MEASUREMENT OF LEATHER SURFACE: VARIABILITY IN THE MEASUREMENT USING ELECTRONIC AND PIN WHEEL DEVICES ON DIFFERENT KIND OF LEATHERS

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Abstract. The measurement of the surface of leather represents the most important measure for tanneries and their customers. From tanneries point of view, the entire tanning process is economically quantifiable by the amount and value of the surface of the leather sold. However, compared to the other goods and raw materials whose value is defined by a measure, the determination of leather surface is not univocal. Many different aspects do not allow a clear and accurate measurement. For leather area, in fact, there are no certified reference materials, the measurements can be performed with different devices and there is a high variability in measurements depending on the product characteristics of the different items on the market (e.g. leather for gloves, automotive, footwear, etc). The reference tolerances for leather are defined in the International Contract No. 7 established between ICT and ICHLSTA. These tolerances are simply assessed by the percentage difference between the value of the purchased surface and the area checked by an institution from the list agreed between ICT and ICHLSTA on a batch sample. The main problem is that the same contract prescribes the pin-wheel machine as the control device in the event of legal disputes and the ISO 11646:2014 as reference standard for measurement with the consequent difficulties in comparing results, due to the obsolescence of pin-wheel machines that are no longer in use by tanneries in favour of optoelectronic machines. From the other side it is only recently available a standard for area measurement using these machines, that is the ISO 19076:2016. So, with the aim to provide data to clarify area measurement issues, a wide data collection campaign was organized, involving the leather supply chain stakeholders with the aim of qualifying the behaviour of the different leather articles with the different measuring machines, including the pin-wheel machine.

1 Introduction

Finished leather is a material purchased by dimensional measurements. Compared to other goods or raw materials, which value is defined by a measure (weight, flow, power, volume), for leather there is no certified reference material able to represent the numerous kinds of articles on the market. From the metrological point of view, the only possible operation is actually a verification of the calibration status of the measurement machines through rubber calibrated templates. Further complication is the existence of different measuring machines using different measurement principles, with the consequent difficulties in data comparison.

As far as the devices available are concerned, the pin-wheels machine was the most used device until the 1960s, period after which the increasingly massive diffusion of electronic machines began. Due to the high costs of maintenance and management, today, the pin-wheel machines have been completely dismissed by tanneries and their customers in favour of conveyor, roller, scanner and digital machines. Roller and conveyor machines are now the most used devices by tanneries and by their customers, moreover, cutting tables with digital image acquisition and scanners are quite common among leather users. Except for leather for automotive and furniture, whose surface is measured almost exclusively with roller machines, for other intended uses (i.e. gloves, leather goods, apparel, footwear, etc.) there was a random spread of different devices, not necessarily consistent with the final use. It often happens, therefore, that sellers and customers measure the same item with different machines.

As regards documents on the measurement of leather surface, the reference is still in the International Contract No. 7[1] between the International Council of Tanners and The International Council of Hides Skins and Leather Traders Associations, finalized in the 90s, establishing the tolerances allowed in

leather trading. The contract defines the general tolerance of 2% and also accepts a tolerance of 3% for softer, stretcher leathers, such as gloving and clothing leathers, light-weight suedes, chamois leathers, bellies, and upholstery leather. While the International Contract has regulated the leather trade, on the other hand it has severely limited the development of updated technical standards to new electronic equipment. The contract, in fact, requires that the reference equipment to be used in the event of legal disputes is the pin-wheel machine and the measurement method ISO 11646[2, 3] (Area Measurement using pin-wheel machine, last updated in 2014). Except for some national standards (eg. Italy[6] and Spain[4, 5]) only in 2016, in fact, an international standard for the determination of the leather area using optoelectronic machines was published, that is ISO 19076[7]. This standard provides general characteristics of the modern devices and general procedures for area assessment.

However, the obligation of verification with pin-wheel machines remains, despite only a few units (3-4) are still fully functional among the Institutes agreed between ICT and ICHSLTA for arbitration purposes as at 31st December 2001[8]. Moreover, the entry into force of the MID Directive[9] in 2016, where machines for dimensional measurements are treated, with all consequent requirements regarding maintenance, calibration and test reporting. For the above, an extensive data collection campaign has been carried out involving all the industrial stakeholders of leather. Starting from the participants to Italian Technical Committee for Leather, UNI/CT13, the project was subsequently shared within CEN/TC 289 with the participation of other European partners. 44 participants have been involved: tanneries, brands and users, laboratories, research institutes and devices manufacturers took part in the project, including 4 Institutes agreed for arbitration purposes by ICT and ICHSLTA.

