Quality Control for Leather Finishing in the Footwear Industry

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Abstract

The process of shoe finishing, generally consists of a high amount of manual labour, which is flexible, expensive and time consuming. Therefore, a need for agile and reconfigurable productions systems is required, in order to respond quicker to market changes and fashion trends. Existing solutions of automated shoe finishing, do not concern the area of quality control. A considerable amount of process knowledge is gained through microscopic investigations on untreated, brushed creamed and polished leather. Relevant technologies for classifying these leathers are tested and developed, as quality control system. Roughness testing is examined, to investigate the possibility of implementation as a quality control method. The differences in visual appearance between stages in the finishing process, indicates a potential for developing an image processing solution. Lastly, a system for measuring reflectance of surfaces, is constructed, which investigates the quality, by analysing the behaviour of reflected light.

Keywords: Footwear Industry, Automation, Robotics, Quality Control, Leather Finishing, Brushing, Polishing

1. Introduction

As technology and global economy is advancing, innovation within the field of shoe manufacturing is needed to keep up with competition in the footwear industry. Shoe finishing, is generally considered as consisting of flexible manual labour with high and costly workload. There is a need for agile production systems which can respond quicker to market changes. To solve this rising issue, the implementation of automation is seen as a key area to investigate and further develop. The last stage in the manufacturing of a shoe is the finishing process, which generally consists of three stages; brushing, creaming and polishing. In the last step of the production it is particularly important to have high and consistent quality, that is why the costly manual operations is seen as an obstacle.

The presented article examines the process of brushing, creaming and polishing leather, to gain knowledge about how the manual process can be automated. Relevant technologies are researched and tested, to investigate if they have the possibility of classifying surface quality of leathers.

2. Existing solutions

According to [1], the process of shoe finishing can be automated by use of robotics. A research project named *Robofoot*, was funded by the European Union in 2013 and developed an automatic system for shoe finishing. A consortium consisting of four industrial companies, four research centres and two shoe manufactures has contributed to the research and development of this project. *Robofoot* has demonstrated the possibility of implementing robotic solutions in the footwear industry. These systems seeks to eliminate or reduce ordinary manual tasks, considered most challenging and complex by the industry.

By use of CAD/CAM systems it is possible to automatically generate robot motion trajectories, used in finishing operations for brushing or polishing shoes. Further, these planned trajectories are assisted and adjusted by a constructed 3D scanning system, shown in fig. 1. A regular motion trajectory is generated by the CAD systems, where the 3D scanner fine-tune this robot program to fit the specific shoe at hand.

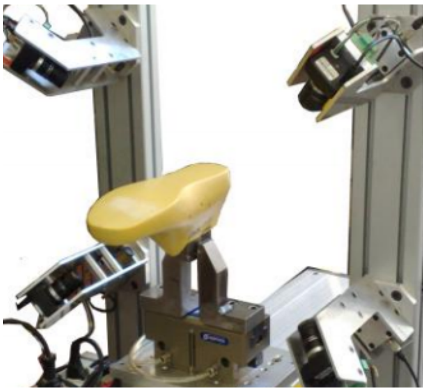

Fig. 1 3D scanning system[1].

[1][2] Using this agile system to handle trajectory planning automatically, provides the solution with a high degree of flexibility. New shoe models are easily introduced into a database of existing robot programs, containing information about required process parameters and motion trajectories. The earlier conducted research, resulted in a simulated and constructed robot cell for custom shoe finishing, fig. 2 & 3.

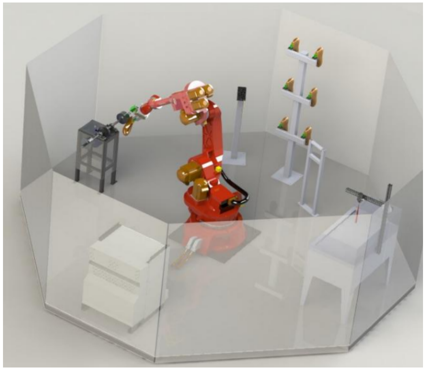

Fig. 2 Illustration of constructed robot cell[1].

