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Strength Evaluation of Bone Implant

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Abstract

Human skeleton plays an important role for giving support to the muscles and decides the structure of body. Mechanical properties of whole bone or bone tissues and bone implant material interfaces are equally important as their morphological or structural aspects. The former is evaluated by mechanical testing and the latter is mostly studied using histological techniques. There is need to understand the strength of human bone. In case of fracture of bone, one can need the implant. Due to this we must have to be aware of the strength and properties of implant material. For this purpose it is required to take various tests like bending, torsion, tensile, fatigue tests etc. to know the respective strengths of implant material. For the bending test there is need of four point bending machine to achieve correct bending strength of the implant material. All other test can be taken as per standard test procedures on relevant machines.

Keywords: *Human Bone, Bone Implant, Mechanical Tests, Strength Evaluation, Properties, Different Machine, Four point bending Machine.*

1. Introduction

The femur, or thigh bone, is the most proximal (closest to the body) bone of the leg Invertebrates capable of walking or jumping, such as most land mammals, birds, many reptiles such as lizards, and amphibians such as frogs. In vertebrates with four legs such as dogs and horses, the femur is found only in the rear legs. In human anatomy, the femur is the longest and largest bone. Along with the temporal bone of the skull, it is one of the two strongest bones in the body. The average adult male femur is 48

centimeters (18.9 in) in length and 2.34 cm (0.92 in) in diameter and can support up to 2 times the weight of an adult .It forms part of the hip joint (at the acetabulum) and part of the knee joint, which is located above.

Biomechanics is an integral part of the study of bone as an organ or tissue. Mechanical testing of bone implant material specimens is a basic method in bone implant material-related research. The mechanical properties of whole bone or bone tissues and bone implant material interfaces are equally important as their morphological or structural aspects. The former is evaluated by mechanical testing and the latter is mostly studied using histological techniques.

One of the most efficient methods to evaluate properties of bone implant material is bending test. The convenient method to carry bending test is by using four point bending method. It is inconvenient to carry out this four point bending test on conventional machines like UTM. So, there was need to design and develop such machine which can carry out this test efficiently. Thus we have design and manufactured four point bending machine which is useful to find bending strength of bone implant material implant material. This machine is useful in bio-medical field to select proper material for bone implant material implant.

2. Methodology

2.1 Principal of Four Point Bending Machine

It works on the principle of Pascal's law of pressure. It states that, the pressure generated by exerting a force on a confined mass of liquid at rest acts undiminished in equal magnitude and in all directions normal to the inside wall of the fluid container.

2.2 Working

1. The motor acts as like a prime mover for pump so that hydraulic fluid from the reservoir suck through strainer and filter by pump and delivers at high pressure.
2. Pressurized fluid from pump passes from 4/3 direction control valve which act in 3 positions.

1st position: forward stroke for applying load.

2nd position: To hold the jaw at certain position at required pressure.

3rd position: reverse stroke.

3. In forward stroke flow can be controlled by FCV.
4. The pressure relief valve is used to relief the pressure of the system when exceeds than allowable pressure.
5. Pressure of fluid at breaking point is measured by pressure gauge.

Fig. 1 Set up Four Point Bending Machine

The circuit in fig.2 uses a valve center condition with the A and B ports blocked, and the P connected to T. This valve lets pump flow go to tank and blocks both cylinder ports. This configuration is often referred to as a tandem-center valve. Notice that the spool lands are wide enough to block the A, B, and P ports – the same as an all-ports-closed valve. However, this valve has a hollow spool and cross-drilled ports at P and both ends at T. The drilled passages provide a path for all pump flow to go directly to tank in the center position. Because the drilled passages also introduce extra backpressure, most suppliers' catalogs show a lower nominal flow or higher pressure drop for tandem-center valves.

