Reverse Engineering Using Laser Scanned And Manufacturing Of A Powered Paraglider Propeller

Mohammed Shaheen
Military Technical College, Cairo, Egypt.

Mohamed A. El Latif
Military Technical College, Cairo, Egypt.

***Abstract*— Propeller design progress in low flight speed regimes seems to have a little advance since the amateur aircraft builders known as the Wright Brothers. Propeller design has remained a black art where secrets of manufacturers have been literally passed from father to son and text books on propeller design inform students of nomenclature while useful approaches to the actual design and fabrication of reasonably performing propellers is almost lacking.**

Measuring propeller geometry requires accurate techniques to identify the aerodynamic surface profile; however the conventional methods used for measuring propeller geometry are either destructive or difficult methods.

In a previous work a two bladed wooden propeller surface profile is scanned using a Faro-arm three dimensional Laser scanner. In this paper, the scanned data is utilized used to manufacture a wooden prototype for the Propeller by handcrafting. Several laminations of wood having different tissue orientation are used instead of a one block to reduce stresses and eliminate of flutter effects.

***Keywords*—Propellers; conventional geometric measuring methods; reverse engineering, three dimensional Laser scanning; cloud data; Hand crafting.**

I. Introduction

Leonardo da Vinci proposed the concept of a "helical screw" to power a machine vertically into the air. The propeller uses a principle to provide propulsion through the air much like how a threaded screw advances. The propeller gains efficiency by using the same airfoil concept as the design of most aircraft wings typically one of the families of NACA sections [2]. The cross section of a propeller has a convex forward traveling surface, while the trailing surface is either flat or slightly concave [3].

Propeller design and manufacturing has been developed significant, this include more materials, analysis tools and along methods of manufacturing [4]. Propellers sizes and style models varies as: Master Airscrew fiberglass-filled nylon, Zinger, Top Flight Super M, APC fiberglass, Top Flight Power Point, Graupner fiberglass-filled nylon. Propellers are manufactured from five types of material Wooden, Fiberglass-filled nylon and Carbon Fiber [5]. Replacements and modifications of propellers used in flying equipment costs a lot. Alternatively reverse engineering can be adopted as an efficient method for creating a 3D CAD model. The CAD model is then numerical analysis, or model prototyping for experimental analysis [4].

Using a general-case CAD tools to create a three dimensional CAD model for a propeller, it is difficult to handle complex shapes and surfaces. The problem is that propellers do not easily conform to linear XYZ space as they rotate and advance along an axis and their natural coordinate system is helical [6] and [7]. Then, it is useful to create the propeller blade CAD model by blade generating software that uses cylindrical coordinate system in dealing propellers [8]. The geometrical propeller parameters that ultimately represent the surface include both global and detailed parameters. Global parameters define the overall size and shape from the stand-point of the 2D blade sections such as: Section series, number of blades, diameter, pitch and blade area ratio. However, detailed parameters identify where the 2D blade sections are located in space, as well as considerations for vibration, clearance, strength and manufacture such as: skew, rake, thickness distribution, pitch distribution and root fillet radius [9].

Reverse engineering of a propeller blade complex 3D shape requires measuring of its geometrical parameters. There are several methods for measuring geometry of solid bodies, and for propeller geometrical measurement there are conventional and non-conventional methods. Most of the conventional methods used for identifying propeller parameters are difficult, destructive, in-accurate and time consuming methods [10]. These conventional methods include: Pitch Gauge, Tracing the Edges, Slicing the Propeller into sections and Using Templates [5].

New technologies have been developed for measuring surface details for reverse engineering process using accurate and non-destructive methods, starting by using touch props for surface measurement which encounters problems in keeping suitable environmental conditions for the assurance of measuring accuracy and then, came the use of three dimensional Laser scanners which has effectively enhanced the measurement accuracy. The new development in the applications of Laser technology has created a new generation of three dimensional scanners capable of measuring the geometry of complex shapes like propellers. Their function is based on the idea of exposing the surface to be measured to light rays represented by a Laser strip and receiving these rays using Laser sensor which interprets the rays reflection into captured positions of points of the surface being measured [11].