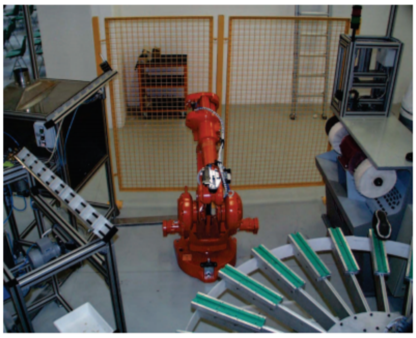

Fig. 3 Picture of constrcuted robot cell, for automatic shoe finishing[2].

The developed systems presented in these papers, concentrate on demonstrating the capability of trajectory planning with CAD systems and 3D scanning. Two constructed automatic robot cells proved the workings of the concepts and corresponding technologies. As a consequence of this, low effort has been put into ensuring a satisfactory surface quality of final products. Since leather is a natural material, considerable variation of its elements is present and therefore it is a necessity to investigate the condition of each product handled. Thereby, integration of automatic quality control systems serve as a key aspect for achieving consistent and reliable surface quality in automation.

3. Analysis of Process

[3]The first main step in the finishing of a shoe, is brushing. For the brushing process a hard brush is used to open up the pores of the leather, this type of brush is shown in figure 4. By using the right parameters, such as the right movement technique, force against the brush and rounds per minute of the brush, the pores will open. Another important factor is time. If the leather is being brushed at the same spot over a relatively long period of time, the fabric will be destroyed. This is due to the high temperature occurring between the leather and the brush.

The next step in the process is applying cream. These different treatments are established for better aesthetics of the leather, as well as for longer durability of the shoe in the specified conditions which they will be exposed for during the customers use. After applying cream to the leather, it needs some time to relax and absorb the product. When the cream is all absorbed, it will give a clear answer if the brushing is good enough and if the pores are opened correctly. If they are not, and there is a lot of cream not absorbed, it is clear that the brushing process has failed.

After the brushing and creaming process is finished the final polishing process is conducted. The basic of this process is to close the surface, locking the products into the pores. To do this, a finer and softer cotton brush is used, this type of brush is shown in figure 5.

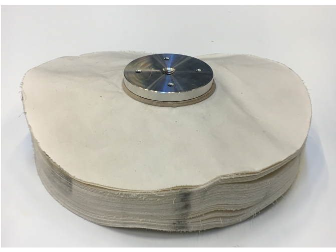

Fig. 4 Hard brush.

Fig. 5 Soft brush.

In order to make an automated solution for implementation in a production, it is important to understand exactly what happens during the process. To get a better understanding of what occurs during the different stages of the process, a macro- and microscopic examination is completed on different leather samples. With these samples, it is possible to investigate what is actually different in each stage.

A number of pictures was captured with a high resolution camera, centred above the flat samples. This resulted in a single picture, giving a clear comparison of the different stages when polishing leather - see figure 6. By evaluating this figure, it is clear on a macroscopic level that some stages differ in appearance. The untreated, brushed and creamed sample, all have different colours. On the other hand, the last two samples, creamed and polished, indicates that they are close to identical.

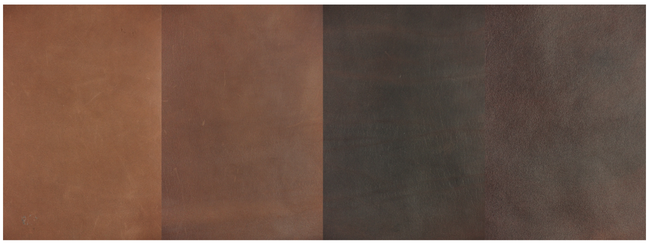

Fig. 6 A closer comparison of the samples. Untreated, brushed, creamed and polished.

