Multifunctional Automated Angle-Controlled Multi-Immersion Coating Machine For Use In Biomedical Implant Coatings

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***Abstract*— Coating of biomedical materials is an industrial need. Dip coating method is preferred in industrial applications due to its practicality. In this technique, biomedical materials are dipped into the solution in a precise and controlled manner at a uniform speed, and removed with a film layer on them. The dip coating method is widely used in industry as it allows high quality coatings even for highly complex shaped materials. However, dip coating machines in industry are limited in terms of their functionality. For this reason, fully automated, flexible dip coating machinery is designed. Using a human machine interface, manufacturing specifications are logged in, allowing flexible coating options, resulting in multi-coatings (6 specimens at a time), to be used in biomedical coatings of implants. So that the needs of domestic industry for biomedical coating applications are to be met locally, providing independence for local implant manufacturers. The prototype of the designed device was produced. The machine performed in compliance with the desired parameters. In the feasibility study, it was observed that all the criteria for coating the implants have been met successfully.**

Keywords — dip coating, industry, implant, coating, human machine interface, flexible machinery.

I. INTRODUCTION

The use of implants and medical devices is a life-saving procedure improving the quality of life of patients in a great extent. They have been widely used since the past half century increasing the life-quality of patients. Orthopedic, cardiac, oral, maxillofacial and plastic surgeons are only examples of medical specialists treating millions of patients each year by implanting devices as diverse as pace makers, artificial hip joints, breast implants, to dental implants and implantable hearing aids [1].

The geometric design, material selection and the structure of an implant need to be compatible with the characteristics of the tissue to be replaced, because they are in direct contact. This adaptation could be achieved by tailoring the exposed surfaces of the implants in view of their chemical, physical, biological and morphological features. Implant materials must be designed to minimise the adverse reactions associated with introducing a foreign material to the body [2]. Body's immune system reacts to foreign substances and results in inflammation. It is therefore crucial to choose a material which will have a minimum negative impact on the body. To enhance the biological performance of medical implants, various researchers utilize surface modification technologies [3]. Coating an implant surface with a suitable material is a very convenient and intuitive approach to obtain a modified surface of the bio-implant. Several traditional techniques have been used to create coatings on metallic implants, such as thermal spraying, dynamic mixing, dip coating, sol–gel coating, electrostatic or electrophoretic deposition, biomimetic coating and hot isostatic pressing[4] .

COATING TECHNIQUES

1- PLASMA SPRAYING

In plasma spraying molten metal or ceramic powder is sprayed onto biomaterials to form a protective layer. In this process, the heat of ionized inert gas (plasma) is utilized. Plasma spraying is an advantageous method in terms of rapid deposition rate, thick deposits and low cost. The disadvantage of plasma sprayed coatings is the weak bond strength between the coating and the biomaterial resulting in poor adhesion. [5]

2-SPUTTER COATING

Sputter coating technique consists of physical vapour deposition (PVD). In this process, gas plasma is used to eject materials from a negatively charged target. The material is then deposited as a coating onto the substrate material. The advantage of this method is that the sputter coating offers better adhesion strength and results in uniform, dense coating, however, it is costly. [5]

3-ION-BEAM ASSISTED DEPOSITION

In a typical ion implantation process, ions are accelerated through high graded potential difference and directed towards a substrate material. Ion implantation technique have an advantage in terms of improving the mechanical, chemical and biological properties of biomaterials. Its use is not very common because it involves costly steps such as beam extraction, beam scanning, beam focusing and

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high vacuuming. Moreover, it is not appropriate for implants with complex geometries. [5]

4-DIP COATING

Dip coating is the precision controlled immersion and withdrawal of any substrate into a reservoir of liquid for the purpose of depositing a layer of material. Many chemical and nanomaterial engineering research projects in academia and industry make use of the dip coating technique.

In this study , we are aiming to provide a solution to the unmet need of an industry for medical applications, by providing a flexible, low-cost, programmable, multi-stationed industrial dip coating machine, which can perform according to pre-defined coating parameters.

II. MATERIAL AND METHODS

Multifunctional automated angle-controlled multi-immersion coating machine can be defined as a system which consists of two subsystems; electronic and mechanical systems.

