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# Surface deformation comparison of leather with different EN ISO 5402-1 flexometer clamps using DIC technologies

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## Abstract

The flexometer in compliance with EN ISO 5402-1 is one of the most used devices for assessing finishing resistance to fatigue (repeated folding) of leathers. The device has been used for decades in quality control of materials in all leather categories: to simulate the conditions of use of a product (e.g. upper footwear), to check the strength of finishings to repeated deformations and to verify the adequate adhesion of the finish to the substrate (e.g. leather for automotive, upholstery for furniture). Until 2017, the device, called "Bally", has always been equipped with one kind of clamps, but, in the revision of 2017 of the test method EN ISO 5402-1, the CEN/TC 289 has published a new version of the standard making small changes in the upper clamp geometry. The scope of this study is to provide evidence of the equivalence between the original Bally clamps and the 2017 standard version in terms of results and effects on the surface of materials, with the aim of ensuring the applicability of the requirements set out in the technical specifications of leather sector. Have been carried out an attempt of comparison of an interlaboratory trial with the analysis of the surface effects using Digital Image Correlation techniques (DIC).

## Introduction

In tanning industry the resistance to repeated flexing is one of the most representative tests for strength verification of the finishing materials and its adhesion on the leather substrate. Till the 2017, at the revision of the EN ISO 5402-1, that is the test method for leather using the flexometer, the geometry of the upper clamp of the device has been always the same. With the publication of EN ISO 5402-1:2017, a new shape of the upper clamp has been introduced. After some years from its publication, due to several comments from stakeholders about this modification, in 2019 the CEN/TC 289 has reactivated the procedure for revising the standard. Changing the shape of the upper clamp, in fact, determined the not compliance of all the devices present on the market with the consequent issues related with accreditation bodies (ISO/IEC 17025) and customers.
To verify the equivalence of the two clamps, in 2021, CEN/TC 289 has organized a comparative interlaboratory trial on different leather samples. For a more accurate evaluation of the two clamps, has been carried out an attempt of analysis of the surface effects using DIC (Digital Image Correlation) techniques.

## Material and Methods

The comparison between the two clamps has been carried out on four different finished leathers in dry conditions (6.2 of ISO 5402-1:2017). For each oscillation level and for each sample, 10 test pieces have been analyzed using both clamps. Four labs have attended to the interlaboratory comparison using ISO 5402-1:2011 clamps (a) and five labs using the 2017 version (b). The surface damages have been classified as following table:

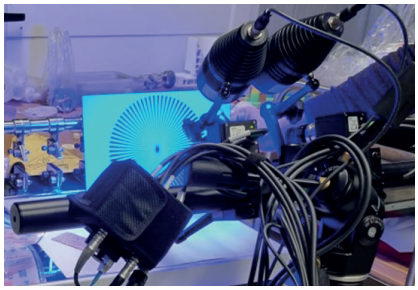
| DAMAGE | TYPE OF SURFACE DAMAGE | | ISO 5402-1:2017 |
|---|---|---|---|
| No damages | | | 7.12 |
| Visible damage | Cracking or crazing of finish with the cracking extending through one or more finishing leather | | 7.8 b) |
| | Loss of adhesion | Loss of adhesion of finish to leather | 7.8 c) |
| | | Loss of adhesion of finish coats | 7.8 d) |
| | Powdering or flaking of the finish coats | | 7.8 e) |

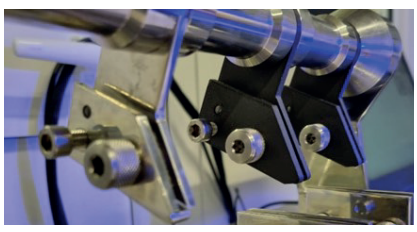
Table 1 - Damage grading for leather samples referred to ISO 5402-1:2017

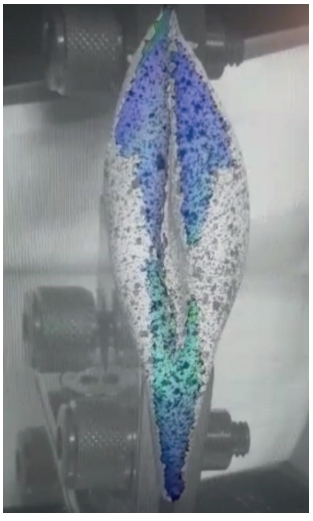
| LEATHER ARTICLE | ORIGIN | EN 15987 | DESTINATION | CYCLES |
|---|---|---|---|---|
| Patent | Ovine | 4.2.2.5 | Footwear | 1.000 - 2.500 - 7.000 |
| Laminated | Ovine | 4.4.2 | Leather goods | 10.000 - 30.000 - 50.000 |
| Bi-cast | Bovine | 4.2.2.3 | Footwear / leather goods | 10.000 - 20.000 - 50.000 |
| Pigmented | Bovine | 4.2.2.3 | Upholstery | 10.000 - 50.000 - 100.000 |

Table 2 - Leather samples and flexing cycles

For each test level and for each sample, 10 test pieces have been analyzed using both clamps. Four labs attended to the interlaboratory comparison using ISO 5402-1:2011 clamps and five labs using the 2017 version. The data have been grouped considering the effects on the finishing in percentage terms, that is the number of damages by type compared to the entire data population.
For a more accurate comparison of the effects induced on the surface by the different clamps the application of Digital Image Correlation techniques during one flexing cycle has been carried out after the application of a superficial pattern using acrilic paint.







