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BIOMEDICAL ENGINEERING – PART OF MEDICINE

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Abstract: Biomedical engineers represent significant multidisciplinary and interdisciplinary interconnection of technical, humanities and natural sciences. By integrating and applying technical, physical science disciplines to the fields of biology and medicine, they enable comprehensive systemic levels of tissues and organisms as a whole to be influenced. The ability of targeted, regulated proliferation, differentiation, tissues / organ / organism reparation enables not only to improve the quality of healthcare but also to improve the quality of life of the injured individual. The goal of biological engineers is to better understand, replace or fix a target system to ultimately improve the quality of healthcare [1]. In this brief, transparent article, we focus on the various areas of biomedical engineering research in the world.

1 Introduction

Biomedical engineering is the fastest growing career and this trend is expected to continue over the next decade. Biomedical engineers educate and prepare next-generation leaders to advance bioscience and biotechnology via quantitative, integrative, and design oriented analysis & synthesis of molecular and cellular biological mechanisms at the intersection of engineering, the life sciences and healthcare. These are several diagnostic, analytical, monitoring, imaging, therapeutic devices, such as medical devices, have been developed by biomedical engineers. For example: cardiological stents, defibrillators, ECG, monotorous equipment HOLTER, mobile cardiology ambulatory telemetry (MCOT), EEG, RTG, CT, MRI, fMRI, PET, cochlear implant, anesthesia monitoring technology, pacemakers, rehabilitation systems, prosthetics, laser surgery, sophisticated da Vinci surgical robot [1].

An increasing gap between organ donation and organ transplantation has inspired scientists to find out alternative approaches and substitutes to make the organs functional. The US National Institutes of Health has defined regenerative medicine as “the process of creating living, functional tissues to repair or replace tissue or organ function lost due to age, disease, damage, or congenital defects” [2]. Tissue engineering provides a generic structure for the emerging field of regenerative medicine that has significant potential for orthopedic applications [3-12]. Advances in molecular, cellular, and tissue biology have led to significant discoveries in biomedical engineering in the areas of nanotechnology, tissue, cell and chemical engineering, stem cell, neural cell research, and so on. They lead to the development of "micro level", neural, prosthetic, telemedicine, etc., resulting in nerve prostheses, bionic vision, intelligent nanoterapies, replacement tissues / organs, parts of systems [1].

Advanced computer models provide the means to accurately interpret diagnostic values in new ways, moving us towards a more personal therapy. In addition to simply providing technical aids, bioengineers enable advanced information, sensors and wireless monitoring technologies to facilitate the interpretation of patient health data and prompt decision-making by physicians on the therapeutic approach.

2 TERM - tissue engineering and regenerative medicine

Regenerative medicine is a relatively new, evolving area in which many medical, biological and physical sciences are used primarily to address the lack of biological organs and tissues available for transplantation or therapy, secondary to organ or tissue pathology. The branches of regenerative medicine are tissue engineering, diagnostic platforms, cell and therapeutic therapies, supportive technologies [8, 9].

Tissue engineering is a field of regenerative medicine in which *ex-vivo* replacement tissues, organs, and other body parts are developed, e.g. skin, ears, and the like. *Tissue engineering* evolved from the field of biomaterials development and refers to the practice of combining scaffolds, cells, and biologically active molecules into functional tissues. The goal of tissue engineering is to assemble functional constructs that restore, maintain, or improve damaged tissues or whole organs.

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The subject of cell therapy research is now increasingly in the therapy of applied pluripotent stem cells for their repair properties in the treatment of pathological conditions. Cellular collection kits and new techniques for their delivery have been developed, which are used as tools of regenerative technologies in the clinical environment (Figure 1). For example: A tissue-engineered graft can be seeded with pluripotent cells and then be maintained in culture media while having mechanical stimulus applied to the graft in order to aid in differentiation and maturation of the tissue-engineered construct. [3, 7-10, 13].

Figure 1 A commercially available bioreactor is depicted in this image (DynaGen bioreactor system, Tissue Growth Technologies, Minnetonka, MN, USA) [14].

Regenerative medicine has evolved tremendously in recent years and appears to be a promising approach in restoring function and regeneration of diseased tissues and organs. Since cell function occurs at the nanometer scale, nanotechnology can influence and even alter cellular behaviour, which ultimately enhances the functioning of tissue or organ. The traditional approaches of nanotechnology in regenerative medicine can be related to: 1) nanoparticles; 2) scaffolds with nanofibers; 3) scaffolds with nanotopographic modifications; 4) drug/gene delivery; and 5) extracellular matrix (ECM) patterning. The newer and rational approaches include a combination of these traditional methods [2]. Supportive technologies appear to be an essential aspect of regenerative medicine. Other of example of regenerative medicine technology is harvesting, isolation, *in vitro* cultivation, proliferation of the pluripotent stem cell of a patient, and subsequent inoculation on scaffolds (Figure 2). The scaffolds are then seeded with cells that have been growing in Petri dishes. These cells can be harvested from either a stem cell line or a donor ideally the recipient of the transplant. The cell-scaffold construct is then bathed in a medium that encourages the cells to grow and multiply. As the cells multiply, they begin to acquire the shape of the scaffold, which eventually breaks down and is absorbed by the tissue. Scaffolds allow three-dimensional orientation, and potentially help in the organization and differentiation of stem cells. In order to promote stem cell differentiation and remodelling into mature end-organ tissue, various growth factors and mechanical stimuli are applied. As a result of the tissue engineering process, a new tissue is prepared for surgery, suitable for transplantation, reconstruction, substitution that is theoretically optimized to accelerate the healing and regeneration process (Figure 2) [14].

