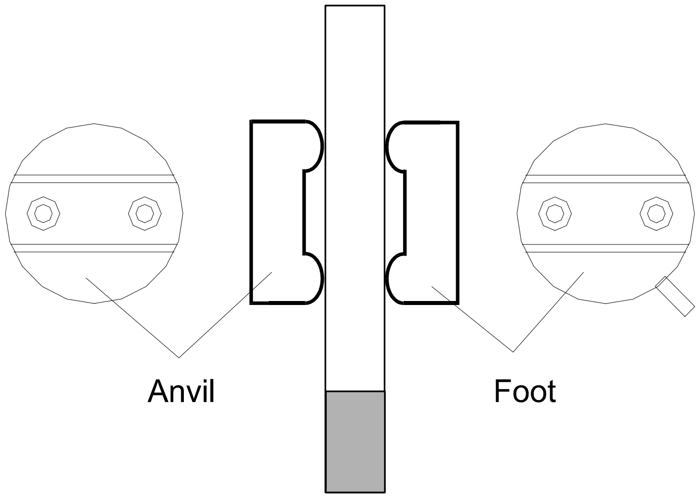
2.2.2. Cerulean

This supplier proposes 3 styles of jaws, A, B and C:

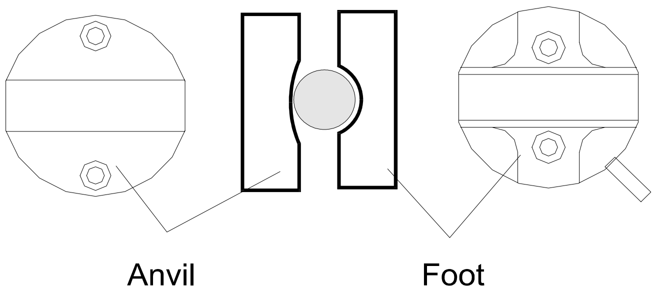
Type A - A circular foot of 12 mm diameter opposed by a lower anvil in the form of a parallel flat surface



Type B - An upper foot and a lower anvil consisting of diametrically opposed 5 mm radii profiles on a 23 mm pitch, running at 90 degrees to the longitudinal axis of the test piece



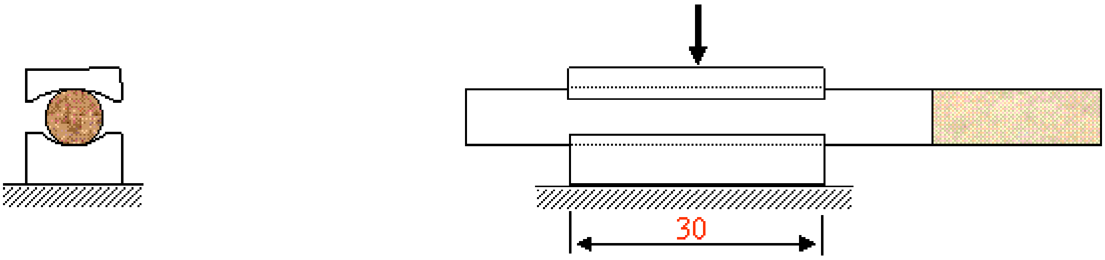
Type C - A semi circular foot with a radius of 5 mm and an anvil that has a shallow curved surface with a radius of 45 mm. Both the foot and the anvil are 35 mm long



2.2.3. Sodim

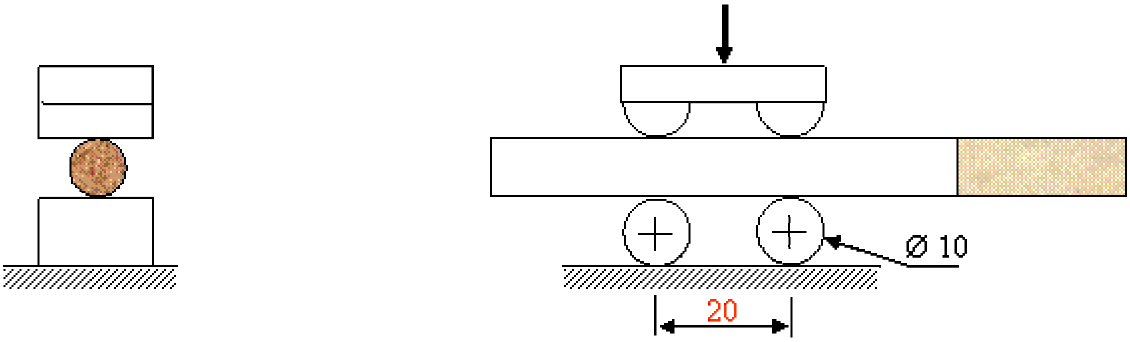
Like Cerulean, Sodim proposes 3 styles of jaw (type 1, 2 and 3), but with slightly different shapes. In the 3 cases with Sodim equipment, the force applied to the test piece is electronically controlled and software adjustable.

