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Computer aided process planning for sheet metal bending: A state of the art

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Abstract

Purpose of this paper is to offer the reader an overview of recently performed and ongoing research related to process planning for sheet metal bending, thus providing a starting point for further exploration of this field. The scope of this review paper is limited to sheet metal bending as performed on numerically controlled press brakes, with special focus on air bending. Automatic process planning requires a good understanding of the material behaviour under process conditions. Therefore, some space has been reserved for an overview of bend modelling efforts and, directly linked to this, in-process measurement and adaptive control methods. Part representation and feature classification methods for bent sheet metal parts are also discussed. Sections are dedicated to the core problems of fully automated process planning in sheet metal bending: bend sequencing, collision detection, tolerance verification and tool selection. The state of the art review is completed with an overview of ergonomic analysis methods for process plan evaluation.

Keywords: Process planning; Bending; Sheet metal; CAPP; Press brake

1. Introduction

Sheet metal forming is one of the oldest manufacturing processes known to mankind [1], and bending can probably be considered its most basic variant. However, the numerous research contributions dedicated to sheet metal bending that have been published over the past decade, and the constant stream of announcements by R&D departments of machine constructors form strong indications that not all research challenges related to sheet metal bending have been exhausted.

Purpose of this paper is to offer the reader an overview of recently performed and ongoing research related to process planning for sheet metal bending, thus providing a starting point for further exploration of this field.

Sheet metal parts are typically produced by a sequence of bending operations. The bending process

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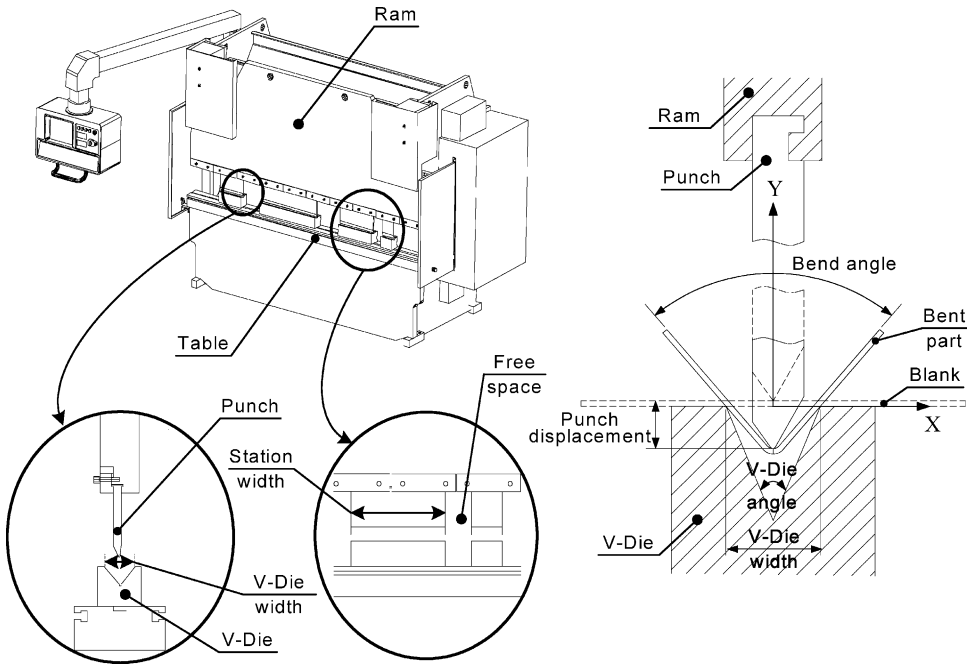

Fig. 1. The bending process and its resources.

starts with a flat workpiece and ends up with a three-dimensional object of interconnected flanges. The bending operations are executed on bending machines – so-called press brakes – using various tools and holding devices (see Fig. 1). Tools consist of dies and punches of different shape and length. Usually, a machine can hold several tools at the same time, while a tool can be applied for different bends, too. Tool selection and operation sequencing is based, first of all, on geometric considerations so as to avoid interferences between the workpiece, the tool and the machine. Furthermore, the planner has to consider a number of issues concerning material properties, tolerances, ergonomics and cost factors.

Main phases of the process of generating as well as executing process plans in sheet metal bending are shown in Fig. 2: definition of the planning problem, automatic plan generation and plan execution. Given a model of the part – including its dimensions, tolerances and material properties – and the description of the bending machine and tools, process planning is aimed at generating an executable sequence of bending operations, together with appropriate part set-up orientations, tools, gauging locations and punch displacements. At planning time, however, due to various simplifying assumptions, one can but approximate the final shape and tolerances of the part. Hence, adaptive processes are applied so as to manufacture what really has been required in the part design. This is the reason why physical bend models play a crucial role in each main phase of plan generation and execution.

Details of automatic process planning are shown in Fig. 3. Planning is a ‘‘wicked’’ problem because its tasks mutually interact: there is no evident ordering of the decisions, and partial solutions cannot be simply combined into a final one. In the chosen overview structure, heart of the planning process is the sequencing of the bending operations. However, bend sequences have to be measured also in terms of hard reject criteria set by gauging location, collision detection and tolerance verification. On the other hand, feasible sequences can be evaluated and compared taking cost-efficiency of the tool set-up as well as ergonomic considerations into account.

This state of the art review is limited to sheet metal bending as performed on numerically controlled press brakes, with special focus on air bending that involves bending of parts on a V-shaped die with a punch. Swivel bending and wiper bending are explicitly excluded from the scope of this review.