Preliminary Design of an Aircraft Automatic Painting and Paint Removal System

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Abstract

The maintenance of the aircraft finish system is executed completely manually at present, involving a big amount of manual labor for a long time and in a hazardous environment. The automation of the process would be able to dramatically speed it up and to decrease manpower involved, with a consequent contraction in costs and environmental risks. It is at the moment an important challenge within the aerospace industry also because of the expectations of airplanes fleet growth over the coming years. Several solutions are being developed, nevertheless, a system able to achieve the maintenance process automatically is not yet available. Along this thesis, a preliminary design of an automatic system for aircraft painting and paint removal has been carried out. The work points out that a low cost solution for this complex problem is possible. As a preliminary study, this is intended to be a starting point for further development on this subject.
Keywords: Aircraft finish system, Paint Removal, Spray Painting Robot, Automatic System, Aircraft.

1. Introduction

As the fleet of commercial aircraft grows, there is an expected increase in the number of aircraft needing maintenance in future [1]. A phase of the aircraft maintenance is the removal and application of the finish system to check the substrate integrity, protect it from corrosion or simply change the aircraft livery [2]. The whole process is, nowadays, achieved completely manually. It requires a big amount of time and labor [3]. Furthermore, it has to be accomplished inside a dedicated hangar for environmental safety reasons, thus only one aircraft per painting hangar is concurrently processed.

To tackle the aircraft number growth, there are two ways: either to increase the number of painting hangars and consequently the number of workers, or to increase the finish system maintenance rate. Using the latter approach, the implementation of an automatic system is a solution to speed up the maintenance process.

As for other industries during the past decades, nowadays a big challenge for the aerospace industry is the automation of the aircraft finish system maintenance. According to Patrick Waurzyniak's studies [1], this solution would induce great advantages under many aspects. First of all, the maintenance rate would increase as well as the quality of the final result. Meanwhile, the whole process cost would drop as a big amount of highly skilled labor is no more required. Moreover, the introduction of an automatic system would drastically reduce the workers exposition to a toxic environment during the painting and paint removal processes and, not least, the environmental impact of the process would reduce thanks to the waste optimization.

Presently, there is no robotic system commercially available able to achieve the coatings system maintenance. Many projects are under development especially for the paint removal automation while only a few involve the painting of aircraft.

For the paint removal the more remarkable projects (still under development) are the Advanced Robotic Laser Coating Removal System (ARLCRS) by Carnegie Mellon Universitys National Robotics Engineering Consortium (NREC) and Concurrent Technologies Corporation (CTC), and the Laser Coating removal Robot (LCR) by STRATAGEM. The first one uses a continuous wave laser mounted on a state-of-the-art mobile robot to remove the coating system from medium to small size military aircraft [4]. The latter implements a 20 kW CO2 laser to evaporate and combust the paint that is vacuumed from the surface and passed through a filtration system; the laser is mounted on a eight Degree of Freedom (DoF) robotic arm and four DoF mobile platform. The developer expects 50% reduction in processing time and 90% labor reduction [5].

For the aircraft coating two systems are operative: the Robotic Aircraft Finishing System (RAFS) developed by Lockheed Martin for the F-35 coating [6] and Automated Spray Method (ASM) developed by Boeing to automatically coat the B-777 wings [7]. Both are composed of six DoF robotic arms mounted on auxiliary axis rails.

2. Specifications and Requirements

The subject of the present work is the preliminary design of an automatic system able to achieve the finish system maintenance.

The maintenance of aircraft finish system can be divided into three main stages: masking, paint removal and painting [8]. Of these, only the automation of painting and paint removal were studied.

The automation of the aircraft masking would give big benefits, as it is a long lasting process that involves a number of workers. Nevertheless, the technology to do it is not yet available and/or the system would get too complex and expensive.

In the present section the factors that mainly influence the automation of the painting and paint removal processes are described.

There are many painting and paint removal methods. The present study was confined to describe the possible solutions available and leave the painting and paint removal method selection to the client.

An automatic system for painting and paint removal is influenced primarily by three factors: the aircraft size and shape, the paint application requirements and the paint removal requirements.

