الآية

قال تعالى:

بسم الله الرحمن الرحيم

﴿ وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَى عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُم بِمَا كُنتُمْ تَعْمَلُونَ ﴾

صدق الله العظيم

سورة التوبة الآية (105)

Dedication

I would like to dedicate this work to my

Father Soul, Mother, my brothers, Sisters, friends, and Everybody who taught me a letter for Their endless and generous support,,,,

Mohammed Ali

Abstract

This research tried to suggest a suitable alternative material instead of that used in manufacturing socket by the national authority for prosthetics and orthotics.

Beside that this research focused on finding suitable alternative material by analyzing these materials properties with ansys mechanical program and comparing the results with the used material.

This research reaches to use (PP) material, which it is more suitable than the alternatives material according to its mechanical properties.

المستخلص

هذا البحث حاول إقتراح مادة بديلة مناسبة للمادة المستخدمة في صناعة المقبس (Socket) بالهيئة القومية للأطراف الصناعية.

بجانب ذلك ركز البحث في إيجاد بديل مناسب عن طريق تحليل خواص هذه المواد باستخدام برنامج (ansys mechanical) ومقارنة النتائج بالمادة المستخدمة.

وقد توصل هذا البحث إلى ان المادة المستخدمة حالياً (PP) مناسبة أكثر من البدائل من حيث خواصها الميكانيكية.

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List of abbreviation:

ICRC	International committee of the red cross
NAPO	National authority for prosthetics & orthotics
PTEE	Poly tetra fluoro ethylene
PVC	Poly vinyl chlorides
PE	Poly ethylene
PP	Poly propylene
UHMWPE	Ultra-high-molecular-weight polyethylene
ULMWPE or PE-WAX	Ultra-low-molecular-weight polyethylene
MHWPE	High-molecular-weight polyethylene
HDPE	High-density polyethylene
HDXLPE	High-density cross-linked polyethylene
PEX or XLPE	Cross-linked polyethylene
MDPE	Medium-density polyethylene
LLDPE	Linear low-density polyethylene
LDPE	low-density polyethylene
VLDPE	Very-low- low-density polyethylene
CPE	Chlorinated polyethylene

Chapter One

Introduction

1-1 Introduction:

During last years the development of many products has been improved by the introduction of computer-aided tools reducing the time and costs of the full development process, and allowing evaluating in a faster and cheaper way different variants of the same product. besides, a great attention has been put on custom-fit products characterized by a close Interaction with the human body or part of It. Innovative computer-aided tools can help to realize custom-fit products with a strict interaction with human body and definitely improve people's quality of life, in particular of persons with disabilities.

The work presented in this thesis refers to this context and to a specific custom-fit product: the prosthesis. Main objective has been to realize an innovative knowledge-based framework, centered on the virtual models of the patient's body, which can guide and support the user during all the steps of the prosthesis design, suggesting rules and procedures for each task. Regarding known introduction of computer-aided tools (ICT), we have verified that they can support some specific tasks of the product development process, but they do not offer any kind of assistance to the prosthetics. In fact, design process decisions and actions are taken on the base of technicians' experience and personal skills. Therefore, it is strategic to integrate within such systems specific domain knowledge, in order to obtain a valid and high quality final product, and to develop for this reason a design framework, which can assist the technician during all the process.

Current ICT tools for product development are focused on a specific task (e.g. geometric modeling, structural analysis, gait analysis) rather than on the full process. Moreover, when considering custom-fit products characterized by a strong dependence and interaction with the human body, they do not focus on user's morphology but at most, they allow a simple adjustment of a standard solution. Various research projects highlighted how custom-fit products, such as helmets, motorcycle saddles or handicapped equipment's, can strongly improve their quality thanks to innovative computer-aided tools. Anyway, the results obtained revealed some limits: both product and process strongly depend on skill and technical knowledge of involved technical staff. Therefore, there is a need of innovative design processes, which can offer in a single framework tools for each different activity, specialize modeling and simulation procedures according to the specific product requirements, and support the operator with the knowledge required to develop the full product development process and the single activity. This thesis work refers to this field and focuses the attention on the specific case of lower limb prosthesis. The development of such prosthesis is prevalently based on hand-made procedures: IT methods and tools play a partial role. A typical example of a custom-fit component of lower limb prosthesis is the socket, the component which needs a total custom-fit manufacturing. In fact, the socket is the most critical component and is shaped by the orthopedic technician around the patient stump. S/he manually manipulates negative and positive plaster casts according to stump anatomy and on the base of his/her knowledge and experience.

Materials are used in the manufacture of socket known and universally popular, but it is costly. The plastic materials are the most commonly used for low cost and plastic properties which is light weight and flexible. National Authority for Prosthetics & Orthotics used polypropylene, which comes by the Red Cross for free. Because of the problems faced by the National Authority for Prosthetics & Orthotics represented in the polypropylene and dependence on the Red Cross as a supporter, because of these it was my duty to try to find an alternative material properties and the possibility of the best manufactured locally.

1-2 Problem of research:

It was observed that there is a problem in the socket made of polypropylene in the National Authority for prosthetic especially in cases of amputation above the knee as it bears no weights and it cracks occurs.

1-2 Research importance:

The importance of research in finding a cure for a very large segment of cases of amputation above the knee, which is estimated at about 60% of the cases that come to state.

1-3 Objectives:

- Suggest the material used in socket manufacturing.
- Modeling of a substitute.
- A comparison between polypropylene and alternative material.

1-4 Methodology of research:

Analysis with ANSYS MECHANICAL program:

ANSYS program was used in analysis process, and to make it work with correctly way it should be:

1-provides mechanical properties for chosen materials.

2-determines the value of the force that imposed on socket and its direction.

1-5 Research schedule:

Activities	First month				second month				third month			
Literature review												
Conceptual design												
Design analysis												
Results discussion												

Chapter Two

Theoretical Studies and Literature review

2-1 Preface:

Prostheses: is a device that compensates for the missing party in the human body. Prostheses consist of different materials of which are made of plastic or wood or metal materials, and are run in different ways some of which are powered by electricity or mechanically operated. And uses prostheses for cases suffering from amputation of the limbs, either in whole or in part was an accident or birth defect since birth (deformation). [1].

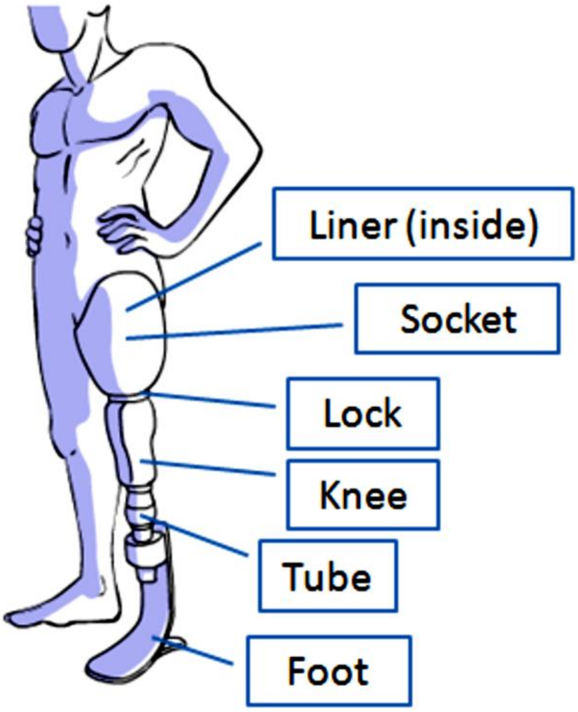

Figure (2. 1) Prostheses

2-2 Advantages of artificial limbs:

- The provision of basic materials needed to make it.
- Light weight.
- Subject to maintenance on an ongoing basis and have spare parts available.
- Are not subject to damage and last for a very long time.
- Have the ability of the movement just like the movement of the original member.
- Cost within the reach of most patients and the disabled. [1].

2-3 Types of prostheses:

Prostheses types are:

In terms of the place of infection:

- Prostheses for upper limbs overhead.
- Prostheses bottom of the lower limbs.

In terms of the time period of use:

- Temporary prostheses.
- Permanent prosthesis.

In terms of function:

- Cosmetic prosthesis is moving.
- Functional prostheses are used to perform the function of the Party amputee in the human body.
- The device is cosmetic and functional at the same time

In terms of manufacturing:

Artificial limbs are made depending on the patient's request (the device is determined depending on the person's age and weight, and condition). Prosthesis is ready.[1].

2-4 Importance of the use of artificial limbs (prostheses):

- Assist in the rehabilitation and rehabilitation of people with special needs.
- Remove the obstacles and difficulties that prevent integration in society and life.
- The performance of activities and functions appropriate to the level of disability at the person.
- Increase the confidence of the disabled person himself, and its dependence on the same.
- Help to further engage and interact in life science, educational and social development. [1].

2-5 Rehabilitation of the injured on the prosthetic (prosthetic devices):

Doctor:

Is responsible for diagnosis of the situation in terms of health and physical and determine the type of device.

Physiotherapist:

Is responsible to conduct exercises after surgery and after installing the device compensatory.

the social worker:

Is responsible to conduct a study of the situation and the family in terms of social, economic, and effects Negative social impact on the injury.

Psychologist:

Is responsible to study the psychological effects of a disabled person and his family, and help him to be accepted Put device and accept compensatory and help him raise his morale and self-confidence.

Specialist Occupational Therapy:

Is responsible for training the patient to use its skills in daily life, and how Use of the device in everyday life.

Specialist prosthetic devices:

Patient on how to use it.

2-6 History:

The idea of artificial limbs after World War II, Germany was among the first countries that started the idea of manufacturing these parties. And the material of wood raw material first used was drilled logs and empties contents geometric tubular or square and then began moving party's idea of the joint where he managed the patient and the extension of the sympathy of the upper or the lower (detailed basin foot knee neck wrist attached) in part until the mid-seventies where the industrialized countries to developing this idea and dissolved the industry where plastic. Instead of wood material for light weight and ease of manufacturing, industry parties then began to evolve effectively in terms of form and in terms of mechanical properties. [1].

2-7 Preparation of artificial limbs:

First of all, you should make a prosthesis based on the size specifications of the person who will need it. In most cases where the cut of the parties it should be amputation of the remaining part of the party before they make him a permanent prostheses. And wrapped the remaining part for several weeks' strongly plastic straps to help them deflation and keep the surface smooth coherent. During this time, the person is to Imrn muscles of the remaining part of the party to maintain muscle strength and movement, and to increase the effectiveness of the circulatory system. Include the next step for the preparation of industrial action by the hollowed plastic installed in the remaining part of the party harmony and comfort. Can be obtained on a template of the hollowed out by wrapping the remaining part of the party straps and rolls can be obtained by wrapping the ligaments wet in wet plaster, and then left to dry and strengthen, and after removing the laces, they used a template. And given the wet mixture is poured into the mold cavity shape. Can be obtained on a template of the hollowed wrap the remaining part of the party as well as the rest of the stump and the stump rolls wet in wet mixture and make it dry and harden. And after removing the rollers are used as a template. And gives the mixture liquid is poured into this mold in the form of the remainder of the party, which was used for the manufacture of cavity. It can also work cavity by molding a mixture of soft plastic in the stump directly, which makes it lightweight and protective layers of cloth and rubber.[1].

2-8 sockets:

The socket is the most critical element of the whole prosthesis because it forms the mechanical interface between the subject and the prosthesis .The quality of the fit is fundamental for the comfort of the wearer .If the prosthesis is uncomfortable to wear of difficult to use, the amputee will be less inclined to wear it. Socket fit is crucial because it is the sole means of load transfer between the prosthesis and the residual limb (stump). The socket can be either an integral part of the prosthesis or made of laminated or thermoplastic materials which are connected to the other hardware .Some established patients still use metal sockets and swear by them. The main purpose of socket is to suspend the prosthesis during swing phase and to support the body weight during stance phase.

Figure (2. 2): Shows *Socket*

The most common materials used in modern socket are:

Laminated materials:

The socket is made up of several layers of strongly woven fabrics such as carbon fiber and fiberglass laminated in resin using a vacuum to create a lightweight but strong and durable material. Almost any fabric can be laminated into a prosthetic socket. This type of material is not available in the Sudan and the cost of imported expensive so it is outside the search.

Thermoplastic materials:

Square sheets of material, generally polypropylene and low density polyethylene, are heated and then placed over a cast (normally a plaster of Paris model) of the residual limb (stump). The thermoplastic is molded to the cast and allowed to cool. Once the socket has been created, the liner locking mechanism is attached. This is the mechanism which attaches the socket to the liner which is worn against the skin of the residual limb (stump this is only necessary for sockets using a locking mechanism for the suspension of the socket. Some areas of the residual limb are able to tolerate pressure, but some are not. The walls of the socket should only press on the residual limb in areas that are able to tolerate pressure .It is difficult to ensure that a finished socket only presses against the load bearing areas without causing discomfort to the non-load bearing areas.

2-9 Polypropylene:

Also known as polypropene, is a thermoplastic polymer used in a wide variety of applications including packaging, textiles stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids.[2].

Figure (2. 3) *Polypropylene*

Chemical and physical properties:

Most commercial polypropylene is isotactic and has an intermediate level of crystallinity between that of low-density polyethylene (LDPE) and high-density polyethylene (HDPE). Polypropylene is normally tough and flexible, especially when copolymerized with ethylene. This allows polypropylene to be used as an engineering plastic. Polypropylene is reasonably economical, and can be made translucent when uncolored but is not as readily made transparent as polystyrene, acrylic, or certain other plastics. It is often opaque or colored using pigments. Polypropylene has good resistance to fatigue.

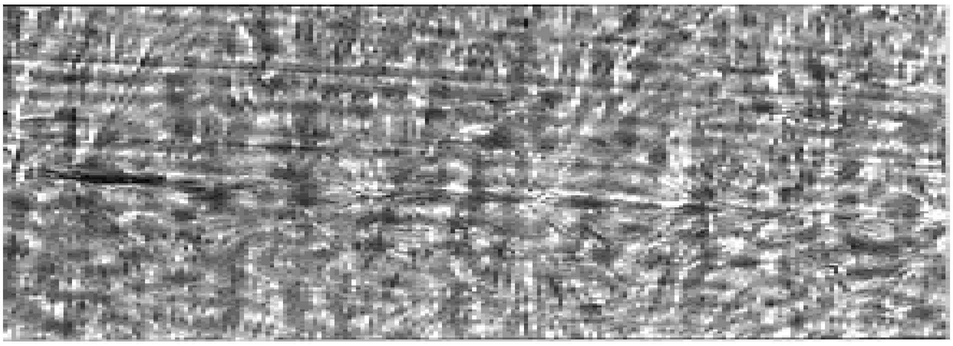

Figure (2. 4) Micrograph of polypropylene

The melting of polypropylene occurs as a range, so a melting point is determined by finding the highest temperature of a differential scanning calorimetry chart. Perfectly isotactic PP has a melting point of 171°C (340°F). Commercial isotactic PP has a melting point that ranges from 160 to 166 °C (320 to 331 °F), depending on atactic material and crystallinity. Syndiotactic PP with a crystallinity of 30% has a melting point of 130 °C (266 °F).

The melt flow rate (MFR) or melt flow index (MFI) is a measure of molecular weight of polypropylene. The measure helps to determine how easily the molten raw material will flow during processing. Polypropylene with higher MFR will fill the plastic mold more easily during the injection or blow-molding production process. As the melt flow increases, however, some physical properties, like impact strength, will decrease.

There are three general types of polypropylene: homo-polymer, random copolymer, and block copolymer. The co-monomer is typically used with ethylene. Ethylene-propylene rubber or Ethylene propylene diene monomer (EPDM) added to polypropylene homo-polymer increases its low temperature impact strength. Randomly polymerized ethylene monomer added to polypropylene homo-polymer decreases the polymer crystallinity and makes the polymer more transparent. [2].

Degradation:

Polypropylene is liable to chain degradation from exposure to heat and ultra valuet (UV) radiation such as that present in sunlight. Oxidation usually occurs at the tertiary carbon atom present in every repeat unit. A free radical is formed here, and then reacts further with oxygen, followed by chain scission to yield aldehydes and carboxylic acids. In external applications, it shows up as a network of fine cracks and crazes that become deeper and more severe with time of exposure.

For external applications, UV-absorbing additives must be used. Carbon black also provides some protection from UV attack. The polymer can also be oxidized at high temperatures, a common problem during molding operations. Anti-oxidants are normally added to prevent polymer degradation. [3].

Medical Applications:

Its most common medical use is in the synthetic, non-absorbable suture Prolene, manufactured by Ethicon Inc.

Polypropylene has been used in hernia and pelvic organ prolapse repair operations to protect the body from new hernias in the same location. A small patch of the material is placed over the spot of the hernia, below the skin, and is painless and is rarely, if ever, rejected by the body. However, a polypropylene mesh will erode over the uncertain period from days to years. Therefore, the FDA has issued several warnings on the use of polypropylene mesh medical kits for certain applications in pelvic organ prolapsed, specifically when introduced in close proximity to the vaginal wall due to a continued increase in number of mesh erosions reported by patients over the past few years .[3].

Prosthetic and Orthotic Applications:

- Ankle Foot Orthotic - AFOs.
- Dynamic Ankle-Foot Orthotic - DAFOs.
- Definitive Prosthetic Sockets.
- Frame Sockets.
- Knee Ankle Foot Orthosis - KAFOs.

Recycling:

Polypropylene is recyclable and has the number "5" as its resin identification code. [3].

2-10 Polyethylene:

Polyethylene (abbreviated PE) or polythene (IUPAC name polyethene or poly (methylene)) is the most common plastic. The annual production is approximately 80 million metric tons. Its primary use is within packaging (plastic bag, plastic films, geomembranes, etc.). Many kinds of polyethylene are known, but they almost always have the chemical formula $(C_2H_4)_nH_2$. Thus PE is usually a mixture of similar organic compound that differ in terms of the value of n. [2].

Physical properties:

Polyethylene is a thermoplastic polymer consisting of long hydrocarbon chains. Depending on the crystallinity and molecular weight, a melting point and glass transition may or may not be observable. The temperature at which these occur varies strongly with the type of polyethylene. For common commercial grades of medium- and high-density polyethylene the melting point is typically in the range 120 to 130 °C (248 to 266 °F). The melting point for average, commercial, low-density polyethylene is typically 105 to 115 °C (221 to 239 °F). [3].

Chemical properties:

Most LDPE, MDPE and HDPE grades have excellent chemical resistance, meaning that it is not attacked by strong acids or strong bases. It is also resistant to gentle oxidants and reducing agents. Polyethylene burns slowly with a blue flame having a yellow tip and gives off an odour of paraffin. The material continues burning on removal of the flame source and produces a drip. Crystalline samples do not dissolve at room temperature. Polyethylene (other than cross-linked polyethylene) usually can be dissolved at elevated temperatures in aromatic hydrocarbons such as toluene or xylene, or in chlorinated solvents such as Trichloroethane or Trichlorobenzene. [3].

Classification:

Polyethylene is classified into several different categories based mostly on its density and branching. Its mechanical properties depend significantly on variables such as the extent and type of branching, the crystal structure and the molecular weight. With regard to sold volumes, the most important polyethylene grades are HDPE, LLDPE and LDPE.

