GATE 2024

GATE

प्रचण्ड Batch

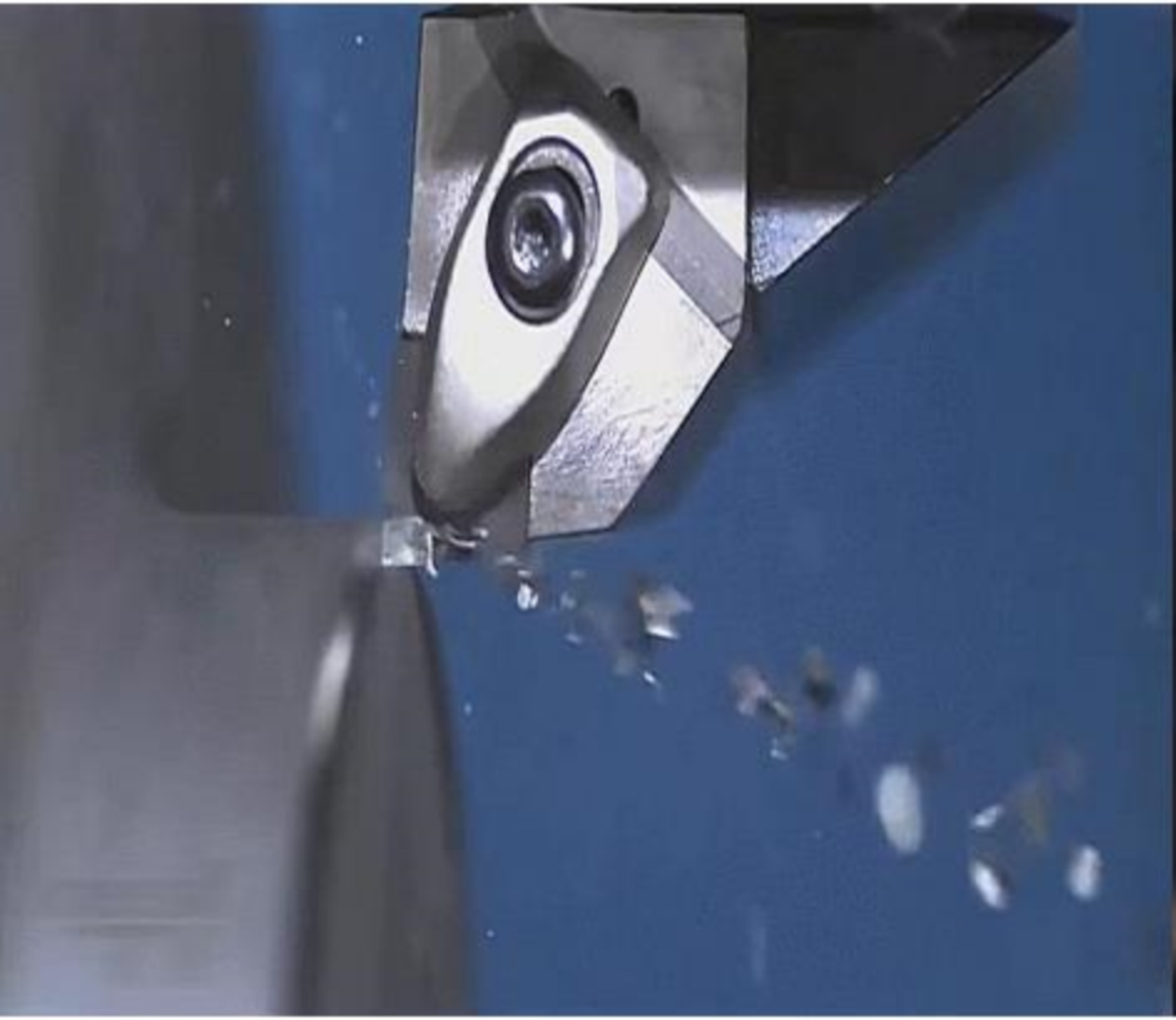
PRODUCTION

METAL CUTTING

LEC-8

Mechanical Engineering

METAL CUTTING



1.Itroduction to Metal cutting

2.Machining operation

3.Turning operation And analysis

4 .Orthogonal Machining Analysis

5 .Side cutting edge angle And end cutting edge angle

6.Nose Radius

7.Shear Angle

8.Velocity in Metal cutting

9.Cutting shear strain

10.Shear strain Rate

11.Force Analysis of Metal cutting

12.Merchant circle Diagram

1.Force Analysis

2.Cases in Merchant circle

3.Limitations of MCD

4.The Force Relation

Merchant Force circle Diagram (MCD)

