POSSIBILITIES OF COMPUTER ANALYSIS EXPLOITATION IN THE PROCESS OF SOLUTION SOME TASKS CONNECTED WITH MATERIAL FORMING

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MOŽNOSTI VYUŽITÍ POČÍTAČOVÉ ANALÝZY OBRAZU PŘI ŘEŠENÍ NĚKTERÝCH ÚLOH SOUVISEJÍCÍCH S TVÁŘENÍM MATERIÁLŮ

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Abstrakt

Na počátku byly úlohy počítačového rozpoznání obrazu zaměřeny převážně na rozpoznání písmen, podpisů a podobně. Teprve později byly řešeny i složitější úkoly. V současnosti umožňuje počítačová analýza obrazu řešit dokonce úlohy spojené s měřením a řízením technologických procesů. Článek ukazuje možnosti aplikace výše uvedené metody pro některé úlohy spojené s procesy tváření materiálu. Máme zde na mysli počítačovou analýzu klínové zkoušky tvařitelnosti při válcování za tepla a úlohu určování teplot vysoce ohřátých materiálů. V procesu určování teplotních polí povrchu zkoumaného objektu je použita analýza barev obrazu objektu a pro jejich vyhodnocení jsou zde použity algoritmy umělé neuronové sítě. Výhody prezentované metody spočívají v dostupnosti, dobré přenositelnosti a možnosti monitorování teplotních polí v místech, která jsou pro operátora těžko přístupná. Z analýzy měření je pak možné určit vhodné možnosti použití různých zařízení pro daný účel, pracovní oblasti a zákonitosti, které mohou měření ovlivnit. Chyby určování teplotního pole se v praxi pohybují do 10 °C. Zvýšení přesnosti metody je dále možné rozšířením vstupů neuronové sítě o doplňující informace jako je například typ osvětlení objektu a podobně. Modifikace výše zmíněné metody dovoluje s dostatečnou přesností odečítat také termogramy a jiné tištěné mapy skalárních veličin vyjádřených pseudobarvami (např. rozložení napětí v materiálu atd.). Využitím počítačové analýzy obrazu pro určení obrysu vyválcovaného materiálu se stává klínová zkouška velmi účinnou, protože přiřazení odpovídajícího průřezu klínu a vyválcovaného vzorku je velmi přesné, což umožňuje významně zlepšit výsledky výpočtů deformačních parametrů.

Abstract

At the beginning tasks of computer picture recognition were concentrated on figure recognition and signatures and only afterwards more complicated identifying tasks were solved.

At present, the image analysis enables to solve even some problems connected to measurement and conducting of technological procedures. The article shows possibilities of the application of the above mentioned method for some tasks connected with material forming processes. We have in mind a computer analysis of wedge test and temperature determination of highly heated materials.In the process of determination of surface temperatures the computer colour analysis is used and artificial neural networks algorithms are used for the evaluation. Advantages of the presented method consist in good mobility and possibility of monitoring of temperature fields in places with difficult access to the operator. From measurement analyses it was possible to define convenience of various devices for the given purpose, work regions and lawful acts affecting measurement. The modification of the method mentioned above allows with sufficient accuracy reading off printed thermographs and other charts of scalar item expressed by quasi colours (e.g. tension distribution in a material, etc.). By exploitation of computer analysis of the outline of the rolled out material, the wedge test becomes very effective because assigning between corresponding cross sections of the wedge and rolled out sample is very accurate, which allows to improve considerably even calculations of deformation parameters.

Keywords: Rolling, equivalent strain, strain rate, computer analysis.

1. Determination of temperature field of surface of the rolled material

1.1 Introduction

In the rolling process and other technological operations with materials heated to very high temperatures it is very important to know temperature distribution in the volume or at least on the surface of the given semi-finished product. Temperature is a decisive parameter which influences physical/metallurgical properties of the material, its deformation behaviour (including distribution of stress and strain in the formed semi-finished product) and structure-creating processes accompanying forming, cooling, etc. Forces, torques, power output in rolling, as well as final dimensions (accuracy, tolerances) of the final product, its microstructure and mechanical properties are strongly influenced by the actual and final temperature distribution in the volume of the rolled stock. Insufficient knowledge of distribution of the temperature field can lead to the fact that required service properties of the product will not be reached.

