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DEVELOPMENT OF A UNIQUE IMAGE CLASSIFICATION TECHNIQUE FOR SPRAY COATED PARTS

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ABSTRACT

Coating deals with alteration of the intrinsic layout of any substrate so as to magnify its useful life and serve as a antidote to wear. This procedure is commonly embraced by key machine tools, which are critical for manufacturing a product and fall prey to perennial wear and friction over their lifecycle. Consequently, it is essential to safeguard them by building resistance to wear and in order to maximize their usability. The present work focuses on thwarting wear of tools by depositing coatings with the aid of electrostatic coating apparatus, including an attempt to blend it with an unorthodox examination system using machine learning to identify coated cutting tool inserts.

Keywords: Electrostatic Spray Coating, Cutting Tool, Machine Learning

1. INTRODUCTION

The production process has been experiencing huge facelifts at breakneck pace ever since the advent of the digital revolution, pushing the traditional procedures into oblivion. Additionally, due to challenges like the ongoing increase in raw material prices and the growing demand for high productivity and reliability of finished goods at reduced production rates, the industry is compelled to move in the direction of ground-breaking technologies like Robotic Process Automation .Along with automation, extending the lifecycle of products by adopting techniques like producing newer materials with superior mechanical qualities and reverse engineering is another major principle that industry players have embraced. Cutting tools are one of the most critical items that have a substantial impact on the industrial sector since they are required to remove extra material from parts. Due to abrasion and continuous contact with the workpiece, they witness significant wear and failure, which has a serious influence on their longevity. Cutting tools are coated with hard materials to extend their useful life, and since the coating process was created, a variety of ways have been used depending on parameters including coating material, application, and size, among others. A technique that has gradually become more popular in industry is electrostatic deposition, which has advantages including low-cost equipment and a high material transfer rate. It is a straightforward technique that enables coating thin films with a variety of morphologies using a nano-texturing strategy. Also, inspecting coatings is important since they need to meet industry requirements. However, there are a number of drawbacks to manual coating analysis, and to address them with contemporary techniques, coating evaluation must be mechanised with little manual involvement. Therefore, this article describes the proposed method to develop an cost effective experimental apparatus to deposit coatings on tools using electrostatic spray deposition and to identify & differentiate them using Artificial Intelligence.

2. LITERATURE SURVEY

Cloupeau, M., & Prunet-Foch, B. [1] outlined the major working mechanisms of electrostatic spraying and specified details of the circumstances under which the multiple variants appear. They also reported that highlighting all of the scenarios under which a given mode is obtained is cumbersome due to the play of multiple parameters. Su, B., et al. [2] used an Electrostatic Assisted Aerosol Jet Decomposition Deposition technique to create nanocrystalline CdS powders and thin films from an aqueous solution of cadmium chloride and thiourea. They examined the microstructure of the powders and films using a blend of transmission electron microscopy, X-ray diffraction, and atomic force microscopy. Law [3] outlined significant advances in the research and development of electrostatic-spraying technology for beneficial agricultural and biological applications during the twentieth century, emphasising critical developments in the field of electrostatics science by universities, industries, and governmental agencies.

Wilhelm, O., et al. [4] developed a mathematical model. In order to create electrolyte films for solid oxide fuel cells, solution droplets were sprayed and their salt content was calculated using a model. Their model was discovered to be congruent with separate electrospray transport and droplet evaporation literature models. In their study, Zhang, G., et al. [5] described how to use deep convolutional neural networks for semantic picture segmentation to automate and objectively characterise coatings using the Chemistry 4.0 technique. To automatically detect the distinctive phases of the Nickel-Chromium-Aluminum-Yttrium coating, the coating/substrate interface, and the oxide layer, Liu, R.,et al. [6] developed an eight-layer convolutional neural network. The Chromium-rich phase and the characteristics of the NiCrAlY coating were assessed and extracted at various oxidation temperatures using the neural network.