* $\beta \rightarrow$ Friction Angle

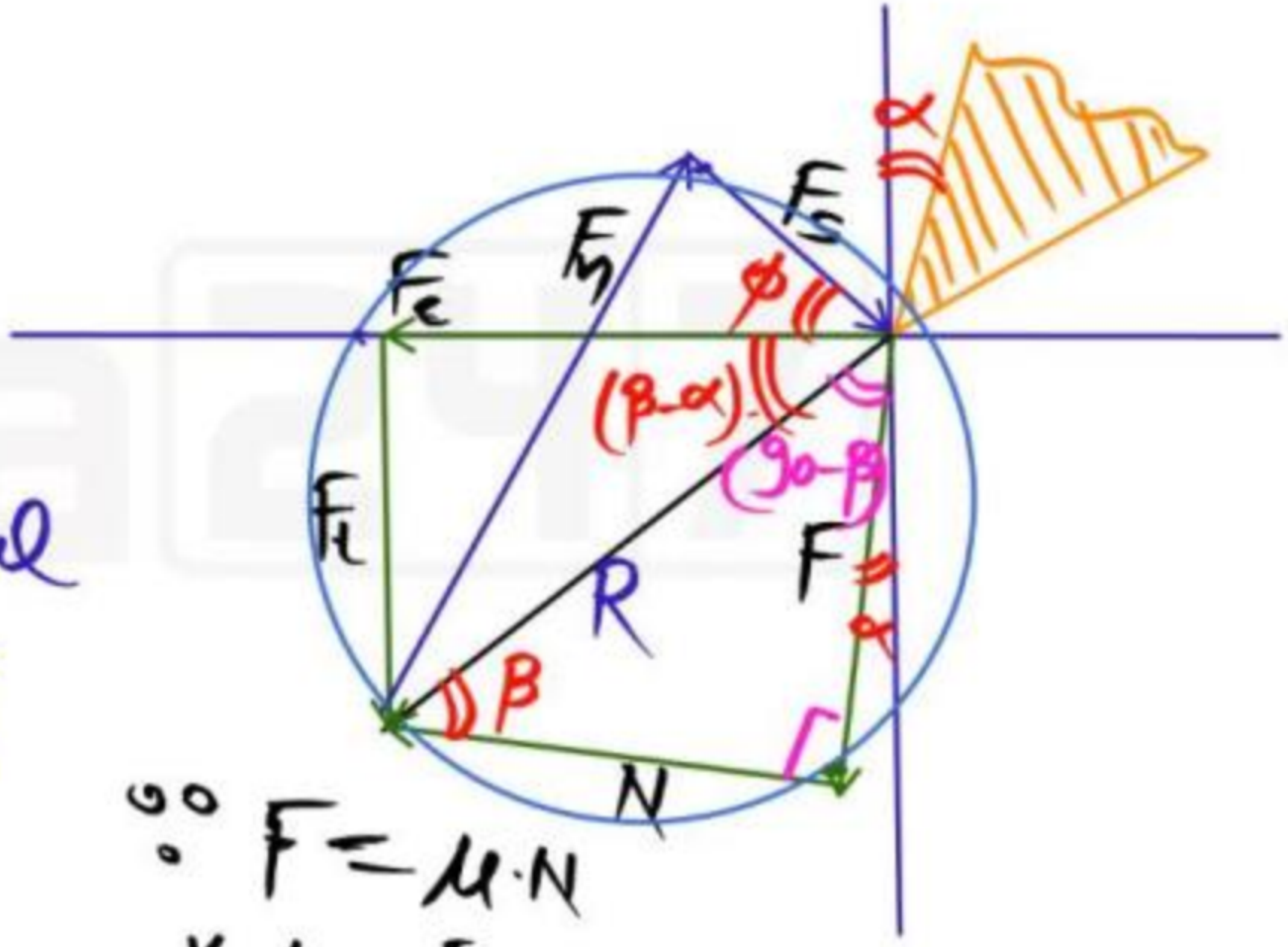
* $x + 90 - \beta + \alpha = 90$

* $x = \beta - \alpha$

* Merchant $\Rightarrow$ circle $\Rightarrow$ orthogonal cutting

* $\tan\beta = \frac{F}{N} \Rightarrow \mu$

* $\tan\beta = \mu$



$\because F = \mu \cdot N$

* $\mu = \frac{F}{N}$

* $\tan\beta = \mu$
* $\beta = \tan^{-1}(\mu)$
* $\sin\beta = \frac{F}{R}$
* $F = R \cdot \sin\beta$
* $\cos\beta = \frac{N}{R}$
* $N = R \cdot \cos\beta$

