14 Years
Previous Solved Papers

GATE 2021

Production & Industrial Engineering

- Topicwise presentation
- Fully solved with explanations

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GATE - 2021 : Production & Industrial Engg. Topicwise Previous GATE Solved Papers (2007-2020)

First Edition : 2020

Preface

B. Singh (Ex. IES)

Over the period of time the GATE examination has become more challenging due to increasing number of candidates. Though every candidate has ability to succeed but competitive environment, in-depth knowledge, quality guidance and good source of study is required to achieve high level goals.

The new edition of **GATE 2021 Solved Papers : Production and Industrial Engineering** has been fully updated. The while book has been divided into topicwise sections.

I have true desire to serve student community by way of providing good source of study and quality guidance. I hope this book will be proved an important tool to succeed in GATE examination. Any suggestions from the readers for the improvement of this book are most welcome.

B. Singh (Ex. IES)
Chairman and Managing Director
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UNIT III

Manufacturing Process-I

Syllabus :

Casting : Types of casting processes and applications; patterns – types and materials; allowances; moulds and cores – materials, making and testing; casting techniques of cast iron, steels and non-ferrous metals and alloys; analysis of solidification and microstructure development; design of gating and riser; origin of defects.

Metal Forming : Stress-strain relations in elastic and plastic deformation; concept of flow stress; hot and cold working – forging, rolling, extrusion and wire drawing; sheet metal working processes – blanking, bending and deep drawing; ideal work and slab analysis; origin of metal working defects.

Joining of Materials : Principles of fusion welding processes (manual metal arc, MIG, TIG, plasma arc, submerged arc welding processes) – different heat sources (flame, arc, resistive, laser, electron beam), and heat transfer and associated losses, flux application, feeding of filler rod; Principles of solid state welding processes (friction, explosive welding, ultrasonic welding processes); Principles of adhesive, brazing and soldering processes; Origins of welding defects.

Power Processing : Production of metal/ceramic powders, compaction and sintering of metals and ceramic powders.

Polymers and Composites : Plastic processing – injection, compression and blow molding, extrusion, calendaring and thermoforming; molding of composites.

1 Casting

1.1 "Matching Exercise". Choose the correct one out of the alternatives *A*, *B*, *C*, *D*

Group 1
P – Sand casting
Q – Centrifugal casting
R – Investment casting
S – Die casting

Group 2
1 – Turbine blades
2 – I.C. engine pistons
3 – Large bells
4 – Pulleys

(a) P-4, Q-1, R-3, S-2 (b) P-2, Q-4, R-3, S-1
(c) P-3, Q-4, R-1, S-2 (d) P-3, Q-2, R-1, S-4

[2007 : 2 Marks]

Statement for Linked Answer Questions 1.2 and 1.3:

In a sand casting process, a sprue of 10 mm base diameter and 250 mm height leads to a runner which fills a cubical mould cavity of 100 mm size

1.2 The volume flow rate (in mm^3/s) is
(a) 0.8×10^5 (b) 1.1×10^5
(c) 1.7×10^5 (d) 2.3×10^4

[2007 : 2 Marks]

1.3 The mould filling time (in seconds) is
(a) 2.8 (b) 5.78
(c) 7.54 (d) 8.41

[2007 : 2 Marks]

1.4 In hollow cylindrical parts, made by centrifugal casting, the density of the part is
(a) maximum at the outer region
(b) maximum at the inner region
(c) maximum at the mid-point between outer and inner surfaces
(d) uniform throughout

[2008 : 1 Mark]

1.5 In sand casting of a hollow part of lead, a cylindrical core of diameter 120 mm and height 180 mm is placed inside the mould cavity. The densities of core material and lead are 1600 kg/m^3 and 11,300 kg/m^3 respectively. The net force (in N) that tends to lift the core during pouring of molten metal will be
(a) 19.7 (b) 64.5
(c) 193.7 (d) 257.6

[2008 : 2 Marks]

1.6 Hot chamber die casting process is not suited for
(a) Lead and its alloys
(b) Zinc and its alloys
(c) Tin and its alloys
(d) Aluminum and its alloys

[2009 : 1 Mark]

1.7 A solid cylinder of diameter *D* and height equal to *D*, and a solid cube of side *L* are being sand cast by-using the same material. Assuming there is no superheat in both the cases, the ratio of solidification time of the cylinder to the solidification time of the cube is
(a) $(L/D)^2$ (b) $(2L/D)^2$
(c) $(2D/L)^2$ (d) $(D/L)^2$

