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Production and Uses of Alloy Materials (Smart Material)

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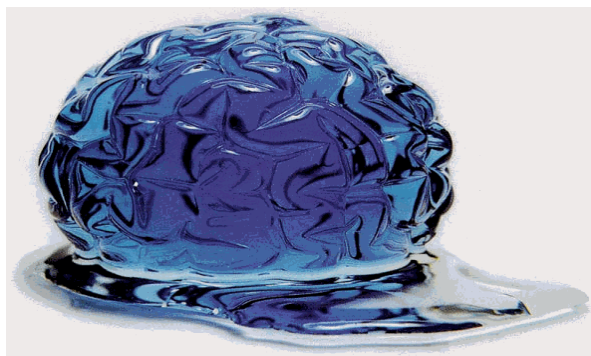
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ABSTRACT: In The Field Of Massive And Complex Manufacturing We Are Now In Need Of Materials, With Properties, That Can Be Manipulated According To Our Needs. Smart Materials Are One Among Those Unique Materials, Which Can Change Its Shape Or Size Simply By Adding A Little Bit Of Heat, Or Can Change From A Liquid To A Solid Almost Instantly When Near A Magnet. These Materials Include Piezoelectric Materials, Magneto-Rheostatic Materials, Electro-Rheostatic Materials, And Shape Memory Alloys (Sma's). Shape Memory Alloys (Sma's) Are Metals, Which Exhibit Two Very Unique Properties, Pseudo-Elasticity (An Almost Rubber-Like Flexibility, Under-Loading), And The Shape Memory Effect (Ability To Be Severely Deformed And Then Return To Its Original Shape Simply By Heating). The Two Unique Properties Described Above Are Made Possible Through A Solid State Phase Change That Is A Molecular Rearrangement, In Which The Molecules Remain Closely Packed So That The Substance Remains A Solid. The Two Phases, Which Occur In Shape Memory Alloys, Are Martensite, And Austenite.

In This Paper We Have Made A Comparative Study Between Sma's And Other Generally Used Materials Or Alloys, And Presented Simple Designs Some Medical Applications Of Sma. This Also Discusses About Conventional Bone Plate Used To Repair Jaw Fracture And Explain How Even A Badly Fractured Face Can Be Reconstructed Using Bone-Plates , The Use Of Sma's In The General Applications Like Robotic Gripper And Aircraft Maneuverability. Finally, From The Comparative Study Of Smas And Other Conventional Alloys We Have Proved That Smas Are Superior To Them In Feasibility, Reliability And Biocompatibility Points Of View.

I. INTRODUCTION

Science And Technology Have Made Amazing Developments In The Design Of Electronics And Machinery Using Standard Materials, Which Do Not Have Particularly Special Properties (I.E. Steel, Aluminum, Gold). Imagine The Range Of Possibilities, Which Exist For Special Materials That Have Properties Scientists Can Manipulate. Some Such Materials Have The Ability To Change Shape Or Size Simply By Adding A Little Bit Of Heat, Or To Change From A Liquid To A Solid Almost Instantly When Near A Magnet; These Materials Are Called Smart Materials.



A Smart Fluid Developed In Labs At The Michigan Institute Of Technology

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II. PHENOMENA OF SMART MATERIALS

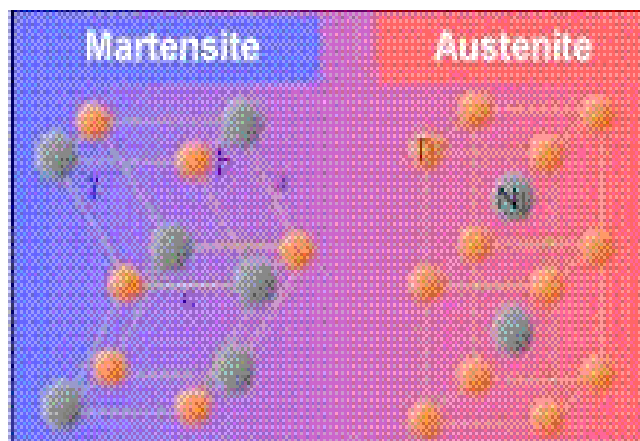
- Shape Memory Alloys
- Piezoelectric Materials
- Electro-Rheostatic And Magneto-Rheostatic