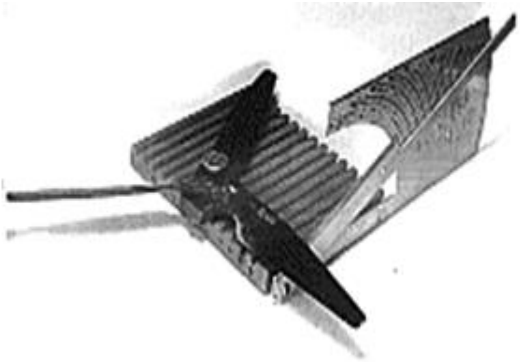


Fig. (a) Pitch gauge

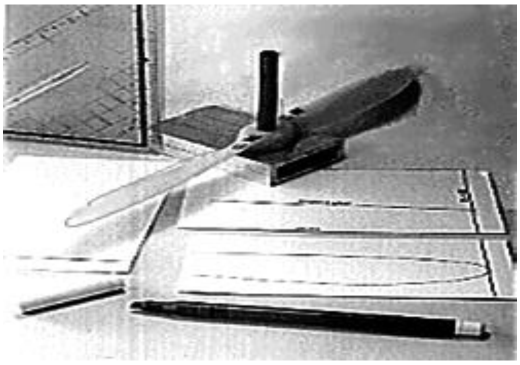
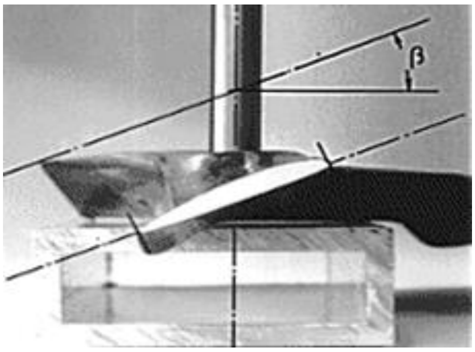


Fig. (b) Tracing the edges



(c) Slicing method

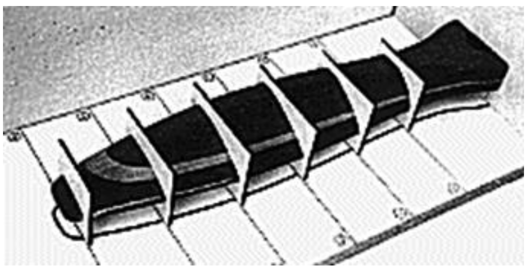


Fig. (d) Using templates

Figure-1 Conventional Methods for Measuring Propeller Geometry [5]

Ismail et al. [12] applied reverse engineering using the digitized resulted point clouds measured by layout machine and translating them into IGES format to create a CAD model for a four stoke piston engine. The accuracy was then checked using a CMM for the manufactured piston. Cheng et al. introduced reverse engineering for 1997 Honda Accord. The CAD model was numerically tested for impact and the results confirmed validation when compared to actual car impact results [13]. Hayat et al. [14] performed an accelerated reverse engineering at a low cost for an optical mouse using the technique of laser scanning.

In this paper, geometric data provided by Laser scanner of a two bladed wooden propeller surface is used to handcraft a prototype for the Propeller formed of multi-laminate glued block to reduce stresses in different directions and vibration applied to the propeller during flight.

II. Three Dimensional Laser Scanning of the Propeller Surface

Using 3D laser scanner with a Faro arm, the scanning operation was performed [1]. The propeller blade is painted using a white spray before scanning to enhance Laser beam reflection out of the surface. Only one blade with the hub is scanned for time saving and reduction of cloud data. Successive scanning shots have been taken for the upper and lower surfaces of the propeller received by the Laser sensor, and the coordinates of the received data is interpreted with reference to a fixed frame and represented as a cloud of points as shown in figure (2).

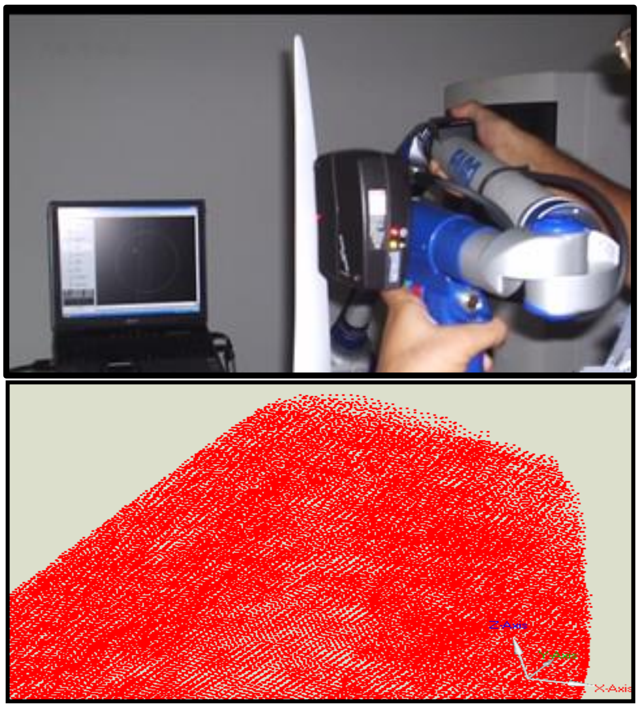


Figure-2 3D Laser scanning of the propeller blade

A 3D Wire frame is constructed for the propeller using the airfoil sections at different radii stations as shown in figure (3).