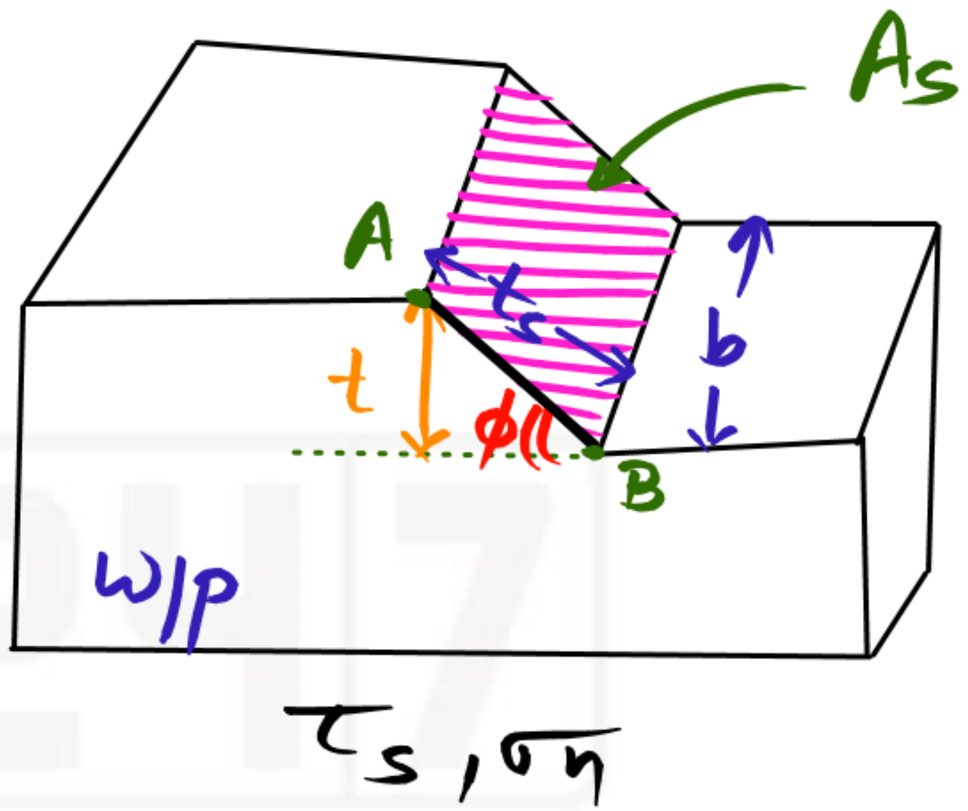
* $F_c = R \cdot \cos(\beta - \alpha)$
* $F_t = R \cdot \sin(\beta - \alpha)$
* $F_s = R \cdot \cos(\phi + \beta - \alpha)$

$R = ?$

* $F_n = R \cdot \sin(\phi + \beta - \alpha)$

Force Analysis

* $b \rightarrow$ width of Shear Plane
* $A_s \rightarrow$ Shear Area
* $F_s \rightarrow$ Shear Force
* $F_n \rightarrow$ Normal Force on Shear plane



☺ Length/Thickness of shear plane

⇓

* $\sin\phi = \frac{t}{AB}$

* $t_s = AB = \frac{t}{\sin\phi}$

Area of Shear Plane (A_s)

* $$A_s = \frac{b \cdot t}{\sin\phi}$$

* Shear force on shear plane (F_s)

* $$F_s = \tau_s \times A_s \Rightarrow \tau_s \times \frac{b \cdot t}{\sin\phi}$$

* $$F_s = \tau_s \times \frac{b \cdot t}{\sin\phi}$$

Normal Force on Shear Plane (F_n)

* $$F_n = \sigma_n \times A_s = \sigma_n \times \frac{b t}{\sin\phi}$$

* $$F_n = \sigma_n \times \frac{b \cdot t}{\sin\phi}$$

* $$F_s = R\cos(\phi+\beta-\alpha) = \tau_s \times \frac{b \cdot t}{\sin\phi}$$

$$R = ?$$

Given Data :→

orthogonal cutting

* $\alpha = 10^\circ$
* $r = 0.35$
* $t = 0.51$ mm
* $b = 3$ mm
* $\tau_s = 285$ N/mm²
* $\mu = 0.65$
* $\beta = \tan^{-1}(0.65) = 33^\circ$

Q. The following data from the orthogonal cutting test is available. Rake angle = 10°, chip thickness ratio = 0.35, uncut chip thickness = 0.51 mm, width of cut = 3 mm, yield shear stress of work material = 285 N/mm², mean friction co-efficient on tool face = 0.65, Determine

(i) Cutting force (F_c)

(ii) Radial force

(iii) Normal force (N) on tool and

(iv) Shear force (F_s).