[2009 : 2 Marks]

1.8 During the filling process of a given sand mould cavity by molten metal through a horizontal runner of circular cross-section, the frictional head loss of the molten metal in the runner will increase with the
(a) increase in runner diameter
(b) decrease in internal surface roughness of runner
(c) decrease in length of runner
(d) increase in average velocity of molten metal

[2010 : 1 Mark]

1.9 Solidification time of a metallic alloy casting is
(a) directly proportional to its surface area
(b) inversely proportional to the specific heat of the cast material
(c) directly proportional to the thermal diffusivity of the mould material
(d) inversely proportional to the pouring temperature

[2010 : 1 Mark]

Answers Casting

1.1	(c)	1.2	(c)	1.3	(b)	1.4	(a)	1.5	(c)	1.6	(d)	1.7	(d)
1.8	(d)	1.9	(c)	1.10	(a)	1.11	(b)	1.12	(c)	1.13	(b)	1.14	(b)
1.15	(a)	1.16	(b)	1.17	(b)	1.18	(190.546)	1.19	(0.9016)	1.20	(c)	1.21	(d)
1.22	(d)	1.23	(a)	1.24	(b)	1.25	(29.2893)	1.26	(36.5898)				

Explanations Casting

1.1 (c)

Given : Group 1 and Group 2

To find : A match between group 1 and group 2.

P : Sand casting is used for making large bells.

Q : Centrifugal casting is used for making pulleys.

R : Investment casting is used for making turbine blades.

S : Die casting is used for making IC engine pistons.

1.2 (c)

Given : A sand casting process.

Base diameter of sprue,

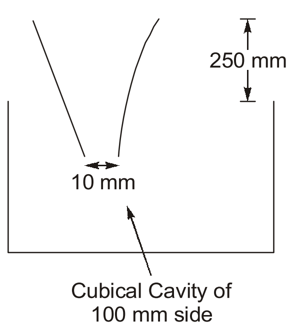
$$d = 10 \text{ mm}$$

Height of sprue,

$$h = 250 \text{ mm}$$

Cubical casting of side,

$$L = 100 \text{ mm}$$



To find : The volume flow rate, Q.

We know that $Q = A \times v$

where A = Area of sprue at end

and v = Velocity of molten metal at end of sprue

$$= \sqrt{2gh}$$

$$= \sqrt{2 \times 9.81 \times 0.25} \text{ m/s}$$

$$= 2.2147 \text{ m/s}$$

$$v = 2214.7234 \text{ mm/s}$$

Area at end of sprue,

$$A = \frac{\pi}{4}(d)^2 = \frac{\pi}{4}(10)^2$$

$$= 78.5398 \text{ mm}^2$$

So, $$Q = A \times v$$

$$= 78.5398 \times 2214.7234 \text{ mm}^3/\text{s}$$

$$= 173943.9691 \text{ mm}^3/\text{s}$$

$$= 1.7394 \times 10^5 \text{ mm}^3/\text{s}$$

1.3 (b)

To find : The mould filling time (in seconds). The mould filling time, T, can be found out using $T = \frac{V}{Q}$, where V = Volume of mould and Q = Volume flow rate.

$$T = \frac{V}{Q}$$

Volume, $V = 100 \times 100 \times 100$ mm as it is a cube of 100 mm side.

and $Q = 1.7394 \times 10^5 \text{ mm}^3/\text{s}$

$$T = \frac{100 \times 100 \times 100}{1.7394 \times 10^5} \frac{\text{mm}^2 \times \text{s}}{\text{mm}^3}$$

$$T = 5.748977 \text{ secs}$$

So, mould filling time,

$$T = 5.748977 \text{ s}$$

1.4 (a)

Due to centrifugal force more material will be there in the outer region so density will be maximum at outer region.

1.5 (c)

Given : Diameter of core = 120 mm = 0.12 m

Height of core = 180 mm = 0.18 m

Density of core material,

$$\rho_{core} = 1600 \text{ kg/m}^3$$

Density of lead material,

$$\rho_{lead} = 11300 \text{ kg/m}^3$$

To find : net force that tends to lift the core.