51 series of tests were carried out using all machines defined in ISO 19076 Section 5.1: n. 15 roller machines (Type A), n. 15 conveyor machines (Type B), n. 1 flatbed scanning machine (Type C) and n. 3 bi-dimensional static measuring devices (Type D). The tests have been carried out on n. 9 conveyor machines with air aspiration and N. 8 pin-wheel machines according ISO 11646.

16 different kind of leather articles, representative different leather uses (gloves, apparel, footwear, leather goods, furniture, automotive), were measured using all the machines above. Thousands of data are now available to qualify the behaviour of the leather for each type of machine with its specific characteristics.

The aim of this work is providing a general frame about how measurements change from a statistical point of view with different devices and according to test results of ISO 11646 and ISO 19076. The purpose is providing objective technical data aimed at updating the regulations and standard in force.

2 Materials and Methods

2.1 Materials

In table 1 samples selected for the project are reported. Each sample consists in a small batch of n. 4 leathers. Samples cover all typical leather destination of use. Different size, shape, origin and tanning process have been chosen.

The calibration and verification of all electronic devices have been carried out using the same 65 dmq and 130 dmq certified templates. These were not suitable for pin-wheel calibration. So different certified templates were used (50, 70, 100 dmq).

Table 1. Samples.

ID.	ARTICLE	ORIGIN	TANNING	SHAPE	DESTINATION
1	Washed	Bovine	Vegetable	Whole	Footwear
2	Wrinkled	Bovine	Chrome	Whole	Footwear
3	Calf	Bovine	Chrome	Side	Leather goods
4	Calf	Bovine	Vegetable	Whole	Leather goods
5	Goat	Caprine	Chrome	Whole	Leather goods
6	Lamb	Ovine	Chrome	Whole	Glove
7	Suede	Caprine	Chrome	Whole	Footwear
8	Washed	Ovine	Chrome	Whole	Footwear
9	Wrinkled	Ovine	Chrome	Whole	Footwear
10	Calf	Bovine	Chrome	Whole	Apparel
11	Calf	Bovine	Chrome	Side	Footwear
12	Interior Upholstery	Bovine	Glutaraldehyde	Whole	Automotive
13	Sofa	Bovine	Chrome	Whole	Upholstery
14	Suede (split)	Ovine	Chrome	Whole	Apparel
15	Ovine	Ovine	Chrome	Whole	Apparel
16	Ovine with hairs	Ovine	Chrome	Whole	Apparel

2.2 Apparatus and Devices

The following devices for assessment of surface have been used:

- Roller machines (Type A, ISO 19076): EDA, GER, WEGA, Selin devices
- Conveyor machines (Type B, ISO 19076): GER, Selin and Mostardini devices
- Flatbad scanner (Type C, ISO 19076): Muver
- Bi-dimensional devices (Type D, ISO 19076): Teseo, Atom and Comelz
- Pin-wheel machine (ISO 11646): Gozzini, Tomboni and Turner

The assessment of physical and mechanical properties of samples have been carried out by:

- tensile testing machine with a 1000 N loading cell class 0,5 according to ISO 7500-1
- thickness gauge accordance with to ISO 2589.

2.3 Procedures and Methods of Analysis

Where possible, all samples have been stored for conditioning for 48 hours in standard (20/65) or alternative (23/50) environment in accordance with ISO 2419:2012.
After conditioning, measuring devices have been calibrated and for each sample calibration procedures have been carried out as specified respectively in ISO 19076 and ISO 11646. Samples have been measured according to ISO 19076, section 8.5 and 8.6. The results, if required, have been corrected using the correction factor F as reported in point 9.3 of ISO 19076.
For the comparison of results, as specified in International Contract No. 7, surface values have been reported as total area to simulate the batch. A batch consisted in three leathers. The fourth one of each sample has been mechanically characterized for identify a possible correlation of results with leather properties.
All three leathers of each sample have been measured 10 times in repeatability conditions for subsequent statistical analysis. From the operative point of view, for each device, parameters with no prescriptions in the standards that could affect the measurement have been identified.

