Kafrelsheikh University
Faculty of Engineering
Mechanical Engineering Department
1st year- bylaw 2007
Final Exam 2016-2017

Materials Engineering & Testing
June 3, 2017, 10 AM- 1 PM
Time :3 Hrs
Total marks : 120

نموذج الاجابة

This exam measures the following ILOs; a.3.1, a.3.2, a.3.3, a.3.4, a.8.1, a.8.2, a.13.1, a.13.2, a.13.3, a.13.4, a.13.5, a.19.1, a.19.2, a.19.3, a.19.4, b.2.1, b.2.2, b.2.3, b.6.1, b.6.2, c.3.1, c.3.2, c.3.3, c.17. 1, c.17.2, c.17.3, and c.17. 1.

Question No. 1(40 Marks):

Put (√) or (×) in the front of each of the following sentence:

1	Close-packed planes are planes with the highest possible planar density.	(√)
2	The units of toughness and resilience are same.	(√)
3	Ductility may be expressed quantitatively in elongation percent as $\%EL = 100(l_f-l_o)/l_f$	(√)
4	Linear elastic deformations are permanent deformations.	(×)
5	In creep test strain rate is equal zero.	(×)
6	Maxwell model cannot be used to evaluate material properties in tensile test	(√)
7	Dashpots have instantaneous response with respect to load.	(×)
8	Kelven and Voiget models are different viscoelastic models.	(×)
9	The true stress strain relation in plastic zone can be expressed as $\sigma = [k/(1+\varepsilon)]\ [\ln(1+\varepsilon)]^n$	(×)
10	For Brinell hardness test three types of indenters are available.	(×)
11	Lattice parameter can be measured within 0.5 – 50 A^o.	(√)
12	All metals in elevated temperature are viscoelastic materials	(√)
13	Viscoelastic behavior is linear elastic behavior	(×)
14	Diffusion coefficient is independent on material and temperature.	(×)
15	Conversations between hardness results of different scales are impossible	(×)
16	Superficial Rockwell are used for microhardness test	(√)
17	Loads used for Rockwell hardness test are 60 kg, 100kg and 150 kg.	(√)
18	Colombia space shuttle was lost due to using FGM	(×)
19	FGMs are used in bone replacement	(√)
20	FGMs are used in electric power transportations	(×)
21	Recently polymers are used in electric power transportations	(√)
22	Elastic modulus of ceramics are lower than that that of metals	(×)
23	Fracture toughness of ceramics are higher than that of metals	(×)
24	Generally, for steel HB and the tensile strength are related according to TS(MPa) = 3.45 x HB	(√)
25	X-ray diffraction method can be used to measure the inter atomic distance of polymers	(×)

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26	Kelven model cannot be used to evaluate viscoelastic material properties in relaxation test	(√)
27	X-Ray diffraction method measures lattice parameter within 0.5 – 50 A^{o}.	(√)
28	Close-packed direction is plane with the highest possible linear density.	(×)
29	Linear elastic deformations are nonpermanent deformations.	(√)
30	In relaxation test strain rate is equal zero.	(√)
31	For isotropic materials mechanical properties from tensile and compression tests are different	(×)
32	For most of metals values of yields stress in shear is twice it value in tension	(×)
33	Strain hardening exponent is equal to true tensile strength at ultimate points	(×)
34	Viscoelastic properties of material can be determine from relaxation test using Kelven model	(×)
35	FGM can be used in manufacturing of fuel cell	(√)
36	Resilience can be defined as the require energy per unit volume of material to induce failure.	(×)
37	Corrective stress strain curve values are lower that of engineering one.	(×)
38	Most of metals are crystalline in the simple hexagonal structure due to its poor APF	(×)
39	Ashby charts are used in metal forming process	(×)
40	X-ray diffraction technique can measure lattice dimensions for polymers.	(×)
41	ASTM is a material properties	(×)
42	Toughness of brittle materials are higher than that of ductile materials	(×)
43	RCC composites strength increases with increasing temperature	(√)
44	Mechanical properties can be determine from tensile or compression test usually	(√)
45	Bucking is a precaution that should be considered in compression test	(√)
46	Friction effect is an important parameter that should be eliminated during tensile test	(×)
47	Design of machine elements depends on plastic properties	(×)
48	Spinning is a metal forming process that depends on plastic properties	(√)
49	Deep drawing process can be used in production of stainless steel pans	(√)
50	Most of metals are crystalline materials	(×)
51	Some of polymers are crystalline materials	(×)
52	Gold electric resistivity is zero	(×)

