ESAFORM Benchmark Grant Proposal:
Investigating geometric accuracy in ISF

Motivation

As a highly flexible sheet metal forming technique, Incremental Sheet Forming (ISF) has great potential for improving the efficiency of production in small batches or for producing unique or customized components. This will allow lower costs, unique designs and a reduction of material waste. Extensive research has been conducted for more than two decades, but main challenges such as process limits and accuracy are still being addressed in order to transfer to an industrially viable process. Many different directions have been followed by researchers all over the world, where extensive process knowledge is spread over several different universities. To leverage technological progress, collaboration should be enhanced. That means process knowledge and experience as well as different techniques for tackling challenges and performing ISF, should be shared among different institutes. As part of the goal to exchange and compare results, an **ISF database platform** is under development. By using a specifically developed online database, the capabilities and experience of multiple research institutes will be used in a World-Wide-Lab to produce complex geometries and to improve the understanding of the underlying causes of geometric deviations. This way, institutes and individuals can easily compare process strategies and the whole community can collect, share and discuss experiences on many different components on a worldwide scale.

These goals: knowledge transfer, exchange of results and saving results in a structured way (including all relevant metadata) are a perfect fit for the ESAFORM benchmark.

Benchmark Committee

The benchmark committee started as a collaboration between the Institute of Metal Forming (**IBF) at RWTH Aachen University** (prof. Gerhard Hirt, David Bailly and Thomas Bremen) and the **Flexible Sheet Metal Working group at KU Leuven** (prof. Joost Duflou, Hans Vanhove and Marthe Vanhulst) for developing an ISF database platform to structure ISF results in a complete and comparable way. The ISF research groups from the **AGH University of Krakow** (prof. Lukasz Madej) and the **University of Michigan** (prof. Mihaela Banu) enthusiastically joined this team. Marthe Vanhulst will be the coordinator.

Benchmark

1. Description of the problem

The main challenges of Incremental Sheet Forming (ISF) currently being tackled are related to geometric distortions after forming. Research has been focused for a significant time on the use of simple benchmark geometries such as pyramids and cones for a systematic investigation of the correlation of various process parameters on geometrical accuracy. These types of geometries have high inherent stiffness and have limited application in real components. This limits the transferability of developed process improvement methods, such as path adjustments, to more complex components. In the context of this benchmark, geometries are to be investigated in which additional stiffening properties, such as multi-axial curved surfaces, have been avoided. According to the current state of the technology, such components can only be produced to a satisfactory level of accuracy after considerable iterative effort. As a benchmark, however, they offer the opportunity to investigate process optimizations and understanding that can be applied to large-scale realistic components.

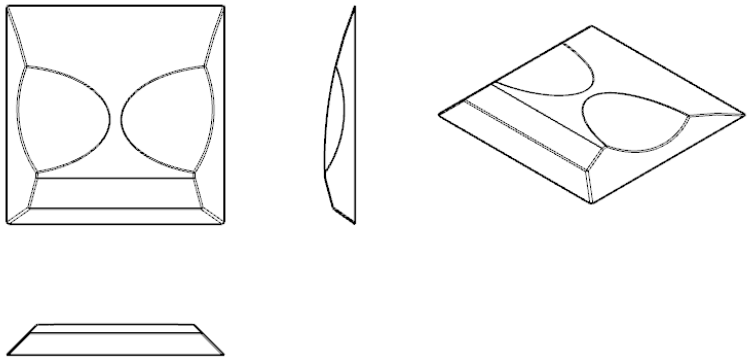
2. Goal

The benchmark project will focus on three main goals: 1) **collecting strategies** to produce the proposed type of geometry, 2) **encouraging cooperation and collaborative learning** between research groups and 3) introducing the **database platform as a tool to compare parts and strategies** for ISF in a structured way.