In order to develop a methodology for two-dimensional examination of the standard of textured surfaces using machine vision to test on polished titanium surface by leveraging laser micro-machining process, Sreedath, P., et al. [7] conducted an investigation. In a similar vein, Szydlowski, M. et al. [8] developed a novel method for computer vision-based micro-milling tool wear inspection. Kohilan, J. &Thenmozhi, G [9] created a shrewd robotic wall painting system using machine vision and an integrated chip micro-processor. For tool condition monitoring in Computer Numerical Control machines, Sun, W. H., & Yeh, S. S.[10] devised a visual monitoring system for the periphery of an insert that uses the ambient light source and an on-machine turning tool insert condition monitoring system .

Wu, W.Y, & Hou, C. C, [11] proposed a system for automatic visual evaluation of metal surfaces. The attributes of the examining pictures were compared to a predetermined confidence interval to establish whether or not the inspecting metal was flawed.

2.3 CONVOLUTIONAL NEURAL NETWORKS

Convolutional neural networks are a vital subset of neural networks used in Artificial Intelligence that transfer data forward. It contains intricate layers joined by neurons, which collect data from them and send it, via a series of mathematical operations, to the artificial brain. Applications for picture classification take advantage of convolutional neural network’s extraordinary capacity to locate spatial features in data. Nevertheless, there is a drawback: in order for these networks to work effectively, they must be trained over a number of rounds and require a sizable amount of data [12]. It is represented in [Figure 1].

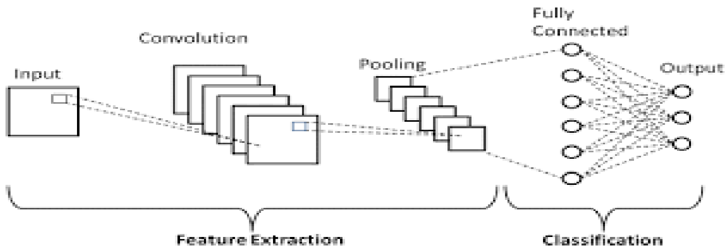

Figure 1: Design of Convolutional Neural Network [13].

2.3.1 ELEMENTS OF CONVOLUTIONAL NEURAL NETWORK

CONVOLUTION LAYER: The weights of the neurons tied to the input data and its numerical arrays are merged to generate a scalar product from which the convolutional layer derives the neuron's response. The convolution layer collects features from an input dataset, and scales down the representation of the input data using a kernel, a form of data filter matrix. Figure 2 depicts the convolution operation.

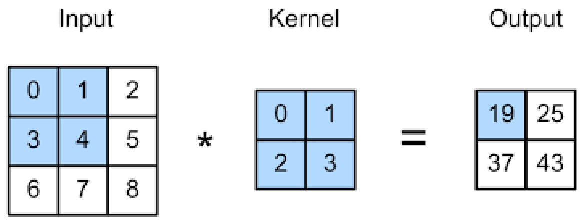

Figure 2: Convolution operation [14]

POOLING LAYER: Pooling layers are utilised to screen the magnitude of the feature data that were acquired during convolution operation using filters in order to limit the amount of computation the network needs execute. As a result, the machine learning model is more adaptable to changes in input features. Max pooling operation example presented in [Figure 3].

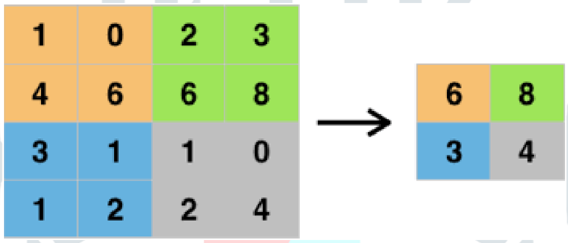

Figure 3: Maxpooling Operation [15]

FULLY CONNECTED LAYER: Neurons in the fully connected layer carry out the essential work of a convolutional neural network, such as collapsing multi-dimensional matrices to linear vectors, and they are also in charge of relaying the results by the aid of mathematical functions. The structure is depicted in [Figure 4].