Currently a series of methods for measurement of temperature exists. One of the possibilities may be determination of temperatures from the computer image analysis of the investigated material, by means of camera, elements of artificial intelligence and image analysis.

1.2 Use of image analysis of the heated material with use of video-camera

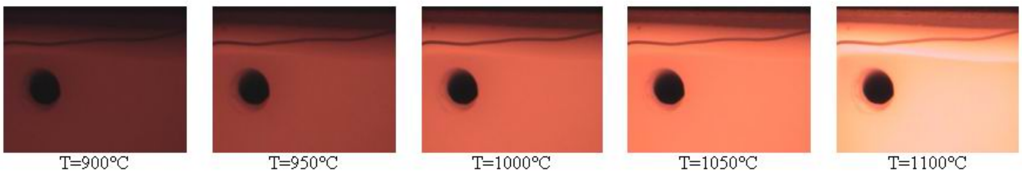

Fig.1 Relationship between colour and temperature of the highly heated material

Every body emits electromagnetic waves into the surroundings, the parameters of which feature its temperature. Many devices for temperature measurement work on the principle of evaluation of this radiation. Most of them work in the area of longer wave lengths (infrared radiation), but also pieces of information on temperature coded in spectrum of the visible light are possible to process. Experienced operational workers are even able to estimate temperature from colour of the heated material very successfully because colours of the material heated to high temperatures correspond with its surface (see Fig. 1).

One of possibilities how to get information about the distribution of the temperature field of strongly heated materials is use of the image analysis; the image is obtained by optical digital scanning equipment (camera). A principle of this analysis consists in determination of colour-creating constituents of the image – RGB of individual points of the monitored scene, i.e. of colour of the monitored object presented by the scanning equipment. Because every

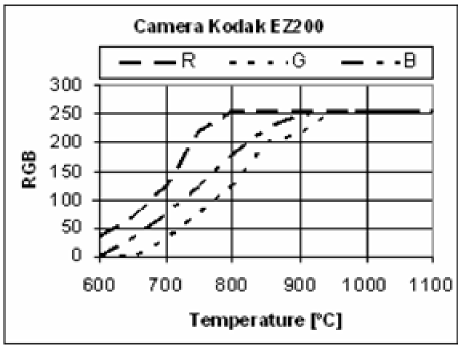

Fig.2 Dependence of colour component RGB on the temperature with web camera COMPRO PS39

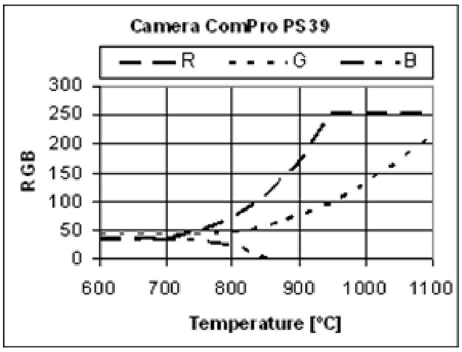

Fig.3 Dependence of colour component RGB on the emperature with web camera Kodak EZ200

equipment interprets colours differently and even one device depicts the scene in a different way, e.g. with change of the diaphragm, no universal relation between temperature and the presented colour exists (see Fig. 2 and 3). For evaluation of temperatures in a given point, the multi-layer feedforward neural network with learning algorithm Back Propagation can be used. In ideal case, when conditions for illumination of the scene are constant, we can use a simple neural network with topology e.g. 3-3-1, which represents 3 input neurons, always with individual constituents R, G, B, 3 neurons in the invisible („hidden“) layer and 1 output neuron, the value of which determines temperature of the particular measured point of the scene (Fig. 4).