The different strategies will be compared in terms of accuracy, thickness distribution and production time. However, the focus will be on creating an environment where researchers are encouraged to work together by providing feedback and exchanging ideas rather than focusing on individual results. We believe sharing bad results is equally important as sharing the good ones, in order to increase understanding of the process and obtain innovative solutions together. Therefore, we created a **forum on the database platform to enable discussions**. In line with the ESAFORM benchmark grant spirit, we will provide a **prize for the best advice** based on a voting round given once the study is finished. This will encourage an open environment where knowledge sharing is key, instead of focusing on reaching the best individual results. The cooperation and knowledge exchange achieved by this project will increase experience for all participants, thereby improving the research of ISF on a large scale.

3. Description of the benchmark shape

The geometry to be studied (see picture below) is relatively simple but has been proven to raise multiple problems, such as the pillowing effect, the tent effect and large geometric distortions after unclamping. The chosen shape consists of a few flat sides with a discrete change of angle, as well as a slightly curved side at a low wall angle and a small waist section, prone to instability in larger constructs. These properties have shown to be difficult to form with high accuracy. The component will be made from **Aluminium 5754**, an alloy often used for automotive applications, with a **thickness of 1 mm**.



The dimensions of the benchmark shape are chosen to be as large as possible, such that the deviations are clearly visible and the differences between forming strategies are clearly distinguishable. On the other hand, a component that is too large might not be producible by some institutes due to set-up limitations. This led to a trade-off resulting in dimensions that do not exceed 410x410 mm. Researchers who do not possess the production platform capabilities to produce components at this size will be able to send in their toolpaths for production by one of the committee members.

4. Parameters

For better comparability of the results and to create a common foundation for the exchange of experience, the process boundary conditions will be fixed for the first experiment. In this "**basic trial**", only Single Point Incremental Sheet Forming (SPIF) shall be used for forming without the use of additional tools (except a suitable backing plate). In addition, no post-treatment other than the trimming process may be performed before the resulting part is uploaded to the database.

For all further experiments, the participants are free to choose the boundary conditions and forming strategies at their personal preference for the best possible results (see defined objectives). The only remaining requirement is the use of Incremental Sheet Forming as the main forming operation. The flexibility to choose the experimental parameters and strategies should help to motivate a creative idea-generation process through the collaborative database platform. This ensures that innovative ideas are found to address the problems mentioned.

Communication

At this moment, ISF institutes have been contacted all over the world and 11 additional institutes (on top of the 4 committee members) showed a clear interest in benchmark activities. They can choose between **three levels of participation**:

1. Make the benchmark part, measure it and upload the results and all metadata (toolpath, machine information, desired shape, tools, process, post treatment, …) to the ISF database. These results are called results type 1 in the planning.
2. Make the benchmark shape, then send it to a committee member who will measure it. The results will be filled in the database platform together (by the participant + committee member that is responsible for the measurements). This is a good option for groups that do not have the desired measurement equipment. These results are called results type 2 in the planning.
3. Create the STL and toolpath for ISF, then send it to the committee that will handle production and measurement. Uploading the results on the database platform will still be done together (participant + committee member that is responsible for the production and measurements). This gives institutes that do not have a sufficiently large set-up or mostly focus on numerical studies the ability to participate in the project. This way, they can simulate the results or make smaller components themselves, test them and send a toolpath of the required dimensions to one of the committee members. Due to time and logistic constraints, the number of toolpaths that can be sent in per institute is limited to three. These results are called results type 3 in the planning.

After all experiments are carried out, the results are gathered in the database. The **best five results will be repeated** on the same machine. If the results cannot be repeated properly. They are considered to have been entered incorrectly or incompletely into the database platform. The experimental campaign will lead to a comparative study that will enable cooperation between institutes and knowledge transfer. This investigation and proposed strategies will be complemented by a series of numerical simulations to investigate the material behavior during the forming and possible implications with the final geometrical result.