Shape Memory Alloys

Shape Memory Alloys (Sma's) Are Metals, Which Exhibit Two Very Unique Properties, Pseudo-Elasticity, And The Shape Memory Effect. Arne Olander First Observed These Unusual Properties In 1938 (Oksuta And Wayman 1998), But Not Until The 1960's Were Any Serious Research Advances Made In The Field Of Shape Memory Alloys. The Most Effective And Widely Used Alloys Include Niti (Nickel - Titanium), Cuznal, And Cualni.

How Shape Memory Alloys Work

The Two Unique Properties Described Above Are Made Possible Through A Solid State Phase Change That Is A Molecular Rearrangement, Which Occurs In The Shape Memory Alloy. Typically When One Thinks Of A Phase Change A Solid To Liquid Or Liquid To Gas Change Is The First Idea That Comes To Mind. A Solid State Phase Change Is Similar In That A Molecular Rearrangement Is Occurring, But The Molecules Remain Closely Packed So That The Substance Remains A Solid. In Most Shape Memory Alloys, A Temperature Change Of Only About 10°C Is Necessary To Initiate This Phase Change. The Two Phases, Which Occur In Shape Memory Alloys, Are Martensite, And Austenite.



The Martensite And Austenite Phases Martensite, Is The Relatively Soft And Easily Deformed Phase Of Shape Memory Alloys, Which Exists At Lower Temperatures. The Molecular Structure In This Phase Is Twinned Which Is The Configuration Shown In The Middle Of Figure .Upon Deformation This Phase Takes On The Second Form ,On The Right. Austenite, The Stronger Phase Of Shape Memory Alloys, Occurs At Higher Temperatures.. The Un-Deformed Martensite Phase Is The Same Size And Shape As The Cubic Austenite Phase On A Macroscopic Scale, So That No Change In Size Or Shape Is Visible In Shape Memory Alloys Until The Martensite Is Deformed.

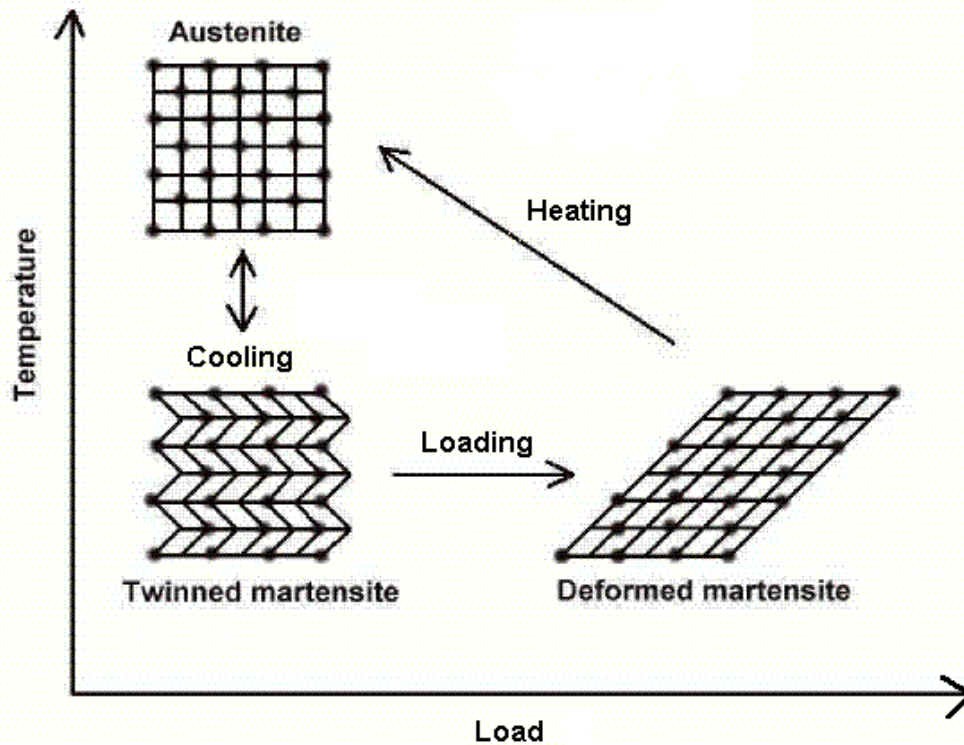
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Shape Memory Effect

