The Potential for Electromagnetic Metal Forming for Plane (Car Body) Components

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Abstract

Classical quasi-static technologies of sheet metal forming are not the only domain of the Fraunhofer Institute for Machine Tools and Forming Technology (IWU). It also delves into techniques for high-energy rate forming, such as gas generator technology, and it will be dedicating greater efforts to electromagnetic metal forming. Electromagnetic metal forming processes major potential for innovation and development in manufacturing car-body components since the benefits to be derived from this technique (such as extending the limitations of forming, enhancing spring back behavior, and delivering a high degree of flexibility in production) have this sector's key problems in mind.

The Fraunhofer Institute for Machine Tools and Forming Technology focuses its research on coming up with technology, tool and plant strategies suitable for manufacturing medium-sized and large car-body components. There are two technological directions that IWU targets in this field of research. First of all, given the existing technical and physical process constraints, it is studying the possibilities of large-scale and partial deformation since both directions are of importance for the targeted products. However, these two approaches have very different requirements for designing and tools. The first approach forms components without preforming. Several forming steps are required for mapping typical car-body component shapes either with serial workstations or a flexible tool system. The partial electromagnetic metal forming approach means using integrated plant components, i.e. combining conventional press equipment with a magnetic forming plant. This can tap a potential that encompasses the technological benefits mentioned above while hiking productivity and scaling down the expenditures for investing in equipment.

Keywords:

Electromagnetic metal forming, Sheet metal, Forming, Accuracy, Calibration, Deep drawing

1 Introduction

The car body is one of the most important components, meaning that it has a major bearing on quality. The trend towards increasing perfection in automobile engineering (not just quality in terms of appearance, but also physical quality) means that car body engineering is subject to an ever-increasing demand for new ideas. In this domain, it is the application of new materials and joining technologies that force spring back behavior in conventional forming techniques into a continually limited tolerance range, making it virtually unmanageable. This directly results in reduced deformation reproducibility combined with dwindling production stability. The pressure to produce higher-quality cars is accompanied by the pressure exerted to scale down costs, forcing companies to constantly augment the efficiency of their manufacturing processes. These costs include not only personnel, but first and foremost the expenditures for plant equipment that jeopardise modern production technologies. Electromagnetic metal forming, from the techniques of high-energy rate forming, is the main process that promises the potential for providing relief from the aforementioned problems.

2 The Potential of Electromagnetic Metal Forming

In contrast to quasi-static forming techniques, the essential benefits to be derived from the electromagnetic metal forming technique for manufacturing car body components are:

- it achieves higher deformation ratios since its strain rates are in the range of the hyperplasticity of the material,
- the component has little spring back or none at all, meaning high dimensional accuracy,
- the process can be well reproduced and automated,
- it is inert to instability (folds and dents),
- the material has a high degree of strain hardening,
- it is a contactless process, meaning less surface damage, and
- it is environmentally compatible.

Fraunhofer IWU made a comparison of the investment expenditures with a conventional press line and an adequate electromagnetic metal forming plant for manufacturing a large-scale car-body component. It indicated an essential advantageous of cost ratio. The major cost difference is a result of the different plant equipment, while tools and automatic equipment were postulated to be at similar rates. Furthermore, we may also expect additional savings from the costs for tools.

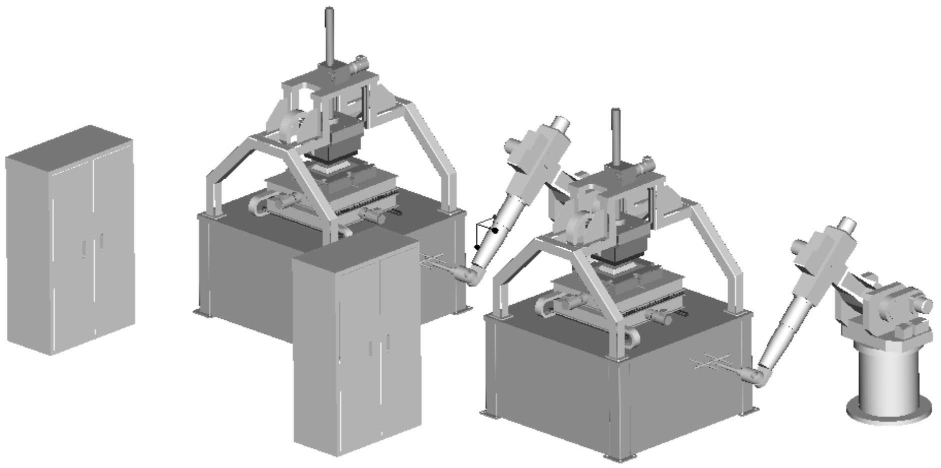

Figure 1: *A study for integrating electromagnetic metal forming plants in production lines*

