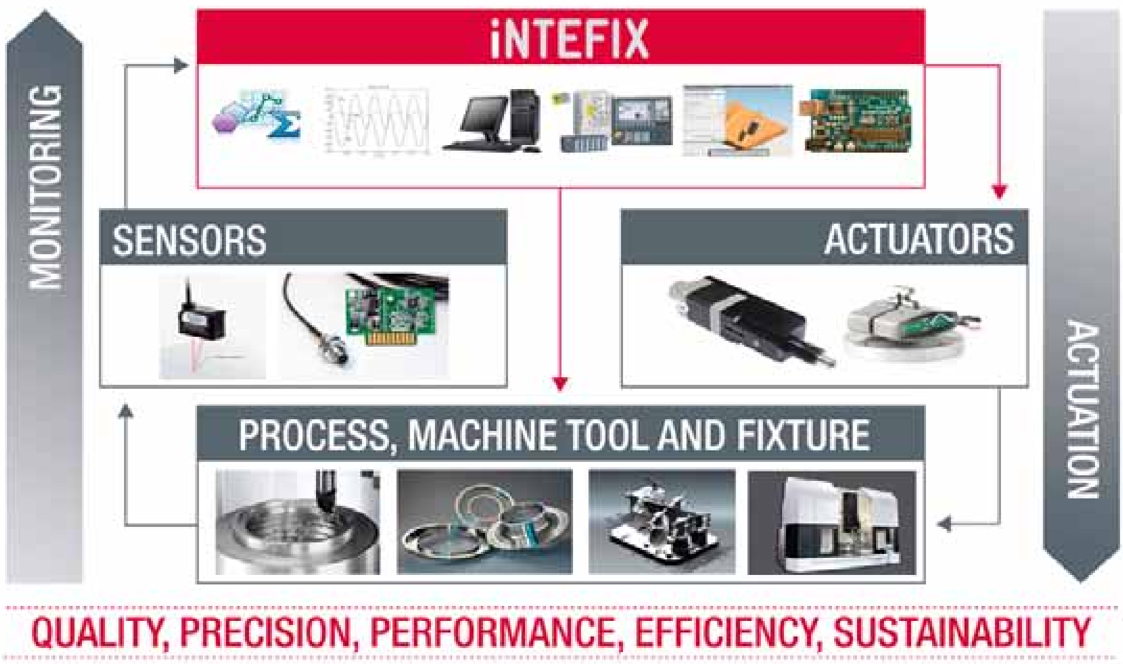
CASE STUDY
June 2014

Advance in the Case Study 2.2
Clamping of thin-walled curved workpieces

INTEFIX project (FP7 Grant Agreement 609306) aims to increase the performance of the machining processes by the use of intelligent fixture systems, allowing the monitoring, control and adaptation of the process to obtain suitable results according to precision, quality and cost requirements.



Normally the main functions of fixtures are to securely hold and accurately locate the workpiece considered as an undeformable body, but nowadays the high required precision and the need of increasing the performance of the manufacturing process drives to other important functions of the fixtures taking into account aspects like the deformations, vibrations and distortions in the workpiece during processing. Furthermore, the machining system (machine-fixture-workpiece) cannot be considered as a stable system due to its dynamic behaviour and geometrical shape variations along the process, so adaptive fixtures can be used to control and adapt the behaviour of the machining system in order to obtain adequate results in manufacturing precision, quality and cost.

Objective

This case study covers one experiment within the INTEFIX project (FP7 Grant Agreement 609306). This application is proposed by TYC (Strojirna Tyc, s.r.o.) and it deals with the reduction of deformation of the thin-walled aerospace part due to clamping forces. The clamping force should be set with respect to the workpiece stiffness that decrease during machining. The participants in this case study include the following companies: TYC, ROEMHELD and RCMT.
The objectives of the task are development of an integrated intelligent fixture point and a thickness sensor.

The workpiece in the focus of the case study 2.2 activities is a part of an airplane wing (simplified demonstration model with all typical and critical features). For security reasons the part is machined from a block of material, Figure 2. Typically, more than 90% of the original material volume is removed. Removing of the material volume means also a change in the workpiece structural stiffness. Thus, the final workpiece accuracy is affected with undesirable deformation caused by clamping forces if the clamping force does not decrease with the decreased workpiece stiffness.