Microscopic Diagram Of The Shape Memory Effect



The Shape Memory Effect Is Observed When The Temperature Of A Piece Of Shape Memory Alloy Is Cooled To Below The Temperature M_f . At This Stage The Alloy Is Completely Composed Of Martensite Which Can Be Easily Deformed. After Distorting The Sma The Original Shape Can Be Recovered Simply By Heating The Wire Above The Temperature A_f . The

Heat Transferred To The Wire Is The Power Driving The Molecular Rearrangement Of The Alloy, Similar To Heat Melting Ice Into Water, But The Alloy Remains Solid. The Deformed Martensite Is Now Transformed To The Cubic Austenite Phase.

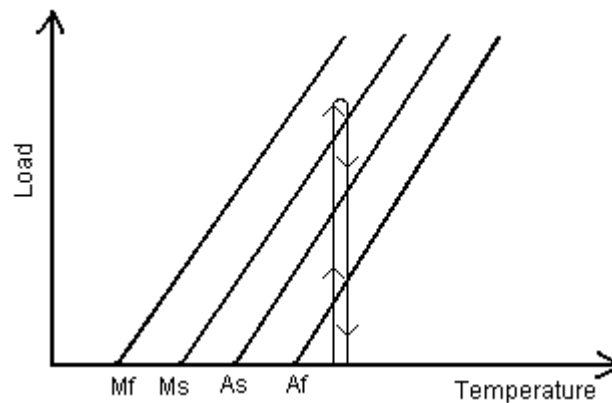
Pseudo-Elasticity

Load Diagram Of The Pseudo-Elastic Effect Occurring Pseudo-Elasticity Occurs In Shape Memory Alloys When The Alloy Is Completely Composed Of Austenite (Temperature Is Greater Than A_f). Unlike The Shape Memory Effect, Pseudo-Elasticity Occurs Without A Change In Temperature. The Load On The Shape Memory Alloy Is Increased Until The Austenite Becomes Transformed Into Martensite Simply Due To The Loading. The Loading Is Absorbed By The Softer Martensite, But As Soon As The Loading Is Decreased The Martensite Begins To Transform Back To Austenite Since The Temperature Of The Wire Is Still Above A_f , And The Wire Springs Back To Its Original Shape.

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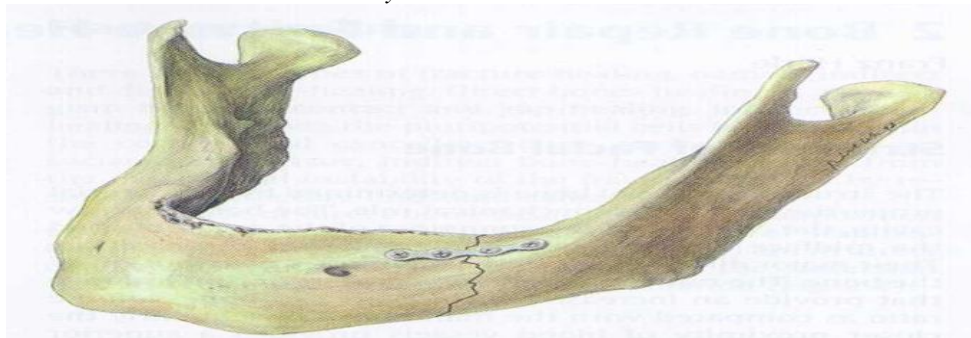
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III.APPLICATIONS