- Ultra-high-molecular-weight polyethylene (UHMWPE)
- Ultra-low-molecular-weight polyethylene (ULMWPE or PE-WAX)
- High-molecular-weight polyethylene (HMWPE)
- High-density polyethylene (HDPE)
- High-density cross-linked polyethylene (HDXLPE)
- Cross-linked polyethylene (PEX or XLPE)
- Medium-density polyethylene (MDPE)
- Linear low-density polyethylene (LLDPE)
- Low-density polyethylene (LDPE)

- Very-low-density polyethylene (VLDPE)
- Chlorinated polyethylene (CPE)

We will address in this research the High-density polyethylene (HDPE)

High-density polyethylene (HDPE):

HDPE is defined by a density of greater or equal to 0.941 g/cm^3. HDPE has a low degree of branching and thus stronger intermolecular forces and tensile strength. HDPE can be produced by chromium/silica catalysts, Ziegler-Natta catalysts or metallocene catalysts. The lack of branching is ensured by an appropriate choice of catalyst (for example, chromium catalysts or Ziegler-Natta catalysts) and reaction conditions. HDPE is used in products and packaging such as milk jugs, detergent bottles, margarine tubs, garbage containers and water pipes. One third of all toys are manufactured from HDPE. In 2007 the global HDPE consumption reached a volume of more than 30 million tons. [3].

Applications:

Polyethylene is ubiquitous in consumer products. In its foam form, polyethylene is used in packaging, vibration damping and insulation, as a barrier or buoyancy component, or as material for cushioning. Polyethylene foam is most frequently seen as a packaging material. Polyethylene foam is buoyant, making it popular for nautical uses. Many types of polyethylene foam are approved for use in the food industry. Found in all types of packaging, polyethylene foam is used to wrap furniture, computer components, electronics, sporting goods, plants, frozen foods, clothing, bowling balls, signs, metal products, and more. Polyethylene, particularly HDPE is often used in pressure pipe systems due to its inertness, strength and ease of assembly. [3].

Advantages of HDPE:

Broad chemical resistance

Good weld strength

Good low temperature properties

Relatively inexpensive

Disadvantages of HDPE:

Potential for stress cracking

High degree of thermal expansion

Poor puncture resistance

Poor multi-axial strain properties

2-11 Teflon:

Polytetrafluoroethylene (PTFE) is a synthetic fluoropolymer of tetrafluoroethylene that finds numerous applications. The most well-known brand name of PTFE is Teflon by DuPont Co.

PTFE is a fluorocarbon solid, as it is a high-molecular-weight compound consisting wholly of carbon and fluorine. PTFE is hydrophobic: neither water nor water-containing substances wet PTFE, as fluorocarbons demonstrate mitigated London dispersion forces due to the high electronegativity of fluorine. PTFE has one of the lowest coefficients of friction against any solid.

PTFE is used as a non-stick coating for pans and other cookware. It is very non-reactive, partly because of the strength of carbon–fluorine bonds, and so it is often used in containers and pipe work for reactive and corrosive chemicals. Where used as a lubricant, PTFE reduces friction, wear, and energy consumption of machinery. [3].

Applications and uses:

Owing to its low friction, it is used for applications where sliding action of parts is needed: plain bearings, gears, slide plates, etc. In these applications, it performs significantly better than nylon and acetyl; it is comparable to ultra-high-molecular-weight polyethylene (UHMWPE), although UHMWPE is more resistant to wear than PTFE. For these applications, versions of PTFE with mineral oil or molybdenum disulfide embedded as additional lubricants in its matrix are being manufactured. Its extremely high bulk resistivity makes it an ideal material for fabricating long-life electrets, useful devices that are the electrostatic analogues of magnets.

Powdered PTFE is used in pyrotechnic compositions as oxidizers together with powdered metals such as aluminum and magnesium. Upon ignition, these mixtures form carbonaceous soot and the corresponding metal fluoride, and release large amounts of heat. Hence they are used as infrared decoy flares and igniters for solid-fuel rocket propellants.

High corrosion resistance favors the use of PTFE in laboratory environments as containers, as magnetic stirrer coatings, and as tubing for highly corrosive chemicals such as hydrofluoric acid, which will dissolve glass containers.

PTFE tubes are used in gas-gas heat exchangers in gas cleaning of waste incinerators. Unit power capacity is typically several megawatts.

PTFE is also widely used as a thread seal tape in plumbing applications, largely replacing paste thread dope.

PTFE can be used to prevent insects climbing up surfaces painted with the material. PTFE is so slippery that insects cannot get a grip and tend to fall off. For example, PTFE is used to prevent ants climbing out of formic aria.

PTFE is also sometimes used as feet for computer mice, to reduce the friction with a mouse pad or other tracking surface. [3].

Advantages of PTFE:

- Inert to practically all commercial chemicals, acids, alcohols, coolants, elastomers, hydrocarbons, solvents, synthetic compounds and hydraulic fluids.
- Rated for steam to 250 psi (406 degrees F) - has low volumetric expansion characteristics - easy to clean and sterilize.
- Not affected by continuous flexing, vibration or impulse pressures - withstands alternating hot and cold cycling
- Easier to move, handle and install than rubber hose with a comparable burst pressure rating.
- The low coefficient of friction of Teflon and anti-stick properties lowers pressure drop while maintaining good service pressures.
- Jackson Hose of Teflon has optional conductive liner for removing static build up through the flow path.
- Will not contaminate material, fluid or gas conducted - Teflon is an FDA recognized material for food handling and pharmaceutical applications.
- Handles substances such as adhesives, asphalt, dyes, greases, glue, latex, lacquers and paints with ease.
- No moisture absorption, ideal as a pigtail in bulk gas handling and pneumatic systems where a low dew point is critical
- Impervious to weather and can be stored for extended periods of time without aging. It will not age during service. [3].

2-12 Polyvinyl chlorides (PVC):

Polyvinyl chloride, commonly abbreviated PVC, is the third-most widely-produced plastic, after polyethylene and polypropylene. PVC is widely used in construction because it is durable, cheap, and easily worked. It can be made softer and more flexible by the addition of plasticizers, the most widely used being phthalates. In this form, it is used in clothing and upholstery, electrical cable insulation, inflatable products and many applications in which it replaces rubber.

Pure polyvinyl chloride without any plasticizer is a white, brittle solid. It is insoluble in alcohol, but slightly soluble in tetra hydro furan. [3].

Applications:

PVC's relatively low cost, biological and chemical resistance and workability have resulted in it being used for a wide variety of applications. It is used for sewerage pipes and other pipe applications where cost or vulnerability to corrosion limits the use of metal. With the addition of impact modifiers and stabilizers, it has become a popular material for window and door frames. By adding plasticizers, it can become flexible enough to be used in cabling applications as a wire insulator. It has been used in many other applications.

Health and safety:

PVC is a useful material because of its inertness and this inertness is the basis of its low toxicity: "There is little evidence that PVC powder itself causes any significant medical problems." The main health and safety issues with PVC are associated with "VCM", its carcinogenic precursor, the products of its incineration (dioxins under some circumstances), and the additives mixed with PVC, which include heavy metals and potential endocrine disruptors. "Fear of litigation ... have all but eliminated fundamental research into VCM polymerization."

Probably the greatest impacts of PVC on health and safety have been highly positive. It has revolutionized the safe handling of sewage and, being affordable, its use is widespread outside of developed countries. [3].

Recycling:

PVC is recyclable and has the number "3" as its resin identification code.

Advantages of PVC:

- PVC is the most widely used polymer for cables production in Europe. It is mainly dominant in the low voltage and some specialist applications. Telecommunication is also an important application for PVC. PVC cables have a number of benefits, such as:
- Good electrical and insulation properties over a wide temperature range Inherent fire safety
- Excellent durability and long-life expectancy Easy processing characteristics to achieve desired specification for end-products Cost-effectiveness Recyclability - no cross-linking therefore the ability to be reprocessed back into cable applications, see further down Compares favourably to alternative materials using LCA methodologies primarily due to lower usage of non-renewable resources i.e. 43% derived from oil/gas and 57% derived from salt highly resistant to degradation by ultra violet light Cheap. [3].

Disadvantages of PVC:

It is not recommended for use above 70° Celsius although it can be taken to 80° for short periods.

1- Sensitive to UV and oxidative degradation.
2- Limited thermal capability.
3- Thermal decomposition evolves HCI.
4- Higher density than many plastics.

2-13 previous studies:

The researcher, Dr. JUMAA SALMAN JABBAR \ college of Engineering \ MUSTANSIRIYA University to conduct research and practical experience of socket, artificial leg amputated above the knee and reaching a new socket is made of fibers jute and Palm fronds can be used instead of fiber glass. Through this study, they are similar to those discussed in the objective of the study is to improve the performance of the socket, and how analysis using CAD CAM programs and (Ansys). But it disagreed with this search in the articles of the proposed alternatives.

2-14 National Authority for Prosthetics & Orthotics:

The Factory is divided Into Two Lines:

(A): Line of Physiotherapy and Psychological:

The center has a number of doctors to prepare patients psychologically and disclosure of the patient's condition and his ability to wear the Prostheses and training him to walk through it.

Figure (2. 5) Doctor to prepare patient psychologically

(B) Line of engineers and technicians:

It contains workshops of manufacturing (sockets) and assembly Prostheses by a number of skilled workers and technicians.

In this line measurements were taken from the patient and the plaster model will be made and the polypropylene will be entered in the oven at (3000-4000 ° C) to be easily machined, Then it takes the form of plaster by using hoods, after that the technician finishing (sockets) and assembly Prosthesis.

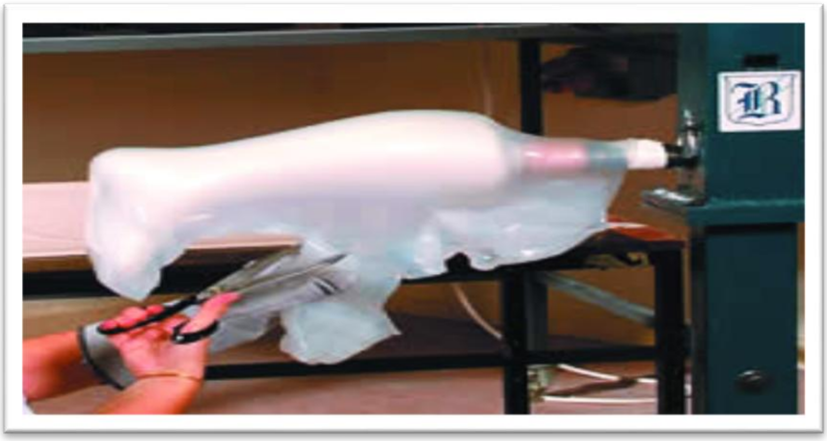

Figure (2. 6) Operation of finishing socket

Plant receives daily 150 cases approximately 25 of them may be new cases. Also there are branches of Authority and workshops in cities of Sudan (Kassala - Dongola - Gedaref - Damazin - Nyala - Kadugli) and there is a portable workshop.

Materials used in manufacturing sockets:

The National Authority for Prosthetics & Orthotics Using technique of polypropylene (pp. Technology),which is a type of plastic which is a global technology supervised by International committee of the Red Cross (ICRC) starting from Manufacturing materials , support the Authority, and training workers, technicians and engineers.

Figure (2. 7) Sheets of polypropylene

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Chapter Three
Methodology

3-1 AWTAD Company for Prosthetics & Orthotics:

The company has a line of physiotherapy psychological and a line of engineers and technicians. AWTAD uses modern technologies in manufacturing sockets such as carbon fiber and fiber glass. They can also import ready- Prosthetics as requested by the user. This technology is a solution for the problems in polypropylene technology, but they are too expensive.

A case of amputation above the knee is given by Awtad Company for a person 100 kg weight which represents type of cases that fail to use polypropylene as a material in manufacturing socket and also provide me with positive cast (plaster model) for the same case. We used it in the extraction of CAD model by 3-D scanner.

Figure (3. 1) Positive cast

3-2 TAFRAA engineering company:

It is a Sudanese company that specialists in design, analysis, manufacturing and training of engineers and graduates.

This company helped in design a model of socket. Where the picture was taken by a 3-D scanner for a model of that took from AWTAD, and modified this picture by a solid works program to achieve the final design.

3-3 three-dimensional scanners:

Device that analyses models by collecting data such as shape and outside appearance (color).These data are used to create three-dimensional numerical models that used in many applications.

It is a modern way that use laser light to scanning body directly without touch it, these results a bitmap (mesh) for scanned body. We process this bitmap by X-OR program which in its turn utilize the surface in processing this bitmap (transfer mish to solid).

Types of three-dimensional scanner:

1 - Ground scanner laser disk

2 - Ground mobile laser scanner on the vehicle.

3 - Laser scanner air.

Features three-dimensional laser scanner:

1 - Accuracy in data.

2 - A large amount of data for scanned area.

3 - Speed in data capturing.

4- To obtain data without touching body, we use this important characteristic in case of difficulty of access body.

Work steps to create three- dimensional models of plaster using scanner:

1. Putting the model in steadily way.
2. Passing the scanner through the desired surface.
3. After that the bitmap will be created in the device which represents reading for this body.
4. After that we process this bitmap in a computer device using X-OR program where in its turn convert this bitmap to a three-dimension picture.

3-4 CAD CAM system:

Refers to computer aided design and computer-aided manufacturing technology, which means using computer to accomplish specific functions in the design and production.

Computer Aided Design (CAD):

Computer design system associated with improving the concept of computer-graphic, but the concepts of computer design exceed a lot of computer graphics especially in analysis and modeling. There are many reasons for using computer design, including:

- Increased productivity**:** This is achieved by reducing time required for the installation and completion of analysis and graphics design.
- Improving Quality: CAD system allows for designer to complete an accurate design analysis and provides a large number of alternative designs that can be selected, and design errors will be decrease because the high accuracy provided by the system. These factors lead us to better design.
- Unification language of handling and exchange.
- Provide an extensive database of manufacturing process: When you configure the graphics for a product (set dimensions on the product and its parts and determine the material lists and specifications ... etc.), it is available much data can be used in manufacturing processes.

The functionality computer play in design can be summarized in:

1- Geometric modeling.

2- Engineering analysis.

3-project review and evaluate it.

4- Automated drawing.

Geometric modeling in design system using computer allows to designers to create their own models by use special drawing tools and display it on the screen, this happened with the help of three groups of instructions:

The first type of instruction creates the major elements of drawing e.g. line, circuit and point.

Second type associated with editing and modifying operations e.g. delete, rotate, control in measuring and other operations.

Third type allows the possibility of controlling in make all this elements connected with each other in order to display it on screen with a different ways.

The computer play a very important function through offering a sophisticated program in analysis domain especially programs that use the way of selected items.

In this technique the body will be divided into many elements (regularly be in rectangles and triangles shape) which finally create a net for its elements to connected with each other through nodes and points.

By studying the general behavior of each of these nodes we can guess the final status of the body.

The final behavior of body will be analysis With respect to stresses and emotions or heat transfer and the other characteristics by calculating the behavior of each node.

in stage of evaluating the design we use computer in movement tests check via specialists program that able to make this drawing move partially similar to animated movies until we sure that parts will not be cut across among them As it is also make sure the parts will not be overlap, Which means the possibility of dispensing the manufacturing of first model.

There are many programs used in the field of CAD, including for example:

Alibre design, solid Works, auto CAD.

In this research I used solid works in modifying design and ansys mechanical for analysis socket. In the next paragraph I will define solid works and ansys program and its method. [4].

3-5 Solid Works:

The Solid Works Software CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

Document Structure:

This document is organized to reflect the way that you use the Solid Works software. It is structured around the basic Solid Works document types: parts, assemblies, and drawings. For example, you create a part before you create an assembly.

Throughout the document, a bathroom vanity illustrates various tools and functions available to you in the software.

Parts are the basic building blocks in the Solid Works software. Assemblies contain parts or other assemblies, called subassemblies.

A Solid works model consists of 3D geometry that defines its edges, faces, and surfaces. The Solid Works software lets you design models quickly and precisely. Solid Works models are:

• Defined by 3D design.

• Based on components.

Solid works uses a 3D design approach. As you design a part, from the initial sketch to the final result, you create a 3D model. From this model, you can create 2D drawings or mate components consisting of parts or subassemblies to create 3D assemblies. You can also create 2D drawings of 3D assemblies.

When designing a model using Solid Works, you can visualize it in three dimensions, the way the model exists once it is manufactured.

One of the most powerful features in the Solid Works software is that any change you make to a part is reflected in all associated drawings or assemblies.

The solid works application includes user interface tools and capabilities to help you create and edit models efficiently.

Terminology: These terms appear throughout the solid works software and documentation.

Origin: Appears as two blue arrows and represents the (0, 0, 0) coordinate of the model. When a sketch is active, a sketch origin appears in red and represents the (0, 0, 0) coordinate of the sketch. You can add dimensions and relations to a model origin, but not to a sketch origin.

Plane: Flat construction geometry. You can use planes for adding a 2D sketch, section view of a model, or a neutral plane in a draft feature, for example.

Axis: Straight line used to create model geometry, features, or patterns. You can create an axis in different ways, including intersecting two planes. The solid works application creates temporary axes implicitly for every conical or cylindrical face in a model.

Face: Boundaries that help define the shape of a model or a surface. A face is a selectable area planar or non-planar of a model or surface. For example, a rectangular solid has six faces.

Edge: Location where two or more faces intersect and are joined together. You can select edges for sketching and dimensioning, for example.

Vertex: Point at which two or more lines or edges intersect. You can select vertices for sketching and dimensioning. [5].

3-6 ANSYS Mechanical:

ANSYS Mechanical software offers a comprehensive product solution for structural linear/nonlinear and dynamics analysis. The product offers a complete set of element behavior, material models and equation solvers for a wide range of engineering problems. [6].

ANSYS Structural:

Software addresses the unique concerns of pure structural simulations without the need for extra tools. The product offers all the power of nonlinear structural capabilities in order to deliver the highest-quality, most reliable structural simulation results available. ANSYS Structural easily simulates even the largest and most intricate structures.

ANSYS Professional:

Software offers a first step into advanced linear dynamics and nonlinear capabilities. Containing the power of leading simulation technology in an easy-to-use package, ANSYS Professional tools provide users with high-level simulation capabilities without the need for high-level expertise. The package comes complete with a full contingent of linear elements, significant nonlinearities, the ability to solve complex assemblies, and the most requested set of solvers. [7].

ANSYS Design Space:

Software is an easy-to-use simulation software package that provides tools to conceptualize design and validate ideas on the desktop. A subset of the ANSYS Professional product, ANSYS design space allows users to easily perform real-world, static structural and thermal, dynamic, weight optimization, vibration mode, and safety factor simulations on all designs without the need for advanced analysis knowledge. [7].

3-6-1 provides mechanical properties for chosen materials.