The final stages, creaming and polishing, does not show any macroscopic difference, compared to the creamed samples. As a final note, the polished sample hint at a slight change in the reflectiveness of the surface, compared to the creamed sample. Using a microscope to investigate the differences, gave much insight into the actual mechanisms acting on the microscopic level. Also, it is possible to conclude what main factors characterise each stage of the finishing process, see figure 7.

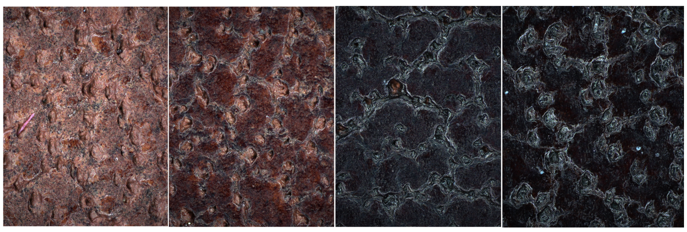

Fig. 7 A combined picture showing the microscopic results. Untreated, brushed, creamed and polished.

Different factors characterise the specific stages of the process. The untreated picture shows a light brown 'background' with small bumps, indicating the location of hair follicles on the skin[4]. After leather has been manufactured in tanneries, the hair itself have been removed and only the follicle is left, this is the pores mentioned earlier[5][6].

The brushed sample have a slight change in colour and the emerging pores are even more significant. The upper surface has to some degree been flattened, and small cavities connecting the pores have been formed. Thereby, the pores are opened up and interconnected via small canals, now ready for application of cream.

The creamed sample, has the highest contrast between the four images. Here it is obvious how the creaming component has filled out the pores and cavities in the material. The 'background' colour is darkened significantly, illustrating the influence on final appearance, of the creaming component.

Finally, the last microscopic image is from the polished sample. It shows how the wax engage in the final surface finish. The earlier filled canals in the material now has another layer on top of the previous one. The wax is filling out all the pores and cavities in the material, acting like a sealer to ensure the creaming component is locked inside the pores and surface.

4. Quality Control Technology

As demonstrated previously, the surface of leathers is changing significantly when brushing, creaming and polishing. Three methods have therefore been selected, which is believed to be able to quantify the main factors which characterise each finishing stage. Roughness testing is expected to detect the change in surface profile, as brushing is flattening the surface and opening the pores. Image processing is assumed to be able to detect changes in visual appearance for the creaming stage. Finally, the reflectance is predicted to be able to classify the last stage of polishing, as this has the highest degree of reflectiveness. Even though, these three methods are selected specifically for each finishing stage, all methods tests its potential on all finishing stages.

Roughness: [7]The test to establish surface roughness of the leather sample undergoing different finish treatments is conducted. Hypothesis is that the results will show a pattern which can be coupled with the leather surface changes, during different treatment process of the leather samples. The brushing process is opening the pores, the creaming is filling them and polishing is sealing the previous steps. This is expected to show changes in the surface roughness. The experiments are conducted on Surfascan profiler from Somicronic company. The maximal sampling measuring distance of the machine is 1.5 mm. The stylus radius in use during the experiments is 10 μm. The Surfascan software is embedded in the computer attached to the profiler and is calculating the values. In this case the Ra which is average roughness and $Rmax$ which is maximal surface roughness, is of interest. The profiler used can be seen in the figure 8

Fig. 8 Profiler used in the expeirments.

Vision: For a vision quality control system, the concept ensures that a controlled environment for capturing images exists. The design is made with a single light source mounted inside a box, where a camera is placed in the top and above a leather sample. The leather sample is fixed inside the box to get the same position for all of the tests. The camera takes pictures and a MATLAB algorithm then analysis the sample. An illustration of the concept described is seen in figure 9. The MATLAB algorithm uses a reference picture and compare the input picture. The comparison is done with the lightness-dimension in the L*a*b* colour space. The average of this lightness variable, is calculated and compared, to pixels of a reference image. The reference image, is split in a 8x16 grid for simpler comparison and for determining in which areas of the sample, additional finishing is required. A visualisation output is then generated, indicating similarities and differences between the two images. White pixels show approved sections and black pixels not approved sections[8][9].