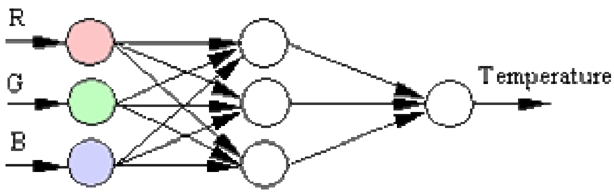

Fig.4 Topology of neural network (schematic)

This solution need not comply in case when parameters of illumination of the scene are changed (e.g. artificial lightening, lightening by daylight, etc.). In this case the disturbing phenomenon could be eliminated by installation of an auxiliary comparison surface and extension of the neural network by next 3 input neurons, with possible enlargement of number of neurons in the „hidden“ layer. In these three new input neurons then RGB constituents, featuring colour of the scanned comparison surface, have to be fed. Use of this method is conditioned by learning of the neural network based on data gained in the phase of teaching by another temperature measuring instrument.

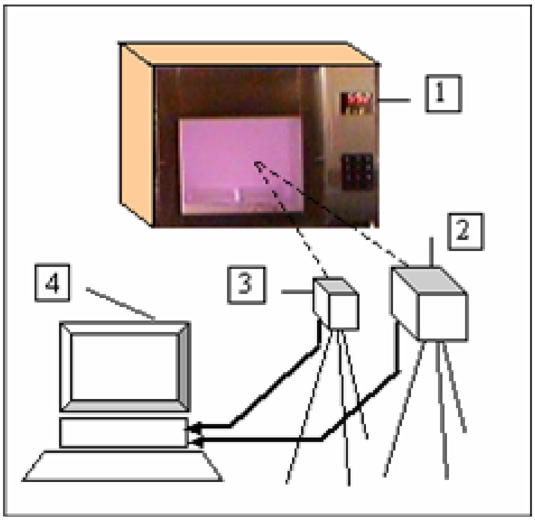

Fig.5 Learning of neural network (schematic)

It means that utilization of this method in practice has to be preceded by careful learning of the neural network in the given conditions, which have to be subsequently maintained. In the phase of learning the results of temperatures measured by a comparison measuring instrument (e.g. colour pyrometer) are compared with actual values indicated by the neural network. The algorithm Back Propagation gradually adjusts parameters of the network in such a way that differences between both values after learning are smallest ones. The situation is described in Fig. 5 where (1) – is measured object, (2) – is comparison pyrometer, (3) – is scanning equipment (camera), (4) – is computer.

The learned neural network then makes it possible not only to determine temperature in a single point, but also to get information on the whole temperature field of the surface of the observed object. If more complex algorithms of the image analysis are used it can partly be eliminated a local influence of scale, steam, etc.

The results obtained during laboratory measurements in the furnace, realized according to Fig. 5, can be seen in the graph in Fig. 6. Here three measurements of temperature executed by means of the colour pyrometer are compared with temperature values calculated by means of the computer image analysis using a simple web camera. Differences between temperatures read from the pyrometer and gained by use of the neural network did not go in the given case beyond ± 4 °C. In practice errors less than ± 10 °C are usual.

When temperature is changed in a small range, good results in temperature determination by a simple web camera can also be achieved. With a constant adjustment of the diaphragm of the scanning unit, the measuring range can be up to 200 °C around the temperature which was recommended by the process engineer.

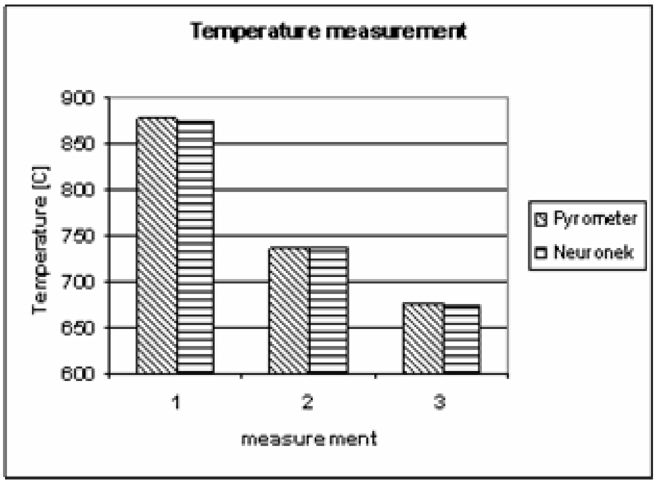

Fig.6 Accuracy of temperature determination

If the scanning equipment enables control of the diaphragm adjustment, the range of measurement can include all temperature values which can be registered by a human eye as a colour change. Nevertheless, in this case the correct computer evaluation requires that the neural network be enlarged by another input which will register data on the actual adjustment of the diaphragm.