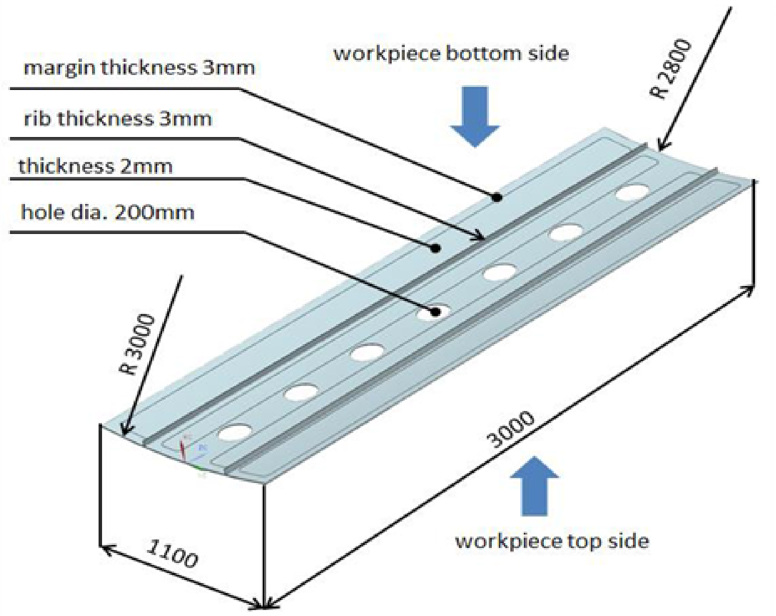


Figure 1: Demonstration part

Machining of the part is done in following steps. The process starts from a raw block of material. The block is clamped on the machine tool table. The top side of the workpiece is fully machined as curved surface (roughing, semifinishing, finishing). The raw part frame remains around the workpiece for stiffening of the workpiece margins. The workpiece is turned around after this operation and re-clamped using the outer fixtures. The curved top side is used as surface for clamping of the workpiece. The vacuum system is used for clamping of the workpiece to the shape support points currently. Then the workpiece bottom side is fully machined (roughing, semifinishing, finishing). As final operation, the supporting frame on the margin is cut-out. The part itself is clamped just with the vacuum fixtures after this operation.

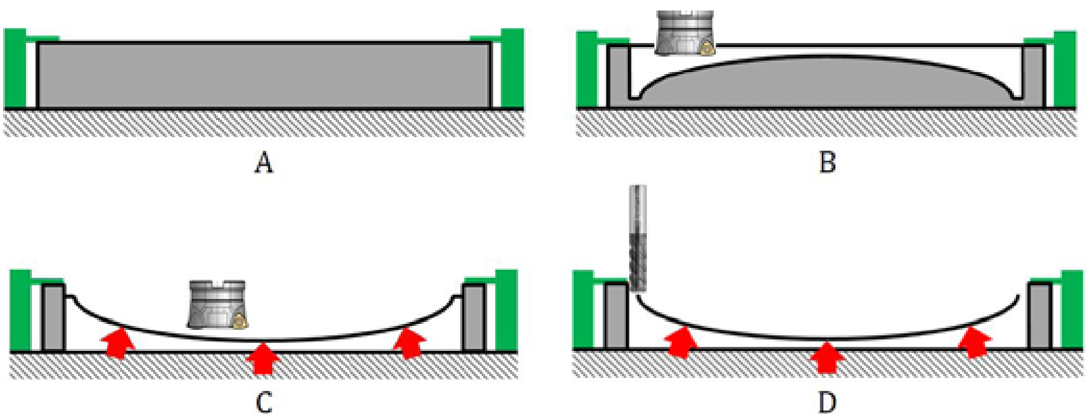


Figure 2: Main Machinig steps: clamping of the raw part; machining of the top side; machining of the bottom side; cut-off of the workpiece from the auxiliary frame

The main problems are related to the machining of the bottom side of the part. All mentioned issue are related to the decreasing of the part stiffness during machining:

- The workpiece is locally deformed if the clamping force is not properly reduced with respect to the workpiece stiffness.
- The workpiece is locally deformed within the vacuum sucker area during clamping if the vacuum clamping force is not properly reduced.
- The number and position of the clamping points and support points is limited due to their outer dimensions.