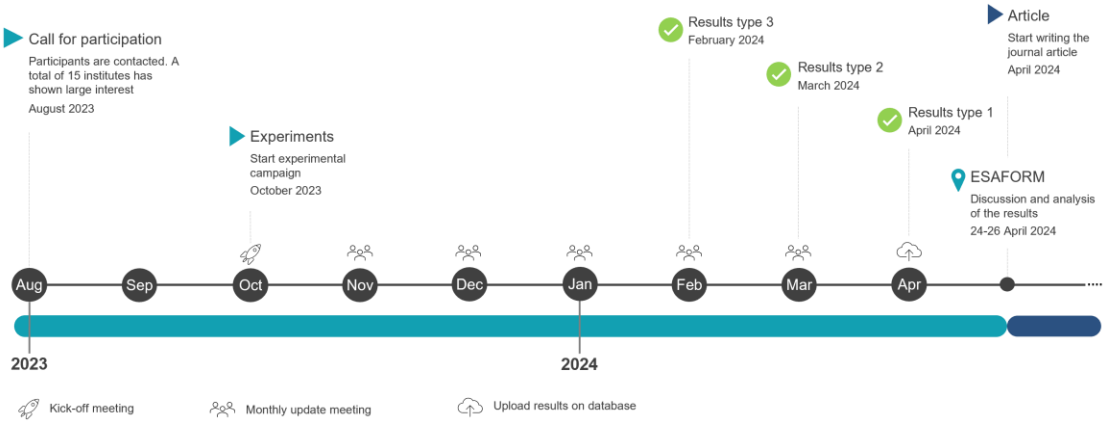
However, as mentioned above, the goal of the project is to encourage knowledge transfer and cooperation. This can be the opposite of having a ranking of the best strategies and searching for a “winner”. The goal of our project will be to focus on **finding an optimal solution as a group** instead of sharing the results of separate research groups. In this approach, implementing a forum for discussions is a key factor, in which providing feedback and exchanging ideas and results will be rewarded more than individual results.

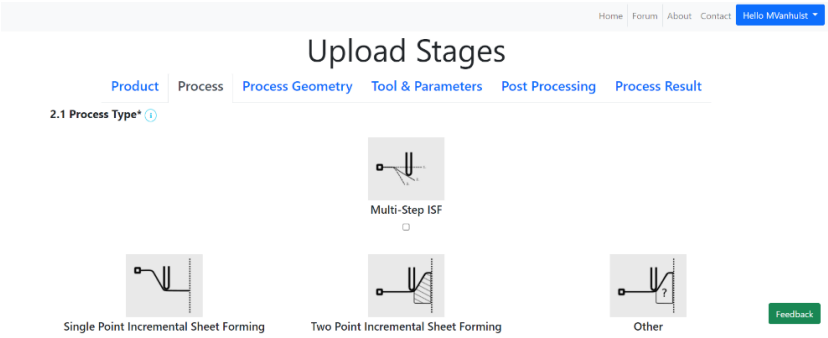
The main **communication tools** for the benchmark project are the following:

- **Email**: for general information, as well as for updates on preliminary results, reminders, etc.
- **ISF database platform**: for gathering the results and collecting all data. Additionally, an overview of all relevant benchmark information will be made available online on the database website, as well as a FAQ page.
- **Discussion forum**: for group communication, discussion, and remarks. Committee members have the moderator rights. The forum also allows linking to components in the database, such that strategies, parameters and results can be referenced in detail during the discussions.

The **time schedule** is given below. Several ISF research groups have been contacted and 11 of them, on top of the 4 committee institutes, have already confirmed participation. A kick-off meeting will be organized in October if the grant is approved. Here, we will provide all necessary information and explain how to use the database platform for uploading results. Afterwards, we are planning to organize a virtual meeting every month. The goal of these virtual monthly meetings is to motivate participants to discuss preliminary results, give updates on their research and ask

questions. Each participation level has different deadlines, since for participation type 2 and 3 additional work needs to be carried out by the committee members.



Result storage policy

The ESAFORM benchmark results will be publicly available on the ISF database platform, where the ESAFORM benchmark grant contribution will be visible. Other results will only be visible to people with an account. This platform will provide access to the data in a structured and complete way for a long time, and will make access by other institutes easy, as well as comparing different results. One of the steps for uploading components to the database platform is visualized below.