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GROUP- 07

MECHANICAL DESIGN.

→ A conductor stretched between two supports have an ultimate strength at which it will fail & the ultimate strength of a conductor depends upon the type of conductor material used for overhead line

→ The relationship b/n tension & sag is dependent on the loading conditions & temp. variations for instance, the tension increases when temp. decreases & there is a corresponding dec. in sag

Loading on conductors

following forces act on a conductor

1. conductor weight
2. wind loading
3. Ice loading.

1. Maximum loading or tension condition →

Tension is maximum

$$T = 0^\circ C$$

$$T_1 = \frac{UTS}{FOS}$$

where UTS = ultimate tensile strength

FOS → factor of safety

sag at this condition

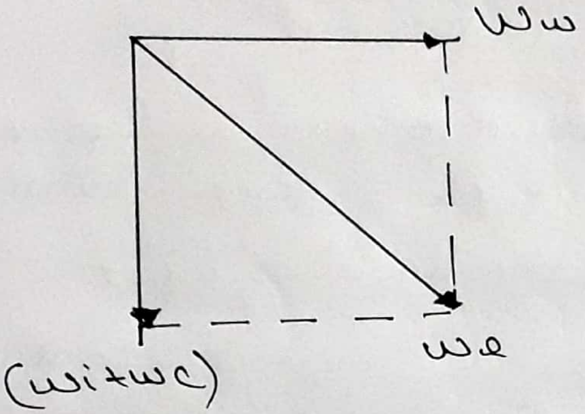
$$S = (w_1 \times l^2) / 8 \times T_1$$

2) Maximum sag condition (final condition)

Sag & tension at 0°C & full wind condition (max. tension condition)

S_{max} → maximum sag

$T_2 = 60°C$



Maximum tension.

$$T_2^2 \left[T_2 - \left\{T_1 - \frac{w_1^2 l^2 EA}{24 T_1^2}\right\} + (\theta_2 - \theta_1)\alpha EA\right] = \frac{W_2^2 l^2 EA}{24}$$

$$S_{max} = \frac{W_2 l^2}{8 T_2}$$

where

T_2 = Tension on the conductor at the time of max sag condition or tension on conductor at the time of final condition (kg)

T_1 = Tension on the conductor at the time of initial condition (kg)

$T_1 = \frac{UTS}{FOS}$

l = span length (m)

w_1 = Effective wt of conductor (kgf/m)

w_2 = Effective wt of conductor under final condition (kg/m)

w_c = wt of conductor (kgf/m)

w_e = Horizontal force exerted by air (kgf/m)

$\left(\frac{2}{3}\right) \times d \times P$

d = Diameter of conductor (m)

P = wind pressure (kgf/m^2)

E = Young's modulus (kg/m^2)

A = Area of cross-section conductor (m^2)

α = coefficient of linear expansion ($/°C$)

θ_1 = Temp of the conductor at the time of max loading or intial condition at $0°C$

θ_2 = Temp of conductor at the time of max sag or final condition at $60°C$

FOS = 2

3) Erection condition

when no wind

$\theta_2 = 30°C$

$$\delta = \frac{w_2 l^2}{8 T_2}$$

For Leopard

① UTS = 4137

② $T_1 = \frac{UTS}{FOS} = \frac{4137}{2} = 2068.5$ kg

③ $P = 100 kg/m^2$

④ $W_c = 0.493$ kgf/m

⑤ $d = 15.84 \times 10^{-3}$

⑥ $w_p = \frac{2}{3} \times d \times P = 1.056$ kgf/m

⑦ Young modulus $Y = 0.809 \times 10^{10}$ kg/m²

⑧ Area $= \pi \frac{d^2}{4} = \pi \times \frac{(15.84 \times 10^{-3})^2}{4}$

$= 1.969 \times 10^{-4} m^2$

⑨ Effective weight of conductor

$w_1 = \sqrt{(w_i + w_c)^2 + w_p^2} = \sqrt{w_c^2 + w_p^2}$

$w_i \approx 0$

$= \sqrt{0.493^2 + 1.056^2}$

$= 1.1654$ kgf/m

⑩ $\alpha = 18.99°C$

for span length 250 m

1. Sag at max. loading condition

$T_1 = \frac{UTS}{FOS} = \frac{4137}{2} = 2068.5$ kg

$\Rightarrow S_1 = \frac{w_1 l^2}{8 T_1} = \frac{1.1654 \times 250^2}{8 \times 2068.5}$

$S_1 = 4.3496m$

$S_1 = 4.4016m$

2. Sag at erection condition

$W_2 = W_c$ (no wind), $\theta_2 = 30^\circ C$

$\cdot W_2 = 0.493 \, kgf/m$

Hence, Tension at this condition can be calculated from eqⁿ 1,

$$T_2^2\left[T_2 - \left\{T_1 - \frac{W_1^2 l^2 EA}{24 T_1^2}\right\} + (\theta_2 - \theta_1)\alpha EA\right] = \frac{W_2^2 l^2 EA}{24}$$

$$T_2^2\left[T_2 - \left\{2068.5 - \frac{1.1634^2 \times 250^2 \times (0.809\times10^{10}) \times 1.96\times10^{-4}}{24 \times 2068.5^2}\right]\right.$$

$$+ \left[30 - 0\right] \times 18.99 = \frac{0.493^2 \times 250^2 \times 0.809\times10^{10} \times 1.96\times10^{-4}}{24}$$

$T_2 = 10^2 \left[-5.5536 + 8.66i, -5.536 - 8.66i, 9.53 + 0.00i\right]$,

$T_2 = 953.14 \, kg, \left(-5.536\times10^2 + 866.16i\right), \left(-5.553\times10^2 - 866.16i\right)\Big]$

Taking +ve value.