Best wishes
Prof. Mahmoud Nemat-Alla

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53	Materials engineering is a recent approach	(×)
54	FGM are conventional composite materials	(×)
55	Elastic deformation is a reversible process	(√)
56	All metals are ductile in elevated temperature	(√)
57	The total number of atoms in the large HCP cell is six	(√)
58	X-ray diffraction method can be used to measure the inter atomic distance of polymers	(×)
59	There are four atoms per BCC cell	(×)
60	For isotropic materials stress-strain curves from compression and tensile tests are same.	(√)
61	Toughness and resilience are same for brittle materials	(√)
62	For ductile materials resilience is less than toughness.	(√)
63	For linear elastic deformation $\sigma = E \varepsilon$	(√)
64	Elastic recovery induced when removing loads during elastic deformation	(×)
65	FCC and HCC have the same packing factor	(√)
66	Vacancy diffusion induced only between the same materials atoms.	(√)
67	Diffusion flux is the mass diffused through and perpendicular to unite cross sectional area per unit time.	(√)
68	Nonlinear elastic behavior is a viscoelastic behavior	(√)
69	For onset yielding strain offset of 0.002 can be efficiently used to identify yield stress.	(×)
70	Creep test is used only in determining viscoelastic properties.	(√)
71	Diffraction condition is $n \lambda = 2 \sin 2\theta$	(×)
72	Ashby charts relate two or more material properties	(√)
73	FGM material properties can be expressed in exponential function or volume fractions	(√)
74	Instantaneous response of spring is equal zero.	(×)
75	Necking occurs just after yield point	(×)
76	Unloading during plastic deformation is parallel to elastic behavior	(√)
77	Relating ultimate tensile strength and hardiness is possible	(√)
78	Stress concentrations are excluded using standard tensile test specimen.	(√)
79	Buckling is excluded by using standard tensile test specimen.	(×)
80	Friction is and important parameter that should be excluded during compression test.	(√)

Best wishes
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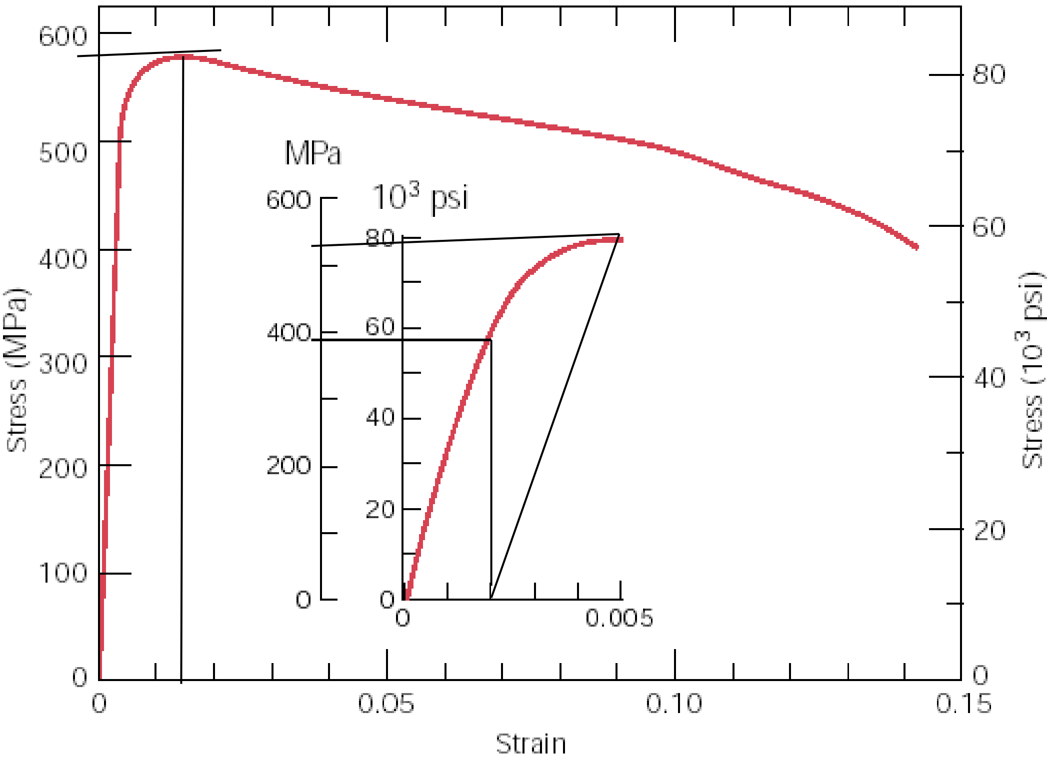
Question No. 2 (`25 Marks):