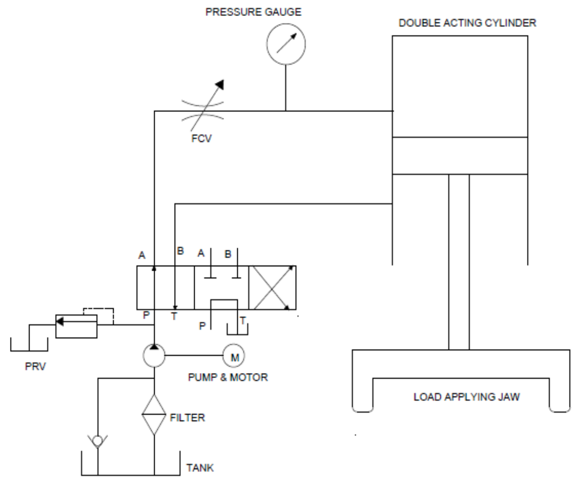


Fig. 2 Actual circuit of Four Point Bending Machine

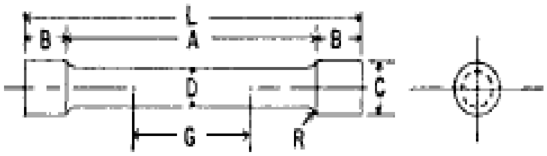
Circuits with tandem-center valves normally have fixed-volume pumps. The pump-to-tank path lets all flow return to tank at little or no backpressure. This saves energy and reduces heat to the point that a heat exchanger is unnecessary in most circuits. Be aware of the reduced flow or higher backpressure when specifying or using tandem valves.

A circuit may look good on paper, but can run hot because of wasted energy. This is especially true when using tandem-center valves in series. The backpressure for each valve is additive. A three-valve circuit can easily require more than 300 psi to unload the pump.

3. Mechanical Testing

3.1 Tensile Test

Tensile test can be one of the most accurate methods for measuring bone implant material properties, but bone implant material specimens must be relatively large and should be carefully machined. Tensile test specimens for bone implant material. Tensile test specimens are designed so that the highest strains will occur in the central portion or gauge region of the specimen. Strain measurements can be obtained by attaching a clip-on extensometer to the gauge section of the specimen. Stress is calculated as the applied force divided by the bone implant material cross-sectional area measured in the specimen midsection.



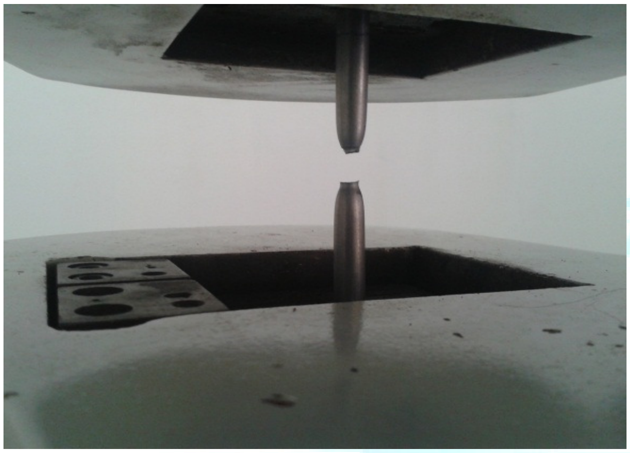


Fig. 3 Tensile Test of Specimen & Bone implant material

A = parallel length
GL = gauge length
m = grip length
e = neck length
r = curvature radius
d = specimen outer diameter
d = specimen gauge diameter.

3.2 Torsional Test

A diaphysis segment from a long bone implant material might be grossly approximated as a hollow cylindrical shaft made from a homogeneous, linear elastic material. Such a shaft might have a certain inner radius, ri, an outer radius, ro, and a length, l. If one end, a, of the shaft is fixed, and a torsional force, t, is applied to the opposite end, b, then end b will rotate in its own plane through some angle with respect to end a, the theoretical torsional share stress can be calculate by using following equation,

$$\frac{T}{J} = \frac{\tau}{R} \qquad (1)$$

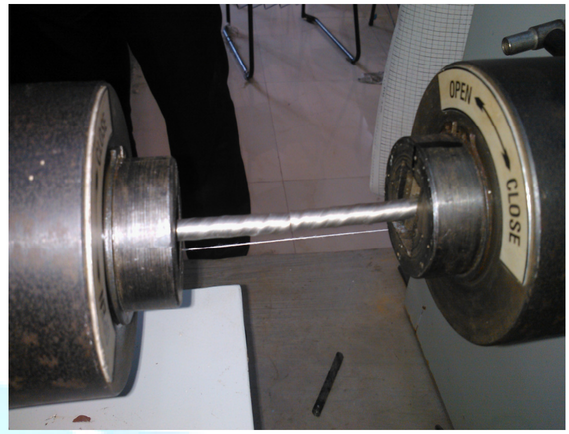


Fig. 4 Torsional Test of Bone implant material

3.3 Four Point Bending

Four-point bending occurs when two force couples acting on a structure produce two equal moments. A force couple refers to a pair of parallel forces of equal magnitude but opposite direction applied to a structure .The bending moment magnitude is the same throughout the area between the force couples; hence, the structure being tested should fracture at its weakest point. This arrangement is advantageous for testing where one might be uncertain about the strongest or weakest point and does not wish to influence the test by locating the maximum bending moment at a specific place. The bending moment magnitude is the same throughout the area between the force couples.

