Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 13 (2017) 283–290

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

Manufacturing Engineering Society International Conference 2017, MESIC 2017, 28-30 June 2017, Vigo (Pontevedra), Spain

Design and manufacturing of a prototype of a lightweight robot arm

S.C. Gutiérrez[a,*], R. Zotovic[b], M.D. Navarro[a], M.D. Meseguer[a]

[a]*Department of Mechanical and Materials Engineering, Universitat Politècnica de València, Camino de Vera s/n, Valencia 46022, Spain*
[b]*Department of Systems Engineering and Automation, Universitat Politècnica de València, Camino de Vera s/n, Valencia 46022, Spain*

Abstract

The aim of this work is to manufacture a prototype of a lightweight robot arm with a low cost budget, fully functional. This prototype is used to test and fix the elements for driving and controlling. During the development process, several tests and studies were performed, such as, strength simulations, dimensional effects after a post-process treatment with acetone, adjustment of control parameters to improve the accuracy, testing of behaviour of transmissions, etc. The prototype must have a low weight overall and a right operation. The results and conclusions, related with material, reinforcements, geometry/shape of the parts, etc., become recommendations for the manufacture of the final lightweight robot arm. The one that will not be prototype.

Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.

Keywords: Rapid prototyping; light robot arm; Fused Filament Fabrication; 3D printing

1. Introduction

The main purpose of this work was to shorten the development cycle of a prototype of a lightweight robot arm, increasing the overlap between the stages of this cycle, in order to allow the concurrent work of different multidisciplinary teams.

These teams are in charge of design, manufacturing, control [1], integration with the patient [2], etc., so, it is important to have a functional prototype in each of its development stages. Although, this prototype is not going to have real application, it will be the basis for the development of new one, able to assist people with disabilities.

* Corresponding author. Tel.: +34 96 387 76 22; fax: +34 96 387 76 29.
E-mail address: scgutier@mcm.upv.es

2351-9789
Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.
10.1016/j.promfg.2017.09.072

The choice of the prototyping technique is usually strongly influenced by the material that the technique can process and by its total cost. In this case, the prototype was made of plastic to reduce weight, using a low-cost prototyping technique and with a short time for processing each part [3].

The 'low cost' to manufacture the prototype includes redesign and reprocessing for some of the parts for their right fit in the final assembly. The request for modifications may come from any of the teams.

The structural parts were obtained using a 3D printing, based on fused deposition, FFF: Fused Filament Fabrication. Simple steel parts were used for drives, shafts and couplings, they were made with a lathe and a milling machine.

The prototype of lightweight robot arm includes the shoulder, arm and forearm, with a total of two degrees of freedom, an image is shown in Fig. 1. (a). The robotic hand [4] will offer the other three degrees of freedom.

Although the prototype of the hand was made in a different project, features, as the fit with the forearm and the space for the power and control wires, were taken into account.

One of the disadvantages of using FFF is the lack of low tolerances close to the required ones. Nevertheless, the use of plastic materials (like ABS, Acrylonitrile Butadiene Styrene), that can be easily reprocessed by machining or using chemicals products, allowing to fit any part in an easy way. An experimental study was made in order to control the behaviour of the ABS under a chemical exposition, and the dimensional changes due to the use of chemicals.

Another peculiarity to have in mind is the way that the 3D printing system works. Due to the superficial melting of the layers and filaments directions, the strength of the manufactured structure differs considerably from that expected according with the mechanical properties of the plastic material used [5]. This point adversely affects the quality of the obtained product. To solve it, the parts were reoriented to leave the filaments favourably oriented to withstand the efforts, and post-process treatments were made.

This paper shows and tests the manufacturing process of a functional prototype of a lightweight robot arm, made by 3D printing of ABS. The materials and elements used are the most similar possible to those that will be used in the final product. The ultimate goal was to realize about all the disadvantages that could arise, find the causes and their implications in the product, and search for suitable solutions.

2. Experimental procedure

The methodology followed can be outlined in these steps:

- To make 3D designs in an environment that allow to check part of the requirements, as well as the feasibility of the final assembly.
- To manufacture at a low cost, without the traditional process-plan and without any type of ancillary.
- To analyse the causes of lack of precision to feed back the design and manufacturing stages, in order to avoid post-process adjustments for other parts and modifications.
- To perform post-process adjustment to meet the requirements, if it is necessary.

The components used for driving and controlling the arm had a strong influence on its geometric shape and dimensions. Even so, the final shape was soften using splines, trying to improve its appearance, Fig. 1. (a).

Being a low-cost prototype, some components were reused, such as brushless motors, Fig. 1. (b) up. Nevertheless, other elements such as drive shafts, gear reducers, sensors, etc., have been chosen or designed, see Fig. 1. (b) down, trying to compact each part and maintain a proportional dimensions on the final product.

The main start restrictions were:

- Search for a low weight for the arm, and therefore for the elements used [6]. The use of scaffolds made with a different material to the shell of the arm parts were avoided.
- A work volume of 200x200x200mm available in the 3D printer. The forearm, arm, shoulder and coupling elements have confined their dimensions to this volume.
- Use optical encoder sets before and after each gear reducer (harmonic drives), Fig. 1. (c). This was necessary for the control tests.
- Compulsory use of wheels coupling connectors (flexible couplings) between the brushless motors and gear reducers to absorb misalignments.