Type 1 – Semi-cylindrical



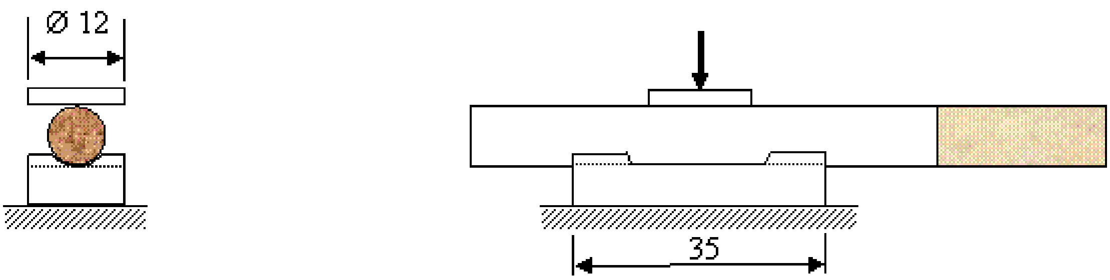
The radius of the upper jaw is 20 mm, and the lower one 5 mm. Both are 30 mm long.

Type 2 – Fingers



The jaws consist of an upper foot and a lower anvil comprising 2 cylindrical fingers each. Upper and lower fingers are diametrically opposed. The fingers are perpendicular to the axis of the rod. The radius of the fingers is 5 mm and the spacing is 20 mm.

Type 3 – Flat disk



A circular foot of 12 mm diameter is opposed by a lower anvil in the form of a parallel flat surface

3. User’s survey

As seen before (§2), there are many combinations of setting parameters (see table 1), both from one device to another and also within a given device: different pre-load, load, jaws or crushing time.

In order to assess the level of standardization within the users, a survey was conducted. A questionnaire was sent and 26 answers were returned from 7 companies (tobacco company, machinery and filter tow/rod suppliers).

The first observation is that the standardization is far from being achieved, even across the same company. It seems that each user has adapted his own procedure following his own choices, constraints, internal studies …

- 5 equipment suppliers
  - Borgwaldt, Burghart, Cerulean (+1 Filtrona), Sodim, Toshi

- 6 different kinds of jaw:
  - Fingers, Foot/Anvil (AHT400 included), Parallel rods, Rectangular (2 sizes), Semi-cylindrical

- 4 different preloads
  - 0 g, 10 g, 30 g, 1000 g (for 10 cig. & 20 contact points)

- 12 different loads (sometimes different for cigarette and filter)
  - 196 g, 205 g, 230 g, 280 g, 290 g, 300 g, 310 g, 450 g, 45 5 g, 2000 g (for 10 cig. & 20 contact points)
  - 97N, 142N

- 8 loading time
  - 3 s, 4 s, 5 s, 10 s, 15 s, 16 s, 20 s, 30 s

- 1 slope threshold
  - 0.2 mm/s

- 4 speed of crushing
  - Regulated, 2 mm/s, 3 mm/s, 19 mm/s

- Expression of the result
  - In mm
  - In %
  - In both units
  - In mm for cigarette and % for filters

- Result correction
  - No correction for 50% of the answers
  - For the rest, a correction of the moisture effect (and weight, diameter, temperature effects in one case)
  - It is important to underline that the issue of the standardization of the moisture determination method has also to be considered behind this correction

4. Conclusions

Currently, there is no standardized protocol for hardness measurement. Methods are based on a same physical principle, but the setting parameters from one user to another differ significantly. Direct comparison of results is therefore not possible. There is no "best method" and all of them are probably strongly correlated. Indeed, a hard or soft product remains hard or soft whatever the method.

Hardness measurements appear to have been developed in response mainly to internal/local specific needs/demands, and not to an international and global need. This explains the lack of standardization within and between the companies.

REFERENCES

[1] P.W. Voisey, R. Crête, Journal of Texture Studies, 4 (1973) 371-377

[2] M.A. Thomas, F.B. Brown, A.T. Hanly, The Australian Journal of Dairy Technology, March 1970, 46-51

[3] J. Buisson, M. Morin, Annales du Tabac, Paris, SEITA, Sect. I-15 (1977) 65-81

[4] G. Cholet, Annales du Tabac, Paris, SEITA, Sect. I-15 (1991) 79-89

[5] S. Colard, L. Chabanne, CORESTA Congress, Lisbon (Portugal) 2000

[6] S. Colard, G. Cholet, R. Julien, CORESTA Congress, Xian (China) 2001