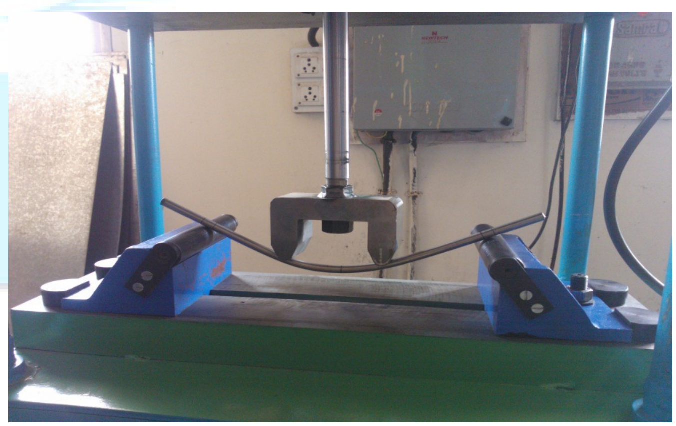


Fig.5 Four point bending of Bone implant material.

4. Result and Discussion

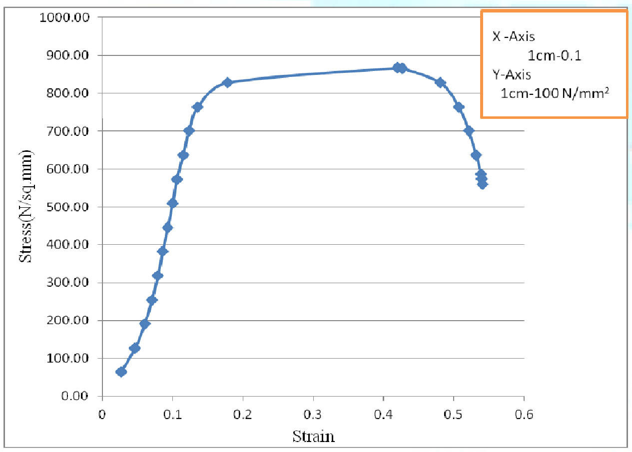
4.1 Testing of stainless steel (SS316L)

Tensile Test

Specification:
Diameter: Ø 10mm
Total Length: 300mm
Gauge Length: 50mm

Table 1: Tensile test result for stainless steel

Speci-men	*Breaking Load (KN)*	*Ultimate Load (KN)*	*Elongation (mm)*	*UTS (N/mm2)*
1	43.89	68.10	27.03	867.1845
2	42.69	68.35	29.38	870.2594
3	42.83	68.14	21.94	867.5856



Graph-1: Stain Vs Stress for specimen-1

Four Point Bending Test

Specification:
Diameter: Ø 10mm
Total Length: 400mm

Table 2: Four Point Bend test result for stainless steel

Speci-men	*Gauge length (mm)*	*Bending Load (N)*	*Max. Bending moment (KN-mm)*	*Bending stress (KN/mm²)*
1	300	2.21895	221.895	2.167
2	300	2.21895	221.895	2.08
3	200	3.28305	164.1525	1.6720
4	200	3.1944	159.72	1.6269

4.2 Testing of titanium alloy bar (Grade 5)

Torsional Test

Specification:
Diameter: Ø 8mm
Total Length: 150mm
Gauge Length: 100mm

Table 3: Torsional test result for Titanium alloy

Speci-men	*Breaking Torque (KN-mm)*	*Twist Angle (Ɵ Degree)*	*Modulus of rigidity (N/mm2)*
1	68	1926.5	503.13
2	70	1938.1	514.56

Four Point Bending Test

Specification:
Diameter: Ø 8mm
Total Length: 400mm

Table 4: Bending test result for Titanium alloy

Spec-imen	*Gauge length (mm)*	*Bending Load (KN)*	*Maxi. Bending moment (KN -mm)*	*Bending stress (KN/mm2)*
1	300	1.2423	124.23	1.2357
2	200	1.3301	66.5457	1.3239

4.3 Discussion

We performed test on both materials (SS316L & Titanium alloy Grade 5) stress evolved in SS316L was higher than that Titanium alloy , hence strength of Titanium alloy is greater than SS316L .