About conveyor machines, it must be noticed that ISO 19076 does not make any reference to air aspiration system. Nevertheless, the tests were performed with and without air aspiration, to verify the effects on area measurement.

For roller machines, both the effects of rollers speed and feeding side have been assessed to determine whether or not they affect the measure. Moreover, for sides leathers (cut in halves on the backbones), the direction of feeding have been evaluated not only as reported in ISO 19076, i.e. the straight edge should form an angle of 10° to 20° with the feeding direction, but also with a 0° angle to the feeding direction.

For flatbed scanner machines, sensor line array could touch samples with evident wrinkles during translation. In these cases, it's usual to flatten the sample disposing a transparent glass over them. This sample manipulation is not expected in ISO 19076, but however additional tests have been carried out.

The effects of all the above have been assessed only for leather n. 1 of each sample. Moreover, in order to verify that the 44 surface measurements did not modify the physical characteristics of samples (i.e. permanent deformation or leather damage), SSIP has carried out the batches measurement both at the beginning and at the end of the trials, with subsequent data comparison.

Finally, a mechanical characterization of samples has been carried out to verify any correlation between the results variability and deformability of the material, due to the application of a specific load, according to ISO 13934-1:2013.

2.4 Statistical Analysis

The behaviour of each leather sample has been defined through a robust analysis, as specified in ISO 13528:2015 *Statistical methods for use in proficiency testing by interlaboratory comparison*. For each device, percentage repeatability and reproducibility (*r* and *R*) have been assessed for each n. 1 leather of samples. Before the robust analysis, a normal distribution test, according to Anderson-Darling, has been carried out on each set of data. Finally, a *t*-test has be used to determine if the averages of two sets of data were significantly different, to evaluate possible differences between the first and the last trial (both carried out in SSIP).

3 Test Results

3.1 Robust Analysis

In table 2 are summarized the results of robust analysis for all samples with reference to pin-wheel machine and electronic devices. For scanning machines, only 1 participant attended to the project, so no statistical assessment was possible.

Where:

- *p* is the number of participants
- *Mean* is the average value assessed in the robust analysis
- *r* is the percentage repeatability
- *R* is the percentage reproducibility

It is evident that for big leathers (automotive and upholstery) is not possible yet any comparison as only roller machine measurements were available.

Table 2. Robust analysis for pin-wheel, roller, conveyor and bi-dimensional machines.

