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# ESTIMATION OF BENDING ANGLES DURING FREE BENDING

*UDK: 621.981./.982*

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**Abstract.** *The experimental estimation of bending angle during free bending is realized both by optical and mechanical methods.*

## 1. General

The experimental estimation of bending angle during free bending is realized both by optical and mechanical methods. Due to the high demands on the precision of the free bending process on a bending device it is necessary to find out ways of a bending angle correction, derived from the actual bending process by online measurements towards to the finished part, which is removed from the device. The effect, also known as the elastic recovery effect, depends from the material properties and the parameters of technology as well.

## 2. Scope of the Investigation

Since the free bending technology is used for several applications, some experience about the influence of technology and material parameters of the workpieces and tools are reported by several authors. Most of the knowledge is given in a qualitative way, but, nevertheless, some remarks could be done on this base:

- It is mostly important to avoid internal stresses in the workpiece, which lead to changes of the material properties during the deformation process, especially in the surface regions of the workpiece.
- Due to the effect of anisotropy of sheet metals during deformation there is a range of the bending angle variation within some degrees.
- Especially in thin sheets there is a strong influence of the variation in sheet thickness.
- Under technology consideration it must be possible to finish a workpiece without any

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second or third step of bending to get the final bending angle exactly.

The best method of bending angle estimation seems to be an online estimation with best fit calculation.

## 3. EXPERIMENTAL SET UP

The investigation was performed at the Forschungszentrum Mittweida e.V. at the department of bending technology, laser processing and production logistics.

The investigations were carried out at a sheet bending system of the Weinbrenner Co. Merklingen. The tool support was completed by a bending angle measuring system. This system included a light source at one end and the optical detector system at the other side.

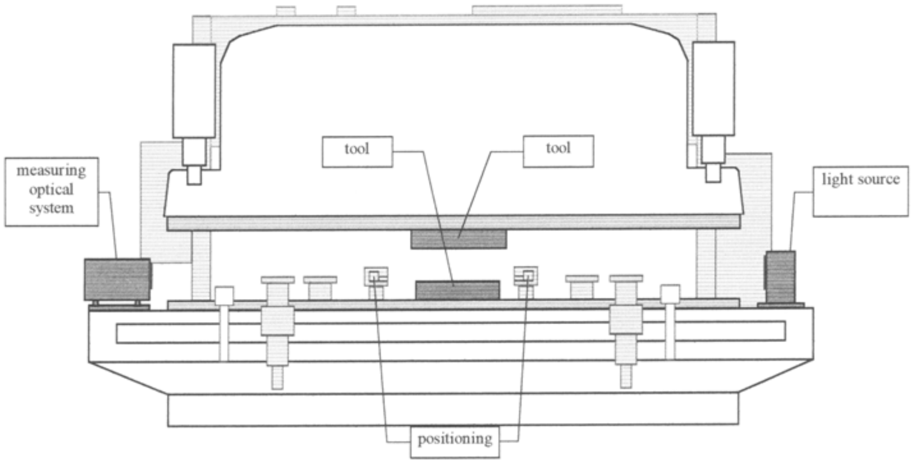



Fig. 1. Scheme of the measuring device

## 4. ESTIMATION OF BENDING ANGLE

### 4.1. Laser and optical methods of the bending angle estimation

Several solutions have been investigated and described in the literature [1,2].

A laser technique was performed from Cybelec Co., which worked by means of a laser source, special mirror systems and an optical detector. The laser light, passing the contour of the sheet was detected by a grid of sensors to form the actual contour of the sheet bent. Another solution is described by Thieme [2], who used a calculation. All these devices need some special tools and are influenced by the surrounding conditions and the calculation time respectively.

Very useful is the method of Geiger [3], who used a linear light source for bending angle estimation. A laser line is produced and calculated by laser triangulation by means of laser diode, scanner and CCD camera integrated in the tool. Another solution is based on a mechanical sensor for the localization of the sheet material (LVD Co., Gullegem

[4]), but in fact, additional information is needed to get an online information about the actual bending angle during and after deformation.

Generally, it is possible too, to use the moire method as described by Steinbichler for contouring measurement. An electronically activated grid producing grid lines on the surface of a sheet is analyzed by picture processing methods to give the bending angle information. Although it is working very sensitive, it needs time for processing 3d-data.

The method used in this investigations consists in gray scale picture processing of the front side of the sheets, analyzed by FRAMES software system [5]. The device itself consists of a measuring system with integrated optical long distance array (2 lenses, 3 mirrors for parallel projection) and CCD camera. The system is beared to allow justifying in two axes towards to the sheet profile. At the opposite side located is the light source. The distance may exceed 0.5m up to 3 m.

### 4.2. Picture processing using FRAMES program

The FRAMES program system is commercially available working on PC with a flame grabber and an additional monitor for picture processing. It brings also in action other optical field measuring methods, such as photo stress methods, moire method for surface strain measurement and contouring, laser speckle interferometry, shearography and holographic interferometry.

