Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 21 (2014) 183 – 188
www.elsevier.com/locate/procedia

24th CIRP Design Conference

Adaptive fixturing system for the smart and flexible positioning of large volume workpieces in the wind-power sector

Edurne Olaiz[a*], Juanjo Zulaika[a], Fernando Veiga[a], Mildred Puerto[a] and Ainhoa Gorrotxategi[a]

[a]*Tecnalia Research and Innovation, Paseo Mikeletegi 7 - Parque Tecnológico, Donostia - San Sebastián, E-20009, Spain*

* Corresponding author. Tel.: +0034 902 760 000; fax: +0034 943 005511. *E-mail address:* edurne.olaiz@tecnalia.com

Abstract

Quality and productivity in a manufacturing process depend considerably on the toolkits used, whose basic functions are to position the component into a right position relative to the cutting tool and to hold the component tightly to avoid displacements during the machining. In this document the design of a smart and adaptive fixture is presented for the accurate positioning of a planet carrier with very strict requirements of tolerances and for an intelligent adjustment during the machining process when required. This device will allow the manufacturer reducing the manual inspections, automatizing the adjustment tasks and improving the machining process setup time, increasing consequently the productivity and achieving the required accuracy and the required geometrical quality of the part. The development of the intelligent fixturing will be focused mainly in the conception of a high precision actuator capable of moving the large part with the required tolerance. Moreover, a testbench has been developed that will allow validating the actuator, assuring therefore its applicability in the future industrialization of the fixture device.

Selection and peer-review under responsibility of the International Scientific Committee of “24th CIRP Design Conference” in the person of the Conference Chairs Giovanni Moroni and Tullio Tolio

Keywords: Fixture design, electromechanical actuator, smart control, flexible positioning

1. Introduction

Fixturing is an essential aspect of the manufacturing process, crucial for workpiece quality and productivity. The costs associated with fixturing can account for 10–20% of the total cost of a manufacturing system [1]. These fixturing and tooling costs reach higher values in short batch manufacturing applications, since normally the fixturing is specific for each workpiece. Therefore, modern manufacturing environment imposes a continuous research to pull towards more flexible and efficient equipments in the field of tooling and fixturing.

A machining fixture has to meet two basic requirements: (i) to position the workpiece to a right position in relation to cutting tools with the appropriate accuracy and (ii) to hold the component tightly so that it does not moved during the machining operations.

Fixture procedure strongly affects the final quality of the workpiece. Workpiece surface errors and fixture set-up errors (called source errors) are inherent to the machining processes; the fixtured workpiece will consequently have position and/or orientation errors (called resultant errors) that will definitely affect the final machining accuracy. Current clamping procedures are carried out with traditional fixturing methods, therefore it implies several steps and the success of the operation usually depends on the skill of the human operator. Therefore to avoid this human error, it is important to automatically clamp workpieces with the use of fixturing devices, for which, firstly a search of the existing actuating technologies is required in order to find the most suitable solution for the fixturing operation.

2. State of the art on clamping technologies

Different actuator solutions have been addressed by the literature in the search for the best solution to meet the fixturing requirements of each application in terms of: stiffness of the solution, geometrical field of application (large or small part fixture), accuracy of the positioning and cost.

Selection and peer-review under responsibility of the International Scientific Committee of “24th CIRP Design Conference” in the person of the Conference Chairs Giovanni Moroni and Tullio Tolio
doi:10.1016/j.procir.2014.03.193

The most commonly employed are: Electro mechanic actuators, hydraulic or pneumatic actuators and piezoelectric actuators.

Concerning electro-mechanic actuator, several mechatronic systems have been designed with the aim of adjustable and flexible fixture devices [2] [3]. In [4] and [5] an adaptronic chuck is presented for precision positioning in lathes together with an optical measurement system and control algorithms. This solution offers the ability to compensate eccentricities by active clamping adjustment. For the best accuracy, syncronous motors are commonly used.

Hydraulic and pneumatic actuators make the actuator function via fluid energy (oil or compressible gas). As an application case of hydraulic actuated systems, in [6], the authors have proposed a numerical controlled fixturing system based on the double revolver principle which arranges locators, clamps and supports on servo-controlled turn-tables with repositionable hydraulic cylinders providing the clamping force.

