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PRACA DYPLOMOWA MAGISTERSKA

pt.

„Application of deep learning approach for identification and classification of scale defects during hot forming process”

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# Introduction

## Motivation

The main requirements of Modern Industry is to create high quality materials, with minimization of costs. Unfortunately, this is very difficult or even impossible to obtain that, using classic methods of production.

Steel industry and hot forming process have same requirements. Direct customers, and next steps of production expect to get high quality products. It causes, that process require constant control quality of product. One of the factors is rating of surface quality. This is a difficult process, because of velocity of hot forming process, multiple different defects and large surface, where we can find defects. One of the known inspections is a visual inspection made by inspector, which observe samples of produced plate. However, technological process provide new, automated solutions. One of the solution is a ASIS (Automatic Surface Inspection System). Main tasks of ASIS is take photos during the process, detection local difference of contrast, which can be a defect, and recognize proper class. The output of ASIS is classified defects map of produced material. This kind of solution allows to limit time for inspections and control of surface. Additional advantage is possibility getting information about state of production.

## Aim of Thesis

Aim of the thesis is to create a classifier of defects which can detect, and classify defect, founded on picture taken during hot production process. Based on local differences of contrast, classifier can detect, and in next step classify the defect. There are multiple different of class. To obtain desirable class, there must be prepared set of classified defects. Based on this set, classifier studies the vision features of pictures, and create a model. This is a typical *blackbox* approach for end user, because it allows to detect defects without specialized knowledge.

As for now, there is many approaches to solve this problem. Many of them is related on artificial intelligence e.g. *decision trees, neural networks etc*. This thesis is focusing on using Neural Networks using Convolutional neural networks (CNN). Convolutional neural networks is a class of deep, feed-forward Artificial neural network that has successfully been applied to analysing visual imagery and classify it. Based on classified set of pictures, solution will try to learn network model. Proper learned model will detect and classify defect. Eventually this solution can be used during hot forming process. Properly trained network provide fast and exact method to detect and classify defects, which can help inspector.

## Content of Thesis

In second chapter, thesis describe hot forming process, current state of sheet metal defect inspection and approximate the theoretical basis phenomenon of scale formation in the hot-forming process. In next chapter, are presented application of deep learning to analysing and classification of pictures. It is focused on *deep learning* and Convolutional neural networks.

# The problem of defects in hot-forming sheets

## Hot forming process

Subject of this thesis is about apply methods of neural networks to classification surface defects of flat sheets. Produced sheets and strips in their section are rectangle, and there have much more width than height. In view of temperature of forming, we can distinguish hot and cold forming process. Thesis is focusing on hot forming process.

Depending on the form, flat steel are divided into: sheets and strips. The sheet is called product which is hot or cold forming, flat with freely formed edges, supplied in form of rectangle sheets with 600 mm width and higher. The strip is called flat product formed on hot or cold, which is rolled into a circle directly after the final operation of forming, etching or continues annealing. Flat steels are used to production of cars, household goods, packing, etc.

Plastic deformation of flat steel at ambient temperature makes their harder, stronger and their changes electrical properties. At the same time, when deformation value increase. In order for the steel to be deformed, without any breaks, they should be restored earlier plastic properties. The phenomenon of reconstruction of the cellular structure, which is leading to recovery of the plastic properties is called recrystallization. Temperature of recrystallization in the absolute scale is described by the following empirical formula:

where Tr is a temperature of recrystallization, and a Ttop is a temperature of melting. For a pure metals the value is equal to 0.4, and for the alloys with the solid structure the value is equals to 0.6.

Hot plastic processing is made above the temperature of recrystallization. Desired shape of sheet or strip is obtained by plastic deformation of the material, between rotating and cooperating rolls. Thesis deals with longitudinal rolling (*Image 1a*), where material performs a translational movement, and rolls with the parallel axes rotate in opposite direction.

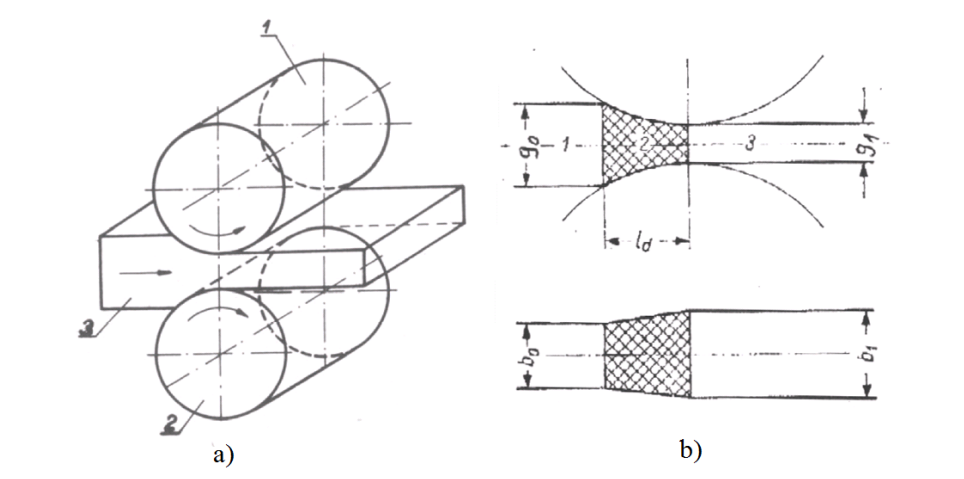


Image 1: a) Longitudinal Rolling, b) Rolling mill

During of the rolling the cross-section is decreased, while the length is growing. Area, where the part of material is deformed is called rolling mill (*Image 1b*). In the rolling mill occurs the reduction of thickness (from g0 to g1), and in the effect are changing: width, cross-section and length of sheet or strip.

Image 2 shows the general concept of the layout of a typical hot rolling mill. The process starts from the loading of the ingot(1) into the furnace(2), which heats it to temperature around 1250 C. Ingots from the furnace will go to the milling line, which leads through the next technological steps. Initial mill(3), which job is initial reduction of a strip, can consists of a single reversing mill or several rolling mills in a similar arrangement. Some rolling mills use an intermediate band winding box (4) to reduce the length of the rolling line and equalization of temperature along the rolled strand. Installation of descaling (5) is responsible for removing scale from the surface of the strip. Group of finishing mills (6) gives the final thickness for the strip. Cooling section (7) sets the winding temperature. One coiler or group of coilers (8) forms the final product – circle of the tape.

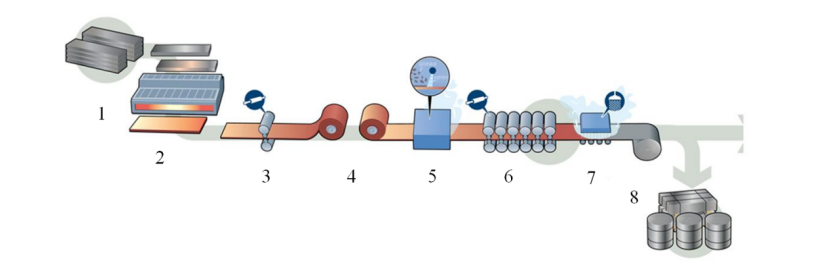


Image 2: Diagram of the hot rolling mill

# Application of deep learning to image classification