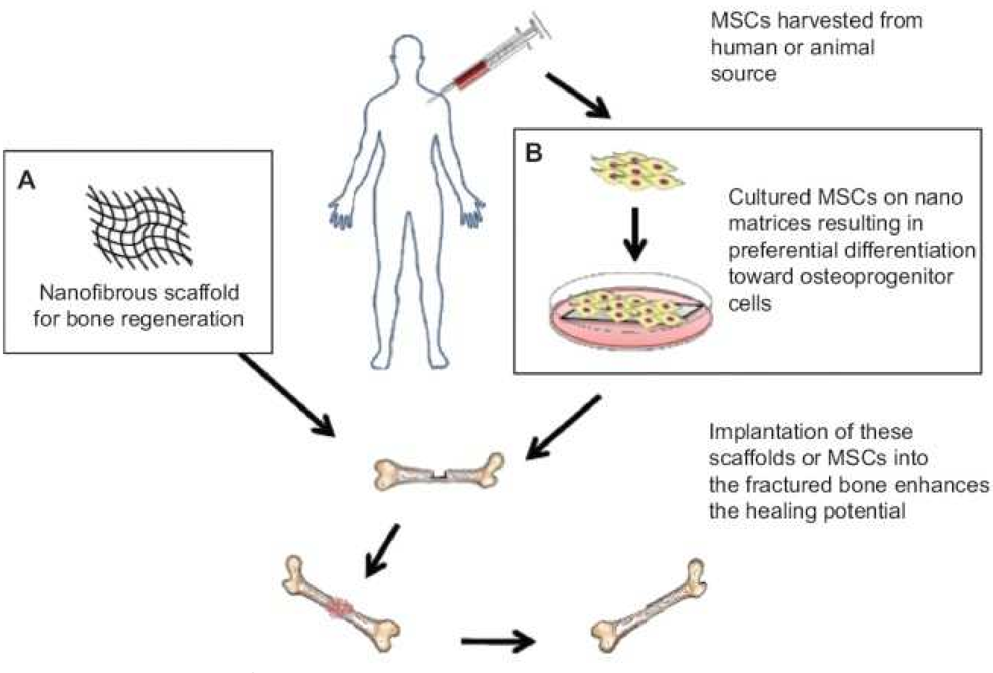

Figure 2: Schematic representation of bone regeneration using nanotechnology. Improved bone healing using (A) nanofibrous scaffold and (B) culturing mesenchymal stem cells on nano matrices [2].

The stem cell field is also advancing rapidly, opening new avenues for this type of therapy. Therapeutic cloning and cellular programming may one day provide a potentially limitless source of cells for tissue engineering applications. While stem cells are still in the research phase, some therapies arising from tissue engineering endeavours have already entered the clinical setting successfully, indicating the promise regenerative medicine holds for the future [14].

The terms “tissue engineering” and “regenerative medicine” have become largely interchangeable, as the field hopes to focus on cures instead of treatments for complex, often chronic, diseases. This field continues to evolve. In addition to medical applications, non-therapeutic applications include using tissues as biosensors to detect biological or chemical threat agents, and tissue chips that can be used to test the toxicity of an experimental medication [15]. The UK government highlighted regenerative medicine as one of the key eight great technologies in their industrial strategy worthy of significant investment. The long-term aim of successful biomanufacture to repair composite defects depends on interdisciplinary collaboration between cell biologists, material scientists, engineers, and associated medical specialties; however currently, there is a current lack of coordination in the field as a whole [16]. Application of regenerative medicine technology may offer novel therapies for patients with injuries, end-stage organ failure, or other clinical problems. Currently patients suffering from diseased and injured organs can be treated with transplanted organs. Scientists in field of regenerative medicine and tissue engineering are now applying the principles of cell transplantation, material science, and bioengineering to construct biological substitutes that will restore and maintain normal function in diseased and injured tissues [17].

Department of Sports Medicine and Department of Orthopedic Surgery, Faculty of Medicine, Wake Forest University, Medical Center Boulevard, Winston-Salem, North Carolina 27157, USA created tissues of urethra, vagina, bladder neck and bladder in association with tissue engineering. They are currently developing vessels, heart valves, animal muscles, ear, fingers, kidneys, nerve, skin, skeletal muscles and trachea [4,6-10,18,19]. The use of new bioprinting technology or microorganisms enabled them to produce microscopic liver structure, tissue structure of the bladder and urethra, testes, cardiac muscle, and kidney structure [6,20-23]. It is hoped that, with ongoing collaboration, these technologies could be applied to patients at the Department of Sports Medicine and Arthroscopic Surgery [3].

3 Biomechanics

Biomechanics and bioengineering are related to engineering, including the application of principles, laws and methods of mechanics to develop and improve medical diagnostics, biomedical devices and biomechanical models [24]. The term biomechanics is used to describe the application of mechanics to biological systems [25,26]. Biomechanics in studying how motor systems create movement and strength often use traditional techniques that are insufficient to clarify the mechanics of living systems. Mechanisms of biological systems are usually much more complex than mechanical systems and require more recent and advanced analytical techniques. As in other areas of bioengineering, biomechanics are applied not only at the macro level, but also where the joints are connected, but can also be studied at the molecular level. In fact, the mechanism of biological systems at the macro level is affected by what occurs at the level of muscles, tissues and molecules.

