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INARAS

Automated Riblets Application on Aircraft Parts

FINAL PROJECT REPORT

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1.1. Project Context

The INARAS project has as objective to develop and test an Integral Automated Riblet Application System to be used on real aircraft parts or mock-up to paint riblets. Riblets are a drag reduction technique that consists of small grooves with sharp ridges and a height in the order of about a hundred microns which are laid on the aircraft surface. This strategy has proved to be efficient in terms of skin friction reduction in areas under turbulent flow.

This project takes advantage of previous investigations covering several aspects related to riblets performance and application techniques. Progress on riblet application techniques to date has shown the need to develop new application strategies that comply with the requirements of the Aeronáutical industry in terms of surface quality, application, maintenance costs and delivery rates.

The **IN**tegral **A**utomated **R**iblet **A**pplication **S**ystem, henceforth “INARAS”, whose development is targeted in this project, will paint riblets automatically applied on a relevant part of an aircraft surface. This will simplify the application process, which is now included into the final painting phase, of an aircraft and will reduce related times and costs.

Schematically, the INARAS will consist on the following components:

- Riblet Application Head (supplied by FRAUNHOFER IFAM)
- Robotic System
- Displacement Platform = Movement System
- Software
- Integration Components

The incoming **aircraft parts or mock-up shape** will be selected according to the identified turbulent flow areas and will be sufficiently representative of the final industrialization conditions.

As stated on the Topic Description it is assumed that the **Riblet Application Head** will be supplied by Fraunhofer IFAM and its efficacy in terms of painted riblets production is supposed.

The **Robotic System** will consist of a set of mechanical links and supports, electrical actuators and control electronic, aimed at providing the required degrees of freedom to the Riblet Application Head.

The **Displacement Platform** will provide displacement capability to the whole system with the required accuracy and repeatability and will consist of a ground based platform

Software aimed at coordinating all the components of the Integral Automated Riblet Application System will be developed.

As well all the additional mechanical, electrical and electronic sensors components required for **integration** purposes will be aggregated.

This project will cover, for each of the described components, the following activities:

- An analysis of the supplied Riblet Application Head.
- Definition of technical requirements for the INARAS.

- A trade-off study of the most suitable components for the Robotic System and the Displacement Platform according to the defined technical and industrialization scale requirements.
- Definition, Design and manufacturing or acquisition of the required integration components (mechanical, electrical, hydraulic, sensors, electronics, etc.).
- Development of software capable of managing all the robotic components.

As a final validating phase, the developed INARAS prototype will be tested on representative aircraft parts or on an alternative relevant mock-up.

These tests will be performed as near as possible to real industrial conditions with the aim to evaluate the technology readiness level of the proposed solution.

Main whole target:

- To use a system to paint riblets in a fully automated way on the aircraft components surface with the main specified requirements.

  - ✓ Application speed at least 2m per minute.
  - ✓ Capability to adjust contact pressure.
  - ✓ A maximum track-to-track deviation of 1mm at a length of 10m
  - ✓ The weight of the application device must be lower than 70kg.
  - ✓ Design aspects for easy maintenance must be taken into consideration.
  - ✓ As a final validating phase, the developed INARAS prototype will be tested on representative aircraft parts or on an alternative relevant mock-up.
  - ✓ These tests will be performed as near as possible to real industrial conditions with the aim to evaluate the technology readiness level of the proposed solution.

1.2. Project Executive Summary

Executive summary can be resumed in the following list:

- Selection and procurement of robotic and track motion systems to perform the tests

- Design and manufacturing of mechanical adaptations from the robot arm to the riblet head.

- Design and manufacturing of mechanical adaptation of the force control between the riblet head and the robot arm.

- Definition of the 7^{th} Axis in order to achieve the reach of 4 mts. required by the test, that could not be reached with the normal 6 axis reach and dimensions.

- Definition of the artificial vision camera needed for detection of the rlblets edges, between two successive passes.

- Definition of required hardware and software to synchronize camera with the robot electronic.

- Mechanical adaptation for the installation of the artificial vision camera in the riblet head.

- Definition of all required ancillaries structure for holding all ancillaries cables and pipes of the riblet head.