Downward force = Weight of core = $\rho_{core} \times V \times g$

V = Volume of core

$$= \frac{\pi}{4}(0.12)^2 \times 0.18$$

$$= 2.035 \times 10^{-3} \text{ m}^3$$

$$V = 2.035 \times 10^{-3} \text{ m}^3$$

Downward force = $1600 \times 2.035 \times 10^{-3} \times 9.81$

= 31.953 N

Upward force = Buoyancy force

= Weight of liquid displaced

Upward force = $\rho_{lead} \times V \times g$

$= 11300 \times 2.035 \times 10^{-3} \times 9.81$

= 225.585 N

Net force that tend to lift core

= Upward force – Downward force

= (225.585 – 31.953) N

= 193.6328 N ≈ 193.7 N

1.6 (d)

Melting temperture of aluminium is high as compared to lead, tin and zinc. So, Aluminium and its alloys are not used in hot chamber die casting.

1.7 (d)

Given:

Diameter of cylinder = D

Height of cylinder = D

Side of cube = L

Casting of cylinder and cube are made of same material.

To find ratio of solidifcation time of cylinder to that of cube.

We know that solidification time,

$$T = \gamma\left(\frac{V}{A}\right)^2$$

where γ = Constant

V = Volume of casting

A = Area of casting

For cylinder,

$$T_{cylinder} = \gamma\left(\frac{\frac{\pi}{4}D^2 \times D}{2 \times \frac{\pi}{4}D^2 + \pi D^2}\right)^2$$

$$= \gamma\left(\frac{\frac{\pi}{4}D^3}{6\frac{\pi}{4}D^2}\right)^2 = \gamma\left(\frac{D}{6}\right)^2 \quad \text{...(1)}$$

For cube,

$$T_{cube} = \gamma\left(\frac{L^3}{6L^2}\right)^2 = \gamma\left(\frac{L}{6}\right)^2 \quad \text{...(2)}$$

$$\frac{T_{cylinder}}{T_{cube}} = \gamma\left(\frac{D}{6}\right)^2 \times \frac{1}{\gamma}\left(\frac{6}{L}\right)^2 = \frac{D^2}{L^2}$$

$$\frac{T_{cylinder}}{T_{cube}} = \left(\frac{D}{L}\right)^2$$

1.8 (d)

We know that frictional head loss is

$$h_f = \frac{4fLV^2}{2gD}$$

where, f = Friction coefficient

L = Length

V = Velocity

D = Diameter

As diameter ↑↑ h_f ↓↓

As roughness ↓↓ f ↓↓, h_f ↓↓

As length ↓↓ h_f ↓↓

As velocity ↑↑ h_f ↑↑

1.9 (c)

We know that solidification time, T_S is given as

$$T_S = \gamma\left(\frac{V}{A}\right)^2$$

where γ = Mold constant

V = Volume of casting

A = Surface area of casting

and
$$\gamma = \left[\frac{\rho_m\sqrt{\pi\alpha}[L + C_m(\theta_P - \theta_f)]}{2k(\theta_f - \theta_o)}\right]^2$$

ρ_m = Density of metal

α = Thermal diffusivity of mold

L = Latent heat of metal

C_m = Specific heat of metal

θ_p = Pouring temperature

θ_f = Freezing temperature

θ_o = Initial temperature of mold

So, solidifcation time is directly proportional to thermal diffusivity of mold.

1.10 (a)

Fluidity of molten metal can be increased by increasing the degree of superheat.

1.11 (b)

Investment casting is the casting process that uses expandable pattern and expendable mould.

1.12 (c)

Given volume of sphere = Volume of cylinder
Casting condition and metal are same.
Height of cylinder = Diameter of cylinder
To find :

$$\frac{T_{sphere}}{T_{cylinder}} = \frac{\text{Solidification time of sphere}}{\text{Solidification time of cylinder}}$$

Volume of sphere = Volume of cylinder

Let r = Radius of sphere
d = Diameter of cylinder
= Height of cylinder

$$\frac{4}{3}\pi r^3 = \frac{\pi}{4}d^2 h \quad (\text{as } d = h)$$

$$\frac{4}{3}\pi r^3 = \frac{\pi}{4}d^3$$

$$r^3 = \frac{3}{16}d^3$$

$\Rightarrow$ $r = 0.5723d$

T = Solidification time
γ = Mold constant

We know that, $T = \gamma\left(\frac{V}{A}\right)^2$

V = Volume
A = Area

$$T_{sphere} = \gamma\left(\frac{4}{3}\frac{\pi r^3}{4\pi r^2}\right)^2 = \gamma\left(\frac{r}{3}\right)^2$$