Generally, the maintenance system has to process airplanes with different shapes and size. To decide the system dimensions, medium to small military and civilian aircraft were selected as system objectives. Specifically, the largest airplane to process is the Lockheed C-130 Hercules in Figure 1, whose dimensions are shown in Table 1.

Figure 1: A C-130E Hercules from the 43rd Airlift Wing, Pope Air Force Base, N.C.[2]

Table 1: C-130 H geometrical features [9].

Length	29.3 m
Height	11.4 m
Wingspan	39.7 m
Fuselage height	4.6 m
Fuselage width	4.3 m
Landing gear height	0.52 m

According to the previous decision, the maintenance system's workspace has the dimensions in Table 2.

Table 2: Dimensions of the maintenance system's workspace.

Maximum height	13 m
Minimum height	0.5 m
Length	35 m
Width	45 m

The aircraft painting process requires compressed air, a paint tank and a spray gun. The maintenance system has to handle the equipment and to apply the paint with the required thickness following the technical prescriptions [8].

Moreover, painting requires at least one painter at each side of the airplane for quality reasons [8]. Finally, because of the solvents inside the paint spread in the air, every component has to be ATmosphere EXplosibles (ATEX) certified.

The requirements for the automation of the paint removal process depend upon the removal method selected by the client. Generally, mechanical and optical methods require high end-effector positioning accuracy and precision, the ability to handle the required equipment (motor-driven sander, laser equipment, etc.) and a sensor to determine if and where the coating has been removed. On the other hand, the chemical removal requires a spray equipment and the scrape of all loosened coatings with a squeegee.

3. System Design

Different possible solutions were devised and evaluated. Between these a trade-off analysis was carried out to select the solution to be developed. The selection criteria rewarded the design with the lowest cost and complexity.

The solution selected is composed of a robotic arm located at one end of a beam which has its longitudinal axis in a ground parallel plane. The beam is supported on the other end by a lifting

[2]URL `http://www.af.mil/shared/media/photodb/photos/990101-F-5502B-002.jpg` [Accessed: 28 September 2016]

system, allowing the beam to move up or down. The lifting system is positioned on an omnidirectional Automatic Guided Vehicle (AGV) that is a vehicle able to move in any direction as well as to perform zero radius turns [10]. In Figure 2, an overview of the system is presented.

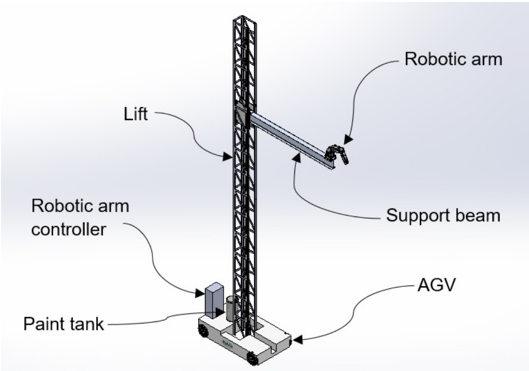

Figure 2: System overview.

The AGV and the lift, provide 4 DoF to the maintenance system and position the robotic arm with respect to the work surface. The arm has to position and direct its end-effector, thus it requires at least 6 DoF. Accordingly, the maintenance system has 10 DoF.

The maintenance system has to be able to locate its end-effector 4 m away from its vertical structure. This is necessary to reach the fuselage center line without touching the structure. Therefore, the length of the beam plus the length of the extended robot arm has to be at least of four meters. The height of the lifting system depends of the height of the AGV and the maximum height to be reached by the robotic arm.

To compete with the state-of-the-art robots under development, the new maintenance system has to ensure high performance and rapid development at the lowest investment and operating costs. Thus, the driving design criteria was simplicity.

Along the present section, the design of each component of the system is described. To start designing the components of the structure, the first step was the selection of the robotic arm. It was essential to know the load the structure has to support as well as the dimensions of the other parts of the system. Knowing the weight and the workspace of the robotic arm, the horizontal beam and the lifting system (from here on called also lift) were designed. Finally, the necessary subsystems and the AGV were selected.