In many cases it is possible to extend the range of temperature measurements using scanning units of better quality, mainly using cameras working in automatic modes. Nevertheless, in some cases this approach can have negative influence on accuracy of measurements and therefore its general use is not advisable.

1.3 Utilization of image analysis gained by thermovision

Another possibility of utilization of the proposed method can be evaluation of archived thermograms gained by thermovision. Based on the image analysis using elements of artificial intelligence, markedly more precise information on temperature field of the object surface can be reached, which appears in the photo in other („wrong“) colours than one is able to recognize with the naked eye. At the same time the digital data interpreting temperatures in monitored places of the object may be gained, which can be used for an arbitrary computer processing.

Evaluation of the thermogram is conditioned by availability of records in an electronic form (independent bit map) or in a printed form; but in this case the electronic form has to be made additionally by the scanner. The thermogram has to be equipped with a comparison scale (see Fig. 7). Also in this case the neural network has to be learned to define temperatures with colours according to the scale mentioned above, namely for each thermogram separately. Then, after careful learning of the network and verification of the results on colours of the scale, it is possible to determine temperature in every point of the picture. Fig. 7 represents an illustrative picture, in which learning and testing of the neural network was carried out by means of program „Neuronek“ [4]. The results accomplished with the use of the given method are very good. Neural network has learnt to assign temperatures for single colours with accuracy ±4°C, which cannot be achieved in the process of bare-eye analysis.

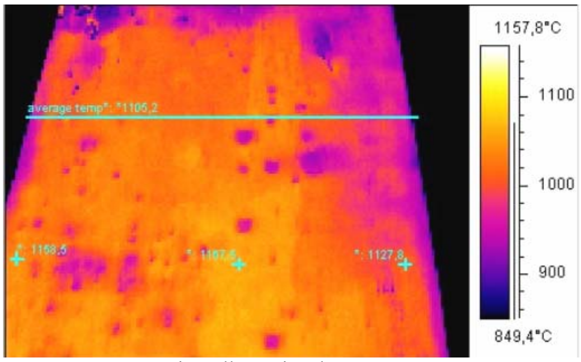

Fig.7 Illustrative thermogram

2. Exploitation of picture analysis in the computer processing of results of the formability wedge test

2.1 Introduction

A simple laboratory test performed by rolling of the wedge-shaped sample on plain rolls enables to investigate both the hot and cold deformation behaviour and above all formability of metallic materials effectively, thanks to its ability to implement a wide range of height reductions (commonly from 0 up to ca 80 %) in a single sample. The formed material's spreading induces tensile stresses at the sample's lateral faces, which can yield in cracking. Formability (or more exactly rollability) of the actual material can thus be evaluated as a function of temperature and strain. It is necessary to notice that this experimental method can not give the exactly defined results comparable e.g. with the results of plastometric tests because of the markedly changing conditions along the rolled sample's length (states of stresses, strain rate, etc.). On the other hand, this method is very suitable for comparison of rollability of some materials with lower plasticity – e.g. those containing some subsurface flaws in the as-cast state.

To increase accuracy and comfort of this method the special software was developed for calculation of equivalent strain and strain rate in whatever cross section along the length of the resulting rolling stock. Calculations are based on comparison of corresponding partial volumes of the wedge-shaped initial sample and resulting rolling stock. The latter has an approximately constant thickness but due to spreading strongly irregular planar shape and size. This factor considerably complicates principle application of the law of the volume preservation, when necessary calculations of partial strain components are carried out. The particular problem outlined was successfully solved by applying methods of computer analysis of a bitmap picture gained by scanning the planar shape of the sample after its rolling and straightening.