Previously, process application was mainly restricted to producing and joining smaller rotation-symmetrical components (such as pipes and sections), and electromagnetic metal forming is applied in simplified sheet metal processing for embossing operations. However, this technology has not been applied to manufacturing larger-scale formed sheet parts either in terms of process design or plant equipment or in a scientific sense or in practice. Hence, after decades of stagnation in the field of electromagnetic metal forming, there are good prospects for furthering this process since new and important electrical and electronic developments have emerged and complex technical conditions (i.e., new materials) and economic conditions (i.e., scaling down costs) are exerting greater force on manufacturers to search for ways to augment efficiency. This is the reason the Fraunhofer IWU is concentrating its research work in electromagnetic metal forming on coming up with technology, tool and plant strategies suitable for manufacturing medium-sized and large-scale car-body components (Figure 2) due to its major potential for saving and the process benefits to be derived. The entire assortment of car body components is included in our deliberations:

- class-A exterior components (such as the roof and exterior door sheet metal),
- interior car body components (such as the interior door sheet metal and floor sheet metal), and
- structural components (such as side members, crossmembers and the A-, B- and C-columns).

In addition, the present range of electromagnetic metal forming processes has the technological and physical peculiarity of implementing the deformation by reducing wall thickness. However, if this process is applied to car-body components with rigidity and safety functions there are tight restrictions in terms of maximum material thinning. Thus, one of the concentrations of our study will be to calculate the effect that any strain hardening has on compensating for these factors and formulating new compensation strategies.

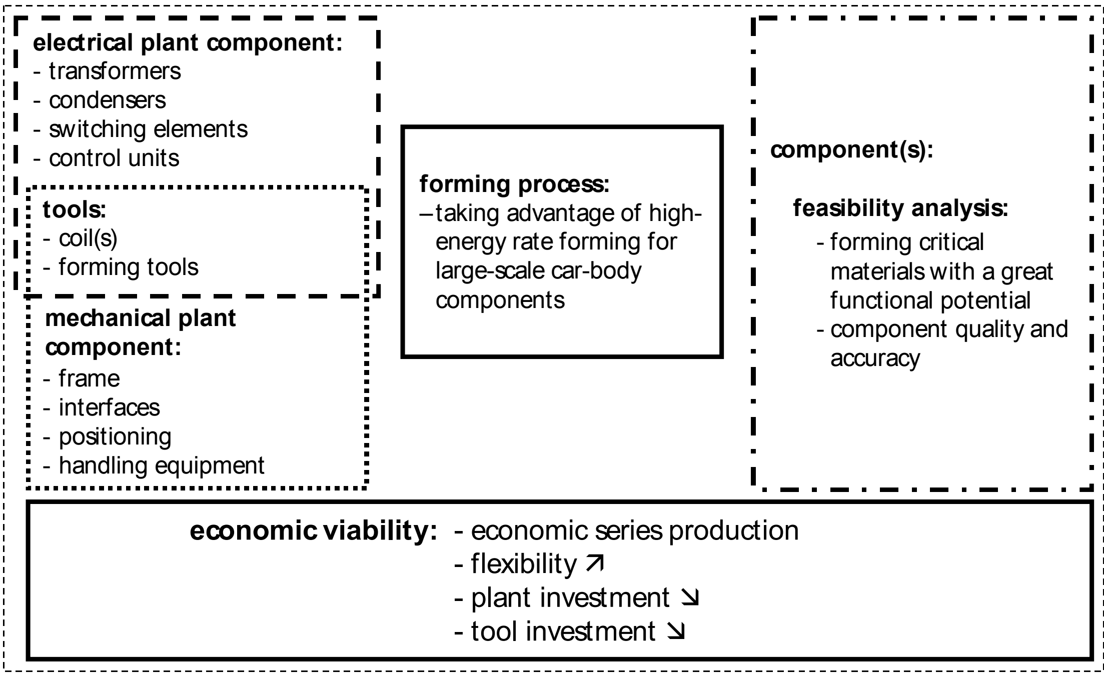

Figure 2: *The Fraunhofer IWU's concentration in electromagnetic metal forming*

3 New Technological Strategies

We can break down our technological strategies into two areas:

- electromagnetic metal forming of complete components (Figure 3) and
- partial electromagnetic metal forming of individual form elements in an integrated plant strategy (Figure 5).