5. Conclusion

Thus we have successfully carried out important mechanical tests on different bone implant materials on conventional UTM as well as on Four-point bending machine.

The following conclusions are reported:

1) For stainless steel (316 L)
- Tensile strength= 868.3431 kN/mm2
- Bending strength= 1.9548 kN/mm2

2) For Titanium alloy (grade 5)
- The modulus of rigidity, G = 503.13 N/mm2
- Bending strength= 1.2798 kN/mm2

3) The material selected for bone implant is said to be suitable when physical strength of bone implant is

greater than or equal to twice the physical strength of the bone, this case is achieved.

4) Ti-6Al-4V has excellent Bio-compatible properties along with physical properties which makes it an ideal implant material for fractures, when compared to stainless steel.
5) Ti-6Al-4V alloy being extremely light with less density does not have any adverse effect on the patient and his movements i.e. while lifting the leg, etc.

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References

[1] H.G.Hanumantharaju & Dr.H.K.Shivanand, "Strength Analysis & Comparison of SS316L, Ti-6AI-4V & Ti-35Nb-7Zr-5Ta used as Orthopedic Implant Materials by FEA", International Conference on Chemical, Biological & Environmental Engineering (ICBEE), 2010, pp.101-105.

[2] Damien Subit, Eduardo del Pozo de Dios, Juan Velazquez-Ameijide,Carlos Arregui-Dalmasesa & Jeff Crandall, "Tensile material properties of human rib cortical bone under quasi-static and dynamic failure loading and influence of the bone microstructure on failure Characteristics", Physics.bio-ph,pp.1-22,2013.

[3] Faisal Wahib Adam, Joshua Ampofo & Raphael Kumah–Ametepey, "Bending Properties of Implants, Rate of Femur Fractures and Implants Failure in Ostoesynthesis, Reported at the Komfo Anokye Teaching Hospital, Kath, Kumasi-Ghana", International Journal of Engineering and Technology, 2013, pp.265-268.

[4] Raji Nareliya & Veerendra Kumar, "Biomechanical Analysis of Human Femur Bone", International Journal of Engineering Science and Technology (IJEST), 2011, pp.3090-3094.

[5] H.G.Hanumantharaju & Dr.H.K.Shivanand, "Static analysis of bi-polar femur bone implant using FEA", International Journal of Recent Trends in Engineering, pp. 118-121, 2009.

[6] C R Oldani1 & A A Dominguez, "Simulation of the mechanical behavior of a HIP implant fixed to bone by cementation under arbitrary load", Journal of Physics, 2007 pp. 142-146.

[7] Yoshihiro Noyama, Noriyuki Nagayama, Koichi Kuramoto & Takayoshi Nakano, "The optimal design of an implant to improve bone quality of implant surroundings based on stress analysis", Journal of Physics, 2009, pp. 1-5.

[8] Yegireddi Shireesha, Dr S. V. Ramana & P.Govinda Rao, Modelling, "static analysis of femur bone by using different implant materials", IOSR Journal of Mechanical and Civil Engineering, 2013, pp. 82-91.

[9] Mahmut Pekedis & Hasan Yildiz, "Comparison of fatigue behavior of eight different hip stems: a numerical and experimental study", J. Biomedical Science and Engineering, 2011, pp. 643-650.

[10] PSG College of Tech., Design Data Book, Kalaikathir Achchagam, Coimbatore, 2011, pp.1.1-1.42.

[11] J.E.Shigley Mechanical Engineering Design, Mc Graw-hill education, Singapore, 1986, pp.291-298, 336-342.

[12] V.B.Bhandari, Design of Machine Elements, 3rd ed., Mc Graw-hill education, New Delhi, pp.26-38, 224-227, 2011, 844-854.

[14] Yuehuei.H.An & Robert.A.Draughn, Mechanical Testing of Bone and the Bone-Implant Interface, CRC Press, Washington, 2000, PP. 3-219.