The stress-strain curve for a steel alloy is shown in the given figure. It is required to use it to find the following:-



1- Elastic modulus.
2- Yield stress.
3- Ultimate tensile strength.
4- Brinell hardness number.
5- Elongation percent.
6- Strain hardening exponent.
7- Resilience

Solution

1- E = sloop = 390/0.002
=195000 MPa =195 GPa

2- σ_y = 530 Mpa

3- σ_u = 580 Mpa

4- Since TS(MPa) = 3.45 x HB
Then HB = σ_u/3.45 =
=580/ 3.45 =168.12 HB

5- $\%EL = 100(l_f - l_o)/l_o = \varepsilon_f \%$ = **0.1425*100 =14.25%**

6- n = ε_T at ultimate point = ln(1+ε_υ)= ln (1+0.014)= 0.0139

7- Resilience = $U_r = \sigma_y^2/2\,E = 530^2/(2*195000)$ **=0.72 MPa**

Question No. 3(15 Marks):

It is required to design a light, stiff, end-loaded simply supported beam with a square cross section. Where, the maximum deflection is expressed as $Fl^3/48EI$. For this we will use the mass *m* of the beam for the performance metric to minimize. Which materials are suitable for such application if the elastic modulus should be greater than 100 GPa.

Solution:

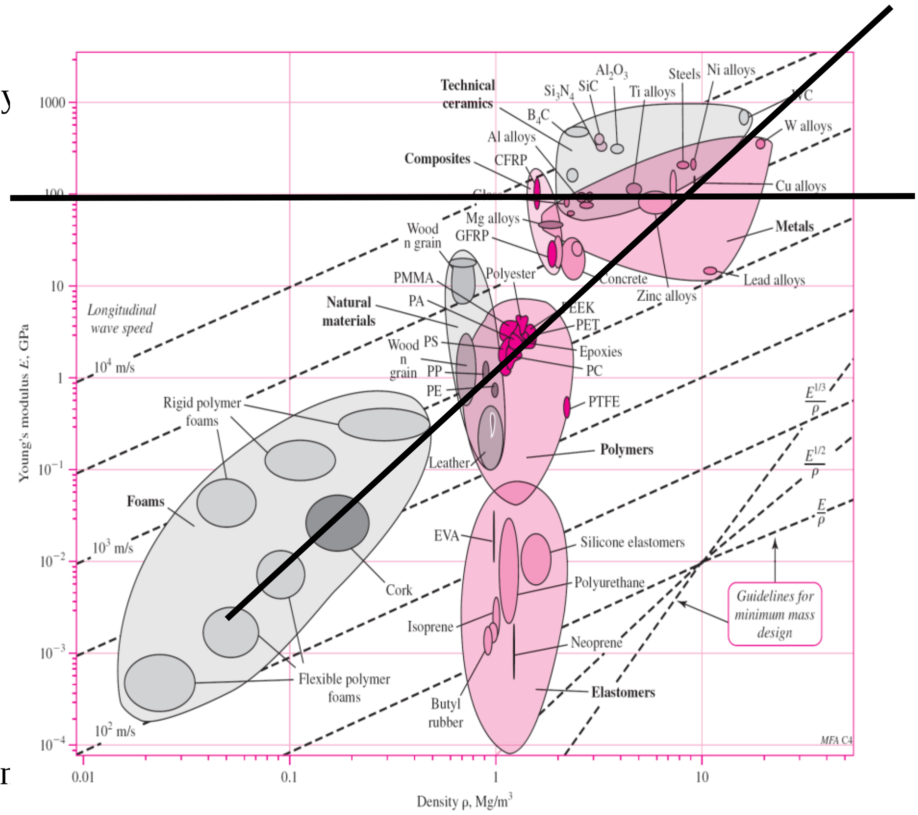
The stiffness of the beam is related to its material and geometry. The stiffness of a beam is given by $k = F/\delta$, where F and δ are the center load and deflection, respectively. The maximum deflection of an the beam is given as $\delta = y_{\max} = (Fl^3)/(48E\ I\ )$, where E is Young's modulus, I the second moment of the area, and l the length of the beam. Thus, the stiffness is given by