The first step taken by the Fraunhofer IWU is to investigate the possibilities and potential of electromagnetic metal forming of complete components excluding the preforming process. However, several forming steps are required for mapping typical car-body component shapes that could be done with serial workstations or a flexible tool system (for instance, multicoil systems with coil and/or workpiece positioning) (Figure 3). To implement this project, the Fraunhofer IWU is presently developing and building a 100 kJ trial plant for its own studies. It will be available in the 3rd quarter of 2004 and it will be dedicated to creating the basic forming, plant engineering, and tool conditions for manufacturing large-scale car-body components. The greatest challenge will be designing the coil, and Figure 3 shows two coil designs out of a series of different possibilities. The most efficient design is forming with a coil and a discharging process, although designs with segmented coils and readjusting the coil would probably be more suitable for forming complete car-body components.

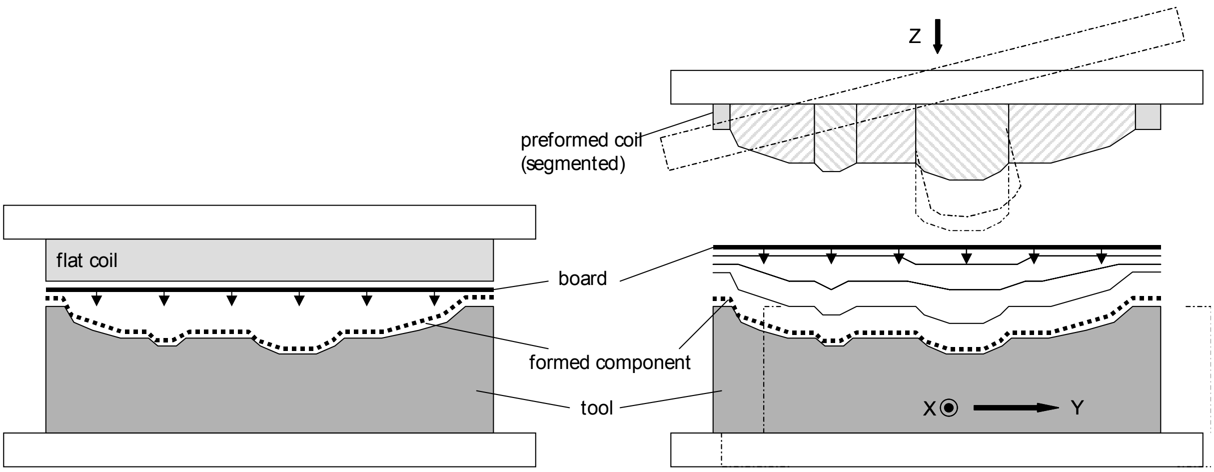

Figure 3: *Electromagnetic metal forming of complete components*

The following detailed procedure is planned:

- calculating the limitations of forming/potential of electromagnetic metal forming as compared with conventional deformation of plane components. Our strategy to study the criteria and influences exerted on thin-sheet components and sandwich structures, such as the maximum potential deformation, deformation distribution, minimum radiuses, the thickness of sheet metal, and the material,
- adapting this process to plane components (basic forms, such as beads and shape elements including possibilities for controlling the material flow),
- ways to solve the problem of scaling this process to large components, and
- streamlining plant and tool designs (i.e., scaling down the number of forming steps) for specific industrial applications in car body component manufacturing.

Given the high productivity of mechanical forming plants, the Fraunhofer IWU is planning other projects for studying the constraints of electromagnetic metal forming in connection with integrating it into conventional forming plants (Figure 4 and Figure 5).