Solution :→

① $F_c = R \cdot \cos(\beta - \alpha)$

* $F_c = 1735 \cdot \cos(33-10)$

* $F_c = 1597.3\,N$

③ $N = R \cdot \cos\beta$

* $N = 1735 \cdot \cos 33$

* $N = 1455.2$ Newton

(iii) * $F_s = R\cos(\phi + \beta - \alpha) = \tau_s \times \frac{b \cdot t}{\sin\phi}$

* $R\cos(20.15+33-10) = 285 \times \frac{3 \times 0.51}{\sin 20.15}$

* $R = 1735\,N$

(iv) $F_s = \tau_s \times \frac{b \cdot t}{\sin\phi} = 285 \times \frac{3 \times 0.5}{\sin 20.15}$

* $F_s = 1265\,N$

(v) Radial Force = 0 (orthogonal cutting)

* $\tan\phi = \dfrac{\gamma \cdot \cos\alpha}{1 - \gamma \cdot \sin\alpha}$

* $\tan\phi = \dfrac{0.35 \cdot \cos 10}{1 - 0.35 \cdot \sin 10}$

* $\phi = 20.15^\circ$

Cases in Metal Merchant circle

(A) If $\alpha = 0$

⇓

Conclusion :→

(1) $F \perp F_c$

OR

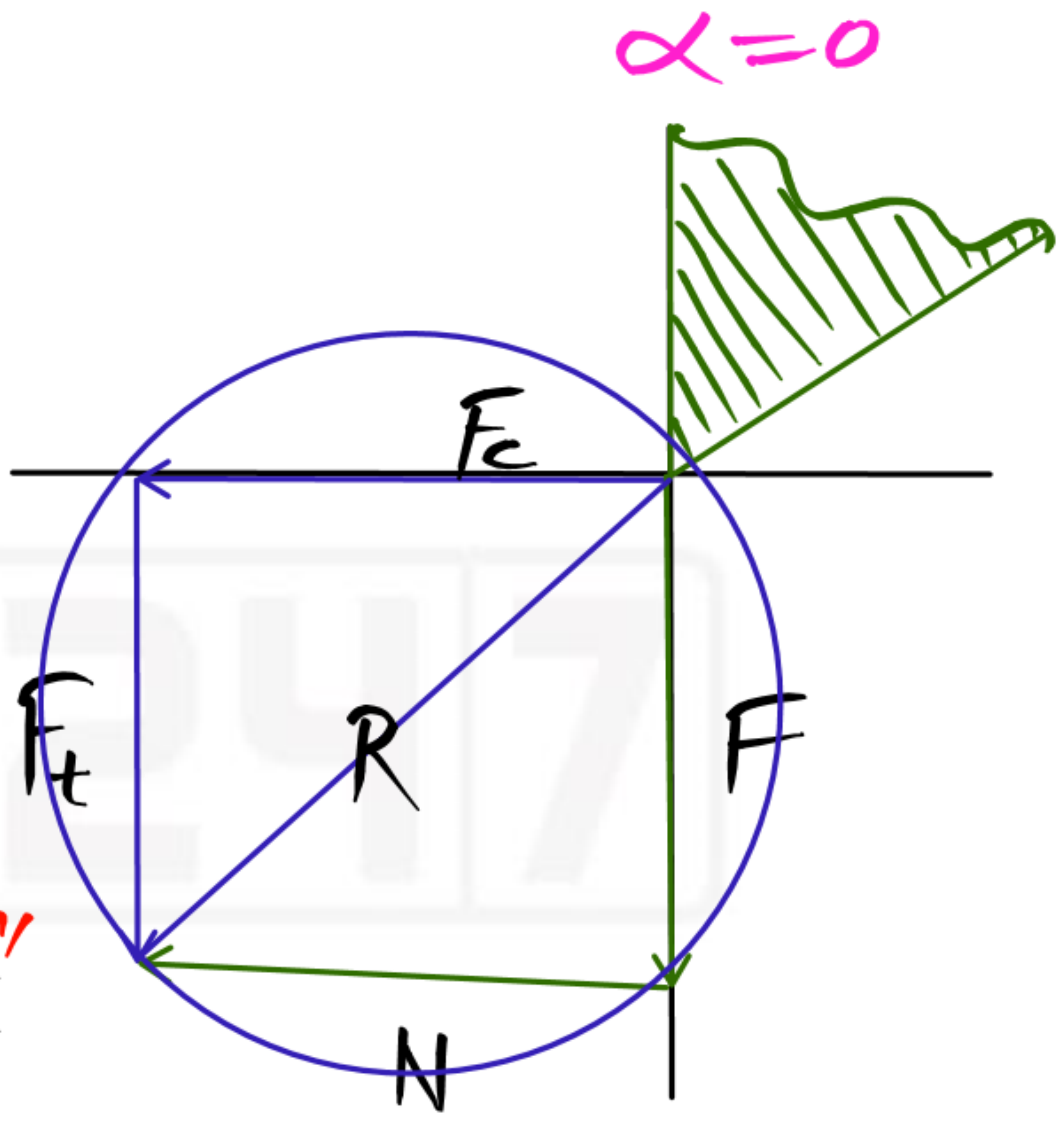
$F \perp V$ ← cutting velocity

(2) F, N, F_c, F_t will form "RECTANGLE"

⇓

✗ $F = F_t$

✗ $N = F_c$



(8) If $\alpha = 0$ And $\mu = 1$ OR $\beta = 45^\circ$

⇓

F, N, F_t, F_c will form "SQUARE"

↓

$F = N = F_c = F_t$

Given Data :→

* d = 100 mm
* f = 0.25 mm/rev
* doc = 4 mm
* $F_c \perp F$
* $F_c = 1500$ N

Solution :→

① $\alpha = 0$

② N = 1500 Newton

In orthogonal turning of a bar of 100 mm diameter with a feed of 0.25 mm/rev, depth of cut of 4 mm and cutting velocity of 90 m/min, it is observed that the main (tangential)cutting force is perpendicular to friction force acting at the chip-tool interface. The main (tangential) cutting force is 1500 N.

Q The orthogonal rake angle of the cutting tool in degree is