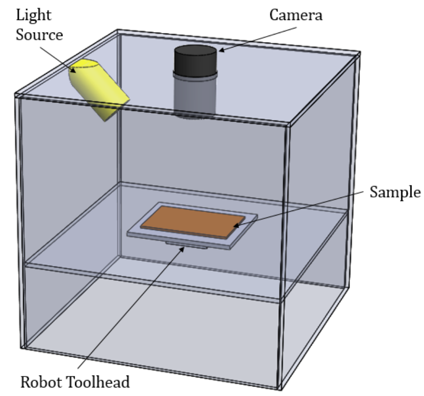

Fig. 9 Development of vision test.

Reflectance: [10] Reflectance of light can be described in two ways, specular or diffuse reflection. It is expected that the reflectance is changing after the brushing, creaming and polishing stages in the finishing process.

[11] For measuring the reflectance of a surface, a concept is developed which carefully and precisely controls the position of a light sensitive sensor. The concept consists of a small thin frame, on which a stepper motor is mounted. On the shaft of this stepper, an arm is mounted which has a light sensor inside. A flashlight is then fixed opposite of the light sensor, in a carefully determined angle. The entire device is placed on top of a leather sample and the arm is rotated in a span over the sample. The concept is illustrated on figure 10.

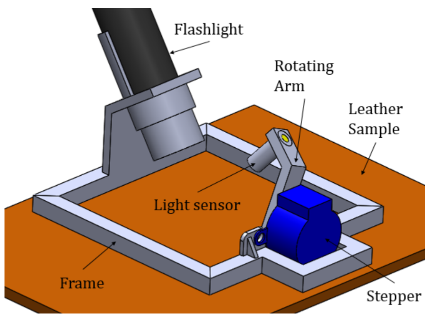

Fig. 10 Development of reflectance test.

5. Results

To verify if the developed quality control systems, can generate a reliable output concerning the quality of leathers, each solution is tested. A number of experiments are performed, examining the surface finish of leathers from different stages in the finishing process. Additional samples that is not approved by the current manual quality inspection is tested, to see differences between approved samples, and not approved samples.

Roughness control: Inspecting the surface quality using a profiler, is expected to generate a comparable output for classifying surface treatments.

The results of this experiment are shown in fig. 11 and 12, samples from each finishing stage has been investigated and is seen in the following.

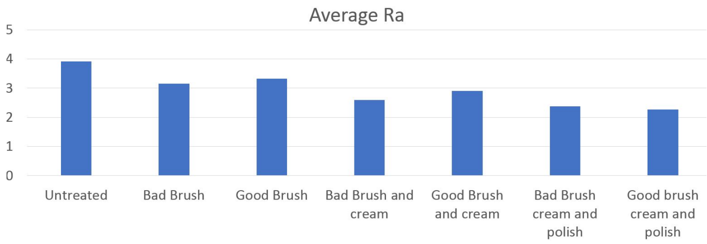

Fig. 11 Results of Ra after different treatment steps.

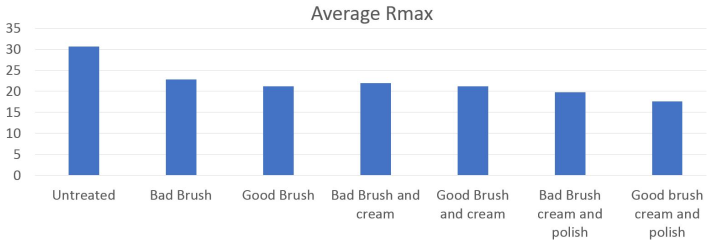

Fig. 12 Results of $Rmax$ after different treatment steps..