3.1. Robotic Arm Selection

To select a robotic arm between the many available on the market the following criteria were applied:

- Lightness
- Workspace equal to or bigger than a human painter
- ATEX certification
- Production company able to ensure spare parts supply in the next decades
- Different end-effector tools

Finally, the robotic arm selected is the FANUC *Paint Mate 200iA/5L* [11]. It weights 37 kg and can handle a payload of 5 kg Its workspace is shown in Figure 3.

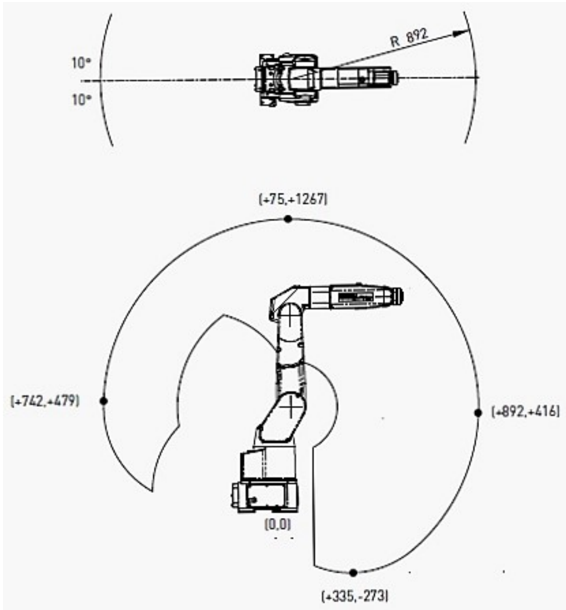

Figure 3: FANUC *Paint Mate 200iA/5L* workspace in mm [11].

The robotic arm can extend up to 1267 mm from its base into the vertical plane. To make a conservative design, the lift structure height has been computed without taking into account the AGV. So the height of the lifting system is 11.7 m. Following the same process, the length of the beam should be 3.1 m but a 3.5 m long beam is used to oversize the system.

3.2. Robotic Arm Support Structure

The robotic arm is mounted at the tip of a cantilever beam supported on the other end by the lifting structure.

The beam has been designed in order to be light and to ensure a small displacement of the robotic arm. To limit the weight, the material selected is the aluminum alloy Al 6061-T6 [12]. In order to use a cheap off-the-shelf component, a constant section I-beam was selected from the American Society for Testing and Materials (ASTM) standard [13].

Using the Euler-Bernoulli theory, a parametric study was carried out to select the beam cross section dimensions taking into account the tip displacement and the beam weight. The beam selected weights 60.8 kg and allows a tip displacement of 2.75 mm. This displacement is constant during the whole operative life of the system, making it possible to be taken into account during the system control design, restricting the error introduction.

The beam is supported by the structure represented in Figure 4, that also connects it with the lifting system. The support is composed of four aluminum alloy plates welded together.

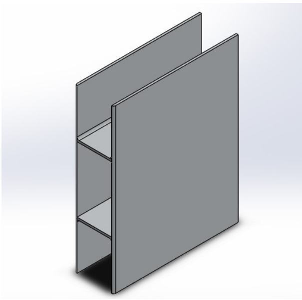

Figure 4: Beam support.

The lifting system is composed of four linear guides and a ball screw mounted on a truss structure as in Figure 5. Eight linear bearings are bolted to the beam support and coupled with the rails mounted on the lift structure. To the beam support is also bolted a screw nut coupled with the ball screw. The bearings are able to transmit to the lifting structure only forces normal to their axis, while the screw holds the vertical load and moves the beam support along the lift axis.

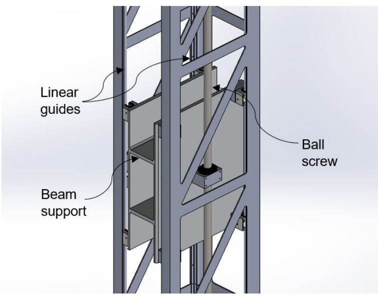

Figure 5: Lifting system.

