

## Response to Reviewer 1

**Comment:** This is an interesting piece of work. The work is generally well presented and easy to follow but requires a few minor improvements to the writing and clarifications, which are itemised by line.

**Response:** Thank you very much for your time and your comments. We believe they have significantly improved the quality of the manuscript.

## Abstract

**Point 1:** Line 10. Don't express in terms of aims, just state that you used SFE data to build and optimize the network

**Response 1:** The sentence has been corrected.

**Point 2:** Line 18. Be careful with the claim that this approach has enabled the automation of the process. This suggests the model is already being used to tailor the properties, is this correct, or does it merely show potential for use in this way?

**Response 2:** We have rewritten the sentence in the abstract since most printers, to our knowledge, do not use a model for the prediction of SFE, but rely on trial-and-error approach or use their experience with the plate material they are familiar with to adjust the plate's SFE, given that manufacturers often recommend the timeframe for the UV post-treatments, not the specific duration. We believe that the approach to the production of a printing plate with tailored surface properties, especially when the new type of plate is introduced, can be improved by our proposed method (application of neural networks).

**Point 3:** Include some indication of the success of the technique (see later points in conclusion).

**Response 3:** We have added the indication of the success by adding the discussion on the differences between the targets and outputs (Chapter 3.3.).

## Introduction

**Point 4:** Line 25 remove "the" from "the packaging.."

**Response 4:** We have corrected the text.

**Point 5:** Line 75 – surface energy instead of surface tension?

**Response 5:** We have corrected the text.

**Point 6:** Line 76 - are waxes carbohydrates? maybe just better to state waxes, rather than carbohydrate compounds

**Response 6:** We have corrected the text.

**Point 7:** Line 78 remove “the” from “the degradation..”

**Response 7:** We have corrected the text.

**Point 8:** Line 79 remove “the” from “the UV..”

**Response 8:** We have corrected the text.

**Point 9:** Line 84 and throughout – I think the term “wetting” would be better than “adsorption”.

**Response 9:** We have corrected the text.

**Point 10:** Line 99 and 100 - What systems is this reference describing? Unless you state what this is used for, it could be inferred that it is used for flexo plates, which it isn't.

**Response 10:** We have corrected the text.

## Methods

**Point 11:** Table 1. I'm not sure you need Table 1 and it could be covered with text, one type was fixed at 10 min while the other was varied from 0 to 20 min in 1 min intervals. Indicate why 5 min and not 10 min for plate C.

**Response 11:** We have removed Table 1 and indicated the reason for 5 minutes for Plate C (start of the visible surface degradation).

**Point 12:** Line 149 - what do you mean by standard ink? Indicate the substrate used as this has an influence on the wetting behaviour and print quality.

**Response 12:** Substrate and ink have been indicated.

**Point 13:** General comment – It might be worth including contact angle data in supplementary material - this could be used to look at the variability (or standard deviation) between measurements - I appreciate this is not practical for SFE - but it would be useful to gauge the reliability of the method, noting that individual SFE values jump around a bit. The model is only as good as the data, so if SFE is subject to variability, this should be mentioned.

**Response 13:** We have added the calculated deviations of SFE, given by the SCA 20 software, to supplementary files (Neural network inputs) to indicate SFE variability. We believe this gives relevant information on the variability of SFE, since the calculations of SFE in the software consider the deviations of measured contact angles.

**Point 14:** Line 159 – suggest “with repeat drops taken on a different locations” (the word parts suggests lines, dots etc.)

**Response 14:** We have corrected the text.

**Point 15:** Line 159 – Reference not referent

**Response 15:** We have removed the reference from the end of that sentence.

**Point 16:** Line 159 - do you need to mention drop shape? all drops are spherical

**Response 16:** We have corrected the text.

**Point 17:** Line 174 – Can you provide a reference for Keras

**Response 17:** Keras is a piece of software. Its documentation is available at <https://keras.io/>. We don't think that providing a reference would be appropriate. It would be equivalent to providing a reference to MATLAB software if it were used instead of Python/Keras.

**Point 18:** Line 179 - Can you give a reference to somewhere that explains these different models?

**Response 18:** They are described in Keras documentation, but as we said in response to a previous point, referencing a piece of software doesn't seem appropriate to us. In the article, we indicated that we used Keras and wrote what it is (a neural networks library for Python). A Google search returns its official webpage <https://keras.io/> with complete documentation.

**Point 19:** Line 181 – mention that models were trained separately for the three different printing plates

**Response 19:** We have corrected the text.

**Point 20:** Line 200 – “after” rather than “for”

**Response 20:** We have corrected the text.

**Point 21:** General point on the charts provided - You have 0 to 20 in 1 min intervals, so why don't you show all the data, since all the data was used in the models and this might better highlight some of the less reliable data points and overall trends. I assume the first reading is for 0,10 treatment, not 0,0. Please provide the datum value somewhere.

