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Springback compensation for spring steels

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Abstract — Spring steel exhibits exceptionally high tensile strengths, leading to large elastic fractions during bending and, consequently, pronounced springback that alters the final geometry. Conventional compensation strategies rely on empirical rules and bending tables and therefore insufficiently account for batch-to-batch variations. This paper proposes an at-line methodology to characterize and compensate springback on a batch-specific basis using a cost-effective three-point bending test. The approach comprises: (1) test execution, (2) identification of the material flow curve from bending data, (3) integration of flow curve into numerical process models to predict springback for the actual tooling, (4) numerical generation of a database that maps springback over target angles and flow-curve variants, and (5) interpolation of expected springback and derivation of the required tool travel for new batches. The method enables rapid transfer of laboratory characterization to process parameterization, thereby accelerating set-up and improving dimensional accuracy. It is applicable across a broad range of materials, and the required investment in three-point bending equipment is modest relative to universal testing machines. Overall, the methodology provides a practical route to efficient, batch-adaptive springback compensation in industrial bending processes.

1 Introduction

A specific type of steel, known as spring steel, is used in the manufacturing of metallic springs. Spring steels exhibit exceptionally high tensile strengths, reaching up to 2200 MPa, which is several times higher than the tensile strength of regular steels (DIN EN 10151, 2003). This means that a large portion of the deformation in bending processes is elastic, which in turn means that the deformation is reversible after the removal of external forces. Thus, after the removal of forming tools, only the plastic portion of the deformation remains. This effect is referred to as springback and must be compensated for by overbending the part.

A combination of experience and bending tables for various steel grades is commonly used by workers to determine the required bending angles for springback compensation. However, it is evident that the exact process parameters for a material can only be determined experimentally, as batch deviations, such as those in alloying, structure, or thickness, affect the springback behavior.

The tensile test is a widely used and versatile method for material characterization. The three-point bending test may be less common, but it is more cost-effective in terms of overall system costs and sample preparation expenses. Therefore, this publication proposes a methodology for characterizing springback behavior using three-point bending tests, which enables batch-to-batch testing and a more straightforward transfer to industrial bending processes. The characterized springback behavior for each individual batch finally supports workers in adjusting the process parameters more quickly.

2 Methods

This publication proposes an approach, consisting of five steps, for considering batch deviations in bending processes by utilizing at-line three-point-bending test data.

Step 1: Three-point-bending-test

The setup and execution of the three-point bending test are described in DIN EN ISO 7438:2021. According to this standard, three different setups are permitted. These are a) A bending device with two support rollers and a bending punch, b) A bending device with a V-shaped die and a bending punch, and c) A bending device with a clamping mechanism. The bending device with two support rollers and a bending punch, as shown in Figure 1, is regarded as the most promising configuration, since it shows less friction than setup b) and a simpler kinematic than setup c). The sample geometry in all setups is a rectangular strip.

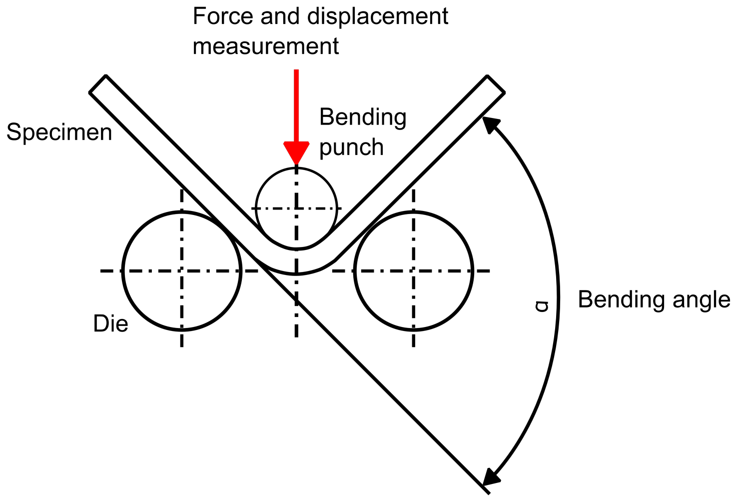

Figure 1 Description of the three-point bending test setup a) according to DIN EN ISO 7438:2021.

Step 2: Determination of the flow curve

Hartmann et al. (2024) describe a method for identifying the flow curve of a material using a three-point bending test. The procedure is shown in Figure 2.

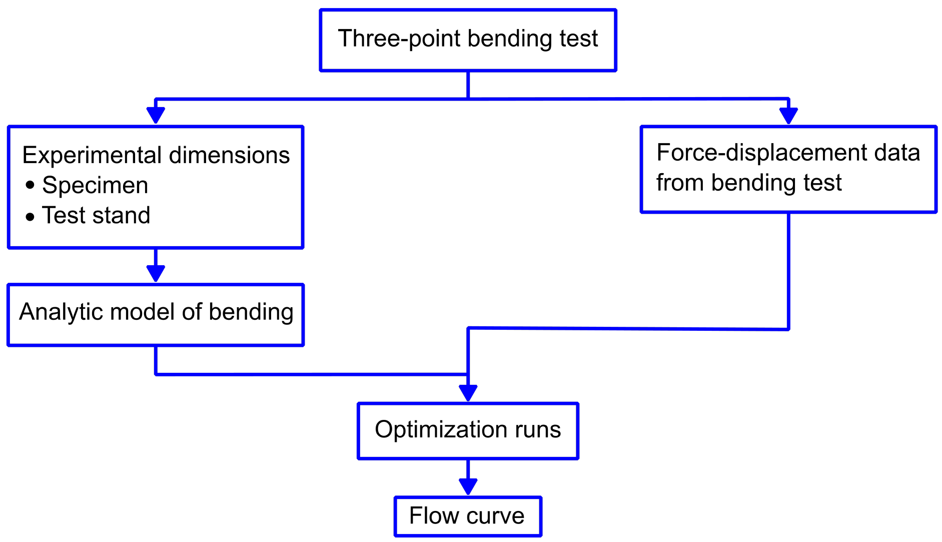

Figure 2 Identification of the flow curve from three-point bending experiments according to Hartmann et al. (2024).

Step 3: Numerical Simulation

Numerical simulations can predict springback in the actual tool that is used in a bending process. The flow curve obtained in Step 2 must therefore be integrated into the numerical model of the process. The simulation can thus predict springback for this particular material and tool.

Step 4: Generation of a database

Since it would be very time-consuming to run simulations for every new batch of material, a database is generated numerically, which comprises the springback behavior for various bending angles and flow curve variations.

Step 5: Harnessing of the database in the bending process

On receipt of a new batch of material, a three-point bending test is to be executed. With the flow curve derived from the experimental results, the expected springback in the bending process can be interpolated from the database. As the kinematics of the tool can be derived from its construction, the corresponding tool travel path for the target angle can be obtained.

3 Conclusions

The proposed methodology outlines a path towards batch-to-batch compensation of springback in industrial bending processes, utilizing an at-line testing setup. The setup and method can be applied to a wide range of materials. To profit from this advanced method of springback characterization, companies must invest in three-point bending machines. However, the investment is small compared to universal testing machines used for the execution of tensile tests.

Acknowledgment

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