Properties of Outline Row 12: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Density	7850	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion	1.2E-05	C^-1
5	Reference Temperature	22	C
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and Poi...	
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa
12	Alternating Stress Mean Stress	Tabular	
16	Strain-Life Parameters		
24	Tensile Yield Strength	2.5E+08	Pa
25	Compressive Yield Strength	2.5E+08	Pa
26	Tensile Ultimate Strength	4.6E+08	Pa
27	Compressive Ultimate Strength	0	Pa

Figure (3. 2) Screen shot of inputting properties on ANSYS MECHANICAL

3-6-2 determines the value of the force that imposed on socket and its direction:

the research deal with case for a person who was weighted 100 kg, and the amputation place was above the Wright knee, and the force weight on socket was determined with 80 kg, suppose the above 30 kg for protection and safe purpose. And for the force direction we analyzed this force that center on special point known as scale seat(thigh muscles)in angel of 20 degree on vertical axis in direction of both X and Y. [6].

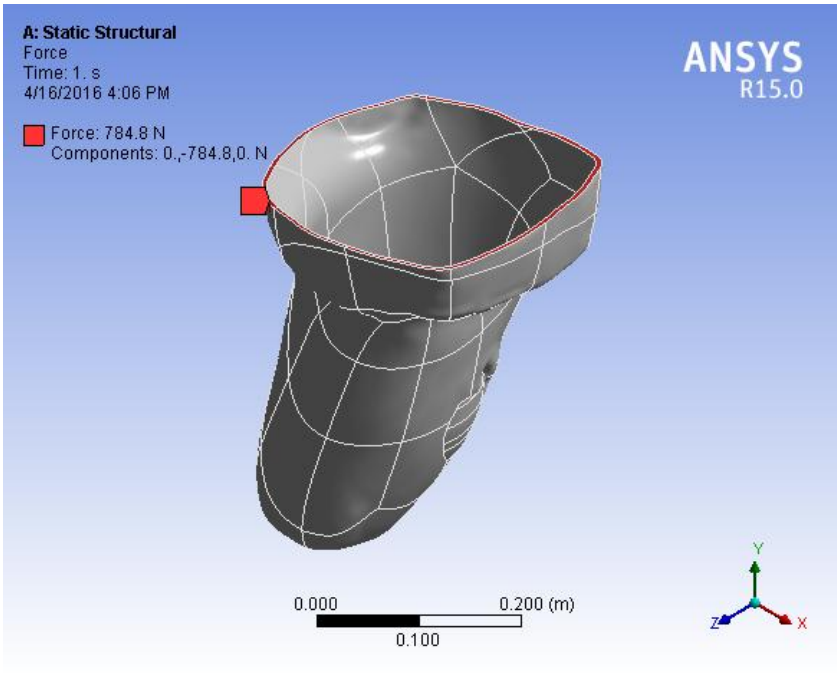


Figure (3. 3) Force and its direction on Y axis

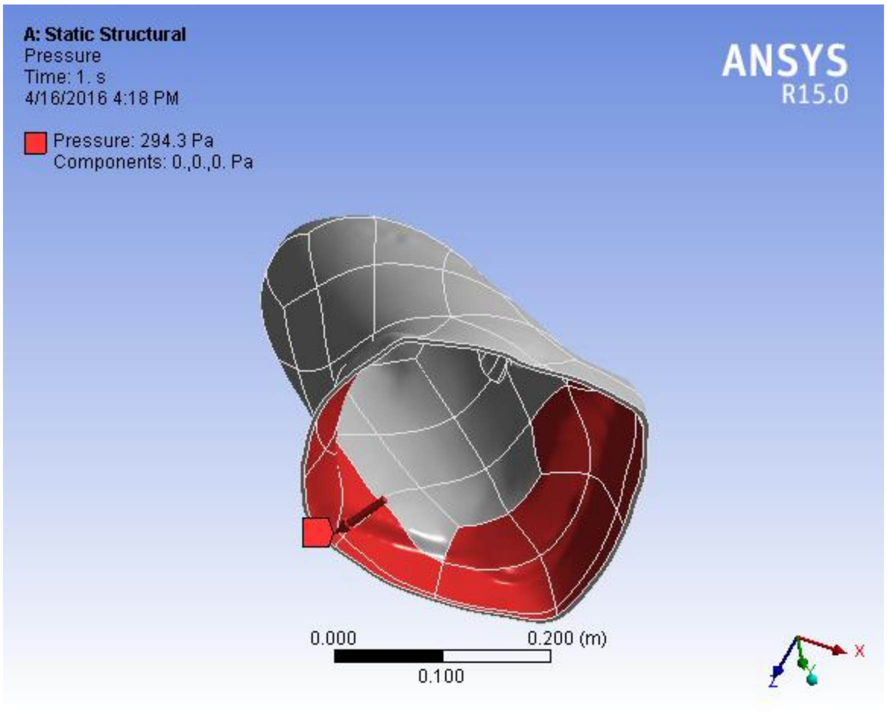


Figure (3. 4) Force and its direction on X axis (pressure)

3-6-3 Determine the fix location:

After activate static structural (in program) that referring to steady of socket. Then determined where to install socket at the bottom.

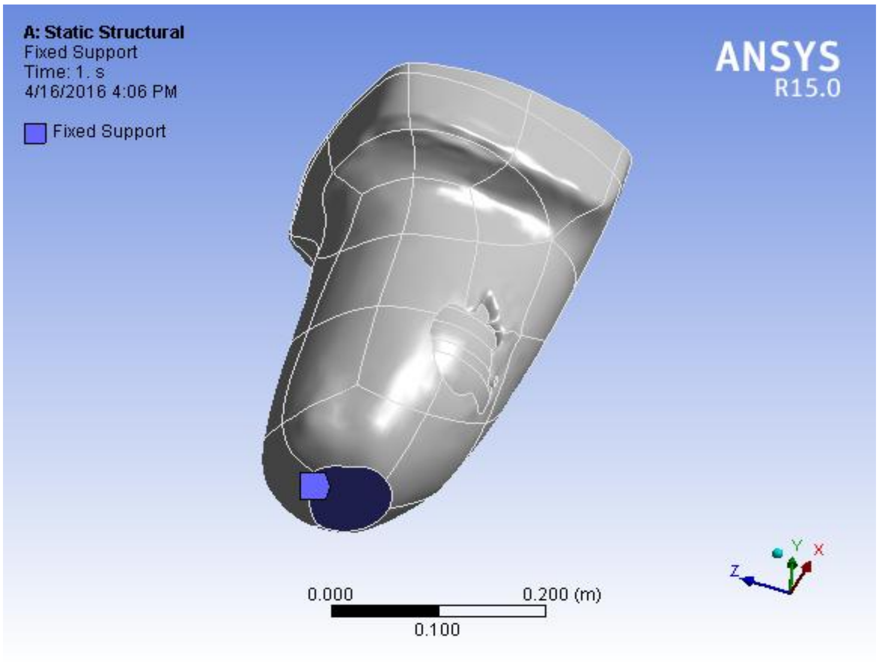


Figure (3. 5) Fix location

3-6-4 creates mesh:

Ansys mechanical generate mesh automatically

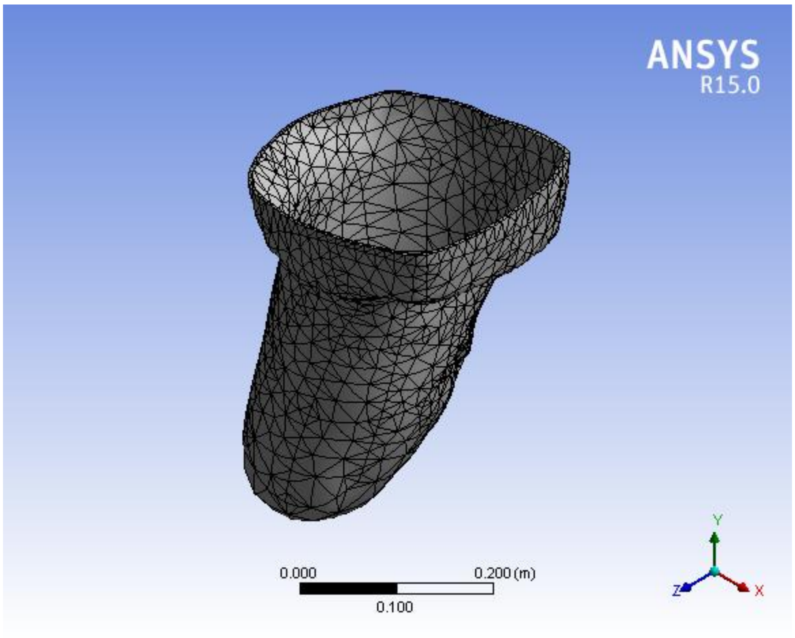


Figure (3. 6) Create mesh

Chapter Four

Analysis & Results

4-1 Preface:

The research discussed in previous sections to the materials used in the manufacture of socket and how to design using three-dimensional scanner, and also touched on how to use the analysis program by ANSYS mechanical and determine the force hanging over socket. In this section the research discuss results of the analysis conducted on the materials that have been selected and then monitor information through charts illustrate the results and describes the suitable material for the manufacture of socket

4-2 Mechanical properties:

After an analysis by a program ANSYS mechanical on the four materials were extracted for each subject report shows the states of matter when the force them to shed.

4-2-1 Yield stress: (in ansys determine maximum principal stress)

(Physics / General Physics) the stress level at which a metal or other material ceases to behave elastically. The stress divided by the strain is no longer constant. The point at which this occurs is known as the yield point Compare proof stress. With some products the presence of a yield stress is not so desirable, leading to, for example, dosing problems in gravity-feed systems or an excess of residue on the sides of inverted bottles. Many products are modified to produce a yield value for the purposes of particle suspension and to keep them from flowing at very low shear stress.

Measuring Yield Stress

Approximate yield stress measurements can be gained by plotting the shear stress values for a range of shear rates, fitting a curve to the data, and extrapolating through the stress axis.

A more exact method for obtaining yield stresses is to use a static vane-based test method. The vane is lowered into the undisturbed sample and then torqued slowly. The sample deforms elastically as the imposed stress increases until a yield stress is attained. At this point the sample starts to flow significantly and the measured stress falls from a peak.

4-2-2 Displacement: (in ansys determine total deformation)

A displacement field is an assignment of displacement vectors for all points in a region or body that is displaced from one state to another. A displacement vector specifies the position of a point or a particle in reference to an origin or to a previous position. For example, a displacement field may be used to describe the effects of deformation on a rigid body.

Before considering displacement, the state before deformation must be defined. It is a state in which the coordinates of all points are known and described by the function:

$$\vec{R}_0 : \Omega \rightarrow P \qquad \text{-----------------------(1.3).}$$

Where

$\vec{R}_0$ Is a placement vector

Ω Are all the points of the body

P Are all the points in the space in which the body is present

Most often it is a state of the body in which no forces are applied.

Then given any other state of this body in which coordinates of all its points are described as $\vec{R}_1$ the displacement field is the difference between two body states:

$$\vec{u} = \vec{R}_1 - \vec{R}_0 \qquad \text{----------------------------(2.3).}$$

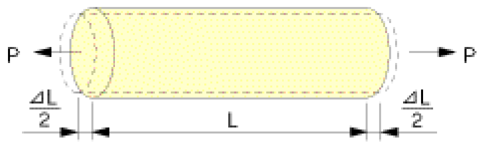
Where

$\vec{u}$ is a displacement field, which for each point of the body specifies a displacement vector

4-2-3 Strain: (in ansys determine maximum principal)

Strain is the definition of how much a material has been stretched (or compressed) when compared to its original length.

External force applied to an elastic material generates stress, which subsequently generates deformation of the material. At this time, the length L of the material extends to L+ΔL if applied force is a tensile force. The ratio of ΔL to L, that is ΔL/L, is called strain. (Precisely, this is called normal strain or longitudinal strain.) On the other hand, if compressive force is applied, the length L is reduced to L- ΔL. Strain at this time is (-ΔL)/L. Strain is usually represented as ε .Supposing the cross sectional area of the material to be A and the applied force to be P, stress σ will be P/A, since a stress is a force working on a definite cross sectional area. In a simple uniaxial stress field as illustrated below, strain ε is proportional to stress σ, thus an equation σ = E×ε is satisfied, provided that the stress σ does not exceed the elastic limit of the material. "E" in the equation is the elastic modulus (Young's modulus) of the material. [8].



$$\varepsilon = \frac{\Delta L}{L} \quad \text{-----------------------(3.3).}$$

ε: Strain

L: Original length

: Change due to force P

4-3 Result of analysis

maximum principal stress:

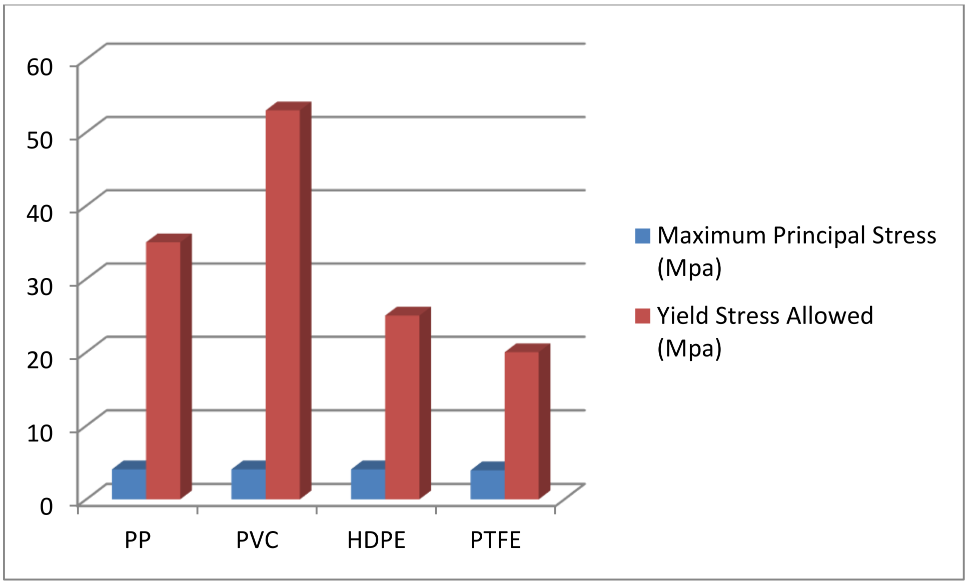


Figure (4. 1) Chart explain result of analysis for max principal stress

Of the chart above found that the yield stress allowed for polypropylene is 35 MPa, while the value of stress hanging is 4.082 MPa, and as the stress hanging lower than the allowable stress so material is succeeded in the test this property.

The allowable stress for material polyvinyl chloride is 53 MPa, while the value of stress hanging is 4.082 MPa and as the stress hanging lower than the allowable stress so material is succeeded in the test this property.

- The allowable stress for material HDPE is 25 MPa، while the value of stress hanging is4.082 MPa، and as the stress hanging lower than the allowable stress so material is succeeded in the test this property.

- The allowable stress for material PTFE is 20 MPa ،while the value of stress hanging is 3.946 MPa and as the stress hanging lower than the allowable stress so material is succeeded in the test this property.

In summary, the test of this property is the success of the polyvinyl chloride and polypropylene more than other material.

Total deformation:

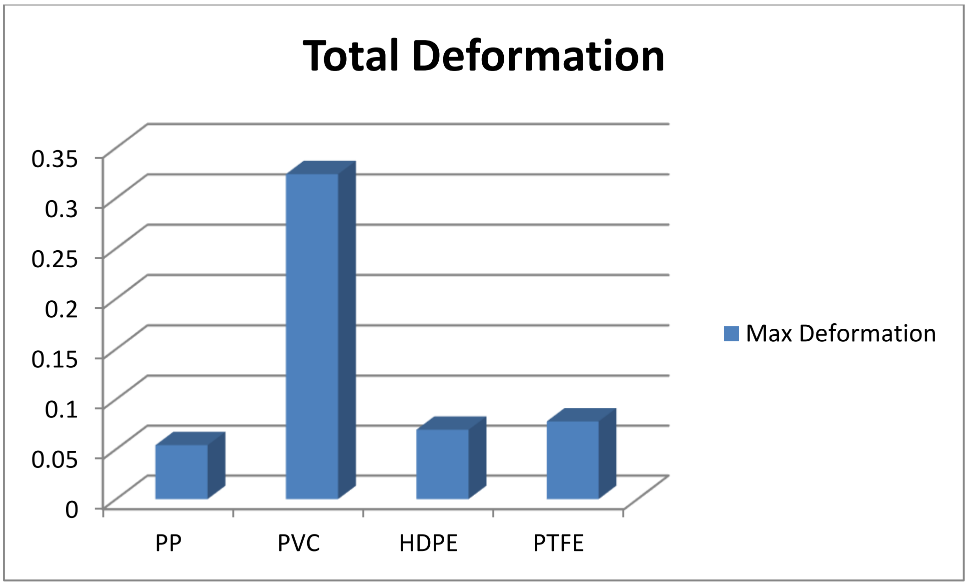


Figure (4. 2) Chart explain result of analysis for Max deformation

Of the chart above found that the amount of Max deformation of the polypropylene is 0.053941 m, while the material polyvinyl chloride is 0.32365m ،high density polyethylene is 0.069353m and the value of a substance Teflon is 0.077693m.

In summary, the test of this property is that material polypropylene is the most successful.

maximum principal strain:

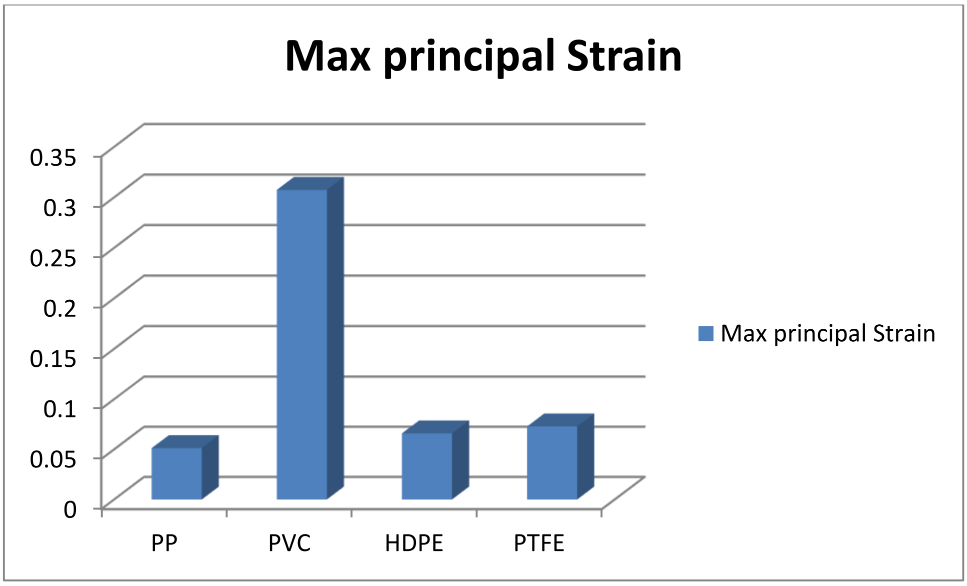


Figure (4. 3) Chart explain result of analysis for max principal strain

Of the chart above found that the amount of max principal strain for polypropylene is 0.051222mm while the value of the max principal strain of PVC material is 0.30733mm and max principal strain of HDPE is 0.065857mm and max principal strain of PTFE material is 0.72862mm.

In summary, the test of this property is that the material polypropylene is the most successful.