Biomechanics provides conceptual and mathematical tools that are necessary for understanding how living things move and how kinesiology professionals might improve movement or make movement safer. The application of biomechanics to human movement can be classified into two main areas: the improvement of performance and the reduction or treatment of injury. Another application of biomechanics is in the medical areas of orthotics and prosthetics, in relation to preventing injury, but many prosthetics are being designed to improve the performance e.f. of disablet athletes etc. Biotribology is a field of biomechanics that deals with friction, wear and lubrication, especially for human joints. For example, questions such as implantation of the knee due to the influence of time, such wear is influenced by the lubrication effects of the synovial fluid and the like.

4 Biorobotics

Biorobotics is a term that loosely covers the fields of cybernetics, bionics and even genetic engineering as a collective study.

With an undestanding of biomechanics, engineers can develop biologically inspired robots with improved and enhanced capabilities over traditional robots, which are how shall we say robotic! Biologically inspired robots have greater mobility and flexibility than traditional robots and often possess sensory abilities. Biorobotic technologies are often utilized to provide assistance to accomodate a deficiency either as fully functioning robots or highly advanced prosthetic, the latter represents one area in which neural engineering and biorobotics intersect as both disciplines are required in order to first signal and then generate movement.Such devices may also be used to measure the state of disease, track progress or offer interactive training experiences than can speed recovery from an injury or stroke. Biorobotics encompasses a diverse array of disciplines with a myriad of application. Researcers in Italy are developing artificial sensing skin that can detect pressure as contact is made with an object [27]. Tactile sensors are important not only for self-standing robots and limb prostheses but as a means of restoring the sense. Stanford engineers create artificial skin that can send pressure sensation to brain cell (Figure 3). Stanford engineers have created a plastic skin-like material that can detect pressure and deliver a Morse code-like signal directly to a living brain cell. The work takes a big step toward adding a sense of touch to prosthetic limbs [28].

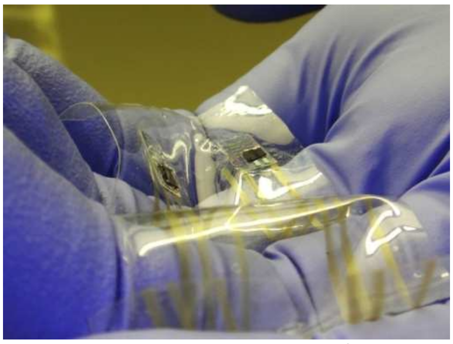

Figure 3 Stretchable skin with flexible artificial mechanoreceptors (Credit: Bao Research Group/Stanford University [29]

The team of engineers and scientists from Caltech and ETH in Zurich have developed artificial skin that can detect temperature changes [30].

Italian scientists are also exploring the potencial for early diagnosis of autism by monitoring sensory-motor development through mechatronic-sensorized toys, such as rattles with force and contact sensors [31]. This one application of biorobotics requires contribution from biomedical engineers studying tissue engineering, neural engineering, biomimetics.

Endoscopic robots at the tip of probe can, for example remove a polyp during colonoscopy. And mechatronic handheld tools allow surgeons to manipulate their hands at the macro level while affecting similar responses from mechanical device opening at the micro level. One day, this could even lead to „ cellular surgery“[1].

5 Bioinformatics and Computational Biology

Computational biology and also bioinformatics draw upon many of the same disciplines to derive distinct, but related information about biological processes. Bioengineers working in computational biology might explore how blood flows through the body or how air flows through the lungs. This „plumbing“ can be mathematically modeled to help determine the health of an individual patient. Computational biology explains how biological processes work at the macro level. By using computer models, various hypotheses are tested to understand how tissues, organs and whole ecosystems function. By better understanding how specific biological pathways work, bioengineers are working to design a better retinal stimulator to restore vision [1].

Within the larger field of computational biology, bioinformatics also known as „computational molecular biology“ focuses on the exploration of biological processes at the molecular level.Sophisticated algorithms are developed to study genes (genomics), gene expression (transcriptomics), proteins (proteomics), lipids (lipidomics), metabolites (metabolomics), and other cell-bound molecules [1,32-35]. Dynamic molecular and cellular processes are revealed by mapping, visualizing and recognizing patterns in sequences and expression of DNA and proteins, analyzing protein structures, modeling molecular pathways [1, 36-39].

The Physiome project represents an international effort to better understanding of physiology using a computational framework that crosses multiple spatial and temporal scales [1].

The increasing need to manage and interpret the large volume of data and information gleaned from these activities has increased research efforts in the areas of databases, computational techniques and tools, and complex human-computer interfaces that allow users to archive and retrieve data. But bioinformatics and computational biology are not to be confused with health informatics, which focuses on the mining of patient data for clinical applications [1].

Conclusions

The use of tissue engineering as well as regenerative medicine technology is an exciting paradigm for solving the problems of orthopedic medicine and prosthetics. Although biological and tissue engineering solutions are currently limited, the future has great potential for the further development of existing technologies that can ultimately improve surgical results, accelerate recovery and reduce postoperative rehabilitation constraints.

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PROCESS OF THE RFID TECHNOLOGY IMPLEMENTATION INTO THE PRODUCTION

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Keywords: RFID technology, process, implementation, production
Abstract: The article deals with RFID technology and its implementation under real conditions. The paper familiarizes reader with RFID technology, functionality of RFID technology and its basic elemets. It offers a complete picture about RFID technology. The main focus of this paper is on guideline for smooth and cost effective process of implementation this new technology into the production processes taking into account real conditions. There are defined steps to follow to meet the requiremets and obtain all proposed benefits after implemetation of RFID technology. This paper helps to avoid complications during process implemenation of RFID technology.