## Results and Discussion

The ILT comparison between the two clamps are reported in the following tables

| DAMAGE | PATENT LEATHER | 1.000 | | 2.500 | | 7.000 | |
|---|---|---|---|---|---|---|---|
| GRADING | CLAMP TYPE | 2011 | 2017 | 2011 | 2017 | 2011 | 2017 |
| 0 | NO EFFECTS | 70% | 94% | 48% | 77% | 18% | 30% |
| 1 | LOSS OF ADHESION | 25% | 0% | 18% | 0% | 3% | 0% |
| 2 | MICRO CRACKS (25X) | 0% | 0% | 0% | 0% | 0% | 0% |
| 3 | FINE CRACKS (4X-6X) | 5% | 6% | 5% | 8% | 3% | 8% |
| 4 | CRACKS | 0% | 0% | 30% | 15% | 78% | 62% |
| 5 | POWDERING OF COATING | 0% | 0% | 0% | 0% | 0% | 0% |

| DAMAGE | LAMINATED | 10.000 | | 30.000 | | 50.000 | |
|---|---|---|---|---|---|---|---|
| GRADING | CLAMP TYPE | 2011 | 2017 | 2011 | 2017 | 2011 | 2017 |
| 0 | NO EFFECTS | 15% | 36% | 0% | 26% | 0% | 20% |
| 1 | LOSS OF ADHESION | 0% | 0% | 0% | 0% | 0% | 0% |
| 2 | MICRO CRACKS (25X) | 8% | 0% | 8% | 6% | 0% | 0% |
| 3 | FINE CRACKS (4X-6X) | 68% | 62% | 38% | 32% | 25% | 32% |
| 4 | CRACKS | 10% | 2% | 55% | 36% | 75% | 48% |
| 5 | POWDERING OF COATING | 0% | 0% | 0% | 0% | 0% | 0% |

| DAMAGE | BI-CAST | 10.000 | | 20.000 | | 50.000 | |
|---|---|---|---|---|---|---|---|
| GRADING | CLAMP TYPE | 2011 | 2017 | 2011 | 2017 | 2011 | 2017 |
| 0 | NO EFFECTS | 20% | 28% | 0% | 0% | 0% | 0% |
| 1 | LOSS OF ADHESION | 0% | 0% | 0% | 0% | 0% | 0% |
| 2 | MICRO CRACKS (25X) | 13% | 10% | 0% | 2% | 0% | 0% |
| 3 | FINE CRACKS (4X-6X) | 40% | 46% | 15% | 26% | 0% | 6% |
| 4 | CRACKS | 28% | 16% | 85% | 72% | 100% | 94% |
| 5 | POWDERING OF COATING | 0% | 0% | 0% | 0% | 0% | 0% |

| DAMAGE | UPHOLSTERY LEATHER | 10.000 | | 50.000 | | 100.000 | |
|---|---|---|---|---|---|---|---|
| GRADING | CLAMP TYPE | 2011 | 2017 | 2011 | 2017 | 2011 | 2017 |
| 0 | NO EFFECTS | 100% | 100% | 95% | 100% | 95% | 100% |
| 1 | LOSS OF ADHESION | 0% | 0% | 0% | 0% | 0% | 0% |
| 2 | MICRO CRACKS (25X) | 0% | 0% | 0% | 0% | 0% | 0% |
| 3 | FINE CRACKS (4X-6X) | 0% | 0% | 5% | 0% | 5% | 0% |
| 4 | CRACKS | 0% | 0% | 0% | 0% | 0% | 0% |
| 5 | POWDERING OF COATING | 0% | 0% | 0% | 0% | 0% | 0% |

With reference to DIC analysis, laminated, bi-cast and patent leather were not suitable for a good camera acquisition and pattern definition using acrylic paint. Only Upholstery leather resulted a suitable material, but the standard frequency (100 cycles/min) of the upper clamp and the typical folding movement of Bally flexometer did not allow a clear and unique DIC analysis of surface deformation.

## Conclusion

The surface comparison of the two samples suggests that there is a light geometrical difference determined by the two clamps. DIC analysis were conducted on a limited number of cases and did not provide useful information due to the impossibility of image acquisition. This is related to the speed of the upper clamp and to the loose of pattern references when the test piece folds inward. , the results lead to some preliminary observations. They suggest that thicker/more rigid leather leads to more repeatable results in terms of sample deformation; in addition, the different clamp geometry can influence the test, in particular when thicker/more rigid leathers are tested.
These results suggest that DIC analysis cannot be applied at ISO 5402-1 clamp speed and using the same materials involved into the interlaboratory trials; further investigation will be carried out using crust leathers, with a slower frequency of oscillation of the upper clamp and analyzing their geometrical effects by superposition of the images using DIC devices.

## Acknowledgements

The authors thank Giuliani Tecnologie for the technical support. R. Mascolo wishes to thank FILK (Germany), PFI (Germany), INESCOP (Spain), CTIC (Portugal), Pegasil by Zipor (Portugal), Muver (Spain) and Giuliani Tecnologie (Italy) as partners into interlaboratory trials.

## References

EN ISO 5402-1:2011, 2017 and 2022 "Leather - Determination of flex resistance - Part 1: Flexometer method (ISO 5402-1:2022)"