**Response 21:** We have added all data to diagrams and provided the information about the first point in diagrams (0 min UVA and 0 min of UVC).

**Point 22:** Question - These plates are varied in their response to UV and A has a much lower starting SFE, why is this? Can you provide an answer in the paper.

**Response 22:** The reason is that UVA radiation initiates crosslinking in the polymer which will notably increase the dispersive and therefore total SFE, and UVC, when long enough, terminates it. Therefore, printing plates that have undergone shorter UVA post-treatment have lower crosslinking degree than the plates after 10 minutes or more of UVA post-treatment, regardless of the prolonged UVC post-treatment. Of course, waxes and start of the material degradation can influence this trend. We have added the explanation to the manuscript (Chapter 3.1., after Figure 5).

**Point 23:** Line 215 – Better to say could be explained, rather than can be explained - I don't think you can be sure unless you verify with some measurement of surface chemistry

**Response 23:** We have corrected the text.

**Point 24:** Line 224 - had a stronger effect

**Response 24:** We have corrected the text.

**Point 25:** Line 236 - this relates to the previous points on the chart, but this inflection would be better highlighted if you used all the data points rather than every 5 minutes

**Response 25:** We have included all data in diagrams.

**Point 26:** Line 246 – same point as previously on carbohydrates

**Response 26:** We have corrected the text.

**Point 27:** Lines 248-249 this mechanism should be pointed out earlier in methods when you describe the treatments used

**Response 27:** Waxes are in the composition of only one plate in our research (Plate A) and are generally not something all flexo plates have in their composition. They have been pointed out in line 77. In our opinion, discussing them in methods would necessarily require the discussion on other used plate materials (specifically, their surface compositions and the changes occurring under UV radiation), which would shift the scope of the manuscript away from the aim of the research and scope of *Machines*.

**Point 28:** Line 251 – “but at the same time” this sentence is unclear from here. I would break it up.

**Response 28:** We have corrected the sentence.

**Point 29:** Line 257 – Title for section is at the end of the page. If this happens,, it is best to move it forward so that it is on the top of the following page

**Response 29:** After other changes in the text, the title is not at the end of the page anymore. This might change after the additional review and proofreading, and if so, it will be corrected in the final stages of proofreading.

**Point 30:** Line 259 - demonstrated outlined edges rather than had the outlined edges

**Response 30:** We have corrected the text.

**Point 31:** Line 269 - negligible rather than neglectable

**Response 31:** We have corrected the text.

**Point 32:** Line 270 - if it the component is negligible, how can it influence the result. Don't you mean that the transfer is dominated by dispersive forces, with negligible polar component

**Response 32:** We have corrected the sentence. Negligible polar component even after prolonged UV post-treatments influences the ink transfer indirectly, in a sense that it does not contribute to the increase of total SFE and improved ink wetting – since dispersive forces are dominant.

**Point 33:** General point on microscope images – these are not very high quality. Can images be provided without compression, can a scale bar be added?

**Response 33:** Scale bar has been added. Resolution of the original figures 6, 7 and 8 uploaded separately is as high as it could be given the size of the original images - 300 dpi, with width of 12.5 cm, and height of approx. 2.68 cm – it should be fine for online viewing.

**Point 34:** Line 278 and 298 – apparent rather than visible

**Response 34:** We have corrected the text.

**Point 35:** Line 279 result in rather than resulted with

**Response 35:** We have corrected the text.

**Point 36:** Figure 7 - I don't understand how these lines are wavy - is the plate distorted as it is too soft? Please clarify.

**Response 36:** The plate was deformed in the printing process because of too short UV post-treatments, specifically UVA. Low hardness can definitely contribute to distorted printed lines, but different elastic deformation of the material can, as well – and it is not necessarily directly correlated with hardness. For example, Plate B is actually harder than Plate A. However, we did not discuss these material properties in this article. If we did, the aim of the research would shift significantly to the domain of materials and away from neural networks and prediction of plates' SFE. Other methods of measurement and analysis would have to be applied, and the manuscript would fall outside the scope of the journal.

**Point 37:** Line 287 – resulted in

**Response 37:** We have corrected the text.

**Point 38:** Line 298 – “in an” rather than “with the”

**Response 38:** We have corrected the text.

**Point 39:** Line 301 – note that the crosslinking increases the hardness of the plate

**Response 39:** We have corrected the text.

**Point 40:** General points - This information helps the reader interpret the effect of plate surface energy on the print, but this is of no consequence for the model - which only looks at predicting SFE from treatment parameters. I am not suggesting you do this but the model would be useful if it could also indicate print outcome. This is potentially more interesting as the print depends on hardness and SFE which are both affected by UV treatment yet have different effects.