Chapter Five

Conclusion & Recommendation

5-1 Conclusions:

Through study and analysis of the nature of the material used in the manufacture of socket and materials of the proposed alternative as well as from the results of recent studies reported after the analysis of information extracted from the simulation findings of this study to the following:

1- Through the research and analysis found that the POLYPROPYLENE material more capable of performance and specifications than the alternative material that's means No need to change material used in NAPO and POLYPROPYLENE is the best suitable.

2 - National Authority for prosthetic not using material without polypropylene to the absence of government support and community, and adopt entirely on the Red Cross Society who embrace technology polypropylene of support and training for technicians and rehabilitation.

3 - Polypropylene may fail to carry the body in cases of long amputation, but not failed in general.

4 - through research and visits and studies found that the polypropylene material available and cheap.

5 - There is an improvement in the techniques used in the design, analysis and manufacturing by the computer in most state-owned enterprises, but examination and testing and quality control techniques by computer-existent.

6 - Because of the many cases receive the National Authority for prosthetic daily between old and new amputation, which exceed the 150 cases to be of great interest by the country and officials in this segment of society.

7 - in the National Authority for prosthetic skilled workers and technicians have highly qualified and eligible by the Red Cross Society.

8- One of the problems which faced research the difficulty of conducting laboratory tests of materials selected for the lack of materials in the image that should be tested on them.

9- Difficult to make a model of the PVC and PTFE material that are not available in the form of sheet.

10- One of the problems which faced research there is no previous studies on this topic in the NAPO.

5-2 Recommendations:

The following are recommended:

1- Through the research I| recommend to produce of PVC and PTFE material in the form of sheet so that are manufactured the samples socket and tested them.

2- One of the problems which facing the produced socket in Sudan the multiplication of research in this aria.

3- Also Work on the establishment of specialized centers for the testing of materials.

4- - Also using computers in design and manufacturing operations in all phases of the produced socket because manufacture requires high precision.

5- Using means testing, this is a key factor to quality control.

6- Work on the study material PVC and HDPE to more availability and manufactured in the form of sheet fit with the method in use in the manufacture of socket in the NAPO.

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Appendix

Table (1) Teflon (PTFE) properties

Property Name	Value	Units
Elastic modulus	60	MN/m^2
Poisson's ratio	0.46	NA
Mass density	2250	kg/m^3
Tensile strength	30	MN/m^2
Yield strength	20	MN/m^2

Table (2) High-density polyethylene (HDPE) properties

Property Name	Value	Units
Elastic modulus	70	MN/m^2
Poisson's ratio	0.42	NA
Mass density	950	kg/m^3
Tensile strength	30	MN/m^2
Compressive strength	81	MN/m^2
Yield strength	25	MN/m^2

Table (3) Polypropylene (PP) properties

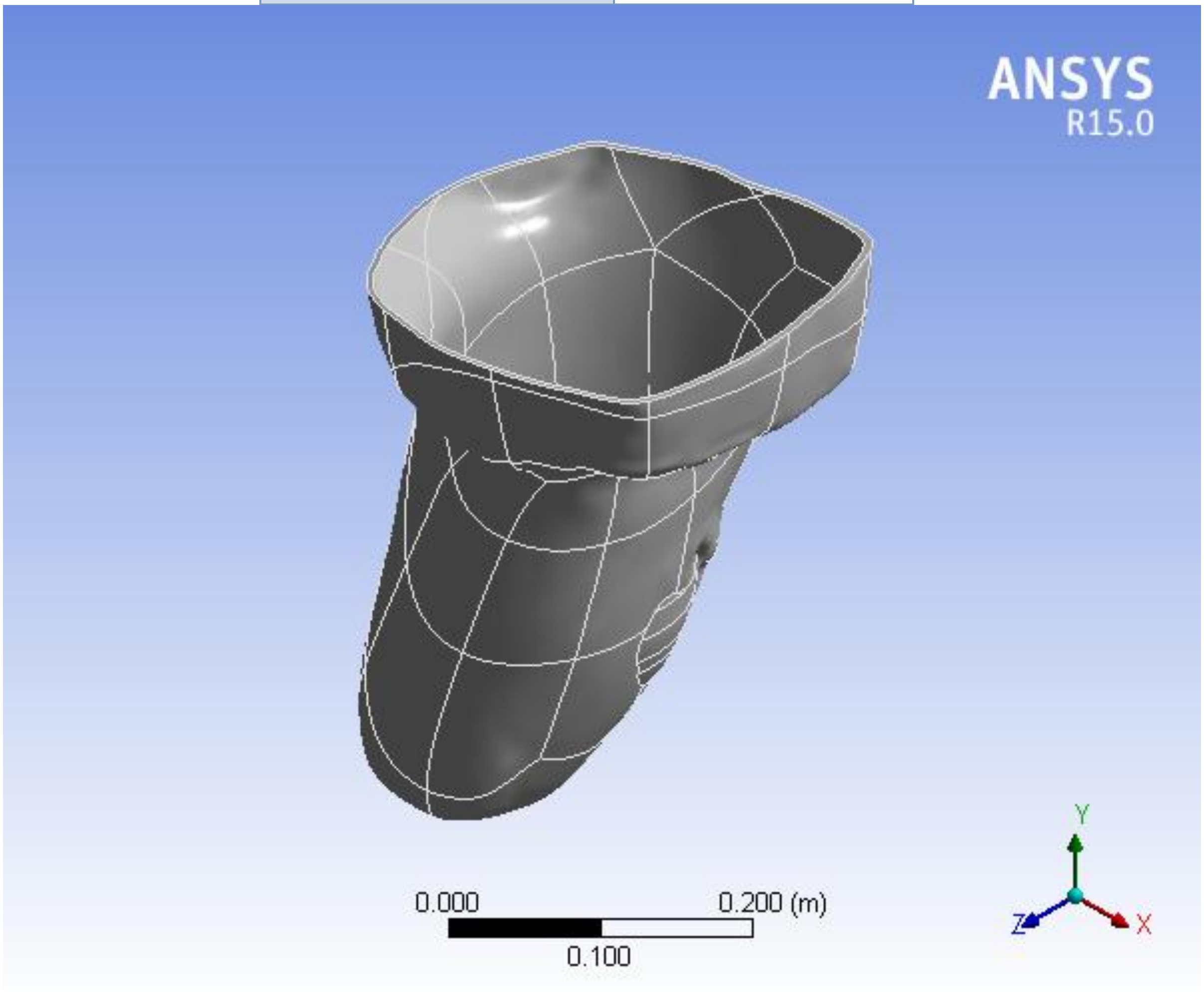
Property Name	Value	Units
Elastic modulus	90	MN/m^2
Poisson's ratio	0.42	NA
Mass density	890	kg/m^3
Tensile strength	32	MN/m^2
Compressive strength	84	MN/m^2
Yield strength	35	MN/m^2

Table (4) Polyvinyl chloride (PVC) properties

Property Name	Value	Units
Elastic modulus	15	MN/m^2
Poisson's ratio	0.42	NA
Mass density	1400	kg/m^3
Tensile strength	63	MN/m^2
Compressive strength	83	MN/m^2
Yield strength	53	MN/m^2

Project

First Saved	Saturday, April 16, 2016
Last Saved	Saturday, April 16, 2016
Product Version	15.0 Release
Save Project Before Solution	No
Save Project After Solution	No



Contents

Units

TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

Geometry

TABLE 2

Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\shooter\AppData\Local\Temp\WB_SHOOTER-PC_shooter_6700_2\unsaved_project_files\dp0\SYS\DM\SYS.agdb
Type	DesignModeler
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	

Length X	0.3174 m
Length Y	0.4178 m
Length Z	0.29219 m
Properties	
Volume	1.3924e-003 m³
Mass	1.2392 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	11507
Elements	5691
Mesh Metric	None
Basic Geometry Options	
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Compare Parts On Update	No
Attach File Via Temp File	Yes

Temporary Directory	C:\Users\shooter\AppData\Local\Temp
Analysis Type	3-D
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3

Model (A4) > Geometry > Parts

Object Name	*Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Polypropylene (PP)
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	0.3174 m
Length Y	0.4178 m
Length Z	0.29219 m
Properties	
Volume	1.3924e-003 m^3
Mass	1.2392 kg
Centroid X	-3.7805e-002 m
Centroid Y	-0.2233 m
Centroid Z	1.866e-002 m
Moment of Inertia Ip1	3.1942e-002 kg·m^2
Moment of Inertia Ip2	1.3843e-002 kg·m^2

Moment of Inertia Ip3	3.0207e-002 kg·m²
Statistics	
Nodes	11507
Elements	5691
Mesh Metric	None

Coordinate Systems

TABLE 4

Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. m
Origin Y	0. m
Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Mesh

TABLE 5

Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium

Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	2.9228e-003 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Patch Independent Options	
Topology Checking	Yes
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	11507
Elements	5691
Mesh Metric	None

Static Structural (A5)

TABLE 6

Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 7

Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Nonlinear Controls	

Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Off
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Contact Miscellaneous	No
General Miscellaneous	No
Store Results At	All Time Points
Analysis Data Management	
Solver Files Directory	C:\Users\shooter\AppData\Local\Temp\WB_SHOOTER-PC_shooter_6700_2\unsaved_project_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	mks

TABLE 8

Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Force*	*Pressure*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Face		21 Faces
Definition			
Type	Fixed Support	Force	Pressure
Suppressed	No		
Define By		Components	Normal To
Coordinate System		Global Coordinate System	
X Component		0. N (ramped)	
Y Component		-784.8 N (ramped)	
Z Component		0. N (ramped)	
Magnitude			294.3 Pa (ramped)

FIGURE 1

Model (A4) > Static Structural (A5) > Force

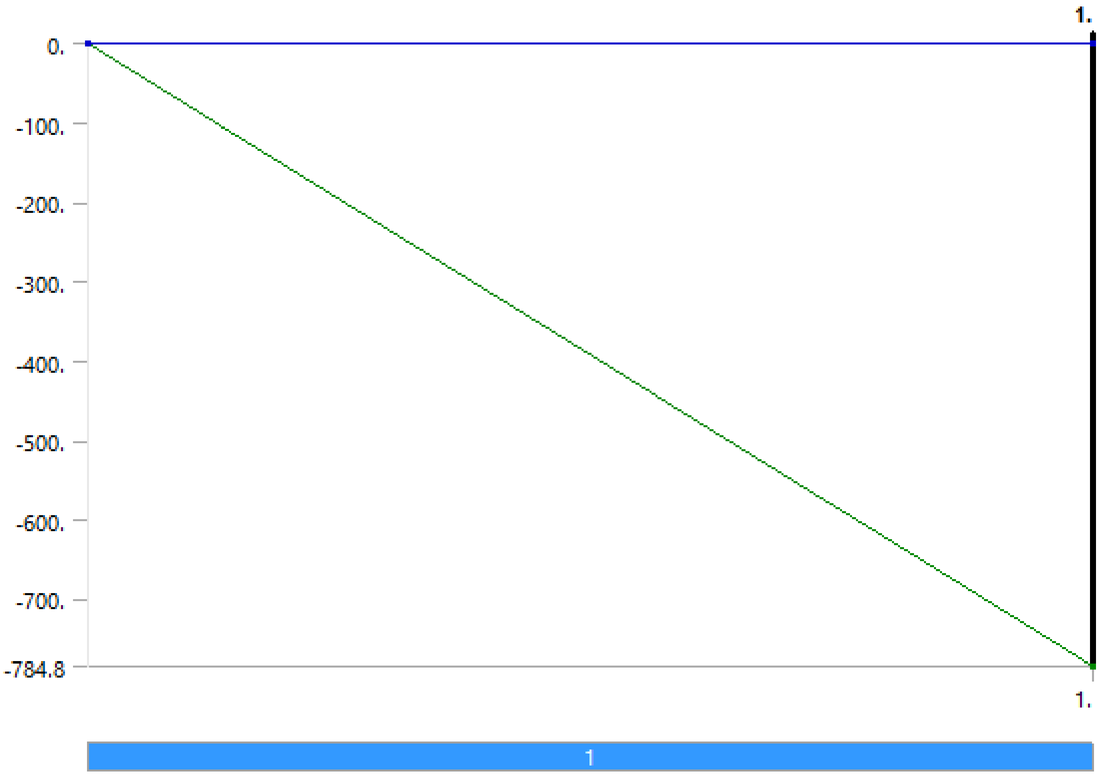
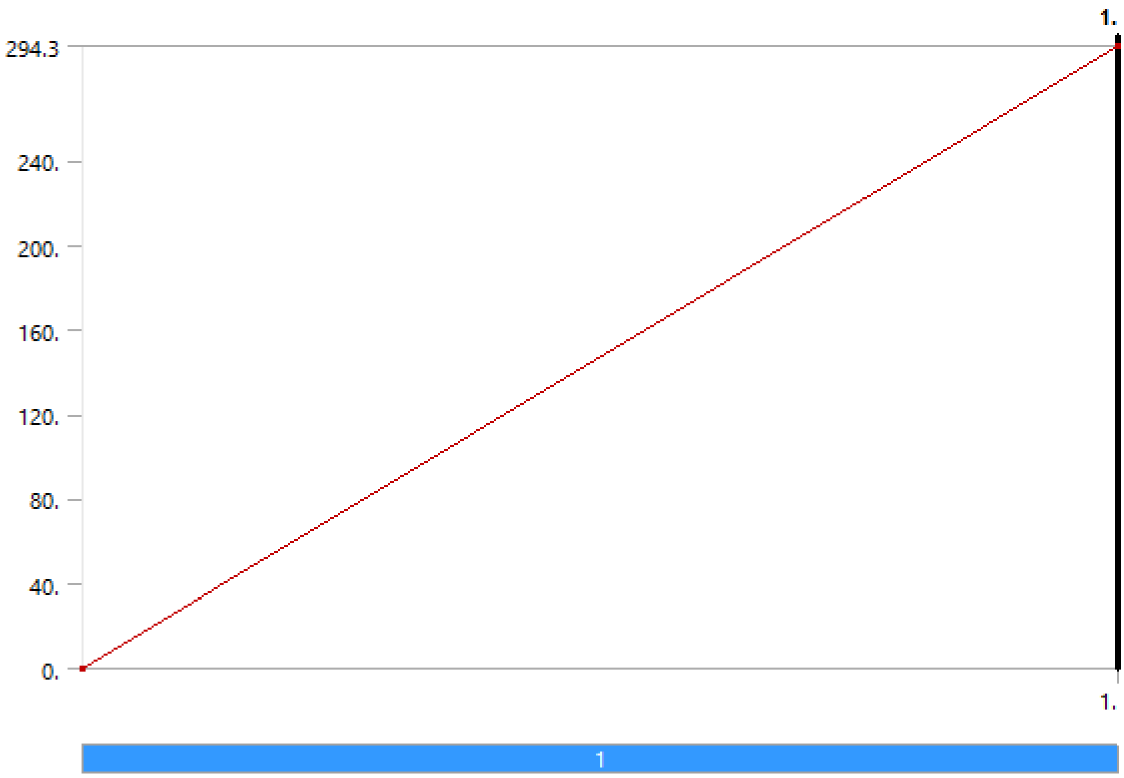


FIGURE 2

Model (A4) > Static Structural (A5) > Pressure



Solution (A6)

TABLE 9

Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

TABLE 10

Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	

Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 11

Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Maximum Principal Stress*	*Maximum Principal Elastic Strain*	*Total Deformation*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Maximum Principal Stress	Maximum Principal Elastic Strain	Total Deformation
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		
Results			
Minimum	-1.754e+006 Pa	1.2309e-004 m/m	0. m
Maximum	4.082e+006 Pa	5.1222e-002 m/m	5.3941e-002 m
Minimum Value Over Time			
Minimum	-1.754e+006 Pa	1.2309e-004 m/m	0. m
Maximum	-1.754e+006 Pa	1.2309e-004 m/m	0. m
Maximum Value Over Time			
Minimum	4.082e+006 Pa	5.1222e-002 m/m	5.3941e-002 m
Maximum	4.082e+006 Pa	5.1222e-002 m/m	5.3941e-002 m

Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

Material Data

Polypropylene (PP)

TABLE 12

Polypropylene (PP) > Constants

Density	890 kg m^-3
Coefficient of Thermal Expansion	2.3e-003 C^-1

TABLE 13

Polypropylene (PP) > Isotropic Secant Coefficient of Thermal Expansion

Reference Temperature C
40

TABLE 14

Polypropylene (PP) > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	9.e+007	0.42	1.875e+008	3.169e+007

TABLE 15

Polypropylene (PP) > Tensile Yield Strength

Tensile Yield Strength Pa
3.5e+007

TABLE 16

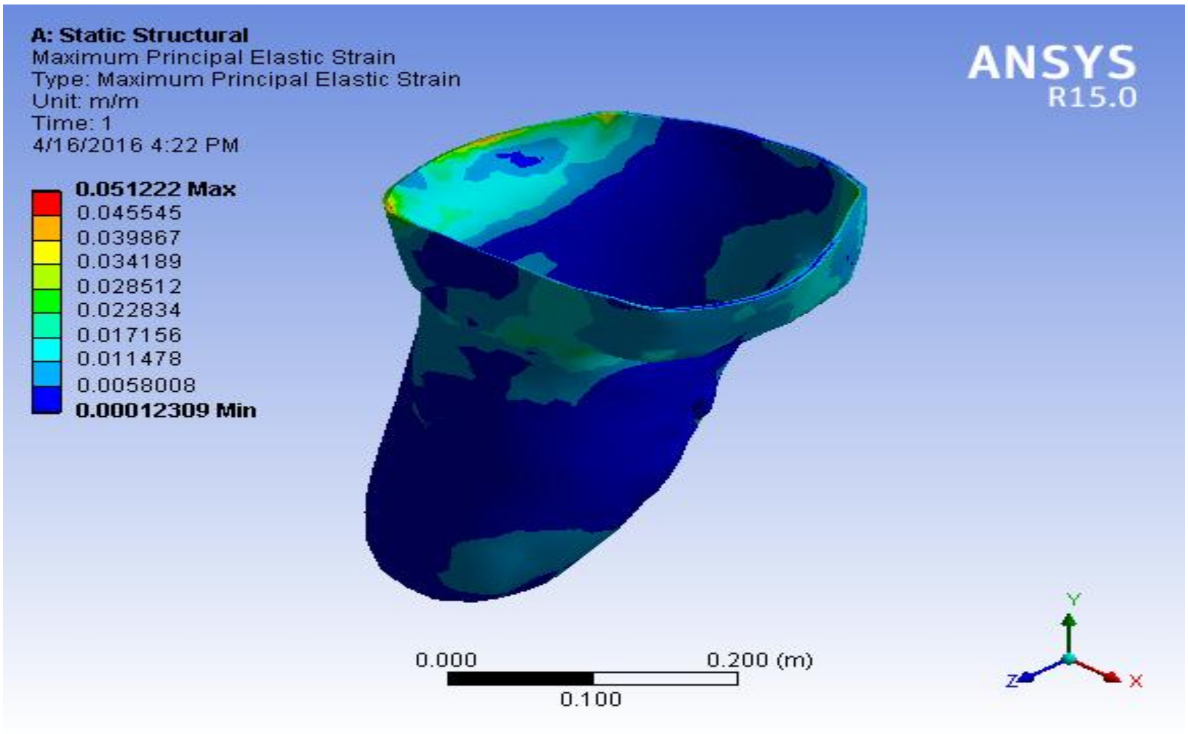
Polypropylene (PP) > Compressive Yield Strength