The results do not indicate any particular pattern, which can be coupled to different stages in process. Additionally, the measurements performed at different locations on a single samples, show a high variation in the resulting surface profiles. This implies that manually prepared samples, does not have sufficient consistency for use in this technology. Also, the profiler is measuring a distance of $1.5mm$, which is considered as inadequate for describing the profile of an entire sample.

Vision: For inspecting the quality using vision and image processing, several experiments are conducted in a controlled environment. Samples from different stages of treatments are compared to a reference picture, and then calculated if similarities between these two, exists. The differences between two samples, are indicated as black squares on the visualisation images.

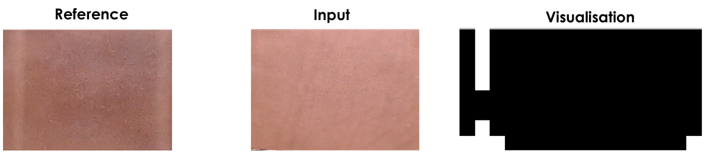

Fig. 13 Brushed sample compared to an untreated sample.

The first experiment conducted, compares a good brushed sample and an untreated one. As seen in figure 13, the good brushed sample has two significant untreated lines on each side of its surface. These are also somewhat indicated by the output from the MATLAB algorithm. The remaining areas of the images are noted as different and becomes black in the right picture, which visualise the comparison. However, as the lines are indicated on the comparison figure, this test shows that it is possible to detect that a sample is brushed, compared to an untreated one.

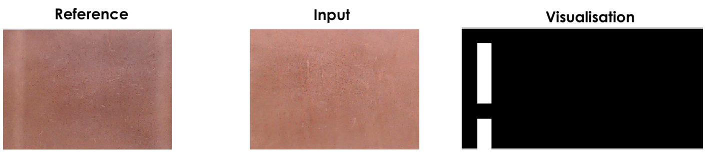

Fig. 14 Good brushed sample compared to bad brushed sample.

The second experiment compares a good and bad brushed sample. Figure 14 shows how the appearance of the two samples differ. The untreated lines on the good sample, is pointed out by the algorithm and the remaining surface area is calculated as different.

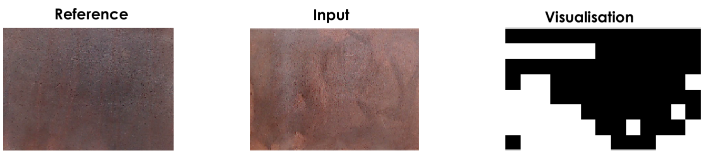

Fig. 15 Sample with good creaming compared to bad creaming. Results shows that some areas are not approved, indicated by black squares.

The third experiment compares a good and bad creamed leather sample. As seen in figure 15, the output shows that most of the areas are not approved, shown as black squares. Even though the input sample is badly creamed, some areas are indicated as good. In the visualisation, it can be seen that the areas which are sufficiently creamed, are white. The solution clearly have room for improvement with regard to this test, but the results shows that some of the areas are similar. This means the sample requires additional creaming, and is marked as not approved.

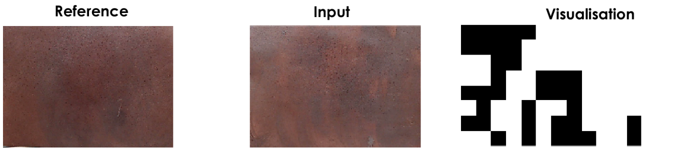

Fig. 16 Good polished sample compared to a bad polished sample.

The next test compares a badly polished sample and a good one, showed in figure 16. It is seen that the output indicates that these samples have some similarities. Some of the badly polished spots in the input sample is not detected, which demonstrates the lack of sensitivity in this stage of the process.