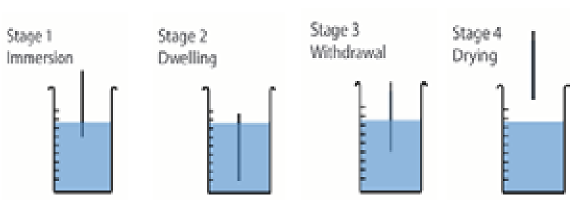

Figure 1 There are four different stages involved in the coating of thin films via dip coating

A. Mechanical Sub—system Components

The system components (Table1) were designed using a Computer Aided Design (CAD) software (Figure 2) in SolidWorks (Dassault Systèmes, Vélizy-Villacoublay, France). The sub-components of mechanical sub-system and their functions are as follows:

1. Trapezoidal stepper motor with vertical axis motion (75 cm) and stainless steel bar fixed as guide on upper chassis passing in 9mm diameter
2. Sample holder table for controlling the immersion angle between 0 ° and 90 °
3. Rotating table with 360 ° rotation of bath units.
4. Chassis provind base

Table1 Mechanical sub-systems components

Materials	**Properties**
1 Aluminum Coupling	it can be set from 6 to 8 mm
1 ball-bearing	8 mm inner diameter
Plexiglas	5 mm thickness, 570 mm diameter
Wood track	70x70cm
1 trapezoidal shaft and nut	50 cm, 8 mm diameter, 2 mm pitch
20x20mm aluminum sigma profile	4 piece 60 cm length, 8 piece 70 cm length
1 stainless steel bar	45 cm length, 9 mm diameter
1 stainless steel rod	1 meter length. 3 mm diameter
3D printer products	PLA filament. Different shapes and features
Sigma profiles hidden corner connection	Channel 6, 20x20mm hidden corner connection is used.

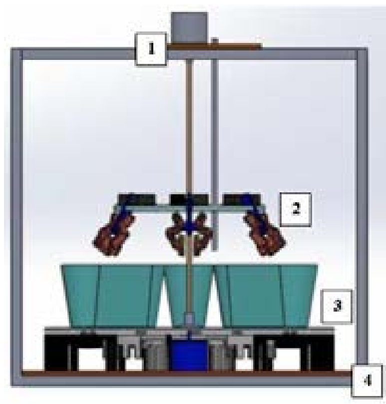

Figure 2 Computer aided design drawing of the dip coating station in side view.

B. Electronic Sub-system Components

Electronical subsystem is used to control the machine for flexible coating parameters. The electronical sub-system components are listed in Table 2. The motions of the mechanical system are controlled electronically. These motions could be classified into three groups ; the vertical linear motion on trapezoidal shaft (with the stepper), the motion of sample holders between 0-90 degree angles (with the servo motors) and the rotation of the chasis (with the stepper) 360°. To control the motion, an algorithm was developed and the code is written with Arduino library (C and C++ programming languages). After the assembly of the mechanical units, electronic connections were completed. The code running the motion was verified and validated by testing with different system parameters. A graphical user interface was developed in C# programming language for the user to enter the desired values into the interface.

Table2 Electrical sub-systems components

Materials	**Properties**
2 Stepper motors (23lm-C355-P6v Stepper)	It works as 360° step controlled rotation
6 Servo motors (TowerPro MG995 servo motor)	It works as 180° limited angle controlled rotation
1 The arduino mega ATmega 2560 Microcontroller	It is a microcontroller board based on the ATmega2560. It has 54 digital pins, 16 analog inputs, 4 UARTs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button
1 Roller	8 mm inner diameter
2 L298N driver module	6-15V , 2A for channel, at the same time 2 dc motor can be controlled
2 Limited switches	1x3 cm, 1x 70cm cable,

The servo motors and step motor was selected according to their holding torques. The length of sample holders was 10 cm, the weight of samples was 350-400 g. The diameter of chasis was 28 cm, total weigth of solution cups was 2.5 kg.

$$T = F * r * \sin(theta) \qquad Eq1$$

$$F = 0.4\ kg\ * 9.8\ N/kg = 3,92 \approx 4\ N$$
$$r = 10\ cm,$$
$$theta = 90^{\circ}\quad \sin(90) = 1$$
$$T = 4\ N * 10\ cm * 1 = 4\ N\ cm.$$

So, the holding torque of TowerPro MG995 servo motor was 9.4 N cm, it was appropriate for sample holders.

$$\sum T = \sum W * r \qquad Eq2$$

$$\sum W = 2.5\ kg\ ,\ r = 28\ cm$$
$$\sum T = 2.5\ kg * 28\ cm = 70\ kg\ cm$$

So, the holding torque of 23lm-C355-P6v Stepper was 6.2 kg cm holding torque, it was not appropriate for chasis. A more powerful stepper was bought, it was replaced with the old one.