2.2 Obtaining of picture of the rolled out sample and its computer processing

On the accuracy in obtaining of dimensions of the rolled out sample depends the accuracy of values computation which represent plastic features of the material, of which the sample is made. Usually, a mechanical deduction of dimensions in several cross-sections is made and the obtained values are averaged. However, the values obtained in such a way do not allow acquiring continuous values of the monitored parameters and are loaded with a statistical discrepancy. Computer technique opens new possibilities of acquiring precise dimensions of the samples with exploitation of picture analysis. There are several possibilities how to acquire a first-rate two-dimensional picture of the plan area projection of the rolled out sample that is crucial for its volume determination.

One of the possibilities is the use of camera or videocamera. In this case however, risk of incorrect deduction of the dimensions may occur. First, because the camera is not always in the same distance of the sample in the process of repeating measurements, and second, because the value of magnification (ZOOM) need not be the same.

Repeatability of the measurements and its technique accessibility as well may be obtained by the use of scanner. While preserving the optimal differentiation ability in DPI, the acquiring of precise absolute values of picture dimensions is assured (see Fig. 8). In the process of rolling, the original sample is deformed and the edges of the sample are irregular with dome-shaped concavity. Also various forms of surface roughness (notches, cracks and so on) result in local changes of colour of the sample. These defects have to be removed because they could have unpleasant consequences in the process of computer analysis of the picture. In Fig. 8 the picture of the rolled out sample is shown before (left) and after (right) picture hand retouching. After the picture is retouched, it can be analysed and a set of values about the sample width along its length may be acquired.

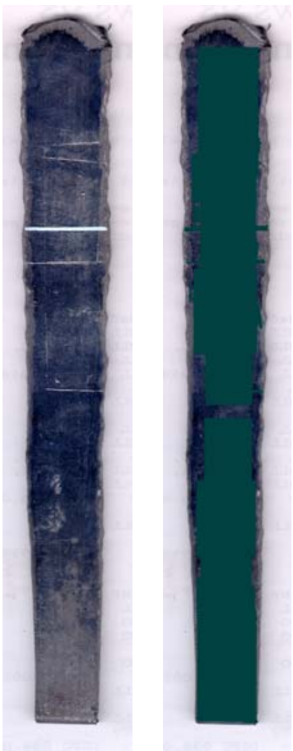

Fig.8 Rolled out sample (right - retouched picture)

Every pixel of the picture is defined by ordered triad of colour components RGB (see Fig. 9). The RGB arrangement is suitable for colour displaying on the computer monitor, but for dimension analysis of the samples of its pictures have to be the RGB values [1] converted to an arrangement that is divided into three components which define Hue, Saturation and Luminance. As the most suitable one HLS arrangement was chosen, the basic expression of colour information of which is apparent in Fig. 10. By choosing an appropriate interval of single components of HLS arrangement [1], the monitored object can be “picked up” from the whole picture and converted to a contrast projection, where the sample has black and its surroundings white attributes of colours. The pre-processed picture can be now further compiled in order to acquire precise layout dimensions of the deformed sample. Dome-shaped concavity of the sample sides after rolling results in problems with definition of accurate width and length of the sample, respectively. In the process of dimensions determination by mechanical measurement (e.g. with a slide rule), the diameter between maximum (outer relief) and minimum (inception of dome-shaped concavity) value is usually taken. Computer analysis enables to increase the precision of this operation. Because of illuminating of the sample by the scanner, the dome-shaped concavities are distinguished by the change of the colour hue and luminance compared to the rest of the sample. By changing the parameters that define the dividing line between the sample and its surroundings and in agreement with the law of the volume preservation the agreement between the known volume of the wedged sample (see Fig. 11) before rolling and computed volume of the rolled out sample can be reached; hence, the high precision of the width and length of the sample is assured.