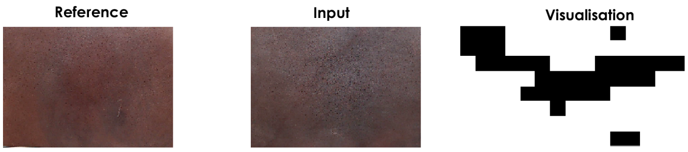

Fig. 17 Good polished samples compared to each other.

The objective of this solution, is to determine whether a leather sample is brushed, creamed or polished sufficiently. Therefore, a final test is presented, where two different leather samples, both good polished, are compared in the algorithm, figure 17. As seen in the figure, the two physically different samples, with the same surface treatment, are recognised as being similar. This shows that the method works as intended and can observe whether samples have been treated sufficiently in the process.

Reflectance measurement: Classifying surface quality by investigating its reflectance, is another approach for inspection. Each leather sample is examined in four areas. This is done, as the area measured by the device is relatively small and an average value representing the entire sample is necessary. The behaviour of the reflection in each area is plotted and an average value is calculated. Thereby, a final behaviour curve of a single samples reflectiveness is generated, see fig. 18.

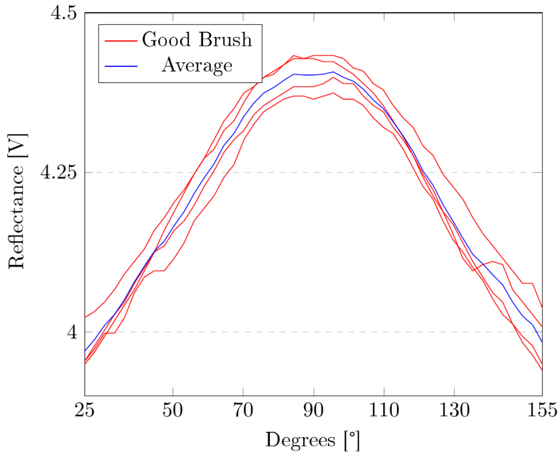

Fig. 18 Plot illustrating the four measurements and the calculated average reflectiveness.

Fig. 19, illustrates plots of average reflectiveness in samples; untreated, bad brushed and good brushed.

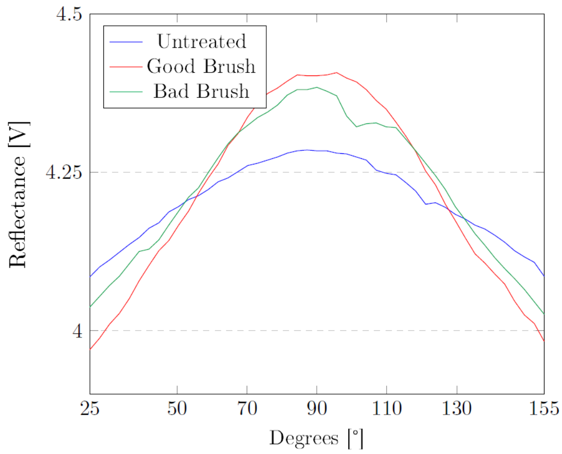

Fig. 19 Plot of average reflectance in samples; untreated, bad brush and good brush.

Figure 19, shows the good brush sample peaking with the highest value, but has the lowest values at its edges. The bad brush reflectance is rougher and has some small valleys in the graph, this is assumed to be caused by defects or small folds in the sample. Also, the edges of the badly brushed sample, is higher compared to the good quality. The untreated sample has the highest value at the edges but lowest peak value. These measurements are as expected, where the untreated sample has diffuse behaviour and brushed samples have specular behaviour. The difference between bad brush and good brush is not significant, which might indicate that the bad brushed sample only requires slightly more brushing for reaching acceptable surface quality.