In principle, the system allows to generate gray scale pictures with 8 bit depth in 512x512 matrix system. To work effectively with flame grabbers it is convenient to produce standard masks of the picture, containing the sheet contours on each side of the tools. So we can avoid the gray scale information of changing background and tool conditions. Next is to determine upper and lower boundary of the gray scale expected in the experiment. It is possible, to expect the outer and/or inner edge of the sheet contour by variation of the gray scale boundaries. Next step is an edge extraction including the influence of the sheet thickness. A linearization is carried out by linear regression processing. The result is given in the estimation of the two edges of the bended sheet, including the bending angle. The value of the bending angle gives an accuracy of less thali 0.1 degrees.

### 4.3. Accuracy of the results

The accuracy of the results is within the range of ±0.09 degrees under the condition of nearly symmetrical position of the edges of the sheet. Otherwise the accuracy may differ in worst cases within 1,5 degrees, especially due to picture areas at the border of the optical system. The calibration of the system is quite easy. The long distance accuracy is proofed by using of two tool segments, arranged at the nearest and farest position. Next step is the determination of the real coordinates to pixel coordinates. This could be done by calibrating picture depth and picture height by help of a known extension of a master piece.

To proof the accuracy of the measuring device, a basic angle of about 90 degrees and 0.8mm of thickness was measured about 100 times after repositioning at several positions of the tools. The accuracy of the angle was in the range of 0.07 degrees. The material was steel sheet.

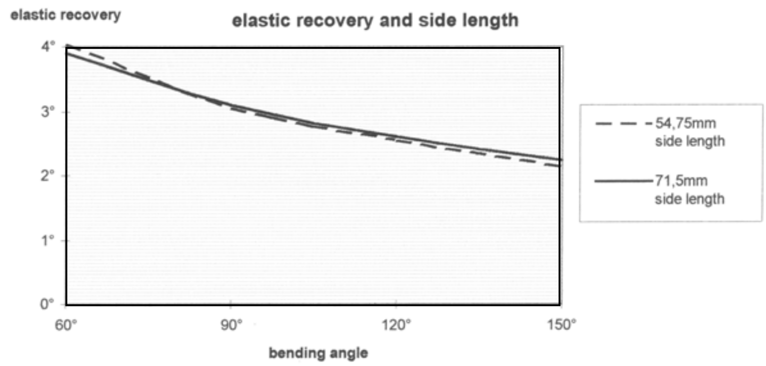
Further investigations were carried out with bending angles of 60, 90, 120, l50 degrees, perpenticulary and in direction of maximal anisotropic coefficients.

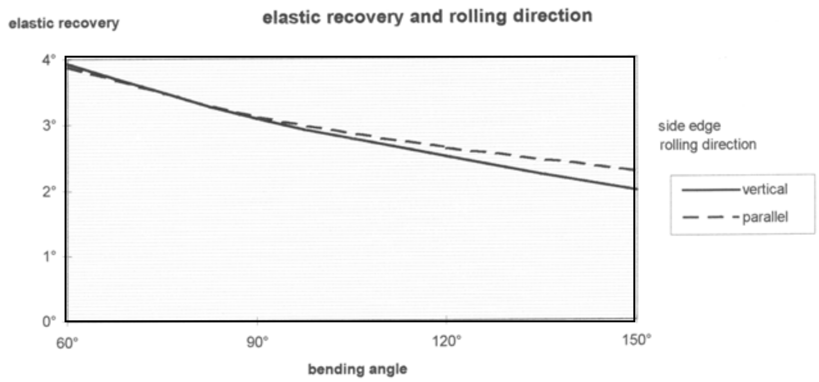
Ten more samples were investigated with bending angle of 70, 80, 100, 110, 130 degrees.