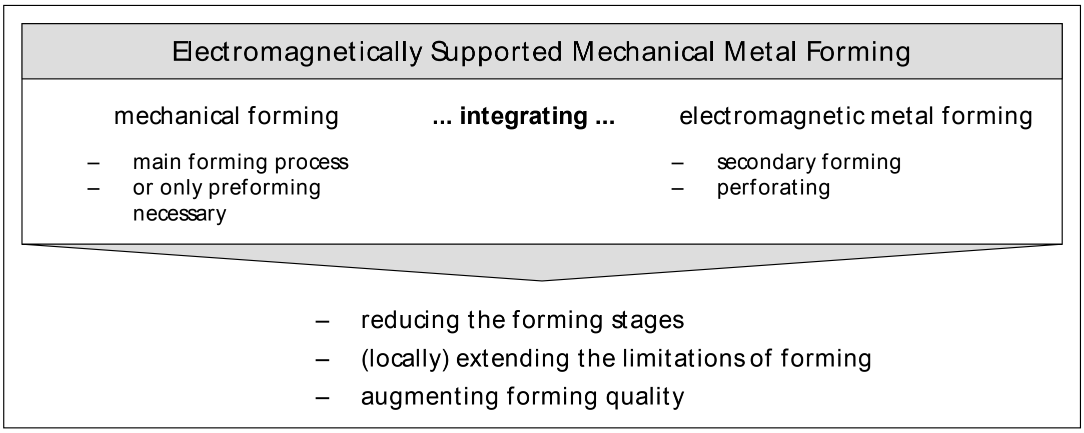

Figure 4: *The strategy for integrating magnetic forming plants into conventional forming plants.*

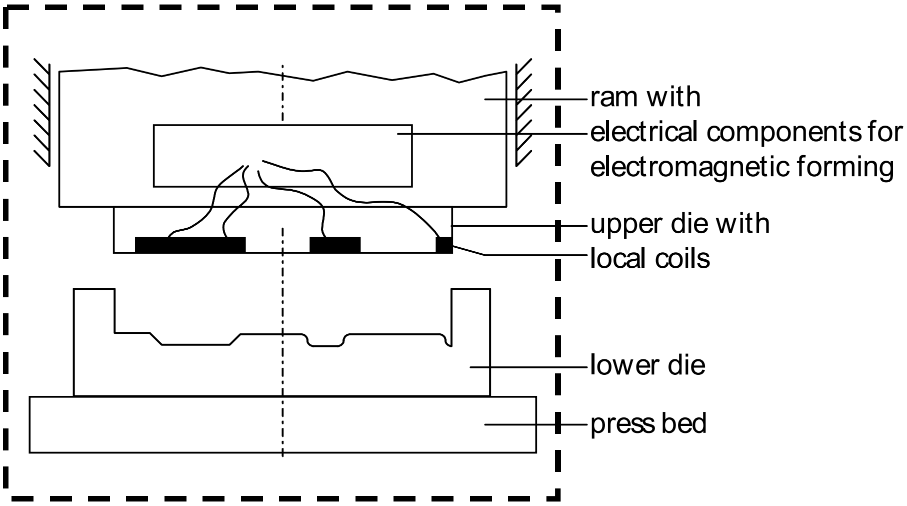

Figure 5: *The principle of partial electromagnetic metal forming while integrating it into a conventional pressing design*

These targets will have the following effects:

- reducing the number of forming steps,
- (locally) extending the limitations of forming while
- augmenting forming quality.

These two approaches have very different requirements for plant and tool design. First of all, since the transmission lengths between the magnetic forming plant and coil are limited (i.e., minimising losses), these two plants have to be positioned very close to one another. This poses the question of system compatibility, for instance in the control units. Then, the problem of how the discharging process can be synchronised for the slide motion has to be resolved (i.e., with a control mechanism or mechanical coupling). However, what is crucial for delivering a reproducible final result is discharging at a defined and very small interval from the lower tool where the drive characteristics of the press figure prominently. There are also design restrictions in terms of other plant components required, such as for ventilating the forming tools. The additional components will either have to be installed in the moving slide or at great transmission lengths depending upon which of the tools (the lower or the upper tool) is engineering for taking up the coils. A final aspect is integrating the coils into the deep-drawing tool while bearing wear criteria in mind where we will have to study whether and under what circumstances magnetic forming would be possible where material has a major influence (such as radiuses in the exterior range of geometry).

4 Conclusions

Electromagnetic metal forming offers major potential for enhancing the economic viability of the manufacturing process of forming components while extending the limits of forming technology. This potential can particularly be seen when we apply this technique to plane components (i.e., special car-body components). This is the reason why the Fraunhofer IWU has dedicated its efforts to applying the electromagnetic metal forming technique to plane components.