Sheet metal forming global control system based on artificial vision system and force– acoustic sensors

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A R T I C L E   I N F O

A B S T R A C T

Forming processes are manufacturing processes based on deformation of raw material applying pressure in one or several stages until getting the final product. This process depends on many factors, e.g. process parameters, material properties or lubrication, leading to possible defective parts. Correct forming of parts is very important as any defective part may result in big economical losses, e.g. the return of a complete set of parts or the loss of some clients. Thus, in our European Craft Pro2Control project, leading German, French, Italian and Spanish companies, universities and forming industries are defining and implementing a zero-defect forming control system, minimizing costs and maximizing the throughput of parts.

Commonly integrated sensors (force and acoustic) do not allow to detect all types of faults in this kind of applications. Thus, we consider a multisensor approach, associating artificial vision to the previous sensors. Vision may allow better understanding and/or characterizing of force and acoustic measures, while it can detect faults that the other sensors may not.

The design of the artificial vision system has been separated into a pre- and post-processing part. The former consists of a proprietary intelligent camera built up by one of the project leaders (Delta Technologies Sud-Ouest or DTSO), which contains a CMOS sensor, FPGAs, RAMs and a USB 2.0 connection, and where parallelizable bottlenecked image-processing algorithms are implemented (whenever image-processing algorithms can be implemented on FPGAs, processing times will be about 100 times faster than on a standard microprocessor). The latter consists of proprietary non-bottlenecked image-processing algorithms, implemented on a regular PC, using open source libraries. This approach provides a fully mastered development, and guarantees durability and maintainability of the system (non-dependence on commercial items), as well as a new scale of production throughputs. The system is customizable, and the multisensor approach will improve fault detection robustness.

1. Introduction

The automotive industry is demanding to their suppliers, higher complexity parts, manufactured with less formability materials, at higher production rates and with stricter quality requisites. The strains suffered by the materials during the forming stage have increased considerably and, as a consequence, even small variations in the properties of the raw material or in the variables of the process (e.g. lubrication or slight material strength variation) may lead to defective parts. However, good forming of parts is a very critical factor, as any defective part may result in big economical losses, e.g. the return of a complete set of parts or the loss of some clients.

Traditional control techniques (e.g. PID and other non-linear methods) have been introduced in order to model forming processes [1]. However, the behavior of the material during its deformation, the friction between tools and material and/or the lubrication, make these processes highly non-linear and almost impossible to be described by a mathematical model, making these traditional control techniques non-practical. On the other hand, during the years, it has been demonstrated that human operators are able to control sheet metal forming processes very successfully. Thus, "intelligent control systems" (e.g. fuzzy logic and expert system, etc.) that perform in a similar way to human expert operators, have been developed (these systems have been successfully used for many years [2,3]).

Besides that, recent advances in micro-electronics and other fields of Artificial Intelligence, permit nowadays faster and more accurate data measurements, making total control of every single

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part at high-speed rates possible. In forming processes, two main sensor families are used: on one hand, force and acoustic emission measuring sensors [4] and on the other hand, computer vision systems [5]. These sensors are complementary to each other, as some faults may be observed by one type of sensors only, while others may be observed by the other type of sensors only. When the same default is detected by both sensors, a data fusion or data integration in a controller may be performed. Sensor data may be sent to an "intelligent control system", which uses them in order to change directly the process parameters or advise the operator of the forming machine [6].

2. European craft pro2control project

Pro2Control is a European Craft project formed by a consortium of leading German, French, Italian and Spanish companies, universities, research institutions and forming industries, with the aim of implementing a zero-defect forming control system, trying to minimize development costs and at the same time, maximizing the throughput of parts. Alzuaran and Garita S.L. are two Spanish forming companies where the final system is going to be installed. Troqueles y Derivados S.A. is a company that produces forming tools for the Alzuaran and Garita presses. Brankamp is a German company that develops and installs force/acoustic sensors. Delta Technologies Sud-Ouest (DTSO) is a French company that builds custom embedded systems and electronic

designs, as well as proprietary software for them. In particular, it has high expertise in development of intelligent FPGA-based cameras with embedded Artificial Vision, and image-processing software. SanGiacomo s.r.l is a company that builds forming presses. The University of Stuttgart (Germany) provides high expertise in industrial forming and the University of Mondragon (Spain) provides expertise in artificial intelligence techniques and is the leader of the project.