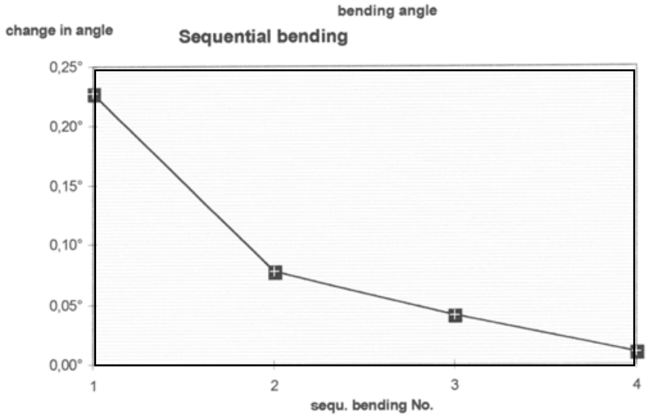
## 5. RESULTS

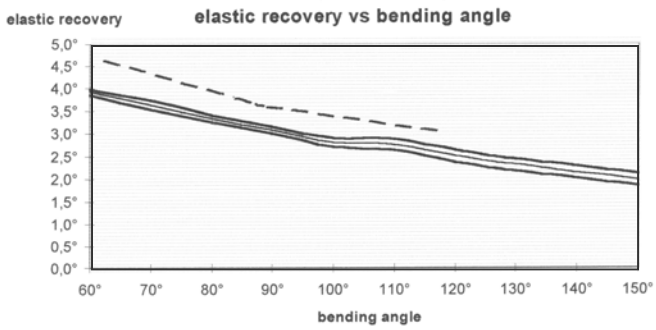
### 5.1. Bending of steel sheets

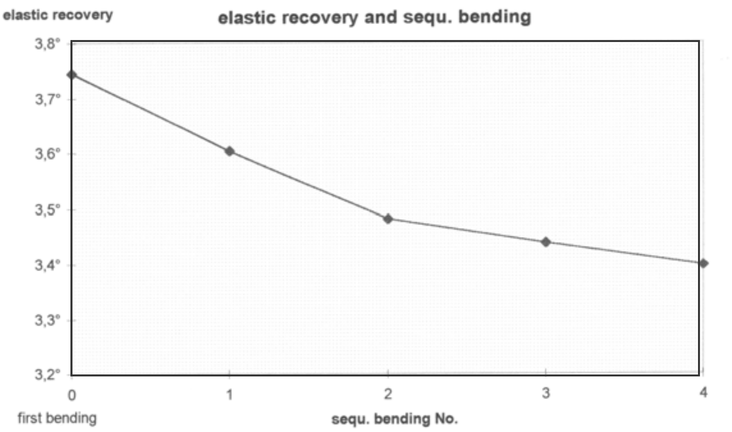
Here are some results of the estimation of bending angles





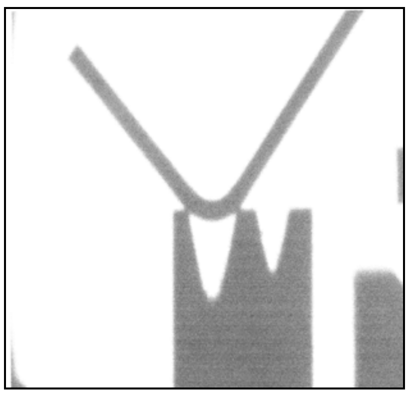



Fig. 2. Gray scale picture without processing steps

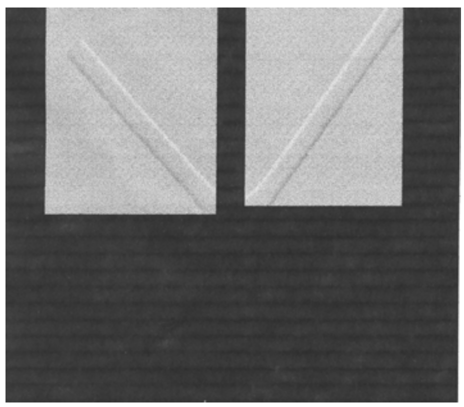


Fig. 3. 2-dimensional picture processing of the gray scale source

Fig. 4. Extraction of the sheet edges

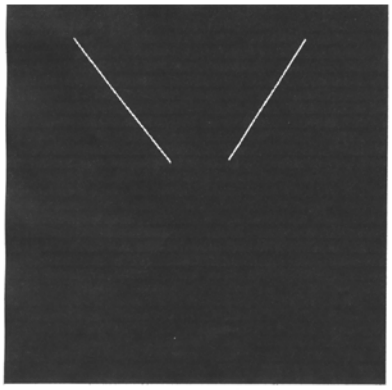


Fig. 5. Extraction of the sheet edges after mask operation

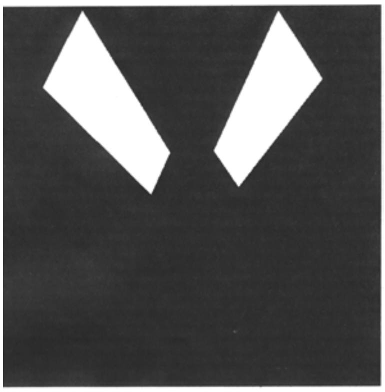


Fig. 6. Standard mask generation

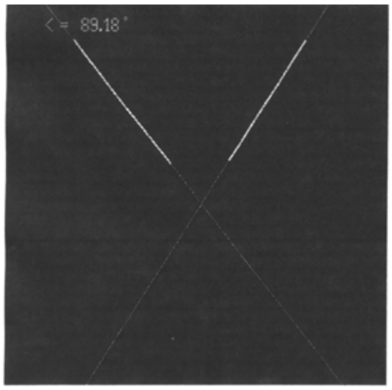



Fig. 7. Final result of picture processing

## 6. CONCLUSION

Among the various methods of the estimation of bending angles during sheet metal forming fast optical picture processing methods seem to be favorite methods in online measurement techniques. The advantages of gray scale methods and laser line methods give effort in the accuracy and in the handling of these combinations with bending devices. More investigations are needed to integrate CNC-controlling and material resp. process parameters. The picture processing with FRAMES system is available in this range successfully.

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# ODREĐIVANJE UGLOVA SAVIJANJA PRI SLOBODNOM SAVIJANJU

## Werner Totzauer

*U ovom radu je realizovano eksperimentalno procenjivanje ugla savijanja pri slobodnom savijanju metalnih limova i to primenom optičkog i mehaničkog metoda.*