Design and Fabrication of Fatigue Corrosion Machine

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Abstract - Static and Dynamic analysis of the biomedical implants and fixators has been tested using the fatigue -corrosion machine . Millions of patients all over the world undergo surgery for implants and orthopedic fixator's .These implants and fixators undergo fatigue [1] and corrosion in human body due to body fluids .Corrosion reduces the strength of the implants and the debris gets dissolved in the blood leading to further medical complications like kidney failure on patients. fatigue occurs on the implants and fixators due to repeated loading and unloading .when corrosion is combined with fatigue the strength of the material reduces to 10% [5]of its actual strength and also may lead to catastrophic failure of the implants and Fixators .Due to this several tones of 316L Stainless Steel implant metals are wasted ,even though Stainless Steel is reproducible , it will have adverse effect on the environment , with the depletion of natural resources ,this will lead to scarcity of material for the future population .A fatigue corrosion machine was designed and fabricated ,the results showed fatigue corrosion taking place in the implants ,this paper recommends the possibilities of new implant metals like 304SS[12] and fabrication technologies such as surface modifications , which has sustainability and less effect on environment.

I. Introduction

The use of titanium dental implants has revolutionized oral implantology. In the USA, about 300,000 patients a year currently receive dental implants. With the aim of improving their biocompatibility and mechanical resistance, their manufacture attempts to achieve adequate design and minimum degradation, dissolution, deformation fracture and corrosion. In USA 4500 Patients are affected due to metal debris from the implants during Total Hip Replacement Surgery. Corrosion is the deterioration of a metal as a result of the surrounding medium (electrochemical attack), which causes ions to be released into the microenvironment. There are "noble" metals[3,4] such as rhodium (Rd), palladium (Pd), iridium (Ir) and platinum (Pt), which owe their resistance to corrosion to high thermodynamic stability. Metals known as passivable, such as titanium (Ti), vanadium (V), zirconium (Zr), niobium (Nb) and tantalum (Ta), are thermodynamically unstable and owe their resistance to corrosion to the formation of a protective surface layer of oxide. No metal or alloy is entirely inert *in vivo*. Corrosion[13,16,17,18] is one of the possible causes of implant failure after initial success. Therefore, management and control of corrosion is a crucial problem from biological, metallurgical en economic standpoints. Corrosion should be analyzed with an interdisciplinary focus and the participation of chemists, biologists, physicists, engineers, metallurgists and biomedical specialists , environment specialist . Biomaterials have good mechanical and biological properties there corrosion resistance is still critical for the overall success of the treatment procedure. It has been long recognized that the corrosion products formed as a result of metal-environment interactions have a significant bearing on the biocompatibility and long term stability of the prostheses/implant. The material used must not cause any biological adverse reaction and must retain its form and properties during function. Human stomatognathus is subjected to varying changes in pH and temperature owing to differences in local, systemic, environmental, economic and social conditions for each individual. Corrosion[15] can result from the presence of a number of corrosive species like hydrogen ion (H+), sulfide compounds (S2-), dissolved oxygen, free radicals (O2,O-),and chloride ion (Cl-) resulting in the metal surface breakdown and a consequent adverse tissue reactions. Fatigue occurs in biomedical implants due repeated loading of the implants due to body weight of the patients. When fatigue combines with corrosion the strength of the implants reduces to 10% of its original strength.

II. Objectives

To design a fatigue corrosion testing apparatus manufacture and analyze .To test the implant material for fatigue and corrosion using simulated body fluids. The requirements of Implants are Compatibility, Mechanical Properties and Manufacturing. The new implant material should compatible with Tissue reactions[11] , Changes in Properties viz., Mechanical[2] , Physical , Chemical ; Degradable leads to local deleterious changes ,Harmful system effects The implant material should have the following Mechanical Properties elasticity , yield stress , Ductility, Toughness , Time Dependent deformation ,creep , Ultimate strength , fatigue strength ,Hardness ,Wear resistance .The new implants should adhere to the following manufacturing techniques ,fabrication methods , consistency and conformity to all requirements ,quality of raw materials ,superior techniques to obtain excellent surface finish or texture ,capability of the material to get safe and efficient sterilization , cost of product . Based on the fatigue corrosion test and above requirements, new processing and fabrication techniques were developed.