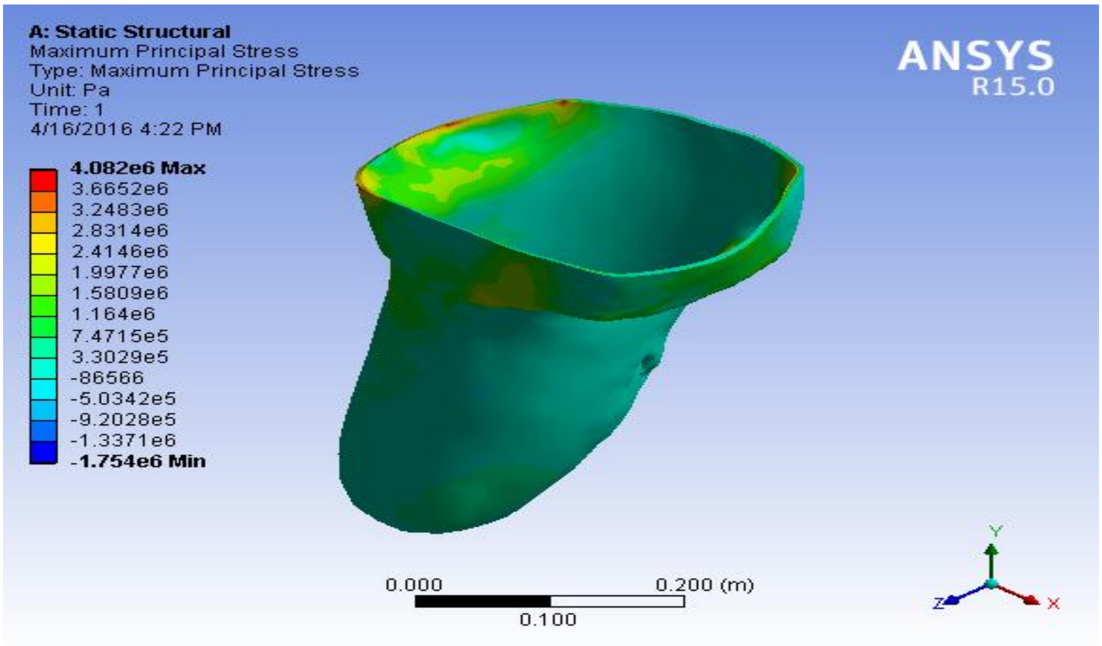
Compressive Yield Strength Pa
8.4e+007

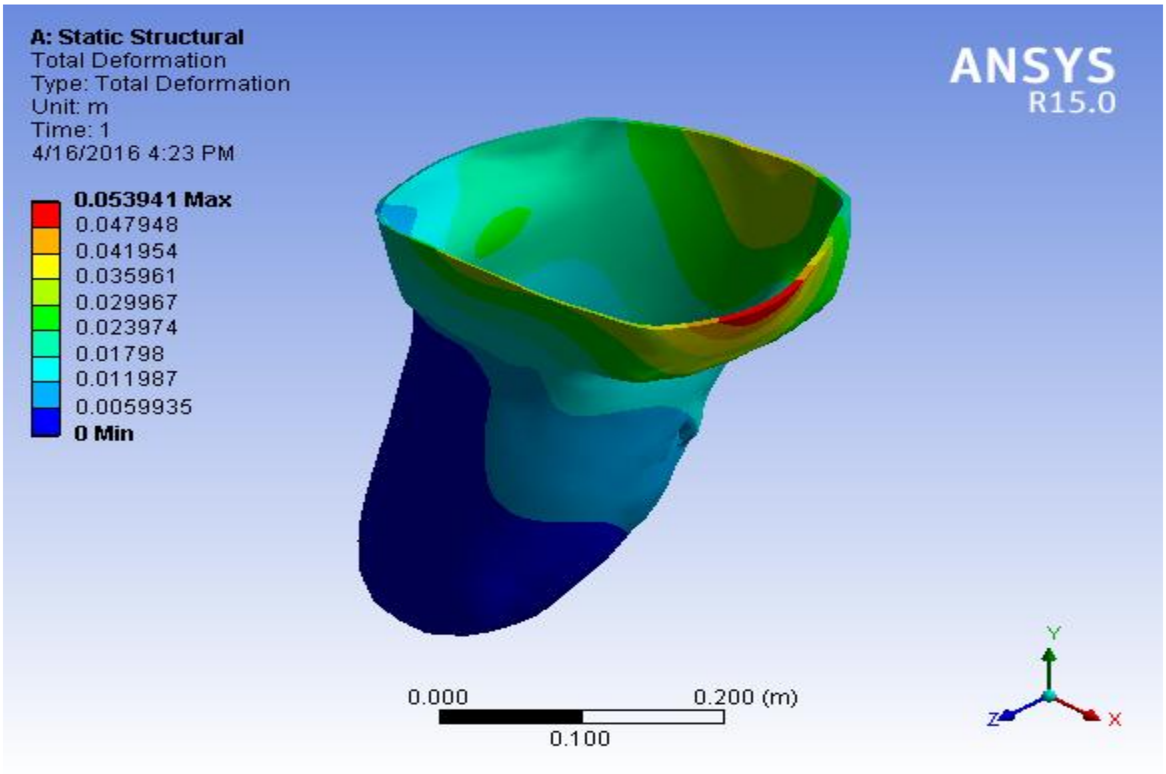
TABLE 17

Polypropylene (PP) > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
3.2e+007

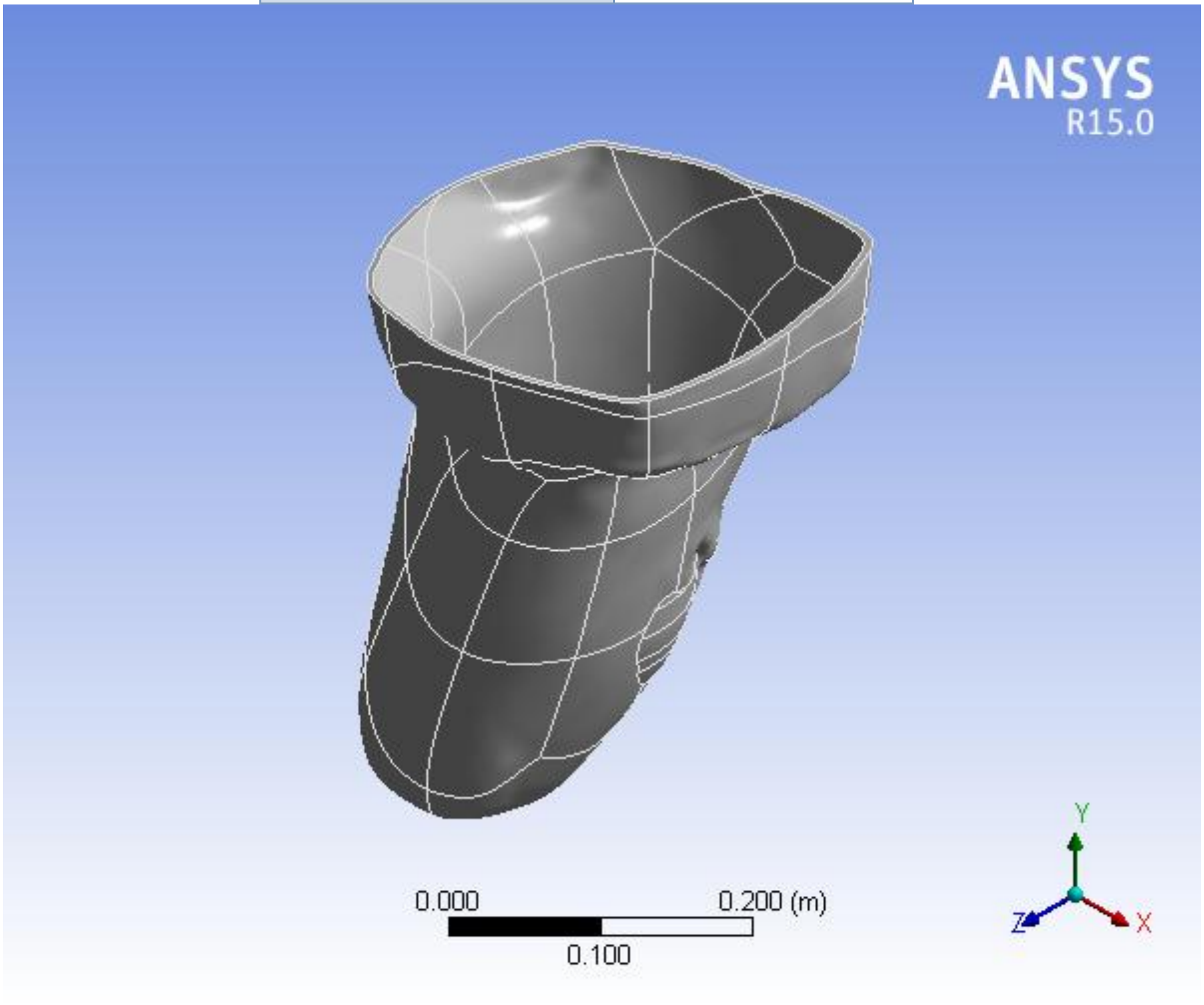

A: Static Structural
Maximum Principal Elastic Strain
Type: Maximum Principal Elastic Strain
Unit: m/m
Time: 1
4/16/2016 4:22 PM
0.051222 Max
0.045545
0.039867
0.034189
0.028512
0.022834
0.017156
0.011478
0.0058008
0.00012309 Min
ANSYS
R15.0
0.000
0.200 (m)
0.100


A: Static Structural
Maximum Principal Stress
Type: Maximum Principal Stress
Unit: Pa
Time: 1
4/16/2016 4:22 PM
4.082e6 Max
3.6652e6
3.2483e6
2.8314e6
2.4146e6
1.9977e6
1.5809e6
1.164e6
7.4715e5
3.3029e5
-86566
-5.0342e5
-9.2028e5
-1.3371e6
-1.754e6 Min
ANSYS
R15.0
0.000
0.200 (m)
0.100


A: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1
4/16/2016 4:23 PM
0.053941 Max
0.047948
0.041954
0.035961
0.029967
0.023974
0.01798
0.011987
0.0059935
0 Min
ANSYS
R15.0
0.000
0.200 (m)
0.100
Y
Z
X

Project

First Saved	Saturday, April 16, 2016
Last Saved	Saturday, April 16, 2016
Product Version	15.0 Release
Save Project Before Solution	No
Save Project After Solution	No



Contents

Units

TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

Geometry

TABLE 2

Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\shooter\AppData\Local\Temp\WB_SHOOTER-PC_shooter_6700_2\unsaved_project_files\dp0\SYS\DM\SYS.agdb
Type	DesignModeler
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	

Length X	0.3174 m
Length Y	0.4178 m
Length Z	0.29219 m
Properties	
Volume	1.3924e-003 m³
Mass	1.9493 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	11507
Elements	5691
Mesh Metric	None
Basic Geometry Options	
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Compare Parts On Update	No
Attach File Via Temp File	Yes

Temporary Directory	C:\Users\shooter\AppData\Local\Temp
Analysis Type	3-D
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3

Model (A4) > Geometry > Parts

Object Name	*Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Polyvinyl chloride (PVC)
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	0.3174 m
Length Y	0.4178 m
Length Z	0.29219 m
Properties	
Volume	1.3924e-003 m³
Mass	1.9493 kg
Centroid X	-3.7805e-002 m
Centroid Y	-0.2233 m
Centroid Z	1.866e-002 m
Moment of Inertia Ip1	5.0245e-002 kg·m²
Moment of Inertia Ip2	2.1775e-002 kg·m²

Moment of Inertia Ip3	4.7516e-002 kg·m²
Statistics	
Nodes	11507
Elements	5691
Mesh Metric	None

Coordinate Systems

TABLE 4

Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. m
Origin Y	0. m
Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Mesh

TABLE 5

Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium

Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	2.9228e-003 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Patch Independent Options	
Topology Checking	Yes
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	11507
Elements	5691
Mesh Metric	None

Static Structural (A5)

TABLE 6

Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 7

Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Nonlinear Controls	

Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Off
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Contact Miscellaneous	No
General Miscellaneous	No
Store Results At	All Time Points
Analysis Data Management	
Solver Files Directory	C:\Users\shooter\AppData\Local\Temp\WB_SHOOTER-PC_shooter_6700_2\unsaved_project_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	Mks

TABLE 8

Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Force*	*Pressure*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Face		21 Faces
Definition			
Type	Fixed Support	Force	Pressure
Suppressed	No		
Define By		Components	Normal To
Coordinate System		Global Coordinate System	
X Component		0. N (ramped)	
Y Component		-784.8 N (ramped)	
Z Component		0. N (ramped)	
Magnitude			294.3 Pa (ramped)

FIGURE 1

Model (A4) > Static Structural (A5) > Force

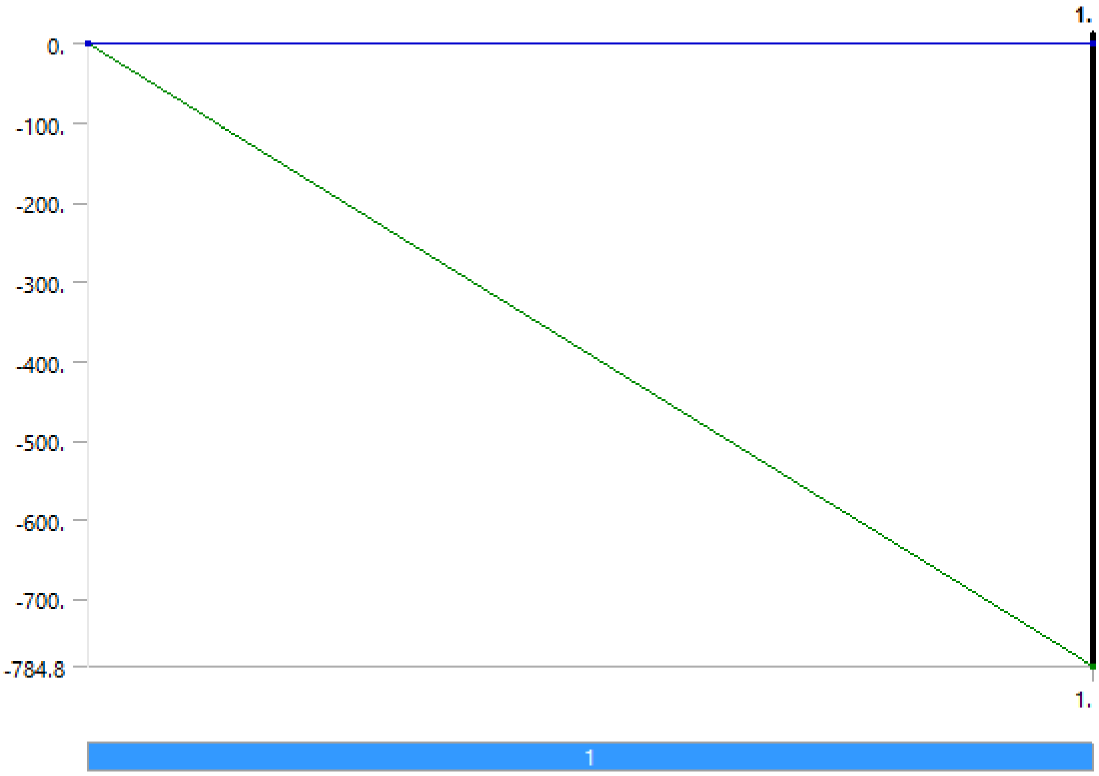
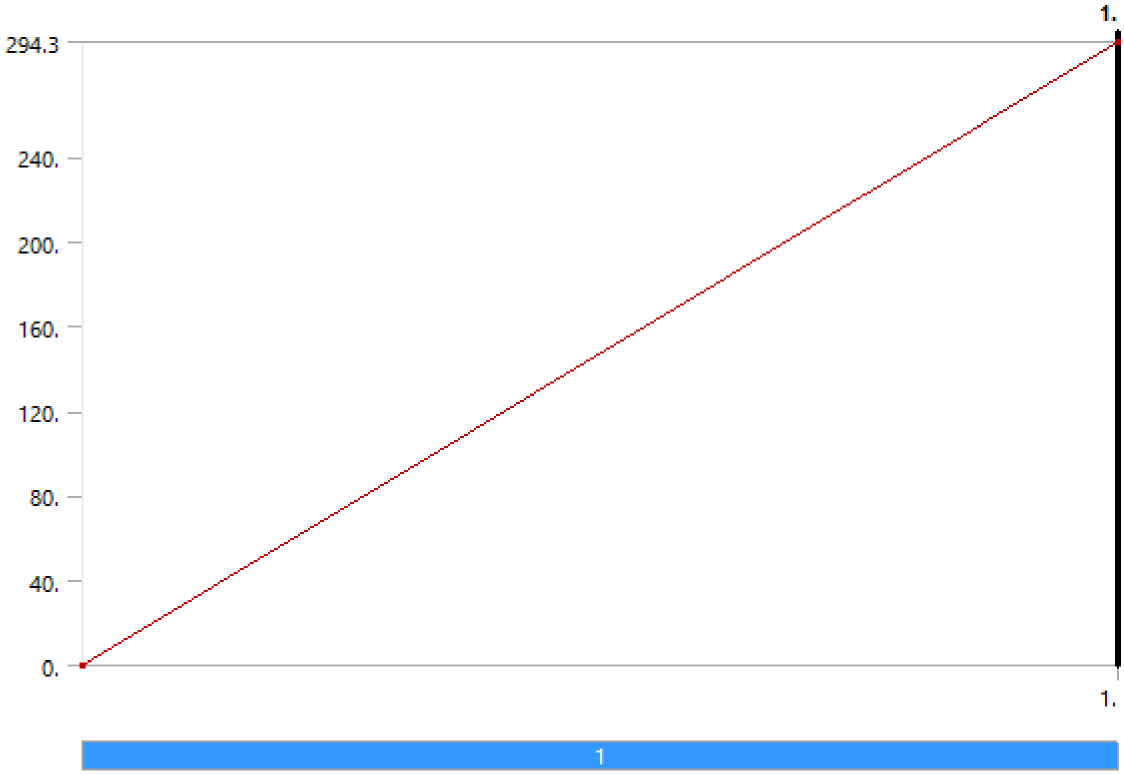


FIGURE 2

Model (A4) > Static Structural (A5) > Pressure



Solution (A6)

TABLE 9

Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

TABLE 10

Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s

Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 11

Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Maximum Principal Stress*	*Maximum Principal Elastic Strain*	*Total Deformation*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Maximum Principal Stress	Maximum Principal Elastic Strain	Total Deformation
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		
Results			
Minimum	-1.754e+006 Pa	7.3852e-004 m/m	0. m
Maximum	4.082e+006 Pa	0.30733 m/m	0.32365 m
Minimum Value Over Time			
Minimum	-1.754e+006 Pa	7.3852e-004 m/m	0. m
Maximum	-1.754e+006 Pa	7.3852e-004 m/m	0. m
Maximum Value Over Time			