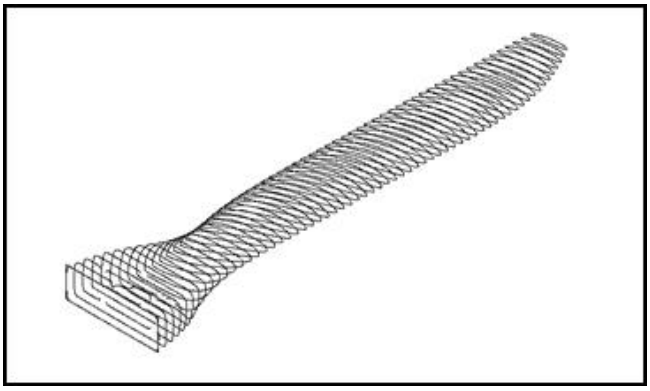


Figure-3 3D Wire Frame created at different Radii Stations [1]

III. Hand Crafting the Propeller using Wood Laminations

A. Propeller Blank Construction

In order to reduce stresses in different directions and to avoid flutter of the propeller, laminations of wood are used to construct the propellers instead of using one block. Also laminations are used to keep the blade from changing shape with ageing and moisture content variations. The number and thickness of the laminations used influence the thickness of the blank. The thickness of each individual lamination is selected so that at least two layers remain at the tip section after handcrafting. Four lamination of thickness (16,12,12 and 8 mm) as shown in figure (4). A rough balance check of the individual laminations is made to avoid getting all the dense or heavy ends on one side.

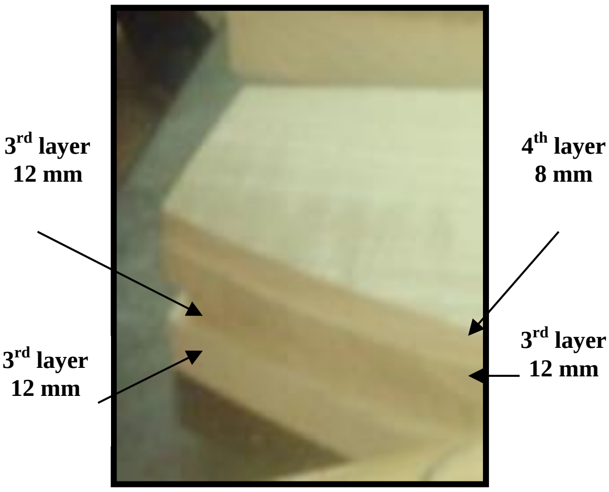


Figure-4 Propeller blank laminations

B. Propeller Blank Glue Lay-up

Weldwood Casine Glue is applied to both sides of each lamination. Weldwood glue is used in a warm room and is allowed to dry for about 12 hours as shown in figure (5) (. The surfaces are painted with water prior to the application of the glue. After gluing the laminations "C" clamps are used to obtain required gluing pressures, a pair of angle iron pieces are placed on top of the laminate stack to help distribute clamping loads and to keep the work piece straight.

Fig. (5) Prop blank lamination gluing

C. Cutting the Propeller Blank to Size

After removing the laminated propeller blank from the "C" clamps, a template for the plan view of the propeller is constructed using a band saw as shown in figure (6). This template was used for cutting the propeller blank to the real edges of the original propeller. A small hole through the hub center is drilled to be used as a reference and the diameter line is then drawn through this reference. Blade station lines are drawn normal to the diameter lines, and the leading and trailing edges are established along the template. The hub circle is drawn with a compass on both upper and lower sides. The leading and trailing edges lines are faired to the hub diameter with a French curve. The propeller blank is then cut to the plan template on a band saw being careful to leave a small margin for sanding as shown in figure (7). Also a side template is used to reach the curvature at the outer part of the leading edge as shown in figure (8).

Figure (6) Propeller plan view template

Fig. (7) Cutting the prop blank to size

Figure-8 Side template

D. Construction of Profile Templates

The airfoil sections Contours of the propeller obtained from the laser scanning are used to manufacture templates of upper and lower surfaces shown in figure (9) using CNC wire cut machine The templates are chosen for each recommended radius stations (25, 40, 50, 60, 70, 80, 90%) of the blade radius. The manufactured templates are compared to the original propeller surface as shown in figure (9) to ensure their accuracy.

Figure-9 Comparing templates with original surfaces

The hand crafting process is done using the same twisted handsaw cutting. The resultant surfaces of the upper and lower surfaces are compared with the manufactured profile templates at previously marked positions at the recommended stations during the manufacturing process as shown in figure (10).