According to Figure 6, the equilibrium equations are written:

$$F_s = W_{house} + V_y = 0.149\ N/mm \cdot w_{bear} + 884.9\ N\,, \tag{1a}$$

$$F_{bear4} + F_{bear3} - F_{bear1} - F_{bear2} = 0\,, \tag{1b}$$

$$(F_{bear1} + F_{bear2} + F_{bear3} + F_{bear4})h_{bear} = M_x + V_y \tfrac{w_{bear}}{2}\,. \tag{1c}$$

where M_x and V_y are moment and force due to the beam and robotic arm weight respectively, F_{bear} are the forces in each bearing, W_{house} is the weight of the portion of the beam inside the support, F_s the screw force and $w_{bear} \simeq w_{house}$.

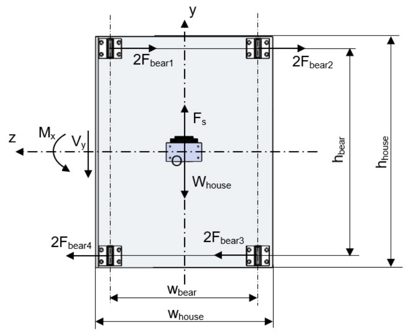

Figure 6: Beam support free body diagram.

To solve Eqs. (1), the following conservative assumptions were made: $F_{bear4} = 0$ and $F_{bear3} = F_{bear2}$. Then, the parametric study in Figure 7 was made to select w_{bear} and h_{bear}. The load on the bearings influences the bearing shaft size and therefore its weight. Thus w_{bear} and h_{bear} were selected equal to 500 mm and 700 mm respectively. Accordingly, the design load on the bearings is 3436 N.

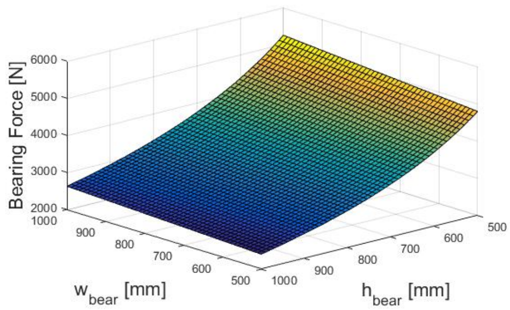

Figure 7: Bearing load as a function of w_{bear} and h_{bear}.

To compute the beam support thickness, one of the two horizontal plates was studied as a cantilever beam supporting all the load due to both the horizontal beam and the robotic arm. The thickness required applying the Von Mises yield criterion is 19 mm [14]. Therefore the support has a weight of 44 kg.

The beam support through the bearing transmits the moment due to the beam and the robotic arm to the lift structure. This is a truss structure as in Figure 5. It is manufactured by an aluminum alloy plate bent and cut. To allow preliminary computations, all its structural elements have the same thickness and width, and were studied as jointed beams.

Buckling analysis of the lift base pillars was carried on to size the structure loaded by its own weight. The computations were then validated using the two-dimensional frame analysis tool Ftool [15]. As a result, the lift structure weights 103 kg and, when loaded by the bearings, deforms almost linearly with a maximum deflection of 17 mm at the tip.

3.3. Lifting System Design

As explained earlier, the lifting system is composed of four linear guides and a linear actuator, namely a balls screw driven by an electric motor. While the linear guides transmit a moment to the lift, the ball screw holds the vertical load and moves the beam support along the lift.

The design criteria of this project was to use as many off-the-shelf components as possible. Then, the linear motion systems were selected from the Thomson Industries catalog. It is a linear motion systems leader company that ensures a spare parts supply along the entire life of the system.

To design the linear guides, the bearings and the rails were selected. The linear rails can be round or square, and end or continuously supported. In this application, the rails have to transmit a moment to the lift structure, then, continuously supported rails were selected. They ensure a reduced bending on the rail itself and do not present bucking problems. Between round and square rails, round rails were selected because they present self-alignment, i.e. the friction increases much less than for square rails when the lift structure, and then the rails, deform [16].

For the bearings selection, the following criteria was applied: between the bearings able to support the load required (3436 N) the one with the smaller shaft diameter is selected. Moreover, it has to be corrosion resistant to ensure a long working life in a polluted environment. The rail shaft diameter is important because the rail weight increases approximately with the squared diameter of its shaft.

Finally, the bearings selected are the SSETWNO M16-CR whose rail shaft diameter is 16 mm, while the rails are the LSRM16. The total weight for the linear guide system is, then, 97 kg.