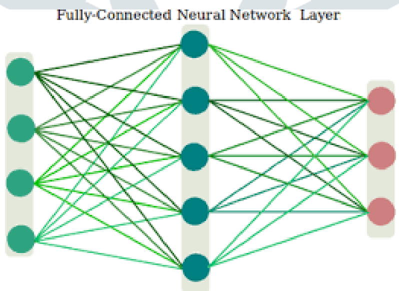

Figure 4: Fully Connected Layer Layout [16].

ACTIVATION FUNCTION: The convolutional and fully connected layers of a network are triggered by activation functions. It determines the weighting of the biases and inputs. According to the situation, the convolutional network frequently utilizes activation functions such as Exponential Linear Unit, hyperbolic tangential function etc.

3. EXPERIMENTAL PROCEDURE

3.1 ELECTROSTATIC SPRAY DEPOSITION

Electrostatic coating is a deposition approach that employs electricity to coat an object with a specific material. Akin to the traditional spraying technique, powder coating is initially applied to an electrically conductive object as atomized liquid or powdered elements. This coating is more practical since a significant magnitude of the powder particles that are sprayed over the surface stick to the target. The coating material is thrusted towards the workpiece by the electrostatic field's strength. It is frequently applied to protect key surfaces and enhance appearance. The process has multiple shortcomings as well. For instance, everything near the coating apparatus must be electrically grounded so as to thwart static accumulation, which may induce an arc that can damage the device. The key parts are the coating system, vacuum chamber, air compressor, spray nozzle, hopper, workpiece, and high voltage electric generator & pipes. The working principle is shown by [Figure 5].

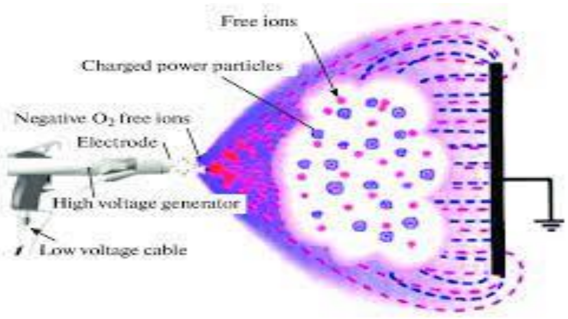

Figure 5: ESD Working Principle [17]

3.2 DEVELOPMENT OF ELECTROSTATIC SPRAY SYSTEM

Following the above-mentioned fundamental description, an experimental apparatus [Figure 6] was designed to deposit silicon carbide powder coating on mild steel sample, as shown in the figure below. An electrostatic nozzle, a high voltage power source, a commercial air compressor, a powder ingredient storage box, and a coating chamber are all components of the complete coating system. The compressed air required for the fluidization of silicon carbide powder material filled in the hopper was supplied by a reciprocating air compressor, which enabled it to traverse to the spray nozzle. The powder was then transported across a portion of the nozzle where it was excited by the potential difference setup provided by a high voltage DC source to the tip of the nozzle. Because of the presence of the electric field at the junction, this assisted in enhancing the conductance of the powder-air mixture. The powder component was drawn to the sample as a result of this process. To strengthen the bonding, the coated material was also annealed in a furnace.

Figure 6: Apparatus Setup

3.3 PROPOSED IMAGE CLASSIFICATION MODEL

Python computer language was used to create the proposed convolutional neural network model from scratch. An array of Python packages such as and fine-tuning parameters such as loss function, optimization function, learning rate and so on were used to design the network. It was meant to sort the pictures of a standard graphite-deposited Tungsten Carbide tool insert and a Silicon carbide coated mild steel sample [Figure 7,8]. In order to train, validate, and test the model, many photographs of these two coated samples were taken, pre-processed, and divided into three datasets with two categories.