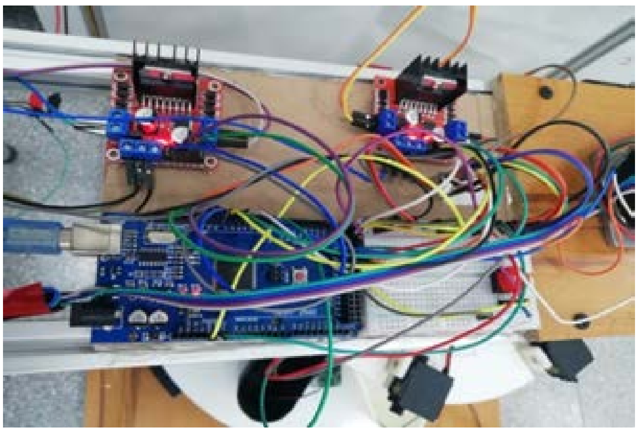

Figure 3 Electronic set-up

III. RESULTS

The prototype was tested by connecting to a power supply. Before the device was energized, the desired angle data was entered (three sets of data ±45° and 0°). Using a gonimeter, sample holder's position was tested against the predefined angle range for validation and verification purposes.The results showed that samples were controlled by 1° Std (0.5) precision.

To verify and validate the translational motion; the sample holder table was controlled to move upwards until contacting to the upper limit switch. Once it contacted the upper limit switch, the rotation table was rotated until contacting to the lower limit switch. At a later stage, the button was pushed and the sample holder table was moved down 30 cm after waiting for 5 seconds, it was moved up . So that the sample holder table moved succesffully, meeting the defined range of motion for the desired coating position.

To demonstrate the specimen replacement, when the sample holder table contacts upper limit switch, the container number is requested from the user.Via user interface, the table is rotated according to the container number. Then the angle value is entered by the user for servo motor. The implant is inserted into the sample holder before the desired angle value is entered, then the angle value is supplied into the designated coating unit space, in the designed user interface. After the implant is secured at the desired angle, the button which is found in breadboard is pressed and the sample holder table travels down by 30 cm to complete the immersion. After the 5 seconds, the sample holder table moves up and stopped when it contacts the upper limit switch.

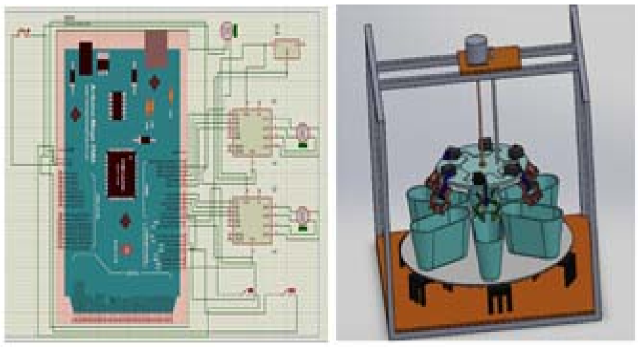

Figure 4 Electronic design demonstration of device in Proteus Design Suite on the left, the final form of device on the right.

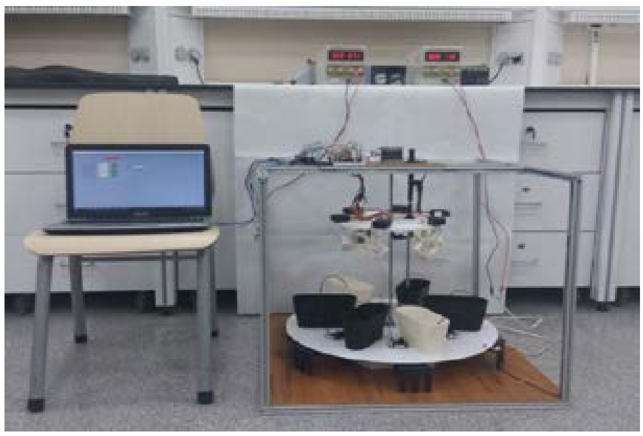

Figure 5 Final state of the project

IV. CONCLUSION

This study has demonstrated that the prototype produced for dip coating of medical implants can perform according to the predefined programmed parameters succesfully. The manufacturing costs are almost half of the exported products. With the improved flexibility and reduced pricing, the study successfully delivers the product,which was previously an unmet need by the medical industry.

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