The other component of the lifting system is the linear actuator. Generally, three types of linear actuators are available: hydraulic, pneumatic and electromechanical systems. An electromechanical system was selected because, despite being more expensive, has low maintenance costs, high accuracy and easy control. Moreover, it holds the load without consuming power [17].

As already mentioned, the actuator is composed by a screw driven by an electric motor. The screw is supported on the upper end by the lift structure while the other end is mounted on the AGV platform and connected to the motor. Two types of screws are available: lead screws or ball screws. For this application, a ball screw is used because of its higher precision and efficiency, lower vibrations and longer operative life; nevertheless it is more expensive [18].

The ball screw is a tall rotating pillar on which the vertical axial load shown in Table 3 is acting. According to the Euler's buckling formula

$$F_{buckling} = n \cdot \pi^2 \frac{E \cdot I}{L^2} \;\Rightarrow\; d_{screw_{min}} = 26.6 \; mm \,. \tag{2}$$

the minimum screw diameter is 26.6 mm, where E is the Young's modulus of the screw material, $I = \frac{\pi d_{screw}^4}{64}$ the screw moment of inertia, L the screw length assumed equal to the lift height and n a coefficient that depends on how the screw ends are supported (in here the screw has both ends fixed).

Table 3: Vertical load on the lift actuator.

Part	Weight [kg]
Robotic arm	37
Horizontal beam	60.8
Bearings	3
Beam bracket	44
Total	144.8

In addition to the previous computation, the screw resonance has to be avoided. The screw angular velocity at which resonance occurs is given by [19]

$$n_{resonance} = 1.2 \cdot 10^8 C \frac{d_{screw}}{L^2} \,. \tag{3}$$

where C is a coefficient that depends on how the screw ends are supported. Then, the maximum angular velocity for the screw is computed multiplying the resonance frequency for a 0.8 safety factor.

The Thomson catalog includes ball screws with 32 mm and 40 mm diameter. In Table 4, the maximum angular velocity and lead are shown for each dimension, where the maximum vertical speed for the beam is computed simply by multiplying the screw lead and the maximum angular velocity.

Finally, the 40 mm diameter screw was selected because, in spite of being heavier, it allows a vertical velocity of 2.5 m/min that is comparable with the vertical velocity of commonly used human lifts. For this screw, the buckling load, computed by (2) is 7250 N that is five times bigger than the total vertical load on the system.

Table 4: Angular velocity, lead and Vertical velocity for different screws.

Diameter [mm]	32	40
Max.angular velocity [RPM]	50.0	62.6
Max. screw lead [mm]	40	40
Vertical velocity [m/min]	2.0	2.5

The screw is driven by an electric motor. Three types of electric motors are generally used for this positioning application: Direct Current (DC), stepper and servo motors. DC motors have a low cost but a low accuracy, thus they are rarely used for accurate positioning. In this project a stepper motor is used, because when compared to a servo motor, it is cheaper, it can work in an open loop, it has higher performance at low speeds, and it requires less maintenance (stepper motors are brushless).

The minimum torque required to the motor is computed by

$$Torque = Screwload \frac{Screwlead}{2\pi\epsilon} = 9.7\ Nm\,. \quad (4)$$

where ϵ is the screw efficiency equal to 0.9. Then, the stepper motor PK599BE-N7.2 by Oriental Motor was selected. It has a torque-speed specification that allows the direct connection of the screw with the motor. In so doing, a gear is not necessary, this design reduces the system weight and transmission looses.

3.4. Subsystems

This section lists, describes and selects the required subsystems not covered in the previews sections.

First of all, to control the robotic arm, it has to be linked to its controller, the R-30iA$^{\text{TM}}$Mate Controller. Moreover, to paint the aircraft, paint and compressed air are supplied to the robotic arm. The air pressure and flow rate depend on the paint technique used. In the manual process, the spray guns are fed by long hoses linked to one or more common air compressors. To limit the weight and the cost of the maintenance system, the air is supplied by hoses linked to an external compressor. This solution also avoids the air compressor to introduce vibrations into the system.

To avoid heavy and expensive batteries on-board, the electric power is also supplied to the system by cable linked to an external power source. Therefore, the maintenance system does not have to stop to recharge or change batteries.