Surgical Tools

Bone Plates Are Surgical Tools, Which Are Used To Assist In The Healing Of Broken And Fractured Bones. They Are Often Applied To Fractures Occurring To Facial Areas Such As Nose, Jaw Or Eye Sockets. Repair Like This Fall Into An Area Of Medicine Known As *Osteosynthesis*.



Currently Osteotomy Equipment Is Made Primarily Of Titanium And Stainless Steel. The Broken Bones Are First Surgically Reset Into Their Proper Position. Then A Plate Is Screwed Onto The Broken Bones To Hold Them In Place, While The Bone Heals Back Together. The Drawback Of This Process Is After Initially Pacing The Plate O The Break Or Fracture The Bones Are Compressed Together And Held Under Some Slight Pressure Which Helps To Speed Up The Healing Process Of The Bone. Unfortunately, After Only A Couple Of Days The Tension Provided By The Steel Plate Is Lost And The Break Or Fracture Is No Longer Under Compression, Slowing Down The Healing Process.

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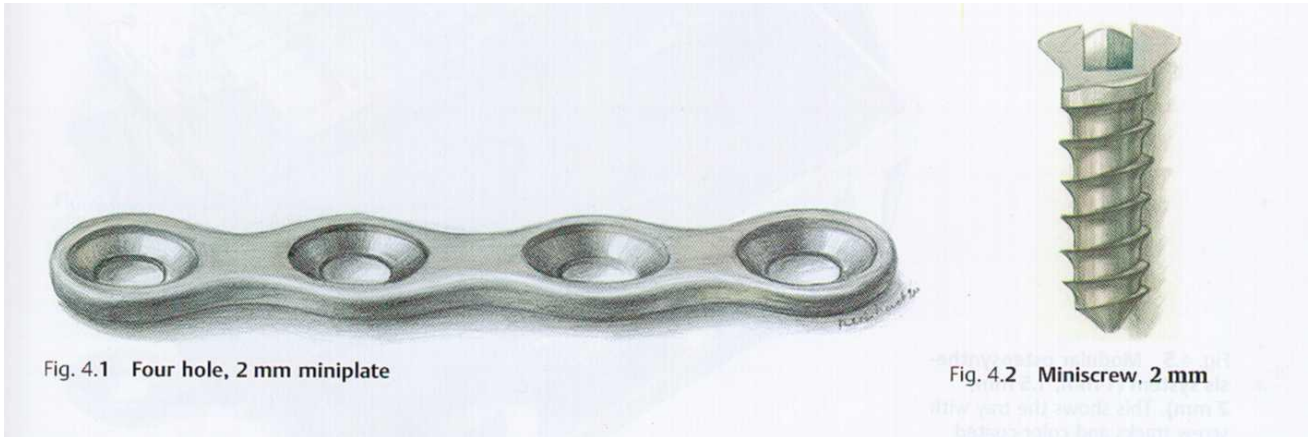
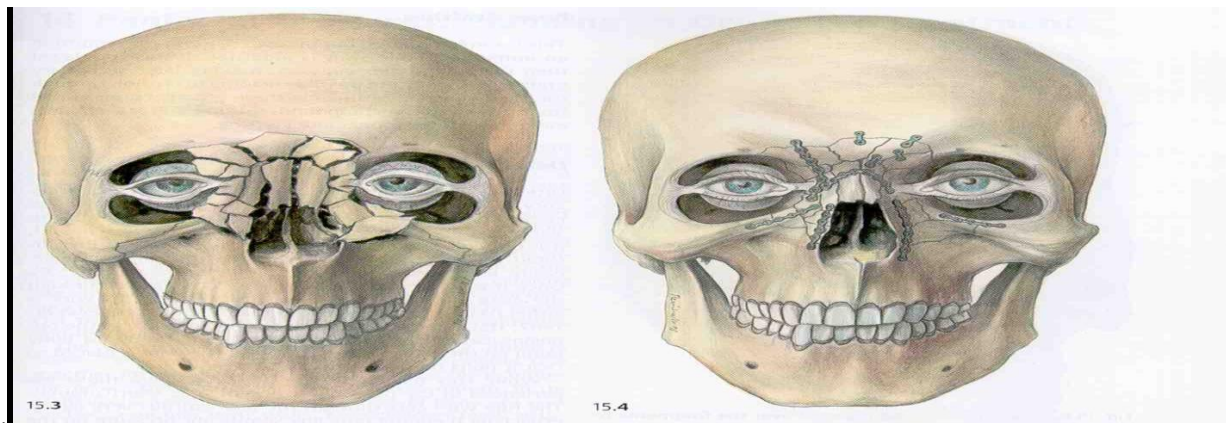