1 Introduction

Data collection is important task to be performed to keep traceability especially in automotive industry. In case of recalls need to be immediately found the root cause and identify amount of possible affected parts to protect final customers. Production data are also essential part for evaluating and managing the systems and processes in general. It is a key element to know status of production and on this bases make a decisions.

There are many methods and technologies for data collection. Considering pressure on cost reduction in nowadays it is highly recomended to automate the process of data collection as much as possible. Suitable is also eliminate influence or work force on data collection and data flow. One of the most modern and effective technologies for data collection and evaluation is RFID technology.

2 RFID technology

RFID is wireless technology which is focused on automatic identification of objects and data collecting. Acronym RFID refers to Radio Frequency Identification. RFID technology was used for the first time during second world war for military applications. Scientists began work on a wider use of RFID at the end of the 20th century.

Figure 1 describes concept of RFID technology which consists from Electronic Product Code (EPC) placed in microchip. Microchip together with antenna is a part of RFID tag which is fixed on objects of interest. RFID tag must be placed in electromagnetig field of reader. RFID technology allows easily identify or count many objects simultaneosly.

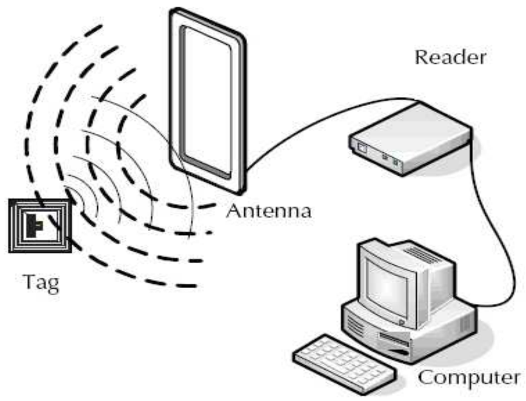

Figure 1 The basic components of RFID technology

RFID tags – based on criteria such as memory type, frequency, power supply type and design it is possible to identify more types of RFID tags. In terms of memory we distinguish read only tags which contain coded data and read/ write tags which is possible to overwrite. Table 1 schows frequency used for RFID tags with its characteristics and the most common usage. Ultra high frequency is the most suitable frequency for RFID technology applied in production field. It has range 1 – 6 meters and it enables to achieve hight speed of reading. According power supply type tags are active, passive and semi passive. Active tags includes own energy source. They are able to collect, evaluate and sending the data. Passive tag provides energy radio field which is made by antenna of reader. Passive tag can only react. It means that they can only sending data saved in microchip. Semi passive tags has own source od energy but they do not use it for communication with reader. Tags can have different size and shape according the needs.

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Table 1 Frequency used for RFID tags

Frequency	Characteristic	Application
Low frequency 125 – 134 kHz	• Range < 50 cm • Low data volume at low speed • Expensive • Readable through liquids	• Attendance systems • Chips for animals
High frequency 13,56 MHz	• Range < 1 m • Readable through liquids • Anticorrosive system	• Smarts cards • Traceability of containers
Ultra high frequency 860 – 868 Europe 902 – 928 USA 950 – 956 Japan	• Range 1 – 6 m • High reading speed • Frequency zone for EPC generation 2	• Traceability of containers • Manipulation with luggage at airports

Reader –It is a device to comunicate with tags. The part of reader is antenna that receives and transmits electromagnetic waves. The most important are directional, polarization characteristics, location, shape and size of antennas. Reader performs encoding, decoding and store data from and to RFID tag.

Server – it is a computer unit that presents data from reader [7].

RFID systems by collecting and displaying data on the terminals provide a clear picture about entire production process in real time. It allows identifying productions issues and supporting operational improvement.

Importance of RFID takes a new dimension when information obtained by RFID is applied into operational application such as MES, ERP and etc.

Implementation of such technology brings many economic benefits such as [8]:

- Easier stocktaking,
- Minimizing labelling costs,
- Simplification in data management and exchange
- Improvement of inventory evidence.

To achieve listed benefits, it is necessary to complete the implementation process of RFID technology.

3 Steps to follow for successful implementation of RFID in production

Companies tend to face many issues to solve while RFID is well implemented and set. Based on practical experiences it is possible to formulate logical steps which give as a guideline how to smoothly implement this new technology on the shop floor (Figure 2).

Decision to make – At the very beginning stage is crucial to evaluate the need of RFID in companie. Expectations from set up this technology must be very clear defined. Implementation of RFID technology is cost intensive investment but on the other hand it brings many benefits and also return of investment. Suitable method that helps to decide about implementation of RFID is to do business case. Business case should clearly define all advantages and benefits of implemetation on one side and necessary cost for implemetation on the another side. It is also important to mention in business case service cost to keep RFID technology working and in good condition. Comparison of results in terms of cost for implementation and savings after implementation give a clear picture that helps easily to decide [10].

Build the team – Implementation of RFID like new technology into the organizaton standars has to be defined as a project. Every project need to have specialist involved to meet all expectations and time scheduling. The team members need to be extremely focuse on RFID project implementation. They have responsibilities for planning, designing and implementing of a project.The right team composition is a key factor for smooth project implementation. Members of team need to be engage and enthusiastic about project implementation and also have all necessary knowledges.