**Response 40:** We agree with the Reviewer and believe this is an extensive and interesting research topic that could include many types of flexo plates, different inks and substrates; as well as developing speed

for appropriate plates, drying temperature of the plate, duration of the main exposure, additives added to inks, surface treatments of the substrates, etc. – since they all influence the print outcome.

**Point 41:** We don't know anything about the ink and the ink properties would also have an influence on the print

**Response 41:** We have added the information about the used printing ink.

**Point 42:** It might be worth drawing a firm conclusion on the effect of UV treatment on print quality here. why are the plates different to one another in their behaviour. Only plate C seems to give "acceptable" results.

**Response 42:** We have added the short indication to the manuscript conclusion – however, since this discussion is not in the focus of this manuscript's aim, nor in the scope of the journal, we have kept it very brief. Our previous research, some of which was cited in this manuscript, has already covered this topic.

**Point 43:** Section 3.3 – I have not provided many comments here as this technique is outside my areas of expertise (although I am familiar with its use). My points mainly relate to the applicability of the findings.

**Response 43:** Thank you for your effort and all your comments, we believe they have significantly improved the manuscript quality.

**Point 44:** In Figure 12 you present the best model for each plate. My question is would it be practical to use different models for different plates if you wanted to develop a predictive tool; this looks a bit like "cherry picking". If you use a plate that is not in this study, how would you know which model is best? Is there one that performs generally better than the others?

**Response 44:** As stated in the discussion following Figure 12, there isn't a single network architecture which performs best in all modeling applications and choosing the optimal architecture is the topic of many research papers. However, in discussion and conclusion we stated that we have narrowed the choices to a smaller number of network architectures which can easily be trained and evaluated in search of the optimal architecture. We have eliminated networks with one hidden layer, two activation functions, and two numbers of neurons.

**Point 45:** You present MSE, but I don't get a feel for how close a prediction could be achieved with this technique. Also, we know how sensitive print outcomes are to SFE/UV treatment, so will this technique give a recommended treatment that will give a decent print, or is it not sensitive enough?

**Response 45:** We have added additional error metrics in Table 2 in Section 3.3.

## Conclusion

**Point 46:** Line 383 – the SFE effect is noted, but hardening of the plate is not, this also occurs and will affect the print quality

**Response 46:** Research on the effect of the UV post-treatments on the hardness of photopolymer materials used in this research has been performed and already published in some of our other articles. Neural network that predicts the hardness of the printing plate as a consequence of the further crosslinking has not yet been built. We agree that the influence of the hardness on the print quality is significant and could be published with extended discussion on the joint effect of the hardness and plate's surface properties on the print quality – all related to the varied UV post-treatment of the plate. That type of the research – where the influence on the print quality is in focus – could be suitable for a journal with adequate scope. For this article, we have added the brief note on the hardness effect to the discussion of the printed lines (Chapter 3.2.).

**Point 47:** General point – The conclusion does not state how reliable this approach could be for predicting SFE, and whether this would be sensitive enough to target certain printing outcomes. There is also the point made earlier about whether this model could be expanded by bringing in print outcomes, and different ink types, since this is really what the printer is ultimately interested in.

**Response 47:** As mentioned in few previous responses to Reviewer's points, many properties of the printing plate that influence the print quality and are related to the plate's composition and to the effects of UV post-treatments, could not be included in only one manuscript. We agree with the Reviewer that combination of plates and ink types would be of high interest to printers, but this extensive research would be more suitable for another journal.

In this research, we have focused on the possibility of using neural networks for the prediction of SFE of three commonly used flexo plate materials. That prediction and possibility of tailoring SFE could be of high importance for experienced printer.

If a printer can adjust the polar and dispersive SFE (in a certain range, of course - depending on a plate material) using UV post-treatments, then he can adjust the wetting and adhesion of chosen type of printing ink (water-based, solvent-based, UV-curable... - which all have different polar and dispersive components of surface tension) and even optimize the print quality and expand the range of the materials used in a printing process where the same type of printing plate is applied, only with different UV post-treatment. This enables manipulation of the properties of print without being limited to using specific plate technology for some purposes, such as Asahi's pinning technology etc. This is why we have chosen SFE as output in neural networks in this research.

Model could be expanded in future research to include hardness of the plate or some print properties as outputs, and different printing inks as inputs. Comment on that has been added to conclusion. Furthermore, reliability of our approach has been discussed in Chapter 3.3., where additional results of the performance of networks with discussed errors have been presented.