Fig. 4.1 Four hole, 2 mm miniplate

Fig. 4.2 Miniscrew, 2 mm

The Bone Plates Can Also Be Fabricated Using Smas, In Particular Ni-Ti Alloys. Using A Bone Plate Made Out Of Ni-Ti, Which Has A Transformation Temperature Of Around Af Much Greater Than 15 C. The Ni-Ti Plates Are First Cooled To Well Below Their Transformation Temperature, Then They Are Placed On The Set Break Just Like Ti Plates. However When The Body Heats The Plate Upto The Body Temperature The Ni-Ti Attempts To Contract Applying Sustained Pressure On The Break Or Fracture For Far Longer Than Stainless Steel Or Titanium.



IV. ROBOTIC MUSCLES



Sma Based Robotic Gripper

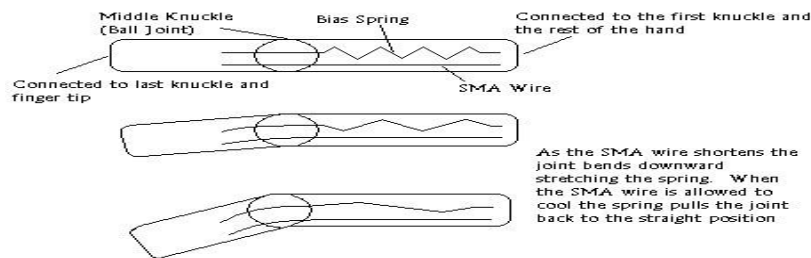
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There Have Been Many Attempts Made To Re-Create Human Anatomy Through Mechanical Means. The Human Body However, Is So Complex That It Is Very Difficult To Duplicate Even Simple Functions. Robotics And Electronics Are Making Great Strides In This Field, Of Particular Interest Are Limbs Such Hands, Arms, And Legs. In Order To Reproduce Human Extremities There Are A Number Of Aspects That Must Be Considered:

- The Gripping Force Required To Manipulate Different Objects (Eggs, Pens, Tools)
- The Motion Capabilities Of Each Joint Of The Hand
- The Ability To Feel Or Touch Objects (Tactile Senses)
- The Method Of Controlling Movement Within The Limb
- Emulating Real Human Movement (Smoothness, And Speed Of Response).



Shape Memory Alloys Mimic Human Muscles And Tendons Very Well. Sma's Are Strong And Compact So That Large Groups Of Them Can Be Used For Robotic Applications, And The Motion With Which They Contract And Expand Are Very Smooth Creating A Life-Like Movement Unavailable In Other Systems.