$$k = F/\delta = 48E\ I/l^3 \qquad (1)$$

The second moment of the area of square cross section is

$$I = a^4/12 = A^2/12 \qquad (2)$$

where a and A are the side length and area of the square cross section respectively.



Substituting Eq. (2) in (1) and solving for A, we obtain

$$A = (kl^3/4E)^{1/2} \qquad (3)$$

The mass of the beam is given by $m = Al\rho$ (4)

Substituting Eq. (3) into (4) and rearranging yields $m = (kl^3/4E)^{1/2}\ l\ \rho$

$$= (1/2)\,(k^{1/2})(l^{5/2})\ (\rho/E^{1/2}\ ) \qquad (5)$$

From Eq. (5) is of the term 1/2is simply a constant and can be associated with any function,. Thus, $f_1(F) = (k^{1/2})/2$ is the functional requirement, stiffness; $f_2(G) = (l^{5/2})$, the geometric parameter, length; and the material efficiency coefficient

$$f_3(M) = \rho/E^{1/2} \qquad (6)$$

is the material property in terms of density and Young's modulus. To minimize m we want to minimize $f_3(M)$, or maximize

$$M = E^{1/2}/\rho \qquad (7)$$

where M is called the *material index*, and $\beta = 1/2$.

Other limits or constraints may warrant further investigation. Say, for further illustration, the design requirements indicate that we need a Young's modulus greater than 100 GPa.

The search region as shown in the Figure further reduced by restricting $E \geq 100$ GPa. Will leads to metals like, Ti alloys, steels and Ni alloys. Also, some kind of composites can be used.

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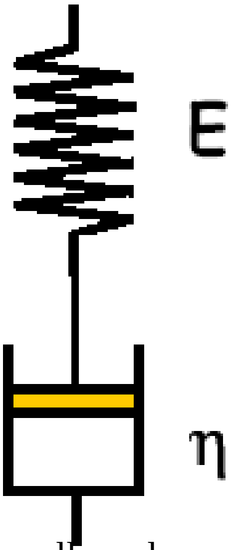
Question No. 4 (15 Marks):

Prove that for Maxwell model E = G(0) and η =E t_1/ln[E/G(t_1)]. Where G(t) is the relaxation modulus and t_1 is an arbitrary time greeter than zero.

solution

Let us assume that the Maxwell system is subjected to applied stress σ (t) that will induce a strain ε (t) therefore,



For dashpot

$$\sigma_d = \eta\,(d\varepsilon_d/dt)$$

but for Maxwell system

$$\sigma = \sigma_d = \sigma_s$$

and $\varepsilon = \varepsilon_d + \varepsilon_s$

therefore,

$$\frac{d\varepsilon}{dt} = \frac{d\varepsilon_s}{dt} + \frac{d\varepsilon_d}{dt}$$

From the above equations the general deferential equation that represents Maxwell mode can be obtained as,

$$\frac{d\varepsilon}{dt} = \frac{1}{E}\frac{d\sigma}{dt} + \frac{\sigma}{\eta} \qquad (1)$$

Relaxation modulus for Maxwell model;

$$\frac{d\varepsilon}{dt} = 0 \qquad \varepsilon = \varepsilon_o$$

For relaxation

Maxwell model general deferential equation for creep, equation (1), will be of the form,

$$\frac{1}{E}\frac{d\sigma}{dt} + \frac{\sigma}{\eta} = 0$$

The above equation can be rearranged as;

$$\frac{d\sigma}{\sigma} = -\frac{E}{\eta}dt$$

The general solution of the above differential equation will be as;

$$\sigma(t) = E\varepsilon_o \exp(-\frac{E_o}{\eta}t) \qquad (2)$$

and the creep compliance of Maxwell model will be

$$G(t) = \frac{\sigma(t)}{\varepsilon_o} = E\exp(-\frac{E_o}{\eta}t) \qquad (3)$$