Concept of RFID within the processes – From range of whole production processes is necessary to identify key processes where RFID technology will be implemented. It is extremly important to know this key processes into the details. For consideration is also to find out how implementation of RFID will influnce performing of this operations. In concept should be also define a level to tag. Tag can be hold on all objects produced or on pallet and boxes where objects are gathered. Tag level influences amount of data that have to be managed and project cost.

It is recomended to draw a scheme shows how is process working with RFID implemented. In another words to do a concept of future state where processes are improved by aplication of RFID technology.

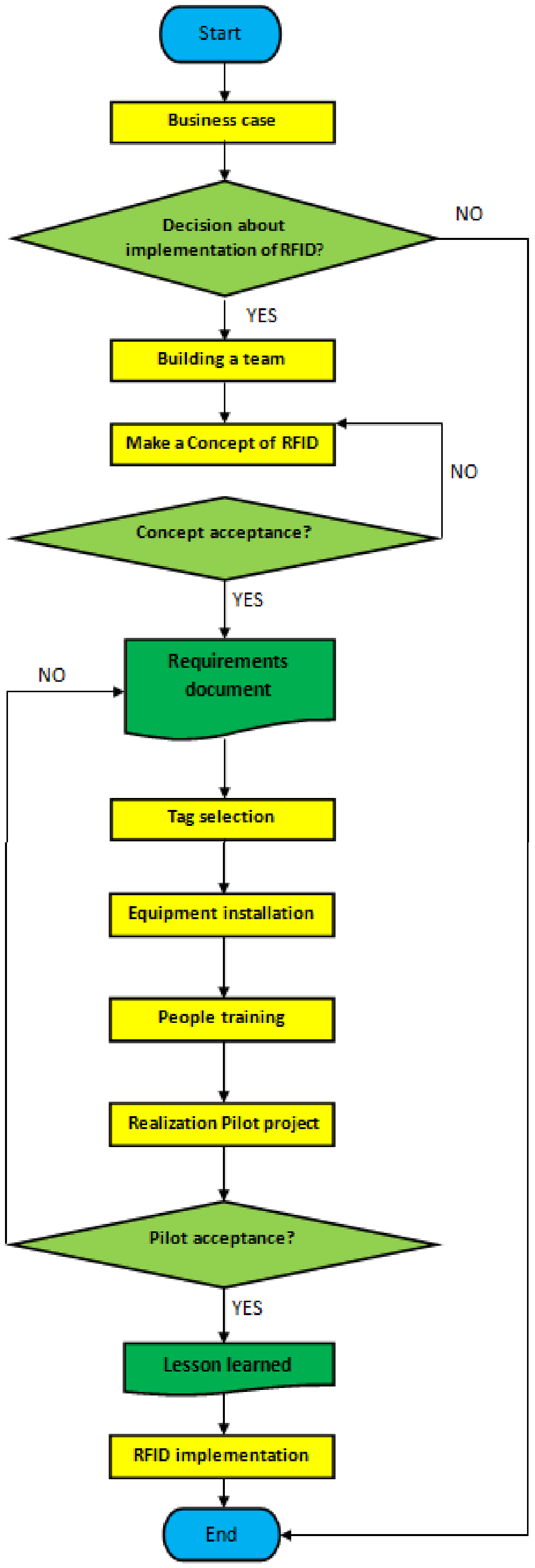

Figure 2 Flowchart of RFID process implementation

For scheme is sufficient to use existing layout of paticular area where read points of tags will be implemented. Concept has to be shared with all stakeholders such as [10]:

- Business management,
- IT department,
- Maintenance,
- Logistics,
- Production,
- Inventory management,
- End users.

All of this parties need to agree about the concept and in this way support the implementation. This is also accurate stage to do changes based on stakeholders feedback that allows to minimalize cost in comparison with doing changes after project implementation.

Requirements document – Finished and approved concept presents all requiremets and resources desired to implement RFID technology into the production. Requirements document should collect all of this indetified tasks. It should be kind of check list where is idenfied what need to be done and when. Inseparable part of requrement document is also defined responsible team members for perfoming the tasks. Main attention in requierement documents should be focuse on software solution and hardware devices, type of RFID tags, networks, environmental factors, security concers and reliability of a system. Usually additional softwares are not desirable for companies. RFID technology could also run under already existing software solution implemented in companie after certain modification.

This documents must be signed by all interested parties. Requiremets documents represents a plan with time scheduling involved for effective process of a project realization and it avoids future misunderstandings.

The Tag selection – Today are planty of tags format on market with wide range of prices depends on their usage. As was mentioned in previous chapter we distinguish few different configurations and functional abilities of tags. Choose proper tag depends on many factors in production. The most important factors to consider are [6]:

- Material of interested object (plastic, metal, fabric, wood and etc.),
- Part of object where tag is going to take a place,
- Temperatures which tag will be expose,
- Supposed distance between tagged object and reader,
- Durability requirements.

Another important factor to considere in selecting the proper tag type is requirement on human readable data. In this case is sufficient to use tags printed with human readable text. Such solution represents back up in case when tag is not readable or data on label is damage. The choice of tag also affects possibilities of tag location and orientation. Tag can not interfere with manipulation or to cause safety issue in production. To help hold tag on the object of interest in desired position there are many accessories such as holder and cases available on market place. In case of temperature as a factor of environment is important to considere duration of tag exposure to temperature.