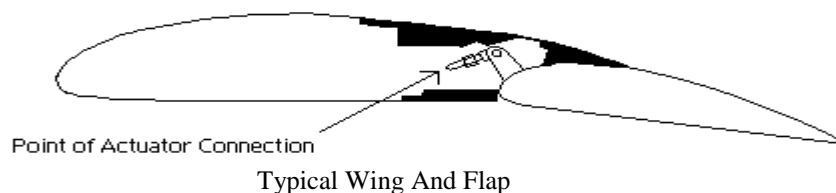
Creating Human Motion Using Sma Wires Is A Complex Task But A Simple Explanation Is Detailed Here. For Example To Create A Single Direction Of Movement (Like The Middle Knuckle Of Your Fingers) The Setup Shown In Figure 1 Could Be Used. The Bias Spring Shown In The Upper Portion Of The Finger Would Hold The Finger Straight, Stretching The Sma Wire, Then The Sma Wire On The Bottom Portion Of The Finger Can Be Heated Which Will Cause It To Shorten Bending The Joint Downwards. The Heating Takes Place By Running An Electric Current Through The Wire; The Timing And Magnitude Of This Current Can Be Controlled Through A Computer Interface Used To Manipulate The Joint.

V. AIRCRAFT MANEUVERABILITY

Aircraft Maneuverability Depends Heavily On The Movement Of Flaps Found At The Rear Or Trailing Edge Of The Wings. The Efficiency And Reliability Of Operating These Flaps Is Of Critical Importance.

Most Aircraft In The Air Today Operate These Flaps Using Extensive Hydraulic Systems. These Hydraulic Systems Utilize Large Centralized Pumps To Maintain Pressure, And Hydraulic Lines To Distribute The Pressure To The Flap Actuators. In Order To Maintain Reliability Of Operation, Multiple Hydraulic Lines Must Be Run To Each Set Of Flaps. This Complex System Of Pumps And Lines Is Often Relatively Difficult And Costly To Maintain.

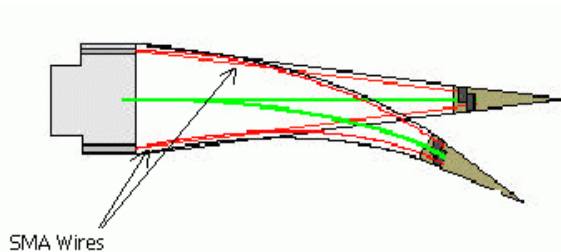
"Smart" Wings, Which Incorporate Shape Memory Alloys, Are Typically Like The Wing Shown In Figure. This System Is Much More Compact And Efficient, In That The Shape Memory Wires Only Require An Electric Current For Movement.



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Hinge Less Shape Memory Alloy Flap

Sma Based Aircraft Picture

The Shape Memory Effect Is Induced In The Wires Simply By Heating Them With An Electric Current, Which Is Easily Supplied Through Electrical Wiring, Eliminating The Need For Large Hydraulic Lines. By Removing The Hydraulic System, Aircraft Weight, Maintenance Costs, And Repair Time Are All Reduced

Advantages Of Sma

- Simplicity, Compactness And Safety Of The Mechanism
- Creation Of Clean Silent Spark Free And Zero Gravity Working Condition
- High Power / Weight Ratios

Disadvantages Of Sma

- Low Energy Efficiency
- Limited Bandwidth Due To Heating And Cooling Restrictions
- Degradation And Fatigue
- Complex Control

VI. CONCLUSION

In Parallel, The Continuous Growth Of Health Monitoring (Hm) Needs (E.G. Commercial Cars, Military Fighter Aircraft, Space Reusable Launch Vehicles) Has Led Us To Prepare And Establish The Bases Of Future Developments. Several New Sensing Technologies Have Been Investigated As Potentially Usable And Promising In Hm Domains Like Civil Engineering, Aerospace Structure, Engines, Storage, Etc. Some Of The Conventional Ones And New Ones Like Optical Fiber Or Holographic Based Are Being Set Up On Test Benches For Comparison And Qualification. As The Final Development Issue Is Toward Intelligent Systems, The Aspects Of Smart Sensors Are Being Studied .

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