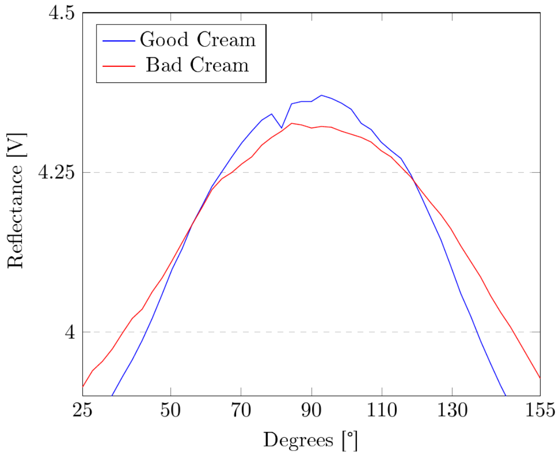

Fig. 20 Graph of the average reflectance measured on a good and bad creamed sample.

Evaluating figure 20, it is seen that the good sample has the highest peak value. Where the bad sample has the highest values on its edges. It is assumed that the bad samples behaviour is a result of poorly applied cream, which has not been absorbed sufficiently into the material. Thereby, the reflectance of the surface is lower, than that of a sample with correctly applied cream. A visual inspection of the two samples, also shows a slight difference in reflectiveness.

The final experiment, concerns the remaining stage of finishing. Here, three different good polished, and a single badly polished sample was measured and compared, see fig. 21.

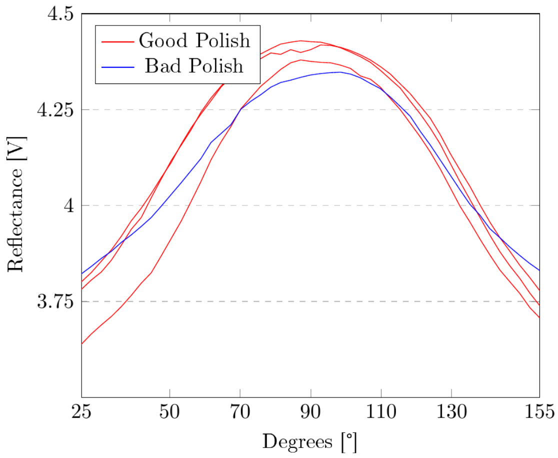

Fig. 21 Graph of the average reflectance measured on three good and one bad polished sample.

Examining the graph, it can be seen that the badly polished reflectance behaviour is below all three good polished samples, considering only the peak value. Regarding the edges of the curves, it is again seen that the badly polished sample has a higher average value at the outer edges on the plot. This corresponds to the theory, where the highest reflectance has a short span and large peak value. Since the badly polished sample, does indeed reflect in a specular manner, it is still concluded as being more diffuse than the reflectance of a good sample.

6. Conclusion

By investigating leather samples, macro- and microscopically, it was possible to determine what main factors define the different finishing stages in the process. Surface roughness, pores, visual appearance and reflectance was the main elements characterising the difference between stages.

The specific profiler, used for examining surface roughness, did not result in the expected findings. High variance between leather samples combined with high sensitivity of the test, affects the final profile measured by the apparatus. It was therefore concluded, that this method does not perform as expected and is not a compatible quality control solution.

The experiments conducted with the image processing system, proved that the system is able to recognise most of the differences between leather samples. Furthermore, the tests shows that it is able to classify similarities between a sample and reference image. The control box set up presented, can be used for the brushing and creaming stage, but have difficulties detecting the quality of the polishing stage, due to high similarities in colour between creaming and polishing.

An automatic device for measuring reflectance, was constructed and shows that the different qualities can be determined. It was expected that this method was usable for the polishing stage, but showed great potential for use in all the stages. However this solution can only measure one small area at a time and not the whole sample.

The tests presented in the article shows that technologies such as image processing and reflectance measurements, with further development, can be implemented as quality control systems for existing automated shoe finishing robot cells.

7. Acknowledgement

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