ID.	PIN-WHEEL MACHINE				ROLLER MACHINE (TYPE A)				CONVEYOR MACHINE (TYPE B)				BI-DIMENTIONAL MACHINES (TYPE D)			
	p	MEAN (dmq)	R (%)	r (%)	p	MEAN (dmq)	R (%)	r (%)	p	MEAN (dmq)	R (%)	r (%)	p	MEAN (dmq)	R (%)	r (%)
1	8	**66**	12,1%	1,9%	15	**63,1**	12,1%	2,4%	15	**60,7**	3,2%	1,7%	3	**61,4**	3,1%	0,5%
2	8	**69**	4,3%	1,5%	14	**68,0**	3,9%	1,5%	15	**66,9**	1,6%	0,9%	3	**68,1**	5,2%	0,3%
3	8	**158**	2,4%	0,7%	14	**157,1**	1,8%	0,5%	14	**157,3**	1,4%	1,1%	3	**158,0**	2,8%	0,2%
4	8	**90**	1,3%	0,0%	14	**89,8**	2,0%	0,0%	15	**89,0**	2,0%	0,9%	3	**90,1**	2,2%	0,1%
5	8	**59**	4,7%	1,5%	14	**57,2**	4,0%	1,9%	15	**56,3**	2,8%	1,4%	3	**57,9**	6,3%	0,5%
6	8	**36**	4,4%	2,0%	15	**36,4**	7,4%	2,2%	15	**35,4**	3,3%	1,5%	3	**36,2**	5,3%	0,6%
7	8	**46**	8,3%	1,9%	15	**44,3**	7,5%	2,5%	15	**43,0**	1,8%	0,9%	3	**43,7**	4,7%	0,5%
8	8	**49**	12,0%	2,5%	15	**47,2**	9,3%	2,8%	15	**46,9**	1,3%	0,8%	3	**47,4**	3,9%	0,3%
9	8	**83**	6,5%	1,3%	14	**81,1**	5,6%	1,9%	15	**80,3**	1,6%	0,7%	3	**81,0**	4,0%	0,1%
10	8	**51**	9,8%	2,3%	15	**49,7**	8,1%	2,6%	15	**48,5**	2,8%	1,7%	3	**48,9**	2,5%	0,6%
11	8	**150**	2,9%	0,9%	14	**147,9**	2,4%	1,1%	14	**147,8**	1,5%	0,7%	3	**147,8**	2,9%	0,2%
12	-	**-**	-	-	14	**464,6**	1,9%	0,4%	-	**-**	-	-	-	**-**	-	-
13	-	**-**	-	-	14	**553**	2,8%	0,9%	-	**-**	-	-	-	**-**	-	-
14	8	**53**	10,6%	2,0%	15	**53,1**	9,5%	2,6%	15	**51,9**	2,1%	0,6%	3	**53,1**	6,2%	0,5%
15	8	**56**	8,6%	1,7%	14	**56,2**	2,7%	0,2%	15	**55,9**	0,6%	0,6%	3	**56,4**	2,9%	0,2%
16	8	**39**	4,6%	2,9%	14	**39,3**	7,1%	3,5%	15	**37,3**	6,2%	2,9%	2	**40,4**	3,4%	1,2%

3.2 Pin-Wheel Results

As demonstrated by results, roller machines show the same behaviour of the pin-wheel ones in terms of repeatability and, above all, reproducibility. It is also evident a systematic overestimation of the results when the pin-wheel machines are used. These higher values are probably due to the absence of a temporary feeding blocking system of wheels (e.g. by manual holding) during measurement, as in many roller machines. This determines a significant alteration of the measurement due to the consequent stretching of leather in the direction of feeding.

Moreover, some pin-wheel machines showed a different feeding of leathers, resulting in a different deformation effect on samples. In general, the results seem to be affected by flexibility, presence of wrinkles and deformability of leathers. It should be noticed that, according to ISO 11646, the side of feeding is always with the flesh side upward.

3.3 Roller Machines Results

The results are very similar to those obtained with pin-wheel machines in terms of *r* and *R*. The lower values of surface measured, as explained above, are related to the possibility to avoid alteration of results when the feeding is blocked (i.e. manual blocking for flatten wrinkles).

It was observed that, as it occurs using pin-wheel machines, the lateral distention of wrinkles and the eventual blocking of samples to prevent folding of edges, represent the operation that most influences the results.

As shown in table 3, the direction of feeding and the rotation speed of the roller determine a systematic variation in results. Different series of area measurement were carried out changing the speed from about 25 m/min to 35 m/min and inverting the side of feeding. The results showed that higher speed determines higher values of area and feeding samples with flesh side upward (as carried out by laboratories to be consistent with ISO 11646 principles) causes an increase of measured area as well. In the first case, the higher values are related to the stretching of samples,

while in the second one the differences are probably be related to the different friction behaviour of leather surfaces. More investigations are needed on these issues.

Table 3. Percentage variations due to roller speed increase and inversion of feeding side.

ID.	SPEED	SIDE
1	+4,2%	+1,7%
2	+0,9%	0,0%
3	0,0%	-0,8%
4	0,0%	-0,8%
5	0,0%	-0,6%
6	+2,5%	0,0%
7	+4,2%	0,0%
8	+2,3%	-1,5%
9	0,0%	-1,0%
10	+3,2%	0,0%
11	+0,9%	-1,2%
12	0,0%	-0,8%
13	+2,0%	-0,6%
14	+7,0%	0,0%
15	-3,0%	-1,9%
16	+1,6%	0,0%

Other interesting results are related to half leathers (side leathers). ISO 19076 standard defines a direction of feeding forming an angle between 10° and 20°. Measuring in such a way, in some cases it was observed that the weight of sample, suspended from the plane down to the floor, can generate an angular momentum with the consequential slippage of leather over the sensors. This slippage could determine a light overestimation of the results.