Solution proposed

The concept of the intelligent fixture includes four main modules: actuator and position measurement system; linear guideway and brake; clamping unit with a support point; communication module. The intelligence of the proposed fixture unit is based on the clamping point position measurement and connectivity to other fixture units, operator PC and the machine tool. The machine tool operator should be able to control the fixture system and also to get all operational information from the fixture via huma-machine-interface on the operator PC. The postprocess check of the workpiece thickness will be possible using the thickness sensor. The main activity will be focused on the development of the software interface between the sensor, Heidenhain control system and the operator PC.

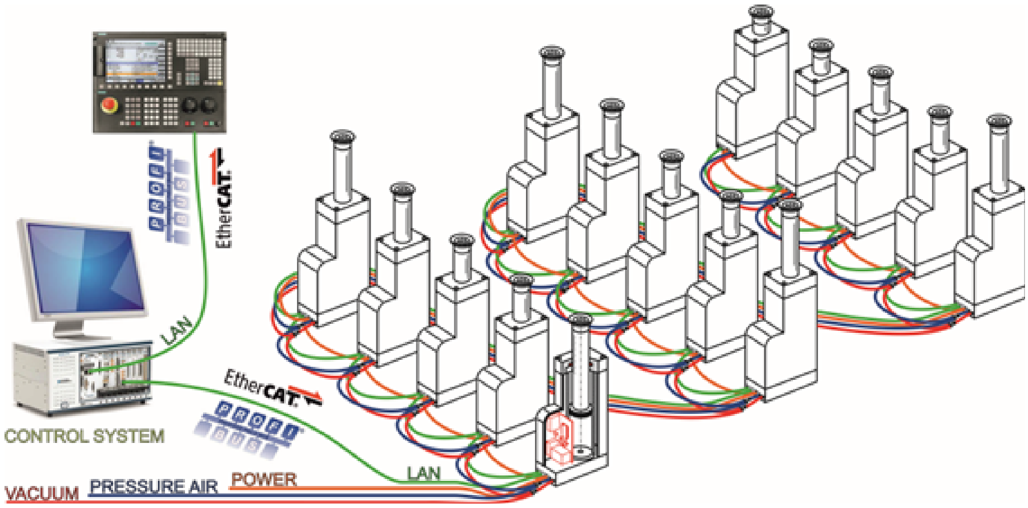


Figure 3: A schema of the fixture group communication concept

Current advance

The case study started in January 2014 and the current work is related to the theoretical and experimental characterization of the dynamic and static behaviour of the workpiece in free and clamped situations. This information is being used to evaluate the needs regarding sensors and actuators.
The clamping force is defined as the product of the vacuum level and the vacuum sucker size. However, these two factors also influence the total workpiece deformation. If the maximal workpiece deformation should remain under defined tolerances, the vacuum level and the sucker diameter should be the limit. This is demonstrated in a FEM simulation for four supporting points and various vacuum level and sucker diameters. The optimal combination should be a subject for optimization, together with the distance between supporting points and the supporting point pattern.