$$T_{cylinder} = \gamma\left(\frac{\frac{\pi}{4}d^3}{2\times\frac{\pi}{4}d^2 + \pi d^2}\right)$$

$$= \gamma\left(\frac{\frac{\pi}{4}d^3}{\pi\left(\frac{d^2}{2} + d^2\right)}\right)^2$$

$$= \gamma\left(\frac{2d^3}{4d^2}\right)^2 = \gamma\left(\frac{d}{6}\right)^2$$

$$\frac{T_{sphere}}{T_{cylinder}} = \gamma\left(\frac{r}{3}\right)^2 \times \left(\frac{6}{d}\right)^2 \times \frac{1}{\gamma}$$

$$= \frac{r^2}{9} \times \frac{36}{d^2}$$

$$= \frac{(0.5723)^2 d^2 \times 36}{9 \times d^2}$$

$$\frac{T_{sphere}}{T_{cylinder}} = 1.31$$

1.13 (b)

Given : Dimension of mould as 100 mm × 90 mm × 20 mm.
Height of molten metal = h
Cross-section at area of gate = A
Mould filling time is t_1.

Now $h_{new} = 4h$ and $A_{new} = \frac{A}{2}$ and mould filling time is t_2.

To find $\frac{t_2}{t_1}$

This is case of vertical gating.

$$t_f = \frac{V}{A_g\sqrt{2gh}}$$

where, t_f = Mould filling time,
V = Volume of casting,
A_g = Gate cross-section area

$$t_1 = \frac{V}{A_g\sqrt{2gh}}$$

and

$$t_2 = \frac{V}{\frac{A}{2}\sqrt{2g4h}} = \frac{V}{A\sqrt{2gh}}$$

$$\frac{t_2}{t_1} = \frac{V}{A\sqrt{2gh}} \times \frac{A\sqrt{2gh}}{V} = 1$$

$$\Rightarrow \quad \frac{t_2}{t_1} = 1$$

1.14 (b)

Given : Solidification time of a cubical casting = 5 mins.

To find solidification time another cubical casting of same material but 8 times heavier, we know that density,

$$\rho = \frac{\text{Mass } (m)}{\text{Volume } (V)}$$

Since, the material of casting is same so their density is same.

1.26 (36.5898)

Given : Dimension of mould cavity as 60 cm × 40 cm × 20 cm.
Solidification time of riser = 25% higher than solidification time of casting
Height of riser, h = diameter of riser, d
To find : Diameter of riser, using Chvorinov's rule.
We know that Chvorinov's rule is given as :

$$T = \gamma\left(\frac{V}{A}\right)^2$$

where, T = Solidification time of casting
γ = Mould constant
V = Volume of casting
A = Surface area of casting

For casting, $T_C = \gamma\left(\frac{V_C}{A_C}\right)^2$

$$V_C = 60 \times 40 \times 20 \text{ cm}^3$$
$$A_C = 2 \times (60 \times 40 + 40 \times 20 + 60 \times 20)$$
$$T_C = \gamma\left(\frac{60 \times 40 \times 20}{8800}\right)^2$$
$$\Rightarrow \quad T_C = \gamma(5.4545)^2 \quad \text{...(1)}$$

For riser, $T_R = \gamma\left(\frac{V_R}{A_R}\right)^2$

$$V_R = \frac{\pi}{4}d^3$$
$$A_R = 2 \times \frac{\pi}{4}d^2 + \pi d^2 = \frac{3}{2}\pi d^2$$
$$T_R = \gamma\left(\frac{\frac{\pi}{4}d^3}{\frac{3}{2}\pi d^2}\right)^2$$
$$\Rightarrow \quad T_R = \gamma\left(\frac{d}{6}\right)^2 \quad \text{...(2)}$$

It is given that

$$T_R = 1.25T_C$$

From eqn. (1) and (2),

$$\gamma\left(\frac{d}{6}\right)^2 = \gamma(5.4545)^2 \times 1.25$$

Since casting and riser have same mould and material so their 'γ' mould constant is same.

$$\frac{d^2}{36} = 1.25 \times 29.7520$$
$$\Rightarrow \quad d^2 = 1338.820661$$
$$d = 36.5898 \text{ cm}$$

So, diameter of riser is 36.5898 cm.

■■■■