From equations (3) for t =0 it can be found that

$$G(0) = \frac{\sigma(0)}{\varepsilon_o} = E\exp(-\frac{E_o}{\eta}0) = E$$

Also, from equations (3) for t =t_1 it can be found that

$$G(t_1) = E\exp(-\frac{E_o}{\eta}t_1)$$

$$\frac{G(t_1)}{E} = \exp(-\frac{E_o}{\eta}t_1)$$

$$\ln\left[\frac{G(t_1)}{E}\right] = (-\frac{E_o}{\eta}t_1)$$

$$\eta = (-\frac{E_o t_1}{\ln\left[\frac{G(t_1)}{E}\right]})$$

$$\eta = \frac{E_o t_1}{\ln\left[\frac{E}{G(t_1)}\right]}$$

where σ_o and ε_o are initial stress and the constant strain, applied load.

Question No. 5 (10 Mark)

State 6 problems solved by materials engineering, then explained one of them in detail.

SOLUTION:

1- Problem of thermal protection system for space chattels
2- Problem of thermal cracking of cutting tools
3- Problem of stress singularities in bone replacement
4- Problem of failure of mud houses and using composite mud.
5- Cracking of fuel cells due to using of dissimilar materials
6- Failure of anode in aluminum reduction cells due to using bi metallic plates.

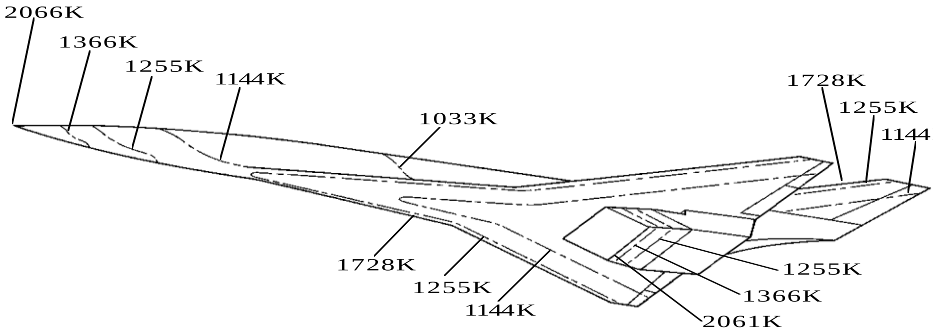


Fig.1. Temperature distributions in the new aerospace craft that flight at a speed of Mach 8 and altitude of 29 km.

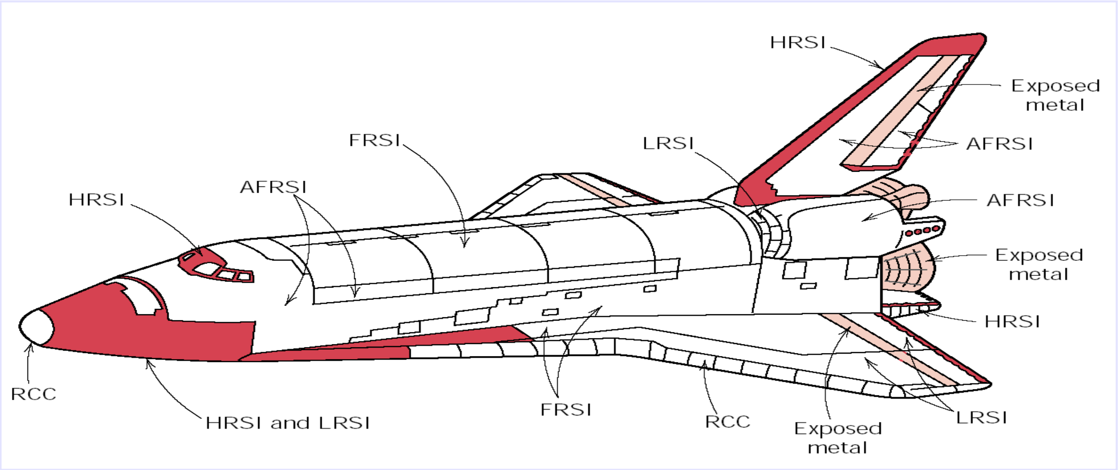


Fig. 2. Locations of the various components of the thermal protection system on the Space Shuttle Orbiter: AFRSI, advanced flexible reusable surface insulation; FRSI, felt reusable surface insulation; LRSI, low-temperature reusable surface insulation; RCC, reinforced carbon–carbon composite. HRSI, high-temperature reusable surface insulation.