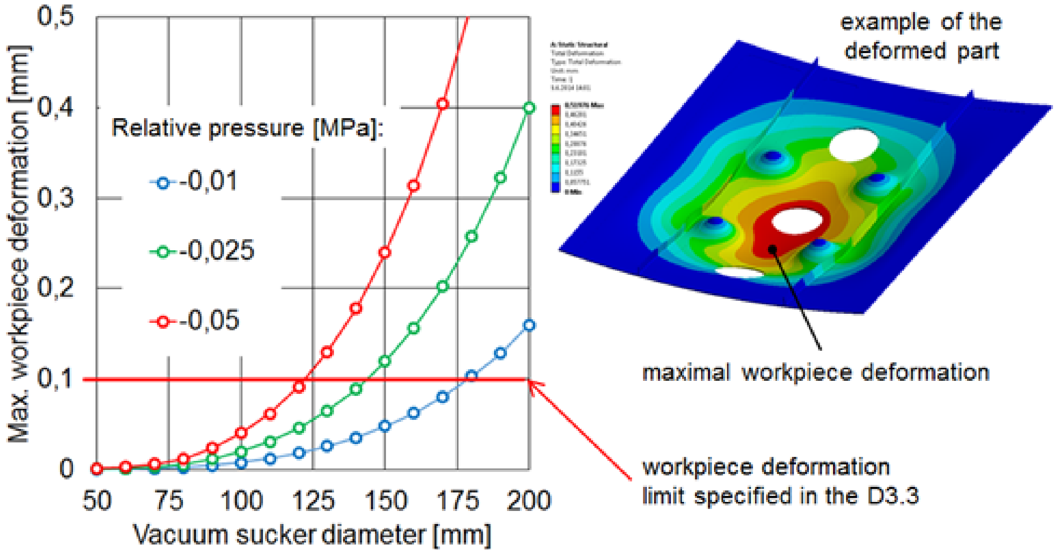


Figure 4: Maximal workpiece deformation dependent on the the vacuum level and the vacuum sucker size. Result of the FEM simulation, deformation due to clamping forces presented only (eigen mass deformation and deformation due to cutting forces are not taken into account)

For research purposes, a smaller test part was designed for easier and less expensive proof-of-the-concept testing. Instead of downscaling of all workpiece geometries, an adaptation to the smaller length is implemented in the test workpiece design so that the machining parameters can be used without modification as in case of real part manufacturing. This procedure has been validated by FEM simulations. In fact, the vibration of the part is also one of the current limitations on the increase in the productivity of the machining process. As can be seen, the test workpiece has a similar range of eigen frequencies and the same character of eigen modes than the real part. It has to be taken into account that the critical vibrations are related to the substructural eigen forms of the free regions of the part.

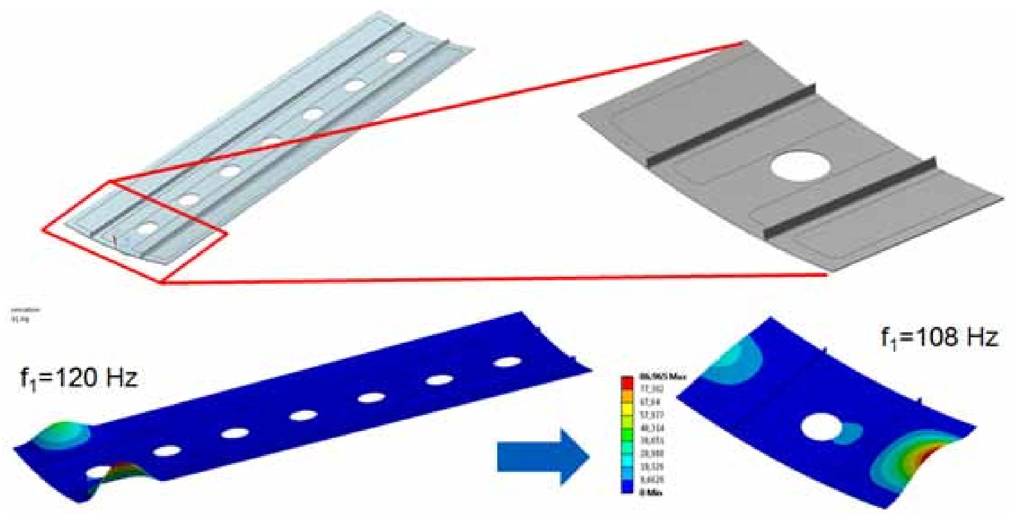


Figure 5: The smaller test part has similar modal properties as the full-scale demonstration workpiece.

About INTEFIX

The INTEFIX project aims to increase the performance of the machining processes by the use of intelligent fixture systems, allowing the monitoring, control and adaptation of the process to obtain suitable results according to precision, quality and cost requirements.

The project is divided in 11 different case studies from different sectors covering different problems and requirements in the manufacturing industry:

- aeronautic
- railway
- automotive
- machine-tool

The results of these experiments in the different case studies will be used to develop systems and methodologies applicable to new workpieces, thus enhancing the exploitability of the project.

Acknowledgements

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