As a result after consideration of all mentioned factors should be identification of one or more tags relevant for real conditions at production. In case of more suitable tags indetified need to be done comparison of selected tags under real conditions. The tags should be hold on object in the required pozition and orientation and run through the production. After testing tag will be expose to the reader to check if is still readeble and in good condition. This testing should be done repeatedly to check the durability of tag affected by environmental factors.

Equipment instalation – All devices idetified in concept or requirement document will be in this stage install according layout specification. High requirements are imposed on IT and maintenace specialists and their cooperation. During instalation is appropriate to minimize connection points and lenght of cables as much as possible because it is causes losses and instability of a system. Correct instalation influences the whole project success during its lifetime.

People trainig – Depending on the purpose of data collection by RFID technology there is still some people who work with collected data. For those people it is important to provide a training to use software and hardware devices to get desired outcomes.

Pilot project - Before finall implementation it is highly recomended to do trial run of a system to prove its functionality. It is last opportunity to do system changes without additional costs. Pilot project shows all shortcoming that need to be eliminated. It is testingsofware and also hardware devices, connections and data collection. In terms of readers and antennas pilot project proves their correct location defined in concept or give an opportunity to improve their ability to read tags by changing a location. During project pilot run is possible to see every competing signals in area which can affect the quality of collected data and do modification for better future state. Real conditions have to be simulate as much as possible during the trial. Suitable is also simulate different scenarious that could appear in production to see how system react. On pilot project should participate all parties to provide a feedbeck for improving of a process. At this stage is clear if expectation defined on the very beginning could be meet [6].

Lesson learned – Lesson learned is common method to end up any project. It is a tool that gather knowledges and experiences from project implementation.This document helps to be aware of similar mistakes and supports to do right decisions for future projects.

4 Conclusions

RFID technology presents future in automatic object identification. It allows having real data at real time especially in nowadays when data driven is the key element for effective productions and logistics processes. However, RFID is not suitable for every application. Decision about RFID implementation needs to be done based on depth analyses. To obtain all benefits from implementing this technology and fast return of investment is essential smooth process of implementation.

RFID technology provides background for future development. The aim is work with data collected by RFID and increases production excellence.

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MANUFACTURING SUPPORT OF FLOAT-SINK METHOD USING SIMULATION TOOLS

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Abstract: Technological processes are an important part of the production system. Behavior and the functioning of these systems can not be predicted with certainty as they belong to a group of probability-determined systems. If we wanted to know the exact behavior of these systems in advance, we would have to know them mathematically or observe the behavior of the system on a real object. Simulation processes does not prohibit experiments outside the actual object, without real intervention, even without the real existence of the system being investigated. In examining systems it is primarily about gaining new knowledge about their state, structure, behavior, it means obtaining useful information.

1 Introduction

Simulation is an experimental method based on experiments using a computer system model. It is a representation of the functioning of a system or process [1]. Through simulation, a model may be implanted with unlimited variations, producing complex scenarios. These capabilities allow analysis and understanding of how individual elements interact and affect the simulated environment. By our research being used the Witness simulation software [1],[2].

The top panel above contains the menu needed to work with the file and functions associated with modeling activities. The project bar shows how to work with the model using a tree structure [3].

The part called "modeling window" has a square base, which facilitates the imagination of the layout of the workplace [4]. At the bottom of the workspace there is an element panel. The element panel is used to create the model.

Elements are sorted by type:

- Basic,
- Transportation,
- Data,
- Transport facilities,
- Graphs,
- Statistic [2].

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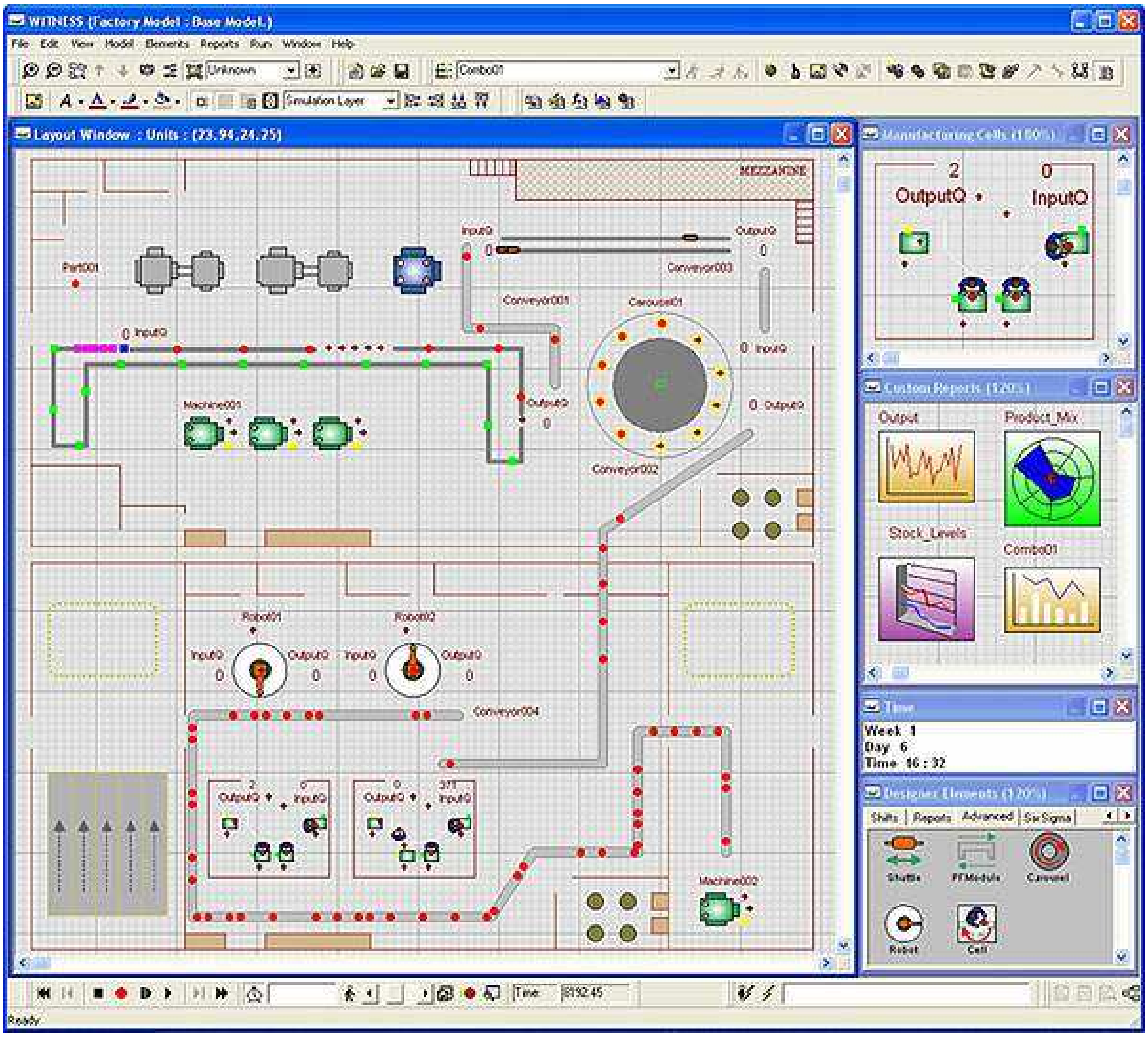