Minimum	4.082e+006 Pa	0.30733 m/m	0.32365 m
Maximum	4.082e+006 Pa	0.30733 m/m	0.32365 m
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		

Material Data

Polyvinyl chloride (PVC)

TABLE 12

Polyvinyl chloride (PVC) > Constants

Density	1400 kg m^-3
Coefficient of Thermal Expansion	2.3e-003 C^-1

TABLE 13

Polyvinyl chloride (PVC) > Isotropic Secant Coefficient of Thermal Expansion

Reference Temperature C
47

TABLE 14

Polyvinyl chloride (PVC) > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	1.5e+007	0.42	3.125e+007	5.2817e+006

TABLE 15

Polyvinyl chloride (PVC) > Tensile Yield Strength

Tensile Yield Strength Pa
5.3e+007

TABLE 16

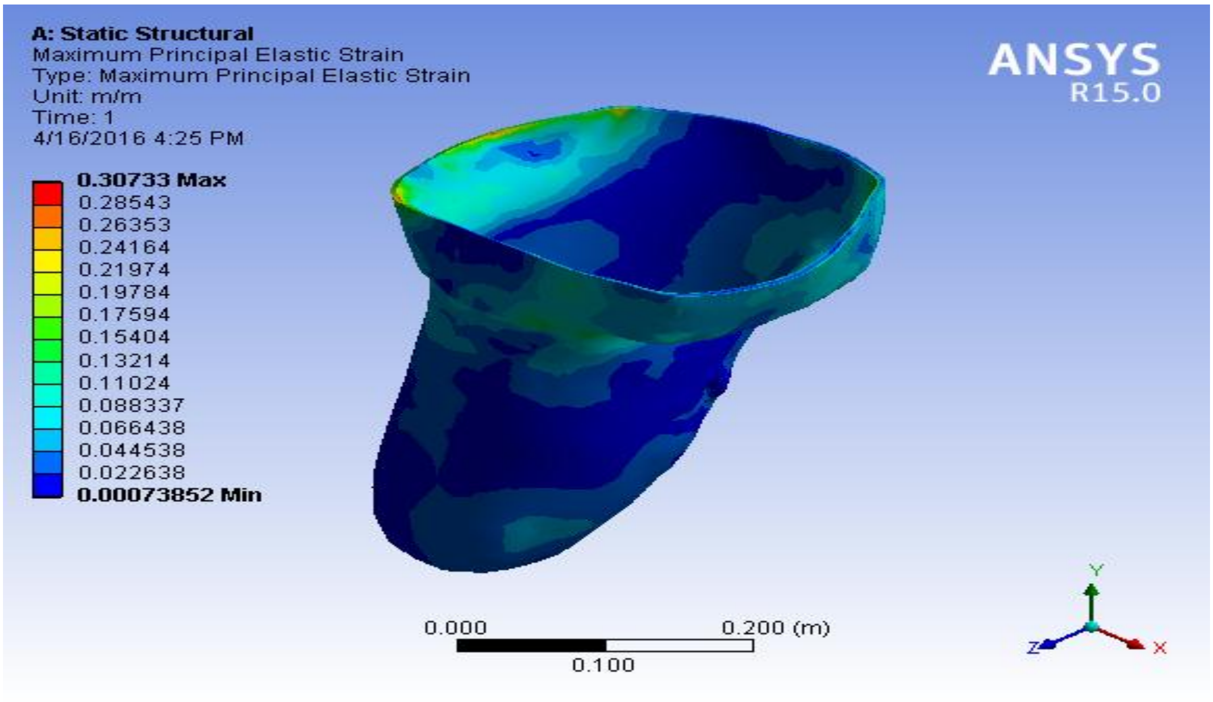
Polyvinyl chloride (PVC) > Compressive Yield Strength

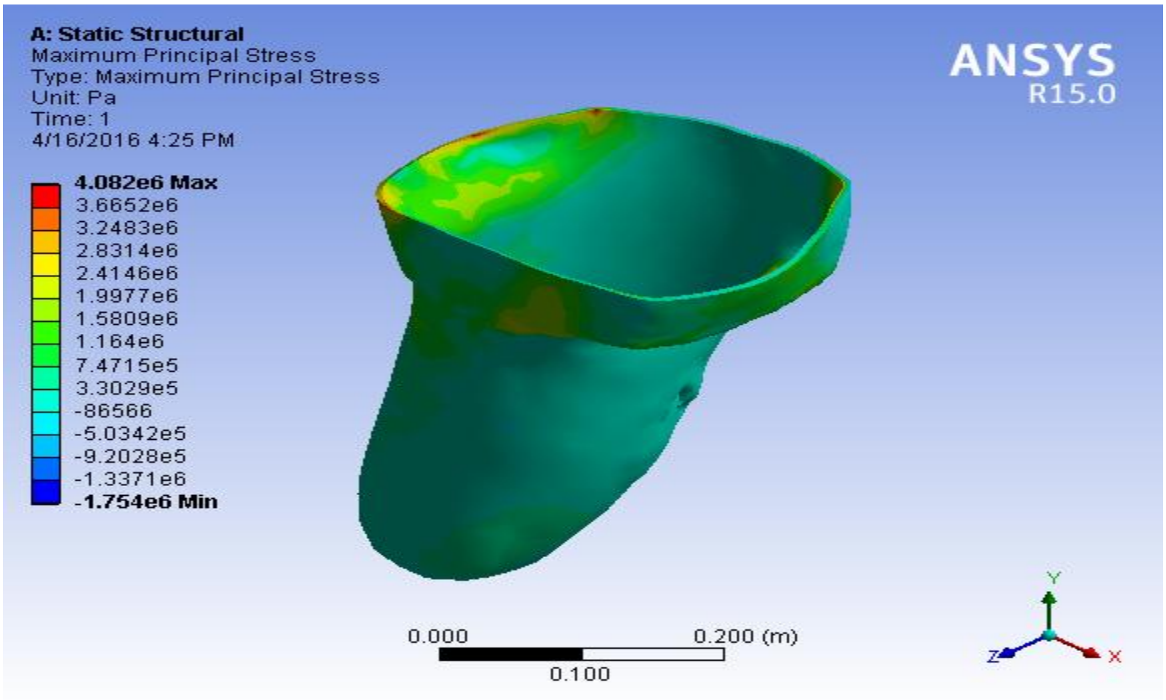
Compressive Yield Strength Pa
8.3e+007

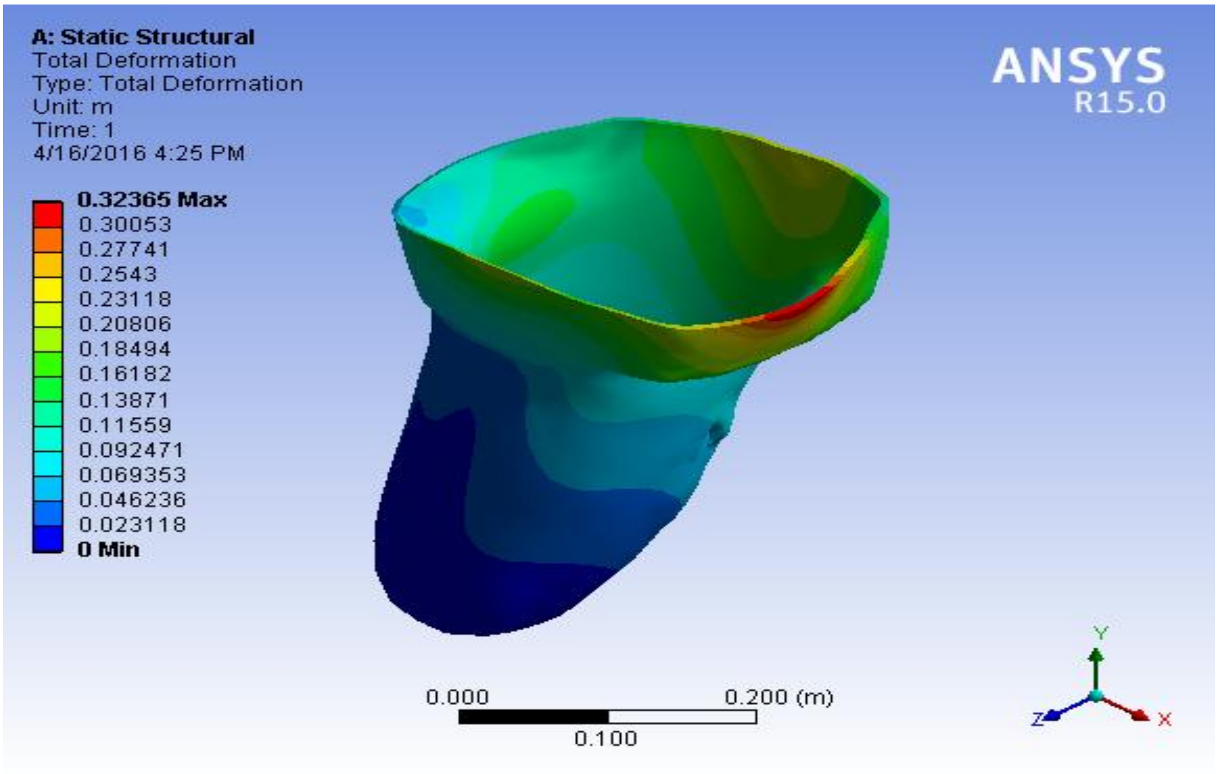
TABLE 17

Polyvinyl chloride (PVC) > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
6.3e+007

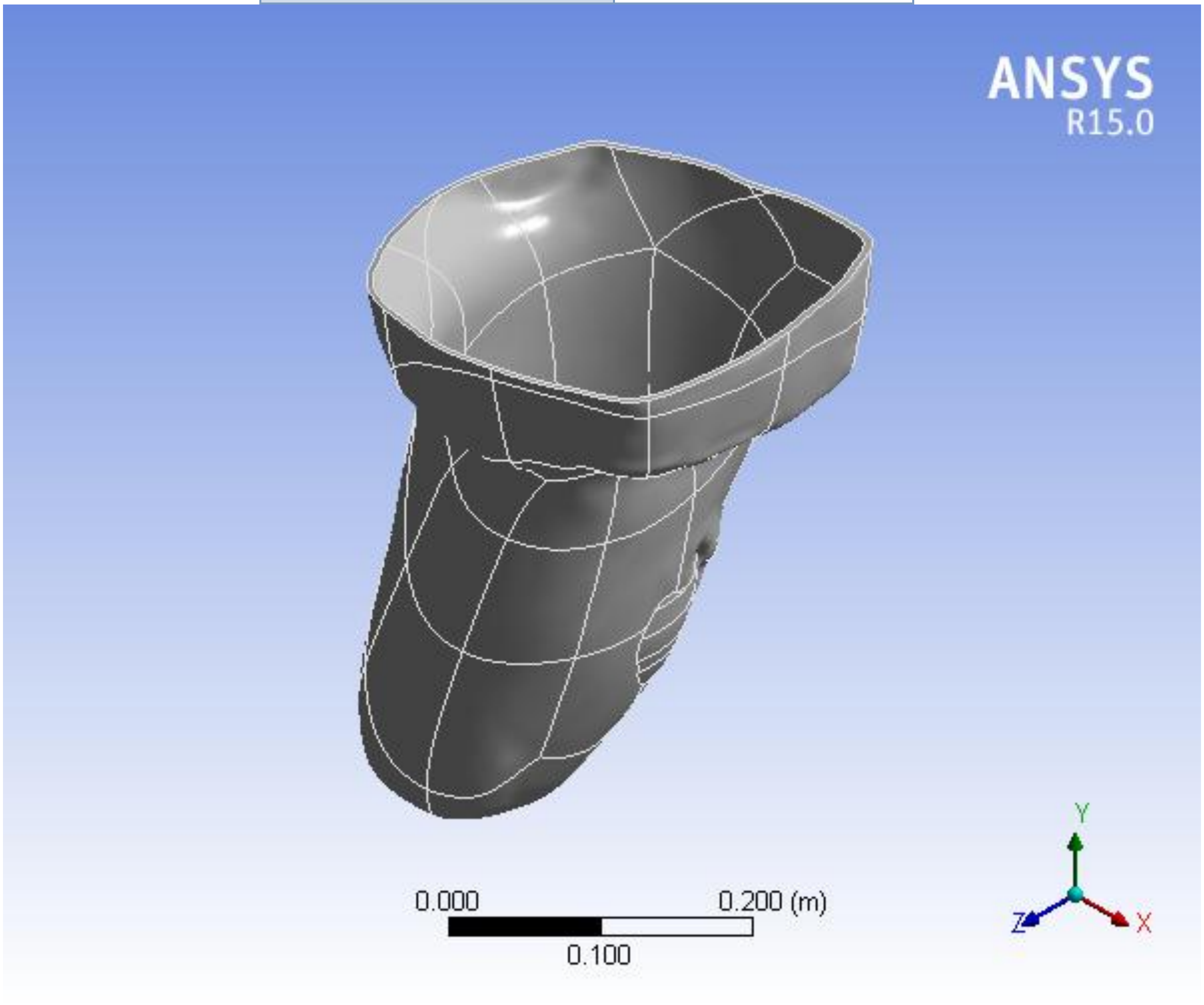

A: Static Structural
Maximum Principal Elastic Strain
Type: Maximum Principal Elastic Strain
Unit: m/m
Time: 1
4/16/2016 4:25 PM
0.30733 Max
0.28543
0.26353
0.24164
0.21974
0.19784
0.17594
0.15404
0.13214
0.11024
0.088337
0.066438
0.044538
0.022638
0.00073852 Min
ANSYS
R15.0
0.000
0.100
0.200 (m)
Y
Z
X


A: Static Structural
Maximum Principal Stress
Type: Maximum Principal Stress
Unit: Pa
Time: 1
4/16/2016 4:25 PM
4.082e6 Max
3.6652e6
3.2483e6
2.8314e6
2.4146e6
1.9977e6
1.5809e6
1.164e6
7.4715e5
3.3029e5
-86566
-5.0342e5
-9.2028e5
-1.3371e6
-1.754e6 Min
ANSYS
R15.0
0.000
0.100
0.200 (m)
Y
Z
X


A: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1
4/16/2016 4:25 PM
0.32365 Max
0.30053
0.27741
0.2543
0.23118
0.20806
0.18494
0.16182
0.13871
0.11559
0.092471
0.069353
0.046236
0.023118
0 Min
ANSYS
R15.0
0.000
0.100
0.200 (m)
Y
Z
X

Project

First Saved	Saturday, April 16, 2016
Last Saved	Saturday, April 16, 2016
Product Version	15.0 Release
Save Project Before Solution	No
Save Project After Solution	No



Contents

Units

TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

Geometry

TABLE 2

Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\shooter\AppData\Local\Temp\WB_SHOOTER-PC_shooter_6700_2\unsaved_project_files\dp0\SYS\DM\SYS.agdb
Type	DesignModeler
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	

Length X	0.3174 m
Length Y	0.4178 m
Length Z	0.29219 m
Properties	
Volume	1.3924e-003 m³
Mass	1.3228 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	11507
Elements	5691
Mesh Metric	None
Basic Geometry Options	
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Compare Parts On Update	No
Attach File Via Temp File	Yes

Temporary Directory	C:\Users\shooter\AppData\Local\Temp
Analysis Type	3-D
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3

Model (A4) > Geometry > Parts

Object Name	*Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	High-density polyethylene (HDPE)
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	0.3174 m
Length Y	0.4178 m
Length Z	0.29219 m
Properties	
Volume	1.3924e-003 m³
Mass	1.3228 kg
Centroid X	-3.7805e-002 m
Centroid Y	-0.2233 m
Centroid Z	1.866e-002 m
Moment of Inertia Ip1	3.4095e-002 kg·m²
Moment of Inertia Ip2	1.4776e-002 kg·m²

Moment of Inertia Ip3	3.2243e-002 kg·m²
Statistics	
Nodes	11507
Elements	5691
Mesh Metric	None

Coordinate Systems

TABLE 4

Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. m
Origin Y	0. m
Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Mesh

TABLE 5

Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium

Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	2.9228e-003 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Patch Independent Options	
Topology Checking	Yes
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	11507
Elements	5691
Mesh Metric	None

Static Structural (A5)

TABLE 6

Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 7

Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Nonlinear Controls	

Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Off
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Contact Miscellaneous	No
General Miscellaneous	No
Store Results At	All Time Points
Analysis Data Management	
Solver Files Directory	C:\Users\shooter\AppData\Local\Temp\WB_SHOOTER-PC_shooter_6700_2\unsaved_project_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	mks

TABLE 8

Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Force*	*Pressure*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Face		21 Faces
Definition			
Type	Fixed Support	Force	Pressure
Suppressed	No		
Define By		Components	Normal To
Coordinate System		Global Coordinate System	
X Component		0. N (ramped)	
Y Component		-784.8 N (ramped)	
Z Component		0. N (ramped)	
Magnitude			294.3 Pa (ramped)