III. Methodology

Fatigue corrosion equipment was constructed to test implants and fixators. The apparatus consists of box made of acrylic plate ,the implant to be tested is connected as working electrode .A standard calomel electrode (SCE) is used as reference electrode and graphite rod as counter electrode .To maintain consistent test conditions ,the electrodes are always positioned in the same locations inside the cell .It is connected to the potentiostat. A double acting cylinder is connected to the compressor, the load is applied to the sample .Ringer solution is filled in the box, current is supplied to the sample .At the same time cyclic load is applied on the sample, The number of cycles (loading and unloading) are counted using an electronic counter for number of cycles .The drop in the voltage is checked using the multimeter .The computer is connected to the fatigue[14] corrosion apparatus for data logging. Metals used in biomedical implants like 316L[7] stainless steel, undergo fatigue and corrosion [9] **,** they have low fatigue strength when in contact with the body fluids[8]. The strength of the material reduces to 10% [6] of its actual strength and may lead to catastrophic failures of the Implants and fixators. A specimen is prepared for the fatigue-corrosion[10] test as per the ASTM Standard and some actual fixators were designed and fabricated they are fixed in the fatigue corrosion apparatus and tested for fatigue and corrosion . To improve the fatigue strength, the metal is heat treated 10% above the crystallization temperature 600^0C to improve the elastic property of the material, and then the metal is immersed in the ringer solution and tested for fatigue life in the fatigue – corrosion testing apparatus. The load applied on the metal is three times the body weight of the human body .The ringer solution used is equivalent to the body fluids .The number of cycles is calculated is with respect to the duration of the implants in the human body. Every 16 hours the corrosion debris are collected from the ringer solution and weighed, the diameter of the specimen is measured, strain is measured, from the strain the stress calculated, A fatigue life graph is drawn with stress in the x-axis, with number of cycles in the y-axis .the above metals are tested for fatigue- corrosion, the results are analyzed , if it shows improvement ,then the metal can be tested invivo . Since the these metals are very costly, metals like 304 stainless steel can be used for orthopedic applications by surface modification technic like acid etching . Finally the mechanical strength of the Fatigue -corroded specimen is tested in Universal Testing Machine and also analyzed using Finite Element methods. Fatigue corrosion behavior of biomedical implants is extremely complex. many types of uncertainty exists in implants fatigue corrosion studies including member geometry shape size of fatigue cracks, types shapes size of defects discontinuities in the structural details corrosion of implants, loading and environmental conditions, thermal and corrosive effects. This article studies a number of factors affecting the fatigue corrosion behavior of metal members .A fatigue corrosion equipment was constructed to study the fatigue behavior of the biomedical implants.

Figure 1 Fatigue Corrosion specimen

Construction of fatigue corrosion equipment

Figure 2 Microcontroller

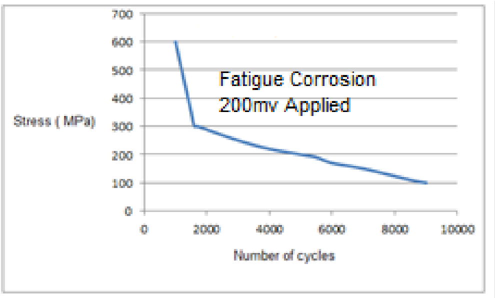
The fatigue Corrosion equipment was constructed as shown in figure 3 and 4, to conduct experiments on stainless steel specimen. A tank was constructed using acrylic plate, A metal housing was constructed using cast iron ,over the housing double acting cylinder was placed .The piston of the cylinder is connected to the load cell by a small rod ,A plunger is connected to the load cell .The specimen is fixed using a special fixture inside the acrylic tank , epoxy coating is given to the fixture ,to avoid corrosion by the ringer solution .The Ringer solution is filled in the acrylic tank ,The stainless steel specimen is fixed on to the fixture .The acrylic tank contains inlet and outlet from the inlet fresh Ringer solution is filled in the tank ,from the outlet Ringer solution containing stainless steel debris is drained in the outlet tank . Electrode is fixed in the acrylic tank. Air from the compressor is connected to the double acting cylinder , The to and fro movement of the piston is obtained ,which in turn gives the force on the plunger , the specimen under goes repeated loads . A microcontroller figure2 ,is connected to make the system fully automatic , A load indicator is connected to measure the load , A counter is connected to the system to count the number of cycles , the specimen under goes repeated loading .

Experimental Procedure - fatigue corrosion

A detailed experiment was conducted on Stainless Steel samples .The samples were created as per ASTM dimensions as shown in the figure 1.A special fixture was manufactured to mount the specimen on the fatigue – corrosion machine . The compressor is switched on, 70 N forces were applied on the specimen, and repeated loading is applied on the specimen. After 16 hours the ringer solution was drained into a separate tank, the metal debris were collected and the specimen was weighed, the decrease in the specimen diameter was measured, the cross sectional area was measured, The weight of the specimen was measured using a weighing machine and the results were noted. The number of cycles were noted using the counter mounted on the fatigue corrosion machine.

IV. RESULTS AND DISCUSSION

The experiments was conducted on the fatigue corrosion machine for 316L stainless steel used for implants and fixators ,the following details were observed from the experiments ,Ringer solution was used as body fluid , since the components of ringer solution are equivalent to the body fluid . It is observed from the experiments, the weight of the specimen decreased by 2gms for every 16hours The specimen was not allowed to fracture since this is an low cycle fatigue test. A graph was drawn with stress in the x-axis and Number of cycles in the y-axis. As shown in the graph 1 . The dissolved metal particles in vitro 2gms will in the blood stream in vivo experiments .It can affect the kidneys and vital organs in the human body .Loosening of the implants will occur , this will result in the removal of the implants from the human body ,it will go as metallic waste , since millions of patients are using implants and fixators , tones of stainless steel material gets wasted , one advantage of stainless steel is that it can be reprocessed ,but the energy involved in reprocessing should be minimized by developing better surface finish and different grade of stainless steel like 304 SS, The cost of these is less compared to 316L.



Graph 1: Fatigue corrosion of 316L Stainless Steel

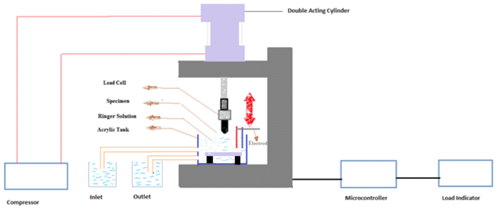


Figure 3: Fatigue Corrosion Machine Layout

Figure 4 : Fatigue corrosion Machine

V. Conclusion

From the above experiment it is concluded that fatigue corrosion affects the implants used for orthopaedic patients. To improve Fatigue corrosion new manufacturing processes like surface modification techniques, like porous surfaces and surface coating is needed for the long life of the implants in the human body.

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