Figure 1 Witness software environment [7]

2 Float- sink method

Before starting the simulation[4], the basic data for each method was summarized. The input parameters were the times for each operation. The working time of Float-sink method is 35 min, it is also necessary to determine the amount of input into the process. In this case, the simulation was solved at a ratio of 50:50 input components, 50% of fabrics component and 50% of PVB The whole simulation is for one product, for one test board measuring 68x150x3 mm. The times entering the process are defined as:

- Operating time - what is the time needed for each operation
- Setup time - time for heating and cooling [5]

Besides the method of cleaning the fabrics component itself, the entire process of the manufacturing process of composite material production was simulated. In the following Table 1 [5] , [6] the basic characteristics are described for each operation of the cleaning of fabrics from used tires. Table 2 [6] is a description of the test sample after molding conditions.

Table 1 Characterization of manzfacturing process

Laboratory conditions	***Characteristics***
Machine	Brabender Lab Station
Pre-heat machine [min]	10
Working temperature [°C]	150
Homogenization of PVB [min]	25
Homogenization temperature PVB v [°C]	150
Homogenization of composite [min]	30
Homogenization temperature of composite [°C]	180

3 Simulation software Witness

The float-sink method is based on the density differences of the individual components that we want to separate [5]. In this method the separation time (30 minutes, for the separation method itself) was entered as an input parameter,

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The following Table 2 [6] shows the statistical data for individual components. The input material was fabric from used tires and recycled polyvinyl butyral (PVB). These two raw materials were homogenized in the kneading machine to form one mixture- a composite. From the composite there were also pressed plates for next laboratory testing.

Table 2 Statistical data for individual components of the manufacturing process[6]

Name	***PVB***	***Composite***	***Test sample***	***Fabrics***
No. Entered	1	1	1	1
No. Assemble	1	1	0	1
W.I.P.*	0	0	1	0
Avg. W.I.P.	0,73	0,23	0,03	0,73
Avg. Time	63,00	20,00	3,00	63,00

*W.I.P. –Work In Process

Figure 2 [6] below is a graphical representation of the individual components entering into the process. The final product a test sample from composite is molded in the laboratory press machine under the prescribed conditions.

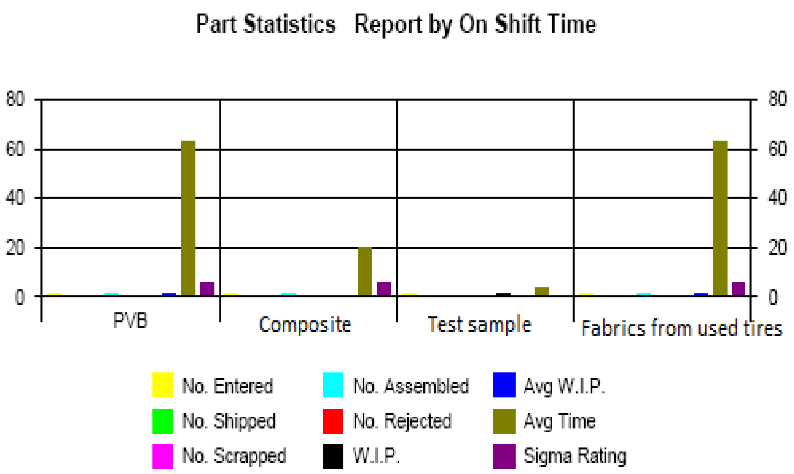

Figure 2 Part statistics data for manufacturing

The following table 3 [6] is a statistical data processing for individual machine equipment using the Float-sink method. From the following is to know the yield of the kneading machine in this operation is 63,95%, whereas the machine for separation itself is used only at 5,81%.

Next figure (Fig.3) [6] shows the machine statistics as a report after simulation.