Using of FGM in thermal protection system.

The structural components and machine elements of space planes, ultra/super/hypersonic air planes for supersonic transport and nuclear fusion reactors are subjected to ultra-high temperatures, ultra high temperature gradient and cyclical changes of ultra-high temperatures as shown in Fig. 1. Such sever thermal loading requires effective high temperature resistant materials to protect and improve the strength of such machine elements, as shown in Fig. 2. .

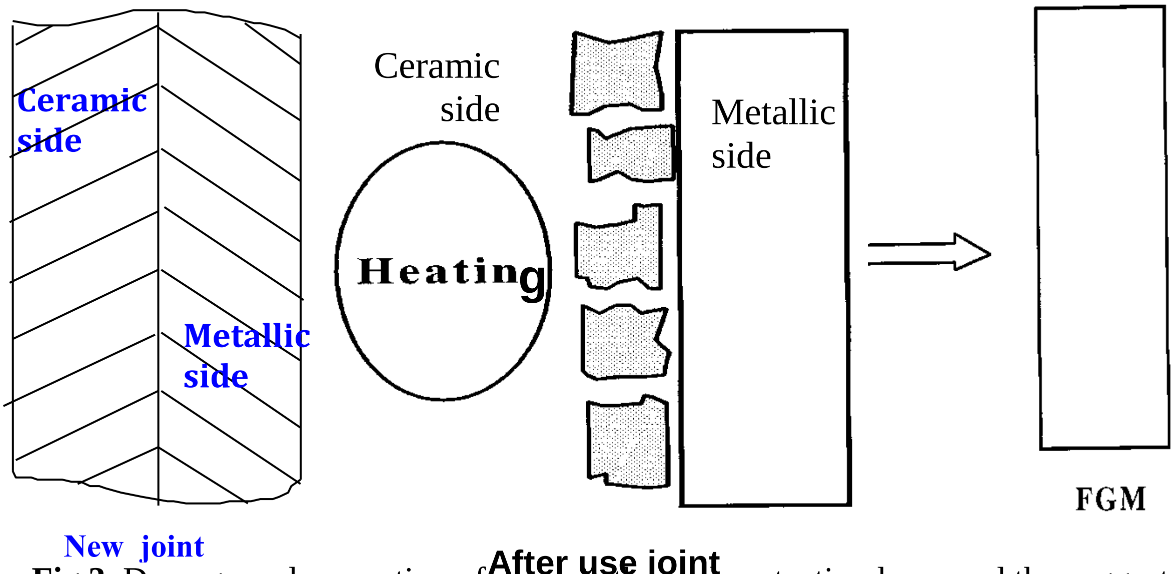
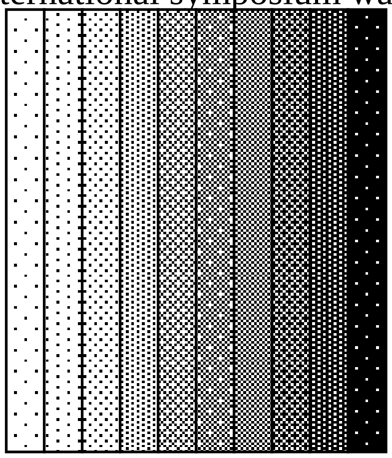


Fig 3. Damage and separation of ceramic thermal protection layer and the suggested solution..

In 1987, a Japanese national project, entitled Research on the basic technology for development of functionally graded materials for relaxation of thermal stresses, was started to introduce such material. Then active and continuous research work was carried out and the first functionally graded material international symposium was held in Sendai in 1990.