One of the most innovative solutions on fixturing large and difficult-to-handle parts using pneumatic solutions are the pin-array type flexible machining fixtures [7]. These fixtures feature an array of pins that hold parts by conforming to their shape. Hydraulic actuators show high level of stiffness, whereas pneumatic actautors have many distinct characteristics of energy-saving, cleanliness, simple structure and operation, high efficiency and are suitable for working in a harsh environment, but are not so suitable for accurate ultra-precision positioning.

The piezoelectric actuators convert an electrical signal into a precisely controlled physical displacement. New integrated piezo-actuators are controlled by micro-controllers, which communicate with an external control desk via Bluetooth. A positioning range of microns in two degrees of freedom can be achieved. In order to control pressure in the clamping cylinders of chucks, force sensors are also integrated [8]. Thus, the centripetal forces are compensated to make a sensitive clamping possible. Piezo-actuators are extremely accurate, but on the other hand it is not a suitable solution with large stoke demand applications.

In [9], the authors focus on automatically positioning by electromechanical actuators and flexible clampling based on magneto-rheologic fluids properties. The fluid is in direct contact with the held part. A magnetic field increases the viscosity of the fluid and this allows the application of clamping forces. Additionally, in [10] a fixturing device with dynamic clamping forces is proposed for rotatory pieces.

Since a commercial solution that meets the requirements for the application under study in this article has not been found in the literature, a compact novel adaptive fixturing device based on high precision electro-mechanical actuators have been developed and that features active clamping for micro positioning of large parts with extremely high precision (under 10 micron in centering positioning).

Intelligent control is based on generalized HIL (hardware-in-the-loop) by combining multiple simulations and real components into a Hybrid Process Simulation (HPS) for positioning with high accuracy the workpiece to be placed, which is not in the same initial position, as it is described in [11].

3. General overview of requirements for adaptive fixture design approach

The design of the fixturing should be determined to ensure stability, repeatability and immobility in the workpiece to be manufactured.

Fixturing devices must satisfy two features, which seem to be opposite:

- to minimize the displacements of the workpiece during the machining process;
- to avoid excessive tensions and strains on the clamped workpiece.

In this case, the fixturing that has been designed is for the manufacturing of small lots of large parts (planet carriers) for the gearbox of wind mills, within the wind-power sector for the Gamesa Company. The machining of components such as the planet carrier is a very demanding process, which is becoming highly complicated as progressively larger parts are being required. Due to the very large size of wind power generation equipment, achieving quick setup times and high accuracy values is really a relevant challenge. Fig. 1 shows a drawing of the planet carrier, made of cast iron. The dimensions of the component go from 1,000 to 2,500 mm of diameter and the weight is up to 3,000 kg.

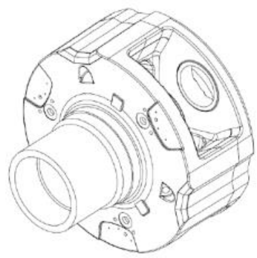

Fig. 1. Isometric view of the Gamesa's planet carrier for the gearbox.

The machining process on the planet carrier takes place in two phases:

- Phase 1. Machining of the upper side of the workpiece. Its orientation in relation to the currently used fixturing can be seen in Fig. 2 a.
- Phase 2. Machining of the bottom side. The orientation of the workpiece (upside down) in relation to the currently used fixturing can be seen in Fig. 2 b.

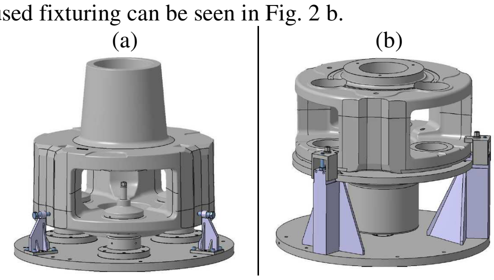

Fig. 2. (a) Phase 1 and (b) Phase 2 of the Gamesa's planet carrier machining process.

The adaptive fixturing has been designed for the Phase 2, as it is the most critical one in terms of required tolerances. In this case, the fixturing has to center the planet carrier relative