Table 3 Statistical data for laboratory machines

Name	***Kneading machine Brabender***	***Euro star IK (Float-sink machine)***	***Laboratory press Brabender***
No.of Operation	1	1	1
% Idle	36,05	94,19	76,74
% Busy	63,95	5,81	23,26

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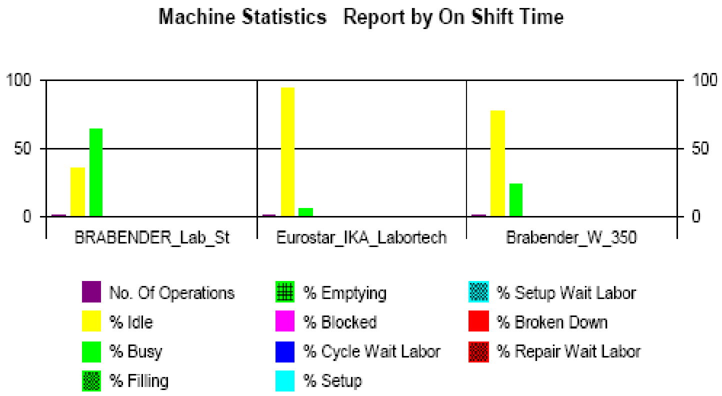

Figure 3 Part statistics data for machine

Table 4 [6] shows fabric cleaning operations and its actual implementation through an operator-worker. It can be seen that the average working time of the operator is between separation technology and the addition of individual components (fabrics and PVB) to the kneading machine, 55 min. At the start of the separation, the total operator handling time is 5 minutes. When preparing a homogenized mixture, the weighing and preparation of the molding takes an average of 20 minutes.

Table 4 Statistical data for operators

Name	***Operator 1***	***Operator 2***	***Operator 3***	***Operator 4***
% Busy	5,81	63,95	0,00	23,26
% Idle	94,19	36,05	100,00	76,74
Quanity	1	1	1	1
No. of Jobs Started	1	1	0	1
No. of Jobs Ented	1	1	0	1
Avg. Job Time	5,00	55,00	0,00	20,0

Figure 4 [6] is a representation of dependence for individual operations performed by the operator.

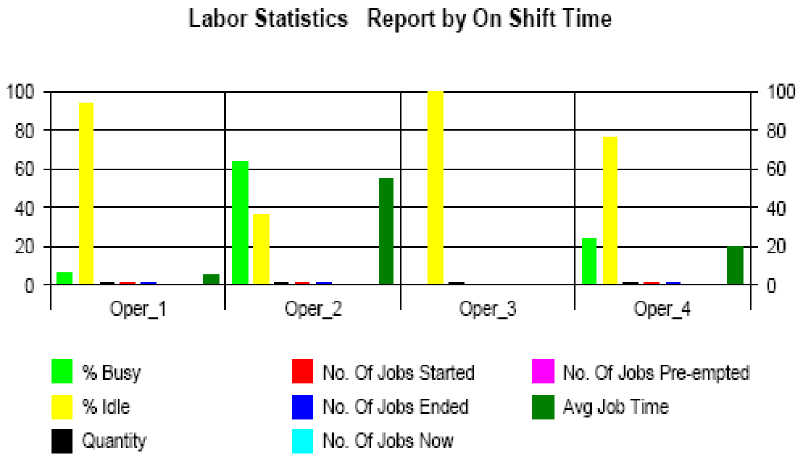

Figure 4 Labor statistics data for operators

Emptying the machine is before each operation. Machine utilization is 96,51%. The machine is in motion about 3,49% of the total time required for this composite material production process.

The figure 5 [6] is simulated manufacturing process of composite materials used float- sink methods by cleaning of fabrics from used tires.

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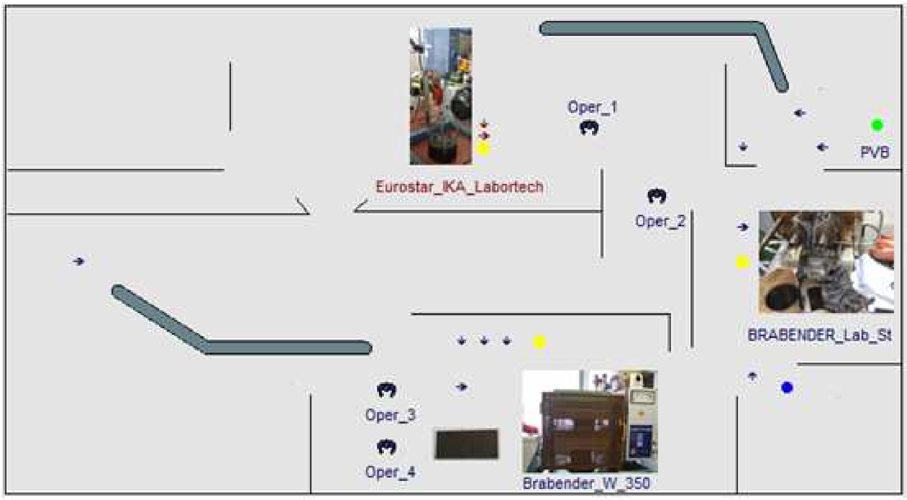

Figure 5 Simulation of manufacturing process used Witness software

4 Conclusions

Finding optimal solutions by manufacturing processes that are based on the use of the model are know in the literature as "Simulation-based optimization" or "Optimization via simulation". The basic simulation model is used in the search for optimal or best solutions.

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