It has to be ensured that the AGV platform does not run over the supply line. Thus, the electric cable and the air hose are mounted on a retractable reel. Two types of retractable reel are possible: spring or motor driven. For this system, electric motor driven retractable reels are used in order to control actively the tension force on the cables and hoses.

The paint tank is located on the AGV platform. To size it, the paint usage was estimated.

The Lockheed C-130 Hercules has a wetted area of 2323 m^2. Assuming two robots painting it, each robot paints 1163 m^2, the half of it. The specifications of different paints were taken into account and the paint volume needed was estimated to be 120 l per robot.

A tank of this size is not required when painting smaller aircraft or with higher coverage paints. It is difficult to clean and handle, heavy, expensive and increases the paint waste due to the paint left-over. To reduce the weight, the cost and the paint waste, a 60 liter tank was selected. This selection implies that when painting larger aircraft a refill of the tank may be required. The total tank weight is then 128 kg (assuming 80 kg of paint).

The subsystems required for the paint removal depend on the method selected. Chemical stripping does not requires any additional subsystem, while to optically remove the paint a laser equipment is necessary. The mechanical removal by water or media blasting requires a dedicated tank and blasting equipment on the robotic arm tip. On the other hand, if the paint is removed by a motor driven abrasive equipment, it is only required to replace the arm manifold. Therefore, further studies are required after the client selection of the paint removal method.

3.5. AGV platform

To select an AGV it is necessary to know the load it supports. According to Table 5, the payload on the vehicle is 635.6 kg. The weight of the parts not yet designed (electric power, paint and air supply lines, bolts etc.) is unknown. Thus, to select conservatively the vehicle, a minimum payload of 1000 kg was assumed.

For the present project, it is required a zero turning radius vehicle and the possibility to guide it with high accuracy. Moreover, it has to be possible to locate the robotic arm at an height of 0.5 m above the ground. The majority of AGVs are used in warehouses or in assembly lines and are designed for much higher payload.

Only one AGV that satisfies all the requirements was finally found. It is the RoboMate 17 by Vetex, equipped with four omnidirectional wheels that support up to 1000 kg each. Unloaded, its maximum speed is 67 m/min. Moreover, it is a modular system and the vehicle structure is designed meating the client requests [20].

The company only sells the vehicle, the navigation control system has to be developed ad hoc for the application and implemented. Many different

Table 5: AGV payload.

Part	Weight [kg]
Robotic arm	37
Arm controller	56
Horizontal beam	60.8
Beam support	44
Ball screw	105
Linear bearings	3
Rails	93.6
Stepper motor	5
Lift structure	103.2
Paint tank	48
Paint	80
Total	635.6

navigation systems have been developed, they include ultra wide band indoor Ground Positioning System (iGPS), laser, and vision based Simultaneous Localization and Mapping (SLAM). Typical accuracy of an omni-directional vehicle under autonomous global navigation can be from +/- 20 mm to +/- 10 mm, depending on the type of system used. Often, when greater accuracies are required, a combination of sensing systems can be used, such as switching from ultra wide band iGPS indoors, to vision based localization at a micro level [21, 22, 23]. The development of the navigation systems is relayed to future works.

With the selection of the AGV, the main components of the maintenance system were designed or selected off-the-shelf.

3.6. Subsystems Location

Locating the subsystem on the vehicle, an even distribution of load has to be ensured. There are two main problems to take into account: paint consumption and positioning of the lift axis in the center of the vehicle. The paint consumption causes a shift of the system's center of gravity, thus the load on each wheel changes during the painting. This problem could have been solved positioning the paint tank in the wheels centroid, but this was not possible because the lift axis has to be located coincident with the centroid. It ensures that, when the vehicle is performing a zero radius turn, the result is only a rotation about the lift axis without any translation.

The Center of Gravity (CG) positioning problem is divided into lateral and longitudinal positioning. Along this section, the AGV is supposed to have a longitudinal and a lateral plane of symmetry.

The lateral CG positioning problem can be solved using the robotic arm controller to locate the CG on the plane of symmetry. The longitudinal positioning cannot be solved without adding more weight. The best solution found is to locate the paint tank as close as possible to the vehicle centroid and use the arm controller to balance the robotic arm and beam moments.