Figure 7: Sample photos of Graphite coated WC tool insert

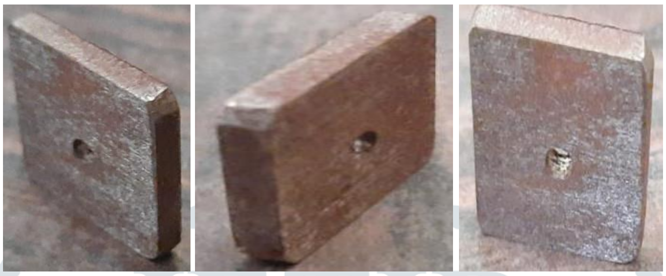

Figure 8: Sample photos of M.S tool inserts

4. RESULTS AND DISCUSSIONS

The mild steel tool insert was coated with silicon carbide powder thanks to an electrostatic spray coating method. The sample's coating can be seen in [Figure-9] following heat treatment. The model was created to predict the category of photos present in the test dataset in order to examine the model's practical value. The following graphs [Figure 10] show how the model's accuracy and loss vary over time during training in relation to epochs. [Figure 11] shown an example estimate for a test image from the machine learning model, which demonstrates that the image belongs to the second category with a label of [1] . In addition, the model's predictions and the actual results were in good alignment.

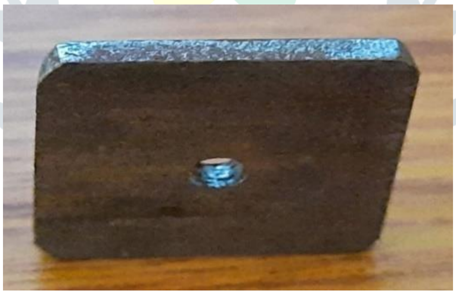

Figure 9: M.S tool insert coated with SiC

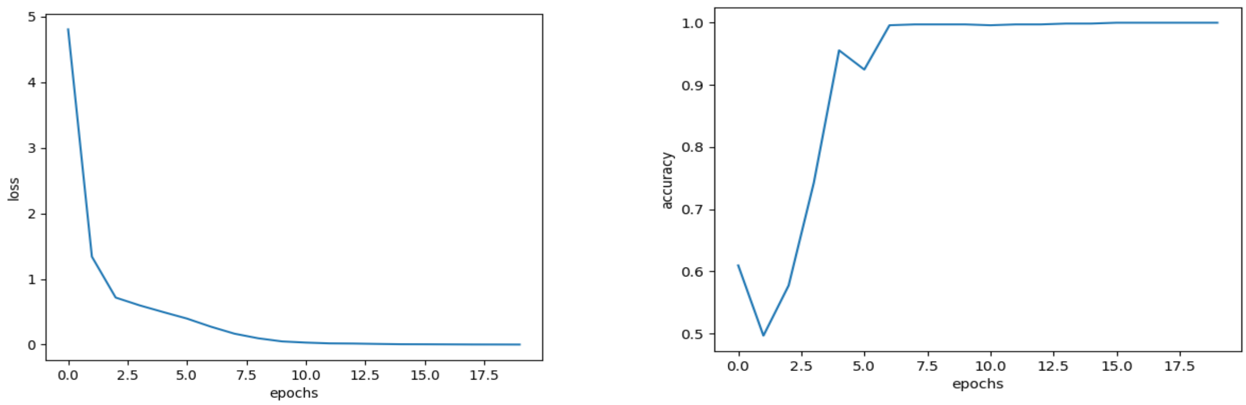

Figure 10: Variation of accuracy and loss as a function of epochs for CNN model

```
Epoch 20/20
4/4 [==============================] - 20s 5s/step - loss: 0.0017 - accuracy: 1.0000 - v
1/1 [==============================] - 1s 550ms/step
[[1. 0.]] [[100.   0.]]
The photo belongs to class: [0]
Model: "sequential"
```

Figure 11 : Result obtained after execution of CNN model

5. CONCLUSION

The electrostatic coating approach was utilized to coat tool inserts by developing a simple, low cost & portable experimental setup. It was noticed that the coating efficiency was greatly influenced by operation parameters including compressed air pressure, standoff distance etc. Moreover, it reaffirmed and highlighted the benefits of electrostatic spray coating over other techniques, although it does have few limitations. Further , the paper documents an endeavor to use machine learning, a disruptive technology, to distinguish coated tool inserts simply based on their photographs. Despite all of its benefits and limitations, electrostatic spray deposition appears to be promising, and in addition to that machine learning algorithm indicated incredible potential in the area of quality control.

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