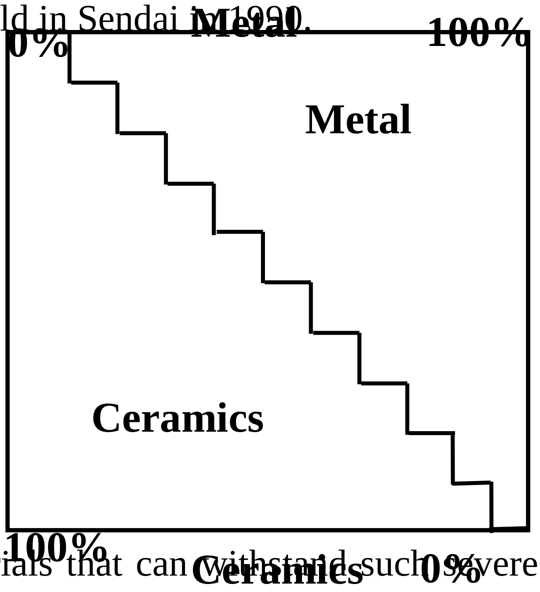
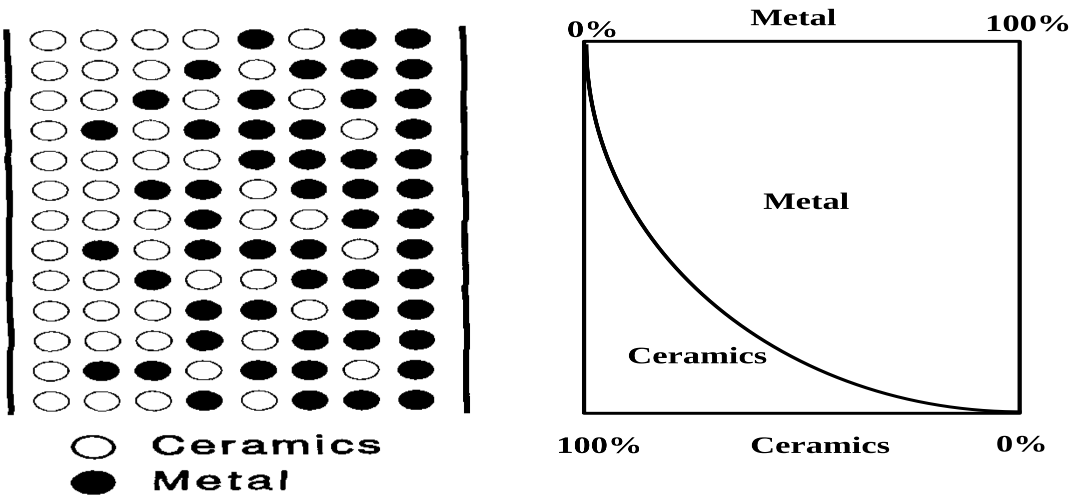


Fig . 4 Functionally graded layers concept

At that time there were no industrial materials that can withstand such severe thermo-mechanical loadings. In the design of such machine elements and structures several different thermal protection materials, pure ceramic tiles, which satisfy the required criteria for a specific region of the spacecraft outer surface are used.

Unfortunately, such design has the drawbacks of the composite layers, cracking, separation through layers interface and low mechanical strength as shown in Fig. 3



(a) **(b)**

Fig. 5 (a) Representation of ceramics to metal distribution in FGM (b) Gradation of ceramic and metal in FGM

<u>Question No. 6 (15 Mark)</u>

Write 15 applications for FGM.

SOLUTION:

1. Functionally graded prosthesis joint increasing adhesive strength of the joint and reducing stress concentrations in the adhesively bonded zone.
2. Functionally graded polyester-calcium phosphate materials used for bone replacement with a controllable in vitro polyester degradation rate and increases live of the replaced bone.
3. Functionally graded Thermal Barrier Coatings TBCs used for combustion chambers increase engine life
4. Functionally graded layer between the Cr–MO shank and ceramic tip of a cutting tool improving the thermal strength.
5. Functionally graded piezoelectric actuators overcome on the stress concentrations and prevent separation that induced between piezoelectric materials and holding plates.
6. Functionally graded thermal protection systems for spacecraft hypersonic, and supersonic planes as explained before.
7. FGMs also find application as furnace liners and thermal shielding elements in microelectronics.

8. Functionally graded materials are used in journal bearing in order to improve its efficiency and life.
9. FGM is used in aluminum reduction cell anode to increase its life and efficiency.
10. FGM is used in fuel cell design to improve it efficiency and increase its life.
11. FGM is used in atomic reactors to improve it efficiency and increase its life.
12. FGM is used in design of concrete to improve it efficiency and increase its life.
13. FGM is used in sensors manifesting.
14. FGM is used to eliminate stress concentrations in dissimilar materials.
15. FGM is used in manufacturing of compassion chambers.