FIGURE 1

Model (A4) > Static Structural (A5) > Force

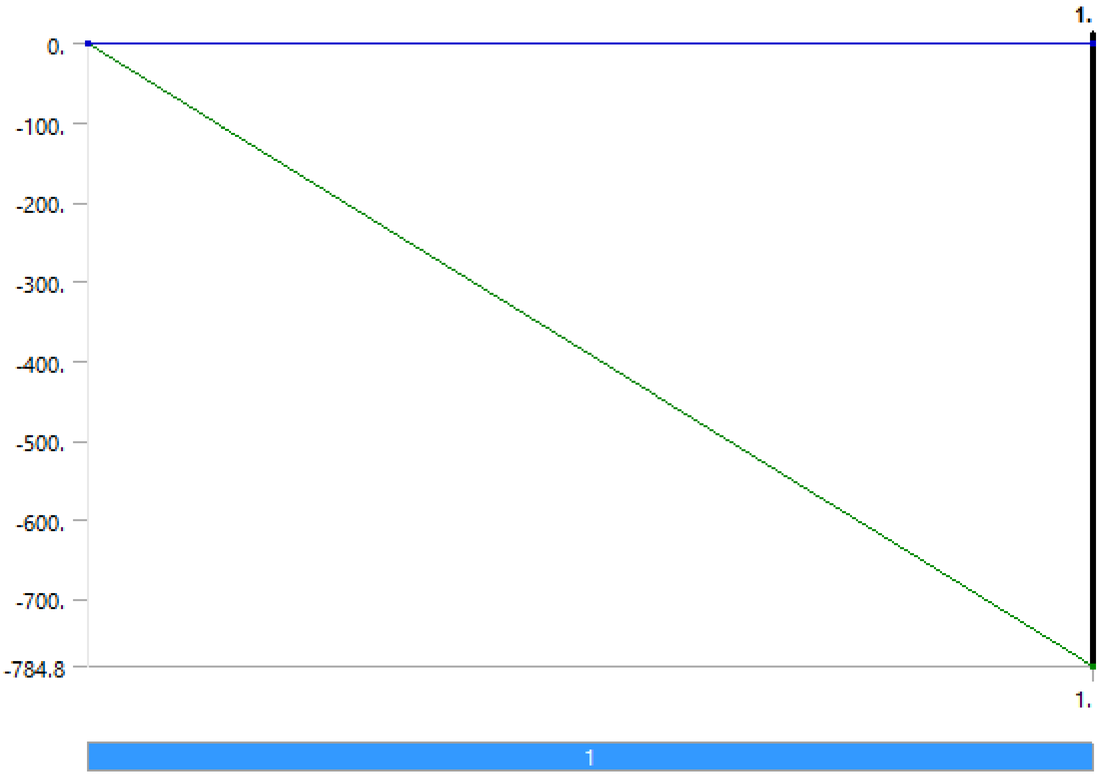
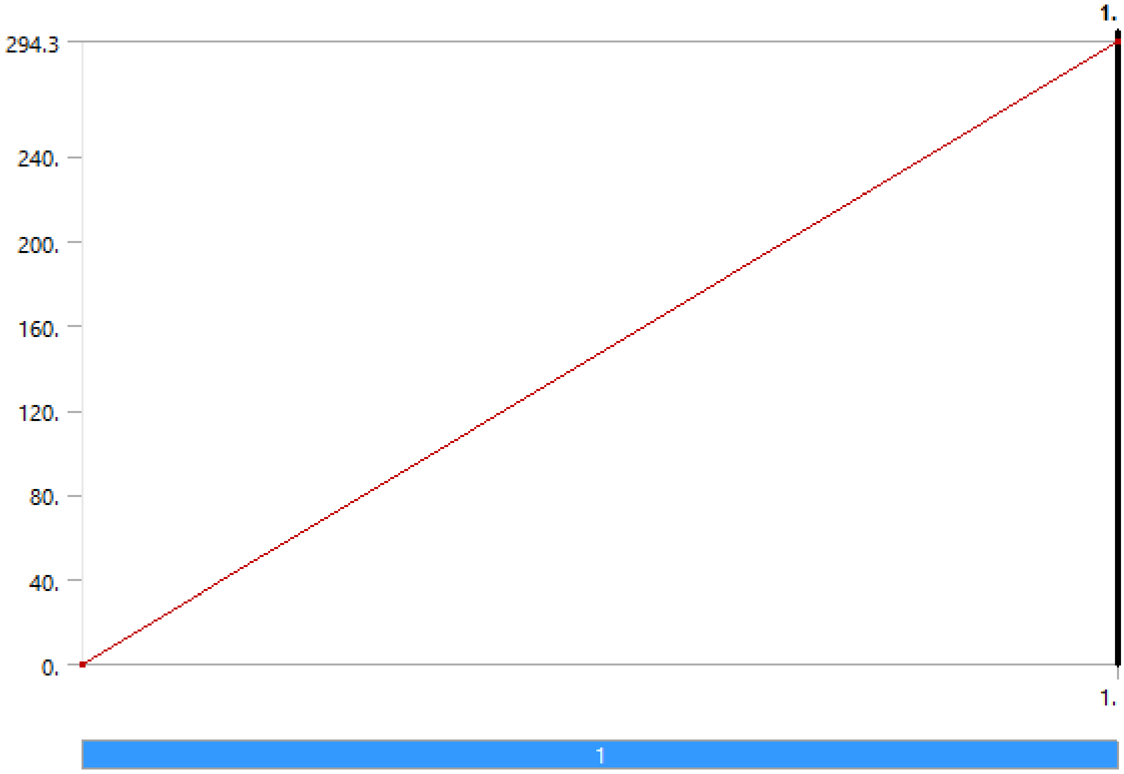


FIGURE 2

Model (A4) > Static Structural (A5) > Pressure



Solution (A6)

TABLE 9

Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

TABLE 10

Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	

Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 11

Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Maximum Principal Stress*	*Maximum Principal Elastic Strain*	*Total Deformation*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Maximum Principal Stress	Maximum Principal Elastic Strain	Total Deformation
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		
Results			
Minimum	-1.754e+006 Pa	1.5825e-004 m/m	0. m
Maximum	4.082e+006 Pa	6.5857e-002 m/m	6.9353e-002 m
Minimum Value Over Time			
Minimum	-1.754e+006 Pa	1.5825e-004 m/m	0. m
Maximum	-1.754e+006 Pa	1.5825e-004 m/m	0. m
Maximum Value Over Time			
Minimum	4.082e+006 Pa	6.5857e-002 m/m	6.9353e-002 m
Maximum	4.082e+006 Pa	6.5857e-002 m/m	6.9353e-002 m

Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

Material Data

High-density polyethylene (HDPE)

TABLE 12

High-density polyethylene (HDPE) > Constants

Density	950 kg m^-3
Coefficient of Thermal Expansion	2.3e-003 C^-1

TABLE 13

High-density polyethylene (HDPE) > Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+007

TABLE 14

High-density polyethylene (HDPE) > Compressive Yield Strength

Compressive Yield Strength Pa
8.1e+007

TABLE 15

High-density polyethylene (HDPE) > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
3.e+007

TABLE 16

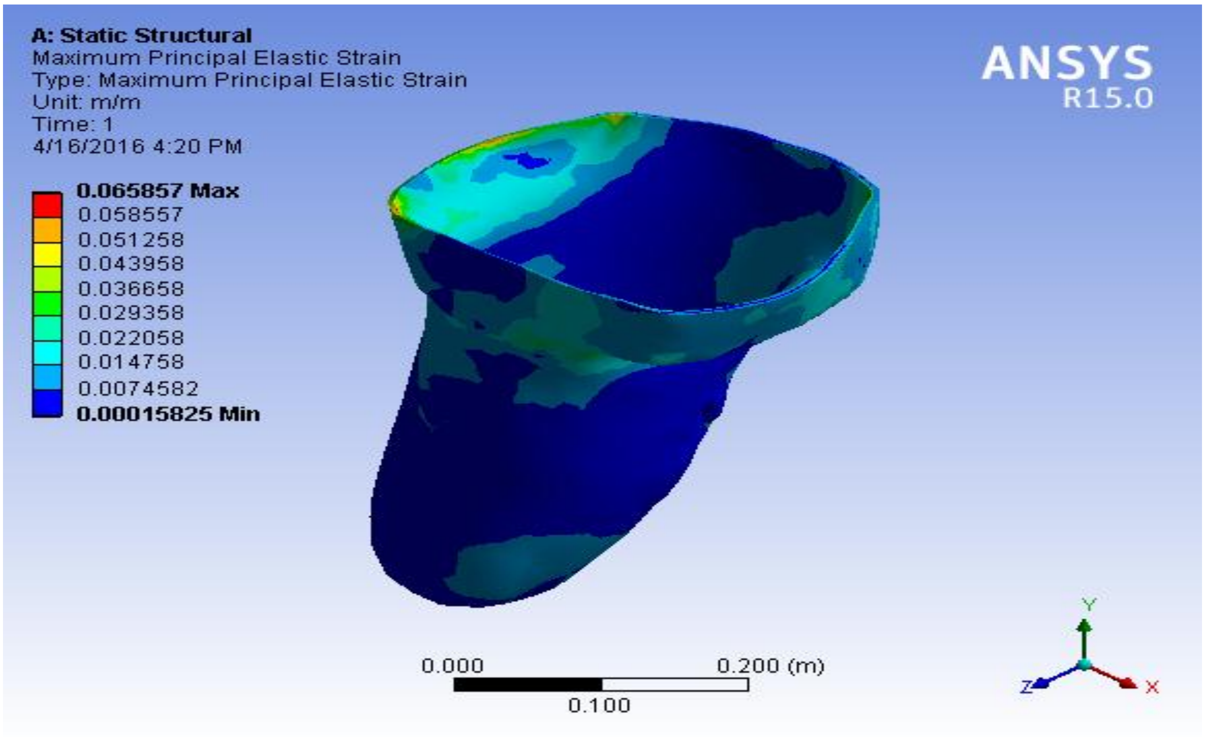
High-density polyethylene (HDPE) > Isotropic Secant Coefficient of Thermal Expansion

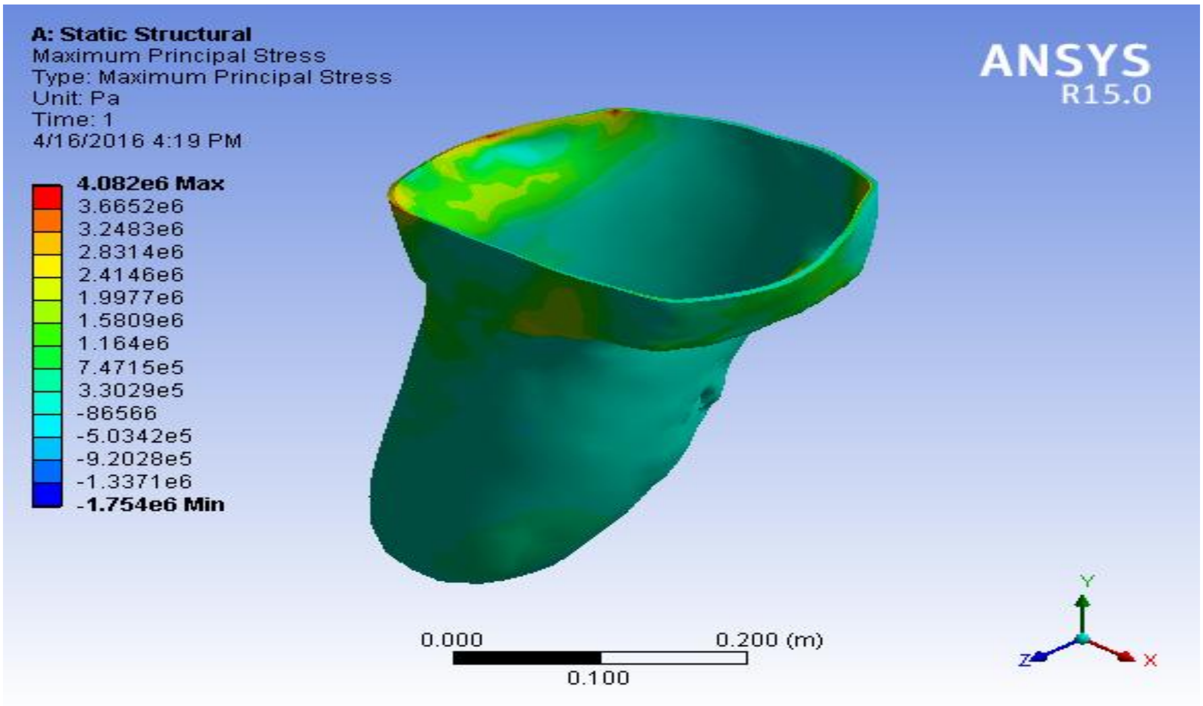
Reference Temperature C
40

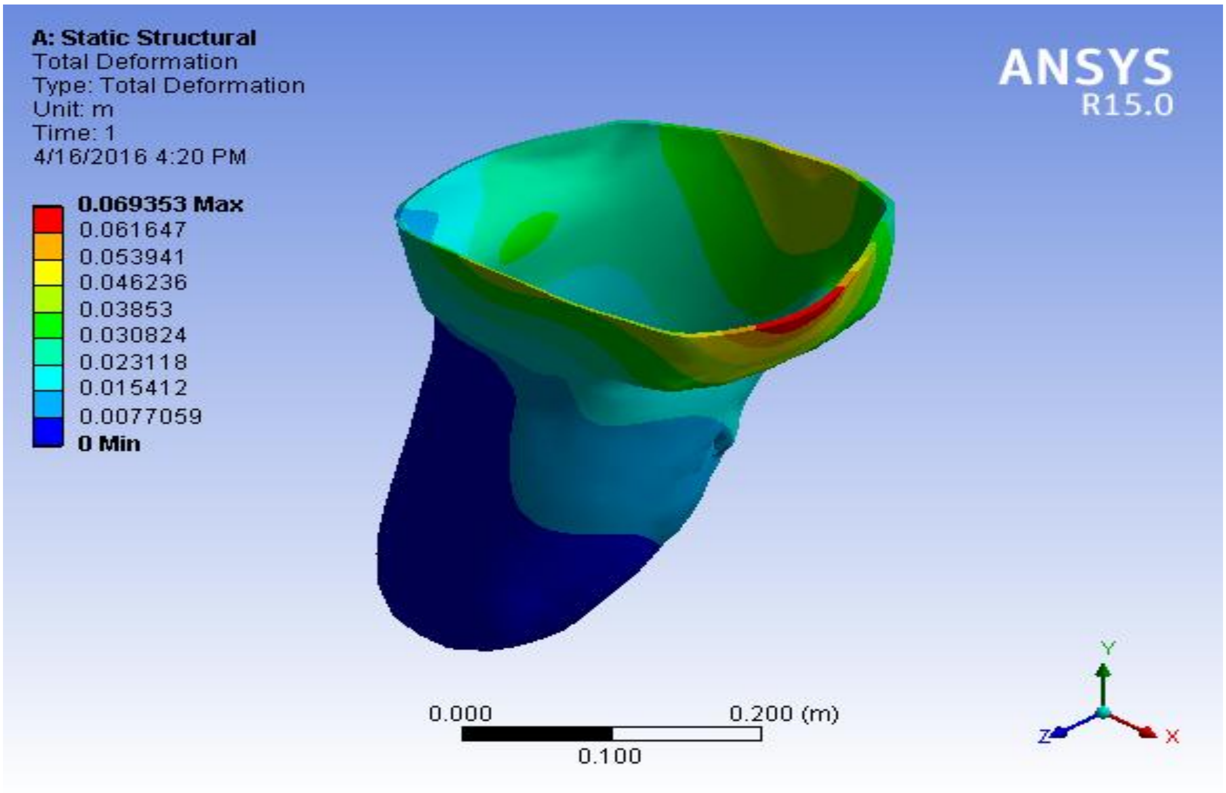
TABLE 17

High-density polyethylene (HDPE) > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	7.e+007	0.42	1.4583e+008	2.4648e+007

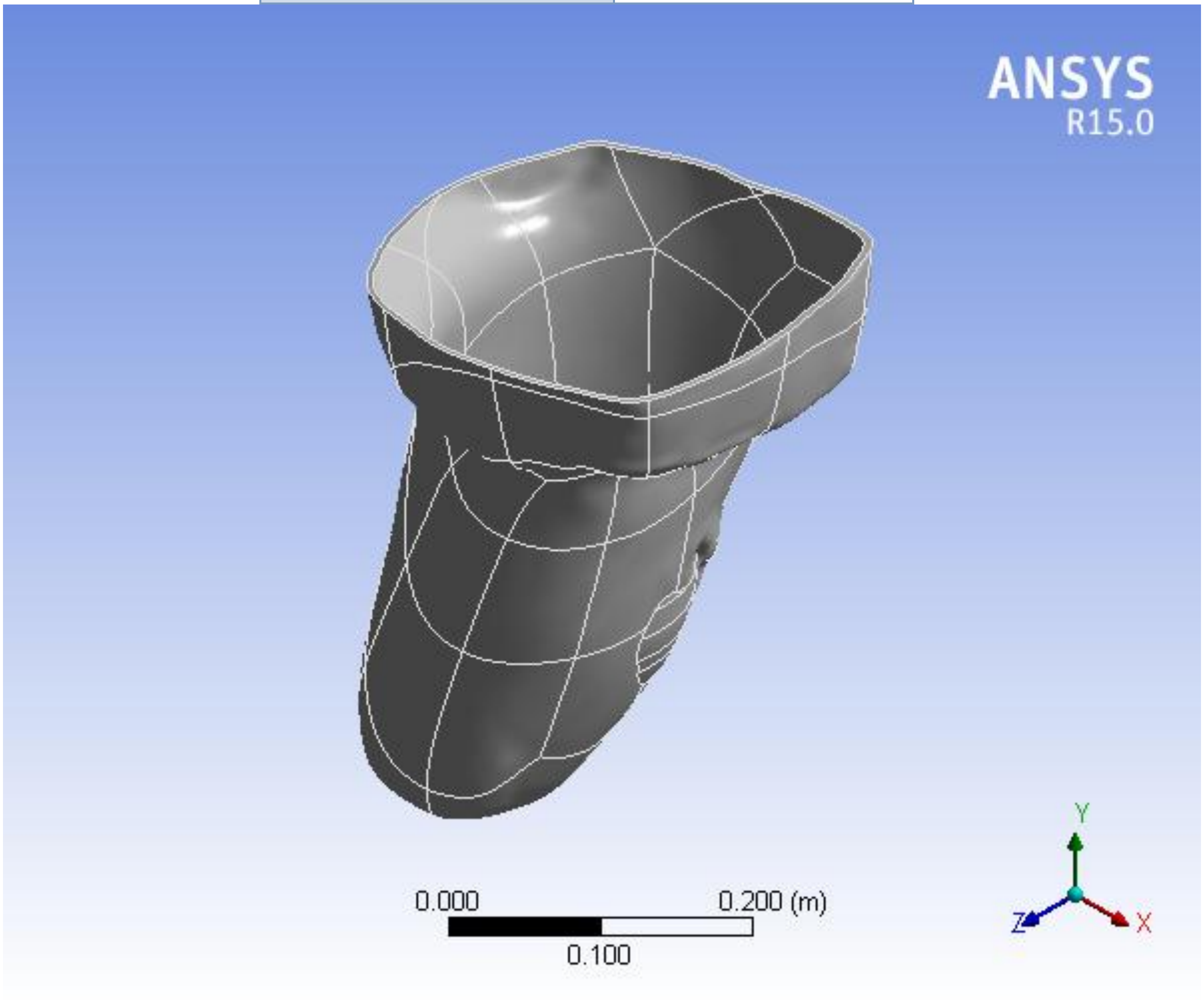

A: Static Structural
Maximum Principal Elastic Strain
Type: Maximum Principal Elastic Strain
Unit: m/m
Time: 1
4/16/2016 4:20 PM
0.065857 Max
0.058557
0.051258
0.043958
0.036658
0.029358
0.022058
0.014758
0.0074582
0.00015825 Min
ANSYS
R15.0
0.000
0.100
0.200 (m)
Y
Z
X


A: Static Structural
Maximum Principal Stress
Type: Maximum Principal Stress
Unit: Pa
Time: 1
4/16/2016 4:19 PM
4.082e6 Max
3.6652e6
3.2483e6
2.8314e6
2.4146e6
1.9977e6
1.5809e6
1.164e6
7.4715e5
3.3029e5
-86566
-5.0342e5
-9.2028e5
-1.3371e6
-1.754e6 Min
ANSYS
R15.0
0.000
0.100
0.200 (m)
Y
Z
X


A: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1
4/16/2016 4:20 PM
0.069353 Max
0.061647
0.053941
0.046236
0.03853
0.030824
0.023118
0.015412
0.0077059
0 Min
ANSYS
R15.0
0.000
0.100
0.200 (m)
Y
Z
X

Project

First Saved	Saturday, April 16, 2016
Last Saved	Saturday, April 16, 2016
Product Version	15.0 Release
Save Project Before Solution	No
Save Project After Solution	No



Contents

Units

TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

Geometry

TABLE 2

Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\shooter\AppData\Local\Temp\WB_SHOOTER-PC_shooter_6700_2\unsaved_project_files\dp0\SYS\DM\SYS.agdb
Type	DesignModeler
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	

