Introduction

For manufacturing small batch sizes of sheet metal products a new technology called asymmetric incremental sheet forming (AISF) has been developed since the early 1990s. The main advantage of this process is its high flexibility, since no or little product specific tooling is needed. Therefore free formed unique parts or small batches can be produced cheaply and speedily. Economic studies show a potential usage for batches up to approximately 500 parts (Tuomi and Lamminen, 2004). Since the forming forces needed are not dependent on the dimension of the part AISF can be used to produce even very large parts with inexpensive machines.

In the realm of architecture Trautz and Herkrath (2009) examined AISF for manufacturing different elements of a double-layered, facet-like folding structure. Katajarinne mentioned the production of metal façade elements as a use case for AISF [2]. There was also a project on responsive skin where AISF was used to manufacture a mold, which is then used for injection molding UPM Profi – a recycled paper composite – at UCLA Architecture & Urban Design [3].

The AISF Process

A fixed sheet is deformed step-by-step by a small, mostly spherical, generic tool. It travels along the surface of the final part geometry. This can be done with a layer or with a helical strategy (Fig. 1).

Fig. 2 shows the different process variants used nowadays. SPIF and TPIF can be used with a machine with at least 3 axes. The left picture in Fig. 3 shows a SPIF setup with a KUKA Quantec KR 210 R2700 prime at IRPA. For DPIF-P and DPIF-L two synchronized machines with at least 3 axes are needed. Robots are capable of such a kind of synchronized movement (i.e. using ABB MultiMove or KUKA RoboTeam technology). The center picture in Fig. 3 shows a DPIF-L setup with an ABB 6620 and an ABB 4400/60 using ABB MultiMove at IRPA.

All kinds of metal such as steel, aluminum, copper, titan, and even some plastics, can be formed. Composite products such as sandwich panels or polyurethane based color-coated metal sheets
Robot Assisted Asymmetric Incremental Sheet Forming

(Katajarinne and Vihtonen and Kivivuori, 2008) are also possible.

The formable sheet thickness depends on the forces the machine can apply. Forming forces are highly dependent on material, wall angle, infeed and tool diameter. Since the sheet is fixed, AISF causes material thinning in formed areas. For simple forming strategies, as discussed here, the sheet thickness $t$ at every point is dependent on the corresponding wall angle. The relationship can be approximately defined by the so called cosine’s law, where $t_0$ is the initial thickness:

$$t = t_0 \cos \alpha$$

All materials have a certain maximal wall angle that can be formed. For many steel or aluminum alloys angles up to 60-70° can be formed in one step. For steeper angles multi-stage strategies can be applied.

**Surface Quality**

Tool diameter and infeed have the greatest influence on surface quality. Larger diameter and smaller infeed leads to finer surfaces. A lubricant should be used to minimize friction and enhance results.

To prevent tool marks on the part, two sheets can be used in combination. In this setup the additional one lies on top of the other. Both are fixed in the blank holder. The tool only interacts with the upper one and the lower one is formed indirectly by the deformation of the upper one. Since the additionally sheet is used only for forming the real product sheet, it is called a dummy sheet (Skjøedt and Silva and Bay and Martins and Lenau, 2007).

![Figure 2 Process variants used in AISF](image-url)