3.4 Conveyor, Digital and Scanner Results

For conveyor machines, the repeatability and reproducibility are lower but, during the measurements, wrinkles and folding on edges can determine an underestimation of the leather surface. The activation of air aspiration flattens wrinkles and avoids folds, resulting in small area increments. It shall be noticed that air aspiration is needed for big half leathers. For these samples (i.e. n. 3 and n. 11) the weight of leather outside the wires o belts of the machine could determine a slippage under the sensors provoking bad results.

As for flatbed scanner devices, the results are very similar to conveyor machines ones. The application of glasses to flatten wrinkles shows a similar effect of the air aspiration of conveyor machine. Table 4 shows the average values of conveyor, bi-dimensional and flatbed scanner machines that are the devices where surface is approximated to the projection of the sample on the horizontal plane.

On the other hand, as for bi-dimensional machines, some problems have been noted during measurements. Image acquisition depends from the identification of the edges and the borders of leathers by the software used and it is strictly related with the colour contrast between the samples and the plane of the device (e.g. white leather on white surface).

Moreover, there have been observed problems in the assessment of the surface of sample n. 16, that is an ovine leather with long hair. During the detection of the borders, hair has been always confused with leather so that the measured area results higher.

Table 4. Percentage variations due to roller speed and side feeding.

ID.	ARTICLE	CONVEYOR MACHINE	CONVEYOR WITH ASPIRATION	DIGITAL MACHINES	SCANNER MACHINE	SCANNER MACHINE WITH GLASS PLATES
		MEAN (DMQ)	MEAN (DMQ)	MEAN (DMQ)	MEAN (DMQ)	MEAN (DMQ)
1	WASHED	60,7	61,5	61,4	60,3	61,8
2	WRINKLED	66,9	67,2	68,1	66,8	67,2
3	CALF	157,3	157,4	158,0	157,6	0,0
4	CALF	89,0	89,3	90,1	89,3	89,4
5	GOAT	56,3	56,5	57,9	56,2	56,4
6	LAMB	35,4	35,9	36,2	35,0	35,3
7	SUEDE	43,0	43,5	43,7	42,8	43,3
8	WASHED	46,9	47,1	47,4	46,6	47,2
9	WRINKLED	80,3	80,8	81,0	80,4	80,7
10	CALF	48,5	49,1	48,9	48,4	48,6
11	CALF	147,8	147,9	147,8	147,7	0,0
12	BOVINE	-	-	-	-	-
13	BOVINE	-	-	-	-	-
14	SUEDE	51,9	52,6	53,1	51,7	52,4
15	OVINE	55,9	56,1	56,4	55,9	55,9
16	OVINE WITH HAIRS	37,3	37,9	40,4	37,6	38,3

3.5 Physical properties of samples

To assess any relation between reproducibility in area measurement and the physical properties of leathers, flexibility and deformability characteristics of materials have been investigated. In particular, the following parameters have been determined:

- Percentage elongation at 100 N, in accordance with ISO 13934-1:2013
- Flexibility, according to an SSIP internal method. In this method, a stripe of leather measuring 300 mm x 50 mm is moved on the border of a horizontal plane to another plane at 45°. The length in millimetre of test piece that folds under its weight till touch the 45° plane is the flexibility of leather. The greater this length, the lower is the flexibility.

The results reported in table 5 are only referred to pin wheel and roller machines, that are the devices whose higher values of reproducibility have been assessed and where the feeding of leather in a stretched mode or in tension could determine more evident variation in the results.

Table 5. Physical performances of samples.