As a result, the position of maintenance system CG is 318 mm in front of the symmetry plane with the empty tank and 210 mm with the tank filled with 80 kg of paint. It corresponds to a load per wheel of 211 kg on the front wheels and of 109 kg on the real wheels. The weight of the AGV itself and of the yet-to-design parts have to be added. Locating them in the rear part of the vehicle, it is possible to reduce the load unbalance between front and rear wheels.

3.7. Cost Estimation

The estimated cost is related to the parts of the system already designed or selected. The labor cost for the development of the missing parts and for the assembly was not considered. Thus, the estimated cost is simply the sum of the costs of the parts.

In Table 6 the cost for each part is shown. Most of this data come from a direct contact with the manufacturers. The total cost for the system was estimated to be 86.6 k€. To this value the price of the parts not yet designed, as the system sensors, has to be added as well as the control system development and assembly costs.

Table 6: Cost estimation.

Part	Cost [Euro]
Robotic arm w/ controller	20000
Horizontal beam	900
Beam support	100
Lifting system	4000
Lift structure	2000
Stepper motor	1000
Paint tank	3600
AGV	55000
Total	86600

4. Conclusions

During the present work, the preliminary design of an automatic solution for the aircraft painting and paint removal was accomplished. To compete with the state-of-the-art robots under development, the system was designed to ensure high performance and rapid development at the lowest investment and operating costs.

To ensure high performance, high accuracy selection criteria were adopted during the design. Moreover, the system was designed to process as many aircraft as possible taking into account different shapes and sizes. Finally, to reduce the costs, it is composed mostly by off-the-shelf components. They do not require to be designed and manufactured but are mass-produced by specialized companies at a lower cost. Furthermore, it is possible to have a spare parts supply during the operative life of the system.

Because this is a complex problem, the development time for a project of this kind is generally long. Especially developing and testing the control system require a long time. To reduce the development time, the system was designed as simple as possible both from the structural and the control point of view.

In details, the system is composed by a FANUC *Paint Mate 200iA/5L* robotic arm installed at the tip of a 4 m long aluminum alloy I-beam. The beam is held by a support that connects it to a lifting system composed by an aluminum truss structure, four linear guides and a ball screw driven by a stepper motor. The whole structure is then mounted on a Vetex RoboMate onmidirectional AGV on which the paint tank and the robotic arm controller are installed. The AGV receives electric power and compressed air from external sources through cables and hoses.

Except for the lift truss structure and the beam support, all the components listed above are off-the-shelf.

4.1. Future Work

Being a preliminary design study, this is a stepping stone for future works. First of all, some components of the system are yet do be designed, i.e. the electric power and air supply lines, AGV chassis and ball screw support.

To lead preliminary evaluations, simplified theories and big safety coefficients have been used. This led to a conservative design from the structural and mechanical point of view. An interesting future work would be to carry on a more precise analysis to reduce the structure weight and increase its stiffness. From the structural point of view a dynamic analysis has also to be done. Especially vibration analysis is required to avoid resonance in the structure.

Based on the present work, an active collaboration with the client is necessary to define in detail the system features. Specifically, painting and paint removal methods have to be selected to advance on the design.

Once the system equipment, structure and mechanics are completely defined, the design of the control system begins. First of all, the accuracy and precision required have to be computed. To do that, tests and simulations for both painting and paint removal processes have to be done. Then, the general approach to the problem has to be selected.

Generally, there are two possibilities: open-loop and closed-loop control. The first one does not use feedback and would process the aircraft based on the drawings and process software without checking its real position with respect to the surface and the result accomplished. The second control technique uses the feedback loop, based on sensors, to check the system error with respect to the required position and nullify it [24]. Besides the control of the system itself, a navigation system has to be designed as well as a collision avoidance system to ensure the aircraft integrity.

Not last, the system cost estimation has to be improved including the control development and implementation costs as well as the operative costs.

As already said, this work is a stepping stone, a lot of future work is required to solve this complex problem. But, as Mattie J.T. Stepanek said, 'even though the future seems far away, it is actually beginning right now'.

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