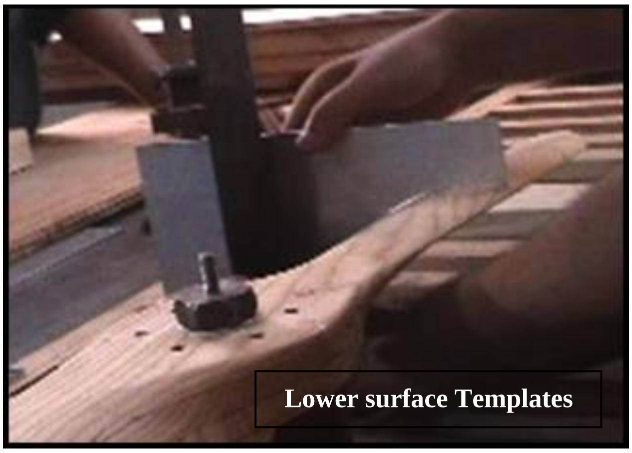


Figure-10 Using Upper and Lower surface Templates for checking the handcrafted Surfaces

Hand rasp and spoke shaving is done after most of the material is removed by the band saw operation. Both blades are worked down to the maximum section thickness. A wood chisel and mallet are handy used for working out the material near the hub where the airfoil section blends into the cylindrical shaped hub circle. A final hand sanding is used in conjunction with “feeling” the surfaces for irregularities. Then, the hole pattern in the hub is a drilled.

E. Propeller Static Balancing

After the hub was bored out, the propeller is statically balanced by inserting a rod in the hub bore and resting it on a level surface as shown in figure (11). Hand sanding near the tip is very effective in obtaining a balance. Then several coats of Urethane Varnish are applied to the prototype surface for polishing and balance test is repeated. Any unbalance is then corrected by painting a transparent spray on the lighter blade.

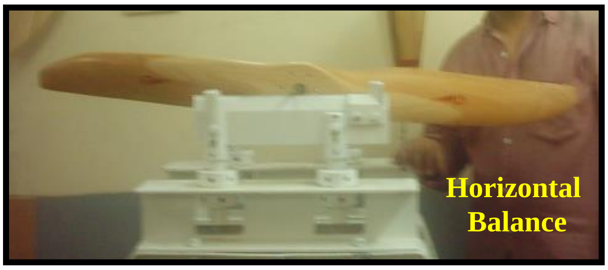
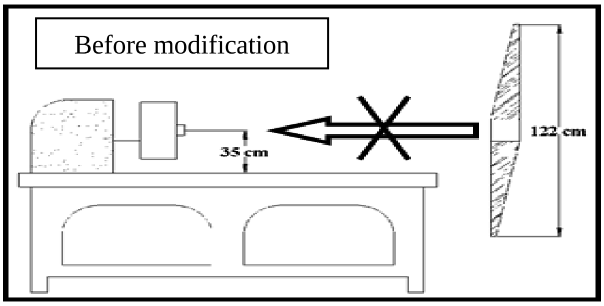


Figure-11 Propeller static Balance in Horizontal and Vertical positions

F. Propeller Dynamic Balancing

In order to avoid vibration due to any mass imbalance, dynamic balancing test is performed in addition to the static test. The available dynamic balance measuring machine is designed for installing parts of 35 millimeters as maximum diameter. The dynamic balance machine is modified by manufacturing and installing a special shaft shown in figures (12). Any imbalance is treated by boring small holes at the proper radii and added lead masses for balance.



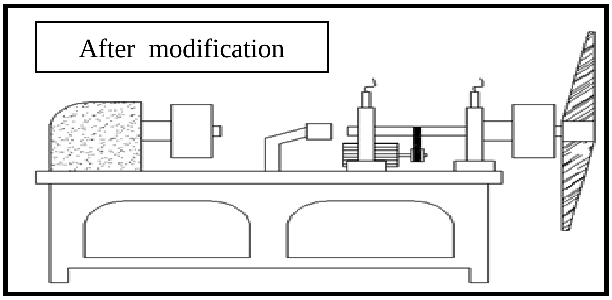


Figure-12 Dynamic Balance for the Propeller

CONCLUSION

Laser scanning technology is a successful mean for measuring, and exporting measured geometric data for complex scanned surfaces like propellers with high accuracy, reliable, robust and nondestructive manner. This provides a great assistance in manufacturing prototypes for the scanned data. In our previous work, reverse engineering of a propeller of a powered Para-glider is performed. The propeller geometry is measured using 3D laser scanner, a 3D CAD model is tested numerically using CFX [1].

In this paper, a prototype is handcrafted for a two blade wooden propeller using a laminated wooden block base on scanning data obtained from laser scanning. Templates are manufactured for the propeller plan, propeller sides, upper and lower surfaces. The propeller is statically and dynamically balanced to avoid vibration during operation.

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