ID.	PIN-WHEEL MACHINE		ROLLER MACHINE		PHYSICAL PARAMETERS		
	MEAN	R (%)	MEAN	R (%)	THICKNESS (MM)	FLEXIBILITY (MM)	%ELONGATION
1	66	**12,1%**	63,1	**12,1%**	1,0	40,0	**20%**
2	69	**4,3%**	68,0	**3,9%**	1,2	16,3	**8%**
3	158	**2,4%**	157,1	**1,8%**	1,5	6,4	**3%**
4	90	**1,3%**	89,8	**2,0%**	0,9	8,1	**4%**
5	59	**4,7%**	57,2	**4,0%**	2,0	22,1	**11%**
6	36	**4,4%**	36,4	**7,4%**	0,8	56,2	**28%**
7	46	**8,3%**	44,3	**7,5%**	1,2	35,4	**18%**
8	49	**12,0%**	47,2	**9,3%**	1,1	25,3	**13%**

9	83	**6,5%**	81,1	**5,6%**	1,1	27,8	**14%**
10	51	**9,8%**	49,7	**8,1%**	0,7	60,5	**30%**
11	150	**2,9%**	147,9	**2,4%**	1,3	20,2	**10%**
12	-	**-**	464,6	**1,9%**	1,7	18,0	**9%**
13	-	**-**	553	**2,8%**	1,0	34,3	**17%**
14	53	**10,6%**	53,1	**9,5%**	0,5	23,4	**12%**
15	56	**8,6%**	56,2	**2,7%**	1,2	36,7	**18%**
16	39	4,6%	39,3	**7,1%**	0,9	49,7	**25%**

3.6 Data Comparison ISO 11644 vs ISO 19076

Finally, in Table 6 are reported the area measurement of the samples considered as a batch, in accordance with ISO 11644 and ISO 19076 for electronic devices.

Table 6. Area of the samples as a batch according to ISO 11646 and ISO 19076.

ID.	PIN-WHEEL (DMQ)	ROLLER (DMQ)	%Δ	CONVEYOR (DMQ)	%Δ	CONVEYOR ASP. (DMQ)	%Δ	DIGITAL (DMQ)	%Δ	SCANNER (DMQ)	%Δ
1	199	192	-4%	183	-8%	185	-7%	185	-7%	182	-9%
2	210	209	-1%	205	-3%	206	-2%	209	-1%	205	-3%
3	512	509	-1%	509	-1%	511	0%	511	0%	508	-1%
4	265	264	0%	261	-1%	262	-1%	265	0%	262	-1%
5	162	159	-2%	155	-4%	156	-3%	160	-1%	155	-4%
6	115	115	0%	112	-3%	113	-2%	114	-1%	110	-4%
7	126	123	-3%	119	-5%	121	-4%	121	-4%	119	-6%
8	146	143	-2%	141	-3%	141	-3%	142	-3%	139	-4%
9	214	209	-2%	207	-3%	207	-3%	209	-2%	206	-4%
10	174	170	-2%	165	-5%	167	-4%	167	-4%	165	-5%
11	422	417	-1%	415	-2%	417	-1%	416	-2%	416	-1%
12	-	1409	-	-	-	-	-	-	-	-	-
13	-	1679	-	-	-	-	-	-	-	-	-
14	156	155	0%	151	-3%	153	-2%	155	-1%	150	-4%
15	182	181	0%	180	-1%	181	0%	182	0%	181	-1%
16	98	100	2%	95	-3%	97	-1%	102	5%	95	-2%

As reported in the International in section 17.2 of the International Contract N. 7, in the table a percentage comparison between the average values from robust analysis for electronic devices with pin-wheel ones has been simulated. Data are the mean of the results of the participants. In table 6 is evident that in some cases, depending on leather type, the percentage difference is not compliant with the tolerances.

4 Conclusions

On the basis of the data of interlaboratory trials, the feedback of participants and the direct observations of measurement activities, the following remarks can be made:

- the pin-wheel machine shows a variability in results like the roller machine;
- the data are strongly affected by the measurement device principle and procedures, so that the comparison between area measurements carried out with different machines could be inconsistent, notably for small, elastic and flexible leathers for which even small differences in measure could determine percentage variations near to the prescribed International Contract N. 7 tolerances.

- the interlaboratory trials revealed the need to update the ISO 19076. The standard should be revised to reduce the variability factors identified in this trial and the measurement procedure should be accurately specified for each device.

However, in general, the aim of this work is not the identification of the best couple leather/machine or indicating a suitable machine. Each machine on the market is suitable for an effective area measurement for any leather as it is evident by data collected.

We would like to thank all participants: electronic machines manufacturers, tanneries, clients, research centres and industrial associations for their availability in this trial. As the list is very long and it impossible to be included in this work, we are going to thank each one personally.

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