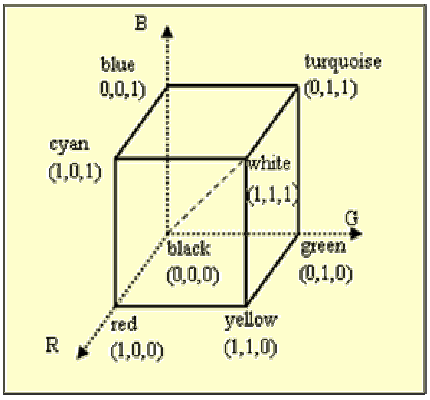

Fig.9 RGB model

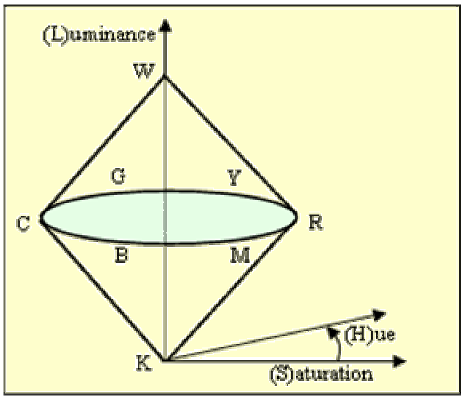

Fig.10 HLS model

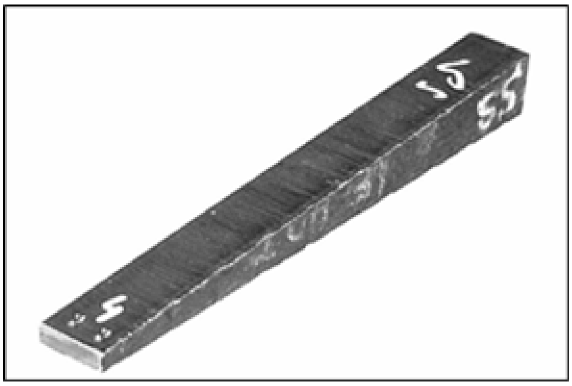

Fig.11 Specimen of a laboratory wedge shaped sample before rolling

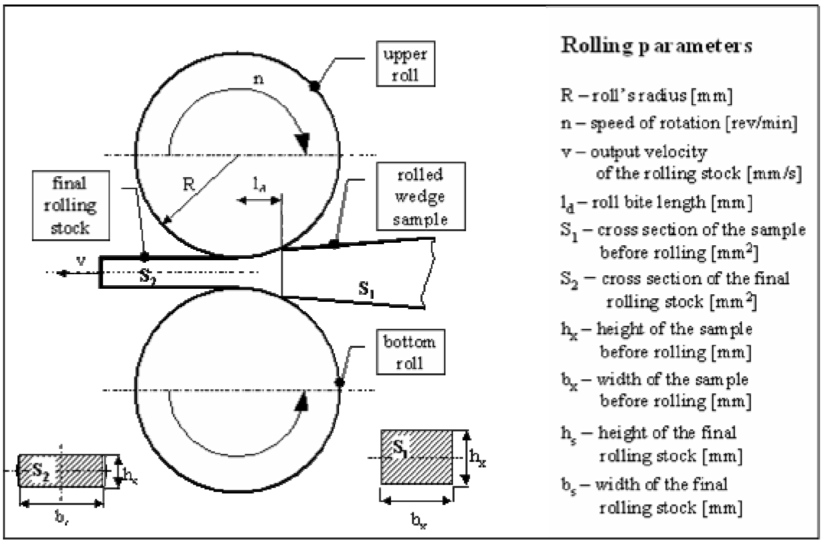

Fig.12 Simplified schema of the wedge rolling sample

2.3 Computation of deformation features of rolled material

A computer program for computation geometric dimensions of the rolled out sample and computation its deformation features was developed. Its intention is not only the improvement of computation but also maximum simplicity, comfort and automation for acquiring and computation of information about the rolled material.