(a) zero ✓ (b) 3.58 (c) 5 (d) 7.16

Q The normal force acting at the chip-tool interface in N is

(a) 1000 (b) 1500 ✓ (c) 2000 (d) 2500

The force Relations (If F_c And F_t ⇒ Given)

* $F = F_c \cdot \sin\alpha + F_t \cdot \cos\alpha$
* $N = F_c \cdot \cos\alpha - F_t \cdot \sin\alpha$
* $F_n = F_c \cdot \sin\phi + F_t \cdot \cos\phi$
* $F_s = F_c \cdot \cos\phi - F_t \cdot \sin\phi$

Given data :→ Orthogonal machining

* $F_c = 1200$ N
* $F_t = 500$ N
* $\alpha = 0°$
* $V = 1$ m/s
* doc = 0.8 mm = t
* $t_c = 1.5$ mm

① $\beta = ?$

② $V_c = ?$

In an orthogonal machining test, the following observations were made

Cutting force	1200 N
Thrust force	500 N
Tool rake angle	zero
Cutting speed	1 m/s
Depth of cut	0.8 mm
Chip thickness	1.5 mm

Q Friction angle during machining will be

(a) 22.6° (b) 32.8° (c) 57.1° (d) 67.4°

Q Chip speed along the tool rake face will be

(a) 0.83 m/s (b) 0.53 m/s

(c) 1.2 m/s (d) 1.88 m/s

Solution :→

(09) * $\beta = \tan^{-1}\mu = \tan^{-1}\left(\frac{F}{N}\right)$

* $\beta = \tan^{-1}\left(\frac{F}{N}\right)$

* $\beta = \tan^{-1}\left(\frac{500}{1200}\right)$

* $\boxed{\beta = 22.6^\circ}$

(10) * $\mu = \frac{F}{N} = \frac{F_c \cdot \sin\alpha + F_t \cdot \cos\alpha}{F_c \cdot \cos\alpha - F_t \cdot \sin\alpha}$

* $\mu = \frac{F}{N} = \frac{1200 \cdot \sin 0 + 500 \cdot \cos 0}{1200 \cdot \cos 0 - 500 \cdot \sin 0} = \frac{500}{1200}$

(2) * $r = \frac{t}{t_c} = \frac{V_c}{V}$

* $\frac{0.8}{1.5} = \frac{V_c}{1}$

* $\boxed{V_c = 0.53 \text{ m/s}}$