- Perform simulation analysis to ensure the reach of the solution to be implemented with the addition of a 7th axis to the standard robot arm.

- Procurement of all required defined hardware in order to perform the final assembly of the whole system including the riblet head.
- Integrate all automation components and check of it in order to be ready to test paiting on mock-up.

- The design of a mock-up with a surface similar shape of a section of a narrow body aircraft wing. This was decided as explained in the mock-up definition, due to it was not possible to find out a real wing section.

- To perform the design and manufacturing of the needed tooling to hold the mock-up.

- Definition of the test to be performed once all automation and mock-up are in place.

- Carry out the validation tests with real riblet head to have samples for checks.

- To carry out the video to be delivered to the Fraunhofer IFAM.

- To perform the financial management of the project to stay in budget

- To keep the planning and the technical targets on track

1.3 Main S & T foregrounds

Detailed Integration analysis of the Displacement Platform, the Robotic System and Riblet Application Head

Following the received drawings of the riblet head and the received dummy head, ASCAMM performed an integration analysis needs, in terms of:

- ✓ Mechanical
- ✓ Electrical
- ✓ Sensing
- ✓ Software
- ✓ Ancillaries installations

The received dummy head allowed ASCAMM to check for movements, alignment and different set up.

Design of additional Integration Mechanical Components, Tooling and Development of the required Hardware and Software for the INARAS

Regarding this task, ASCAMM had to perform design and integration of 7th axis and mechanical adapters in order to integrate the riblet head.
As well the detailed integration (mechanical and software) of the selected camera for edge detection was performed in this task.

INARAS Simulation Analyses
To complete the work performed with the dummy riblet head, ASCAMM has carried out several simulations work, using the selected robot and linear track, with the inclusion of the selected 7th Axis, as well as the shape of the selected mock up, with dimensions of 4 by 7 mts.

Main objective of the simulations was:

- To check reaching of selected system in different positions of the mock up

Gathering of standard material and manufacturing of the Integration Mechanical Components and Tooling
This task was performed in order to procure robotic and carrier system, as well as of different components required for full system integration.

Beside the two main components as anthropomorphic robots and track motion, in this task it was also procured all material to:

- Manufacture and integration of the 7th Axis.
- Manufacture all mechanical adaptors for integration of riblet head, force control, artificial vision camera.
- Manufacture of ancillary holding structure for supporting all pipes and cables that are needed for riblet head operation.
- Manufacture of Mock-up as well as the holding structure.
- Carry out the full integration of the system (cables, connectors, bolts, etc)

Final INARAS Assembly
For the final assembly task, due to the dimensions of the mock-up and the full installation (redefinition of mock-up from 2,5x7 m initially proposed to 4x7 m finally agreed), ASCAMM had to rent a space to make possible the full installation. Finally it was found a space which included the renting of the space and the robot, with the track motion, all in one package.

In the Figure 13 below it can be seen the Lay-out of the rented industrial building as well as the proposal for the installation of the track motion and the study made of all access in order to guarantee that all equipments will fit into the building as well as by the main door.

The work started by the assembly of the track motion and the robot

Prior to pass to other stages checks of robot movements and track motions were performed by ASCAMM, this led to the conclusion that the equipment and set up were ready to the installation of the Mock-up.

Collection of Aircraft part or mock-up for testing the system
It was not possible to find out a real aircraft wing part, as explained before, so early in the project it was decided to use a Mock-up.

The detailed mock-up design was made by W Aeronáutica, following ASCAMM indication on needs for the full system integration.

Due to change in Mock-Up dimensions, as commented previously. The design performed by W Aeronáutica was not used for manufacturing the Mock-Up.

Due to W Aeronautica project withdrawal, ASCAMM had to assume the full design and manufacturing of the Mock-Up.

The conditions defined for the new Mock-Up were:

- Same curvature tan previous Mock-Up
- Dimensions: 4 x 7 mts (Width x Length).
- Metal Skin thickness: Same than previous Mock-Up
- Angle: Between 10 and 20º
- Modularity for transportation and installation, according the working are Access shown below
- Cost effective Mock-Up
- No needed area for overhead painting

Finally ASCAMM designed a modular Mock-up which can be joined by bolts and the modules can be procured as standard welded structures.