In order to build a zero-defect control system, an "intelligent control system" has been developed. This control system combines fuzzy logic and expert system techniques, giving the operator of the machine feedback and advice about what the possible errors/mistakes are, and what to do in order to correct/prevent them. This system is fed by data provided by a force–acoustic monitoring system and by the results of the artificial vision system (Fig. 1). Additional information about the control system can be found in [6].

Alzuaran S.L. and Garita S.L (Spain) have defined which parts to control, as well as the minimum processing speed (depending on the throughput of their forming presses). The parts presented in Fig. 2 correspond to Alzuaran's parts Refs. [1,2]. Both parts are planar and chosen due to their high production rates and because they are representative of other similar parts. Their production throughput is about 60 strokes/min, and two parts are produced per stroke.

The Brankamp PK550 sensor-based monitoring system is used to control tool/facility condition and product quality during
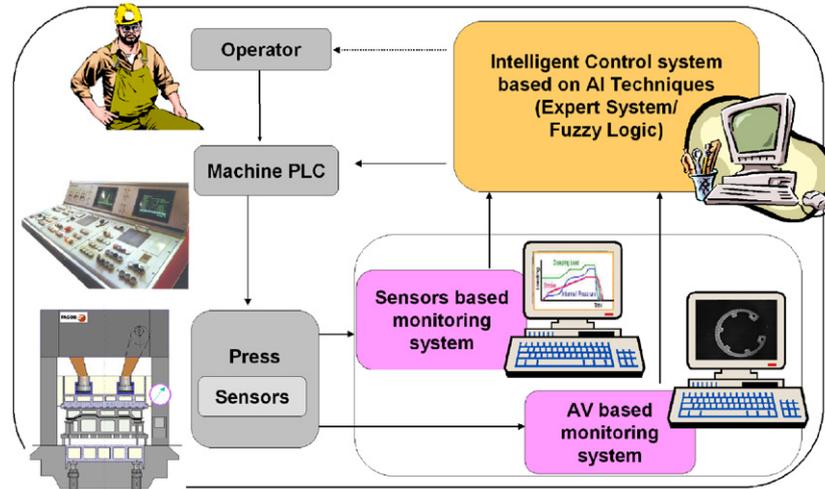
Fig. 1. Intelligent control system architecture.

REF. 1
o Diameter A : [21.56-22.11]mm
o Separation B: [4-6.5]mm
o Width C: [2.25-2.5]mm
o Thickness D:[1.23-1.28]mm

REF. 2
o Diameter A: [37.55-38.30]mm
o Width B: [3.25-3.55]mm
o Diameter C: min 2.55mm
o Width D: max 5.5mm
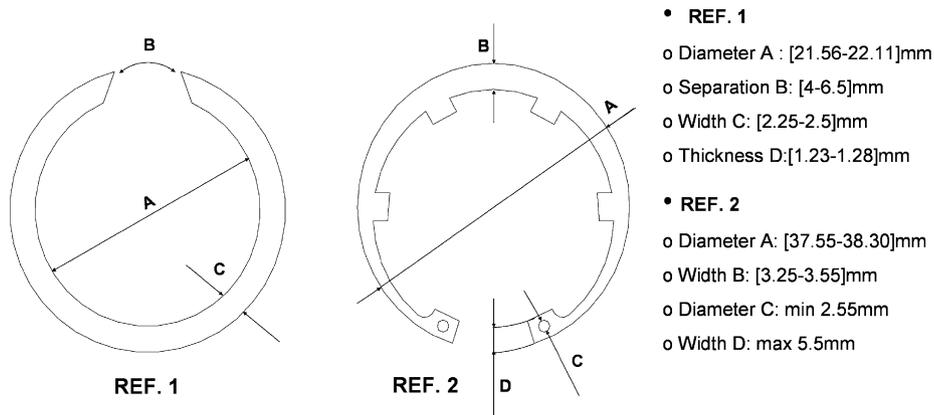
Fig. 2. Refs. [1,2] parts with their tolerances.