When calculating equivalent strain, it is necessary to determine the real roll bite length ld at any place of the rolled sample and assign the selected cross section of the rolling stock to the relevant cross section of the input wedge-shape sample (by comparing the partial volumes of the sample before and after its forming). Equivalent strain e is calculated according to equation

$$e = \sqrt{\frac{2}{3}} \cdot \sqrt{e_h^2 + e_w^2 + e_l^2} \tag{1}$$

where strain in the height direction $e_h = \ln(h_s/h_x)$, strain in the width direction, $e_w = \ln(b_s/b_x)$, and strain in the length direction is calculated according to the law of conservation of volume as $e_l = -e_h - e_w$. Equivalent strain rate $\acute{e}$ [1/s] has been simply defined as

$$\acute{e} = e \cdot \frac{v}{l_d} \tag{2}$$

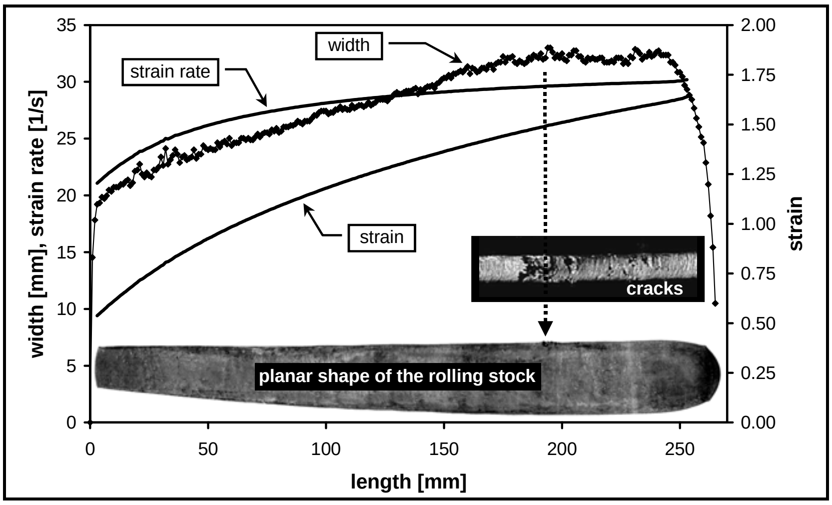

Fig.13 Results of the computer processing of the wedge test of formability

Fig. 13 shows an example of information obtained after the complex computer processing described above – data concerning strain as well as strain rate along the hot rolled wedge-shape sample made from the steel grade 23MnB4 (temperature 950 °C). The initial as-cast state brought about the crack formation (initially at $e = 1.5$ and $\acute{e} = 29.6\ s^{-1}$).

3. Conclusion

Only a few examples of using the image analysis and artificial intelligence for solving problems associated with material forming were mentioned in the article. In the process of determination of surface temperatures the computer colour analysis is used and artificial neural networks algorithms are used for the evaluation.

Laboratory and operational tests were carried out for verification of functions of the mentioned approach. Advantages of the presented method consist in good mobility (the equipment is easily portable) and possibility of monitoring of temperature fields in places with difficult access to the operator. From measurement analyses it was possible to define convenience of various devices for the given purpose, work regions and lawful acts affecting measurement.

For determination of surface temperatures of strongly heated materials normal cameras are sufficient, with the temperature range of ca ±100°C around the temperature, the value of which is given by optimum adjustment of the camera diaphragm. It means that the diaphragm has to be adjusted according to working temperature for the particular technological process. If the diaphragm is adjusted correctly, the influence of change of emissivity of the heated material is partly suppressed. If parameters of the camera are adjusted automatically, the usable temperature range is increased but measurement becomes more sensitive to a change of conditions for scanning the image.

Reproducibility of the method was verified by repeated measurements when data reached in one day served as a training set of the neural network and data from the other day were used as a test set. The measurement error was slightly affected by external lightening conditions. Without elimination of these conditions, by another way of learning of the neural network, the error of the temperature determination was ±10°C, at the maximum, with the elimination the error did not go beyond ±5°C as compared to data gained by the comparison pyrometer.

The modification of the method mentioned above allows with sufficient accuracy reading off printed thermographs and other charts of scalar item expressed by quasi colours (e.g. tension distribution in a material, etc.).

By exploitation of computer analysis of the outline of the rolled out material, the wedge test becomes very effective because assigning between corresponding cross sections of the wedged and rolled out sample is very accurate, which allows to improve considerably even calculations of deformation parameters.

Acknowledgement

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