SMART ROBOTICS FOR FLEXIBLE MANUFACTURING IN AIRCRAFT APPLICATIONS

Martina Panico – Advisor: Prof. Antonio Langella

Curriculum: Tecnologie e Sistemi di Produzione

The project proposal intends to provide an enabling technology for the introduction of collaborative robotics in the aerospace industry. The challenge is the implementation of flexible automation in the aircraft manufacturing, for the execution and quality control of the drilling and countersinking process of panels, realized in homogeneous, non-homogeneous materials and hybrid stacks.

The quality of the holes drilled on aerostructure skins has an important influence not only on its mechanical strength but also on the assembly operations and the durability of aircrafts. Therefore, aviation industry companies are looking for technological solutions, that could be able to guarantee higher quality processes and uniformly high-quality products.

Nowadays, collaborative robots are the new frontier of Industry 4.0 thanks to their versatility of application, but they still represent a challenge for the aviation industry, due to high reaction forces and vibrations, that can destabilize the collaborative robots during the process. To date, there are different contributions offered by the scientific community for the characterization of drilling and countersinking processes. However, traditional tests do not reproduce the real boundary conditions of the test articles, that deviate considerably from a real single structural unit. Moreover, vibrational phenomena caused by the tool-item interaction and possible interlayer gaps are underestimated. For these reasons, there is a high level of unpredictability of the final quality of the hole.

Figure 1. Examples of use of robotics in industrial applications [1].

In that scenario, technological and experimental research activities could be placed. During the research period, the following two main goals are pursued:

- **Qualify the drilling and countersinking processes performed by collaborative robots**.
  In order to reach this goal, the correlation that exists between process parameters, forces and torques generated by the tool-item interaction and product quality will be analytically and experimentally analysed.
  Cutting parameters, such as speed, feed, tool geometry and workpiece material, affect thrust forces and torques during the process and therefore also the quality of the hole: in fact, a variation of them involves different levels of tool wear and therefore a different quality of the hole in terms of surface finish, geometric tolerances and dimensions. Consequently, it is necessary to characterize the process performed with collaborative robots, highlighting the problems and peculiarities related to the chosen technology.

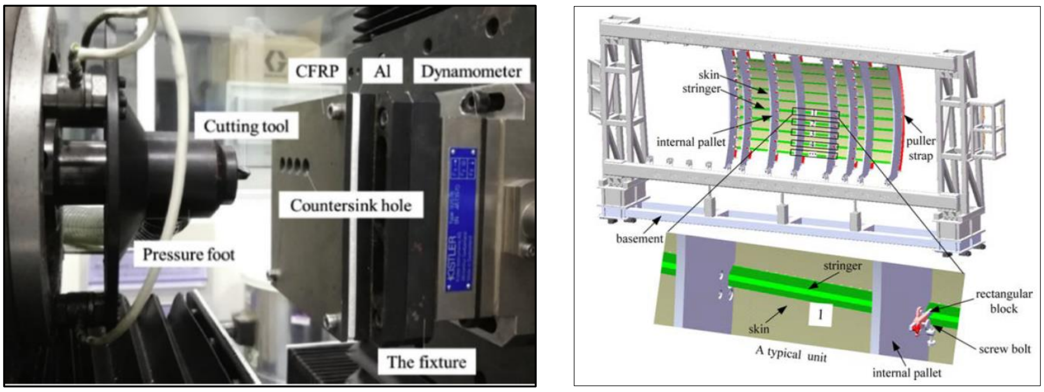

Figure 2. On the left, there is an example of traditional proof [2]. On the right, there is a real structural unit [3].

- **Develop a strategy for the real-time control of collaborative robot process parameters**.
  The goal is to develop a technique that allows the automatic control and adaptation of the process parameters (for example as a function of the progressive tool wear and of the material volume being machined) obtainable through the monitoring of forces and torques, detected from the collaborative robot integrated sensors.

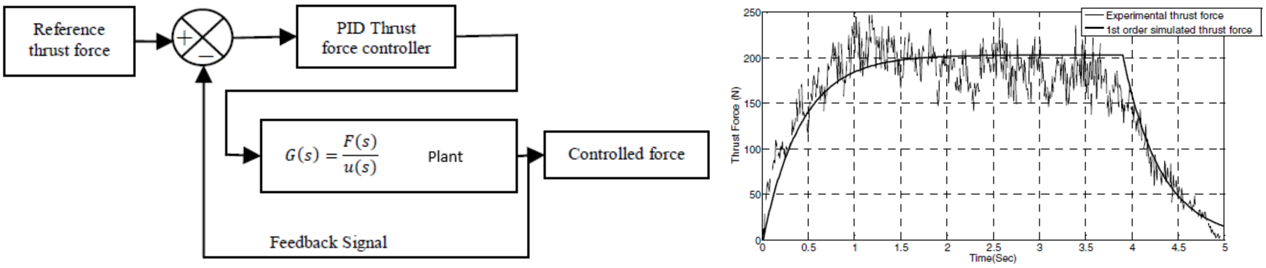

Figure 3. Example of model response of thrust force [4].

References:
[1] The concept of an aircraft hull structures assembly process robotization. V. Serebrenny, D. Lapin and A. Mokaeva – AIP Conference Proceedings - 15 November 2019.
[2] A theoretical model for predicting the CFP drilling-countersinking thrust force of stacks. Yuxi Zhang, Dan Wu, ken Chen - Department of Mechanical Engineering, Tsinghua University, China – 31 October 2018.
[3] Modeling of fast pre-joining processes optimization for skin-stringer panels. Gang Liu, Wei Tang and Ying-Lin Ke – Zhejiang University, China.
[4] Modeling and PID control of thrust force during drilling in composite laminates. Amrinder Pal Singh, Manu Sharma – Panjab University Chandigarh, India – 06-08 March 2014.

Martina Panico, PhD student XXXVII cycle, July 2022