Length X	0.3174 m
Length Y	0.4178 m
Length Z	0.29219 m
Properties	
Volume	1.3924e-003 m^3
Mass	3.1329 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	11507
Elements	5691
Mesh Metric	None
Basic Geometry Options	
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Compare Parts On Update	No
Attach File Via Temp File	Yes

Temporary Directory	C:\Users\shooter\AppData\Local\Temp
Analysis Type	3-D
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3

Model (A4) > Geometry > Parts

Object Name	*Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Teflon (PTFE)
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	0.3174 m
Length Y	0.4178 m
Length Z	0.29219 m
Properties	
Volume	1.3924e-003 m³
Mass	3.1329 kg
Centroid X	-3.7805e-002 m
Centroid Y	-0.2233 m
Centroid Z	1.866e-002 m
Moment of Inertia Ip1	8.0751e-002 kg·m²
Moment of Inertia Ip2	3.4996e-002 kg·m²

Moment of Inertia Ip3	7.6365e-002 kg·m²
Statistics	
Nodes	11507
Elements	5691
Mesh Metric	None

Coordinate Systems

TABLE 4

Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. m
Origin Y	0. m
Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Mesh

TABLE 5

Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium

Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	2.9228e-003 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Patch Independent Options	
Topology Checking	Yes
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	11507
Elements	5691
Mesh Metric	None

Static Structural (A5)

TABLE 6

Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 7

Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Nonlinear Controls	

Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Off
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Contact Miscellaneous	No
General Miscellaneous	No
Store Results At	All Time Points
Analysis Data Management	
Solver Files Directory	C:\Users\shooter\AppData\Local\Temp\WB_SHOOTER-PC_shooter_6700_2\unsaved_project_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	mks

TABLE 8

Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Force*	*Pressure*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Face		21 Faces
Definition			
Type	Fixed Support	Force	Pressure
Suppressed	No		
Define By		Components	Normal To
Coordinate System		Global Coordinate System	
X Component		0. N (ramped)	
Y Component		-784.8 N (ramped)	
Z Component		0. N (ramped)	
Magnitude			294.3 Pa (ramped)

FIGURE 1

Model (A4) > Static Structural (A5) > Force

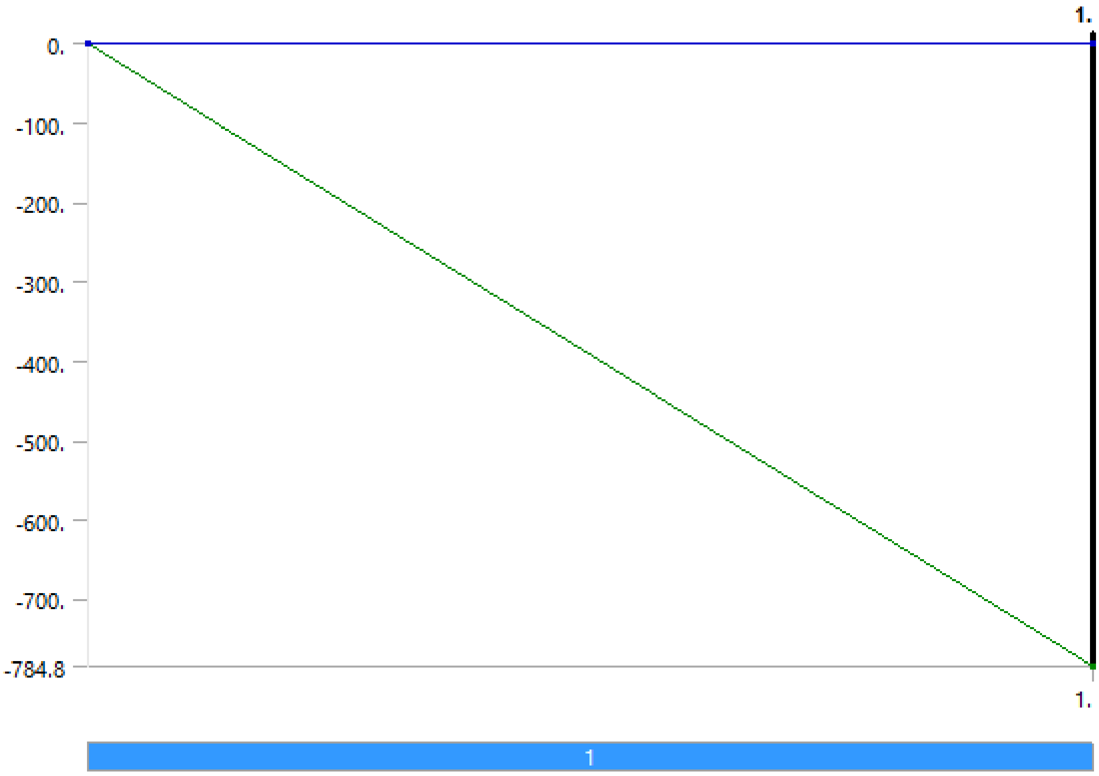
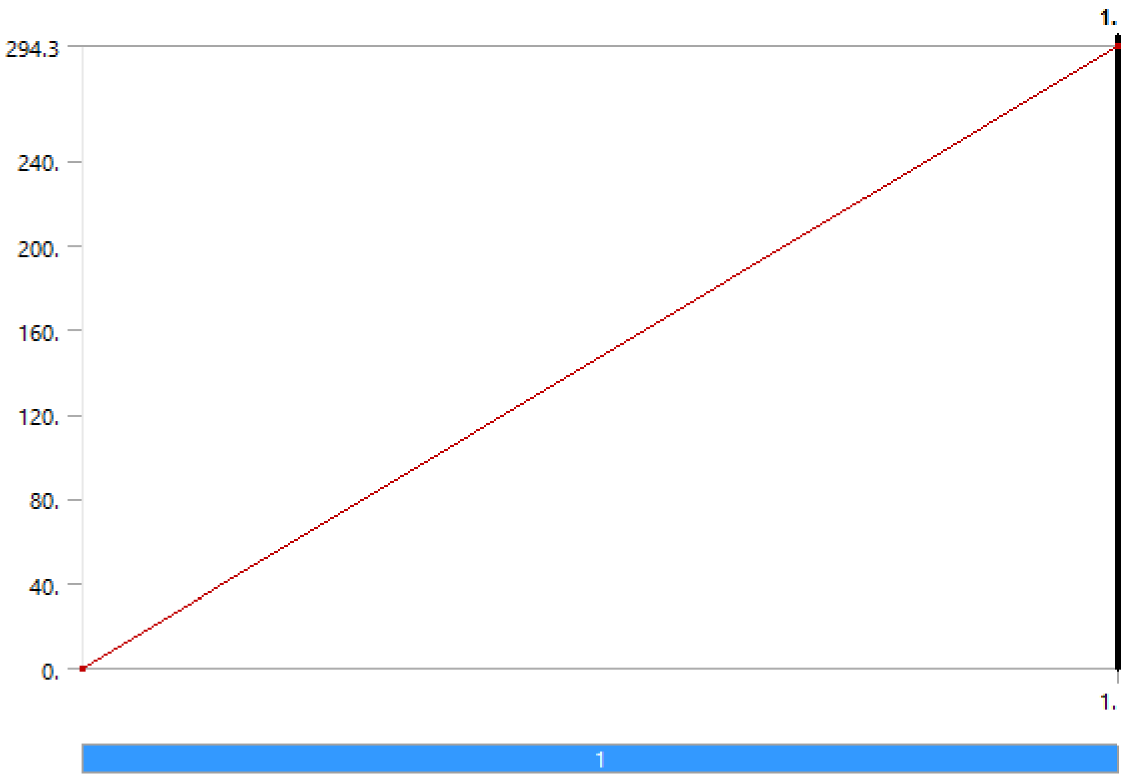


FIGURE 2

Model (A4) > Static Structural (A5) > Pressure



Solution (A6)

TABLE 9

Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

TABLE 10

Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	

Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 11

Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Maximum Principal Stress*	*Maximum Principal Elastic Strain*	*Total Deformation*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Maximum Principal Stress	Maximum Principal Elastic Strain	Total Deformation
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		
Results			
Minimum	-2.4446e+006 Pa	434.59 m/m	0. m
Maximum	3.946e+006 Pa	72862 m/m	77693 m
Minimum Value Over Time			
Minimum	-2.4446e+006 Pa	434.59 m/m	0. m
Maximum	-2.4446e+006 Pa	434.59 m/m	0. m
Maximum Value Over Time			
Minimum	3.946e+006 Pa	72862 m/m	77693 m
Maximum	3.946e+006 Pa	72862 m/m	77693 m

Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

Material Data

Teflon (PTFE)

TABLE 12

Teflon (PTFE) > Constants

Density	2250 kg m^-3
Coefficient of Thermal Expansion	2.3e-003 C^-1

TABLE 13

Teflon (PTFE) > Tensile Yield Strength

Tensile Yield Strength Pa
2.e+007

TABLE 14

Teflon (PTFE) > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
3.e+007

TABLE 15

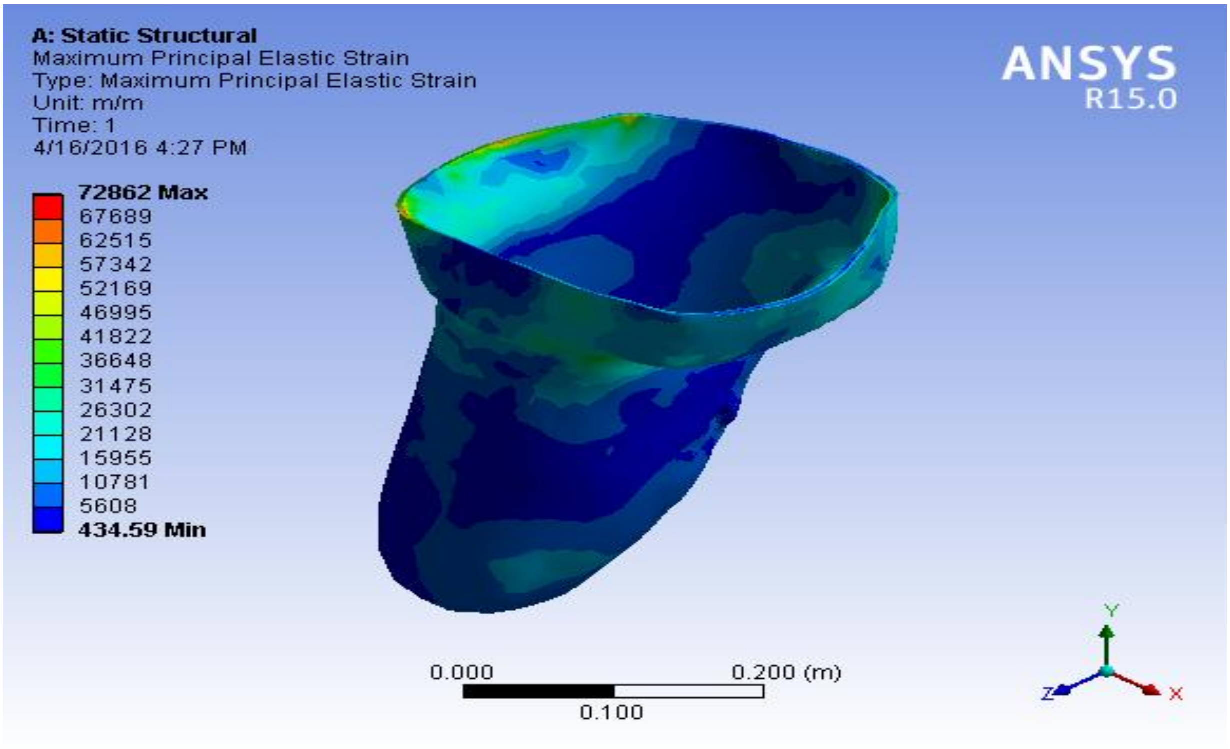
Teflon (PTFE) > Isotropic Secant Coefficient of Thermal Expansion

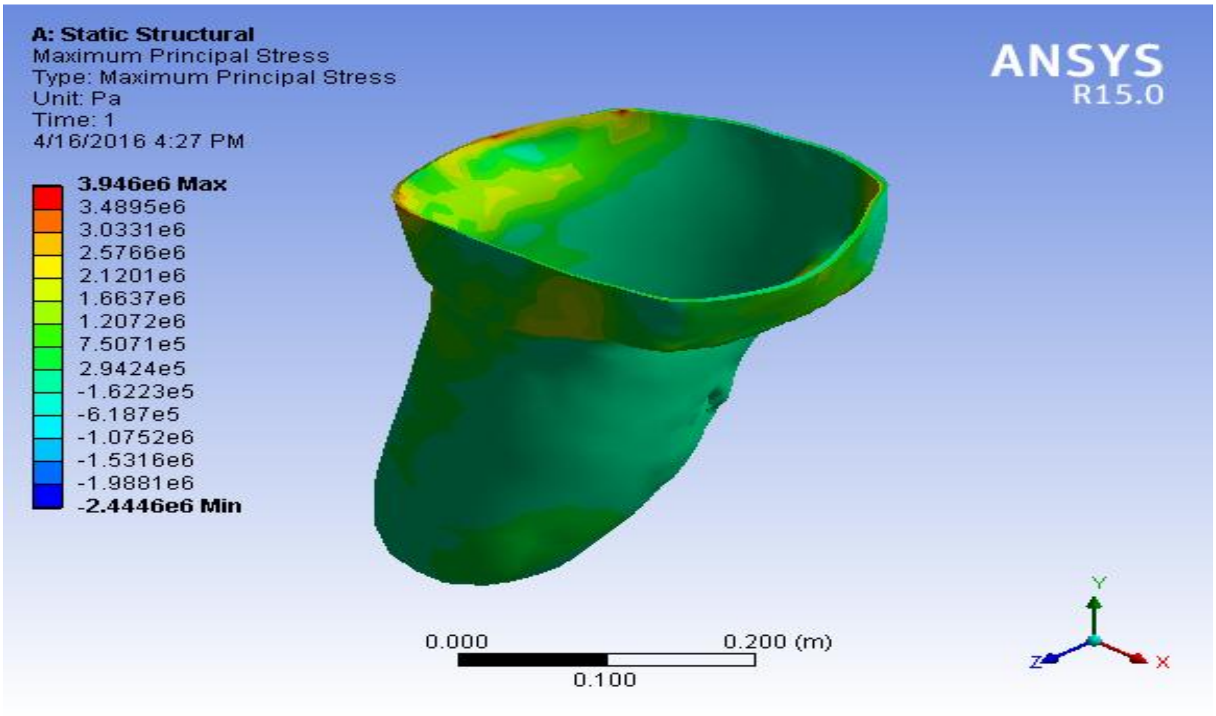
Reference Temperature C
40

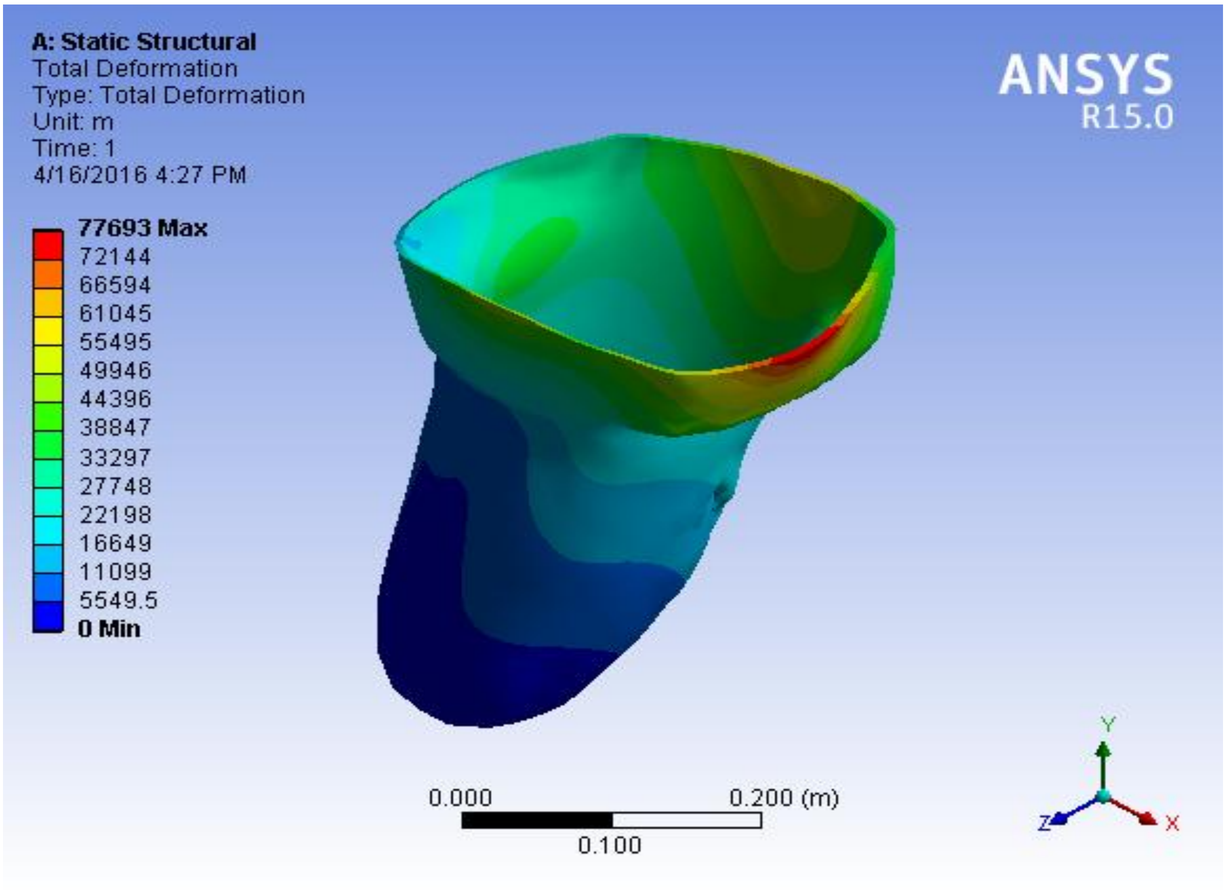
TABLE 16

Teflon (PTFE) > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	60	0.46	250	20.548


A: Static Structural
Maximum Principal Elastic Strain
Type: Maximum Principal Elastic Strain
Unit: m/m
Time: 1
4/16/2016 4:27 PM
72862 Max
67689
62515
57342
52169
46995
41822
36648
31475
26302
21128
15955
10781
5608
434.59 Min
ANSYS
R15.0
0.000
0.200 (m)
0.100
Y
Z
X


A: Static Structural
Maximum Principal Stress
Type: Maximum Principal Stress
Unit: Pa
Time: 1
4/16/2016 4:27 PM
3.946e6 Max
3.4895e6
3.0331e6
2.5766e6
2.1201e6
1.6637e6
1.2072e6
7.5071e5
2.9424e5
-1.6223e5
-6.187e5
-1.0752e6
-1.5316e6
-1.9881e6
-2.4446e6 Min
ANSYS
R15.0
0.000
0.200 (m)
0.100
Y
Z
X



A: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1
4/16/2016 4:27 PM
77693 Max
72144
66594
61045
55495
49946
44396
38847
33297
27748
22198
16649
11099
5549.5
0 Min
ANSYS
R15.0
0.000
0.200 (m)
0.100
Y
Z
X