At the end of this task the Robot, Track motion and Mock-up were ready for the installation of the riblets head, all sensors and ancillary equipment.

Test Specifications Definition with dummy head
In order to have the whole system ready for the tests with the real head, a dummy head was used to check the system performance.

The validation tests with dummy head were defined by Fraunhofer IFAM and before sending the real head with all ancillary equipments Fraunhofer IFAM technicians came to ASCAMM facilities on 15/01/14 to perform the checks on the system behavior and to finish all set up details for carrying out the test with the real head.

Design and Manufacturing of the required holding tooling for the Aircraft Parts or mock-up
In this case the holding tooling was part of the Mock-up due to the modular design achieved by ASCAMM.

INARAS Validation Trials
The week 10/02/14 to 14/02/14 the real head was installed and all validation trials were performed, for this purpose technician from Fraunhofer IFAM and ASCAMM worked together firstly to unpack all the riblet head equipment, secondly to integrate all and perform

system learning and process set up tasks and finally to perform final tests in order to get painted samples.

In particular the fine work performed was:

- ✓ Unpacking of all equipment related with the real riblet head:
  - Riblet head
  - Two dosing pumps, two material hoppers
  - Power supply for mercury vapour lamp
  - Chiller for the lamp
  - Controller for pumps, lamp, shutter of nozzle and drive system of applicator (Siemens S7)
  - Others ancillaries
- ✓ Positioning of all equipments as planned at the meeting of 15/01/2014
- ✓ Installation of supporting structures for pipes and cables to avoid this to be running on the painted surface
- ✓ Installation of the gases extraction system for the UV lamp
- ✓ Installation and check of all equipment related with riblet and its relation with the automation system installed by ASCAMM
- ✓ Installation of plastic film on the mock-up surface in order to paint on it to be able to extract samples
- ✓ Checking of the cinematic of the installation regarding:
  - The absence of visible trembling in the head while the system was moving
  - The ability of the system to perform straight trajectories
  - The ability of the system to control de pressure of the roller on the surfaces
  - The speed of application and displacement between successive layers.
  - To ensure the safety from all points of view, specially from the point of view of using the appropriate personal equipments: Booth, protective glasses among others

1.4 Main S & T results

After tests conclusion the following results were achieved:

- Physical Integration of all riblet application equipment with ASCAMM designed automation equipment was successful

- The design and implementation, by ASCAMM, of the 7th axis as an easy and cost effective way to increase the reach of the robot arm was achieved and successfully proven
- The absence of visible trembling was confirmed for the full installation
- The ability of the system to perform straight trajectories with full installation was as well checked
- The ability of the system to control de pressure of the roller on the surfaces
- The speed of application and displacement between successive layers.
- Safety of use of the installation
- Relevant process parameters that has been checked are:
    - ✓ Painting speed 2 m/min was achieved
    - ✓ Deposited layer thickness, by checking the contact pressure to be 2 N / cm2 was achieved
    - ✓ Track width, according with head silicon band width was confirmed
    - ✓ Detection of edges between pass, by selected artificial vision camera, was achieved
    - ✓ System precision, maximum track-to-track deviation was 1mm at a length of 10m was reached
    - ✓ Design aspects for easy maintenance were OK as all components are available on the market for easy replacement.

At the end of the task a full length and width of mock-up was painted successfully and samples could be extracted from the painted film.

Beside a professional video was carried out by a company contracted by ASCAMM in order to deliver a professional video to Fraunhofer IFAM for proper dissemination of the work performed during INARAS project development

1.5 Social impact of project achievements

The main impacts are:

- Lower fuel consumption by drag reduction by riblet implementation
- Lower CO2 emission
- Lower operation cost of airlines by better efficiency of the used fuel

Taking into account that it is foreseen by aircraft manufacturer that about 30.000 new airplane are needed in the following 10 years, plus the fact of retrofitting possibilities of existing aircraft, this mean a huge save in fuel and CO2 emission reductions