$T_2 = 953.14 kg$

Sag can be calculated as

$$S_2 = \frac{W_2 \times l^2}{8 T_2} = \frac{0.493 \times 250^2}{8 \times 953.14 kg}$$

$$S_2 = 4.5409m$$

3. for maximum sag condition

$$w_2 = w_c \text{ (no wind)}, \quad \theta_2 = 60^\circ C$$

$$w_2 = 0.493 \text{ kgf/m}$$

$$T_2^2 \left[T_2 - \left\{ T_1 - \frac{w_1^2 l^2 EA}{24 T_1^2} \right\} + (\theta_2 - \theta_1)\alpha EA \right] = \frac{w_2^2 l^2 EA}{24}$$

$$T_2^2 \left[T_2 - \left\{ 2068.5 - \frac{1.1654^2 \times 250^2 \times 0.809 \times 10^{10} \times 1.96 \times 10^{-4}}{24 \times 2068.5^2} \right\} \right.$$

$$\left. + [60^\circ - 0] \times 18.99 \right] = \frac{0.493^2 \times 250^2 \times 0.809 \times 10^{10} \times 1.96 \times 10^{-4}}{24}$$

$$T_2 = 10^2 [-9.062 + 7.2892i, \; -9.0602 - 7.2892i, \; 7.4623 + 0.000i]$$

$$T_2 = 746.23 \text{ kg},$$

Taking the value = 746.23 kg

$$S_{max} = \frac{w_2 \times l^2}{8 T_2} = \frac{0.493 \times 250^2}{8 \times 7.4623 \times 10^2}$$

$$S_{max} = 5.1614 \text{ m}$$

For LEOPARD

SPAN LENGTH (m)	Initial condition (full wind) $\theta_1 = 0^\circ C$		Maximum Sag condition (no wind) $\theta_2 = 60^\circ C$		Erection condition (no wind) $\theta_2 = 30^\circ C$	
	T_1(Kg)	S_1(m)	T_2(Kg)	S_{max}(m)	T_2(Kg)	S_2(m)
250	2.068×10^3	4.4016	746.2	5.1614	953.14	4.5409
275	2.068×10^3	5.326	761.7	6.1102	941.90	5.947
300	2.068×10^3	6.338	774.8	7.158	932.22	6.946
325	2.068×10^3	7.4388	785.9	8.282	925.22	8.035
350	2.068×10^3	8.627	795.4	9.491	919.0	9.214
375	2.068×10^3	9.90	803.5	10.78	913.8	10.483
400	2.068×10^3	11.26	810.5	12.16	909.5	12.841
425	2.068×10^3	12.7	816.5	13.631	905.8	13.288

for COYOTE

① $UTS = 4638$

② $T_1 = \frac{UTS}{2} = \frac{4638}{2} = 2316\,Kg$

③ $P = 100\,kg/m^2$

④ $w_c = 521 \times 10^{-3}\,kgf/m$

⑤ $d = 15.89 \times 10^{-3}\,mm$

⑥ $w_p = \frac{2}{3} \times d \times P = 1.059\,kgf/m^2$

⑦ Young modulus $Y = 0.787 \times 10^{10}\,kg/m^2$

⑧ $Area = \frac{\pi d^2}{4} = \frac{\pi (15.89 \times 10^{-3})^2}{4}$

$= 1.98 \times 10^{-4}$

⑨ Effective wt of conductor

$w_1 = \sqrt{w_c^2 + w_p^2} = \sqrt{0.521^2 + 1.059^2}$

$w_1 = 1.180\,kgf/m$

⑩ $\alpha = 17.73^\circ C$

for span length 250 m

1) sag at max. loading condition

$T_1 = \frac{UTS}{FOS} = 2316\,Kg$

$\Rightarrow S_1 = \frac{w_1 l^2}{8 T_1} = \frac{1.180 \times 250^2}{8 \times 2316}$

$\delta_1 = 3.971 \, m$

(2) Sag at erection condition.

$w_2 = w_c$ (No wind), $\theta_2 = 30°C$

$w_2 = 0.521 \, kgf/m$

$\therefore$ Tension

$$T_2^2 \left[T_2 - \left\{ T_1 - \frac{w_1^2 l^2 EA}{24 T_1^2} \right\} + (\theta_2 - \theta_1) \alpha EA \right] = \frac{w_2^2 l^2 EA}{24}$$

$$\Rightarrow T_2^2 \left[T_2 - \left\{ 2316 - \frac{250^2 \times 0.787 \times 10^{10} \times 1.98 \times 10^{-4}}{24 \times 2316^2} \right\} + (30 - 0) \times 17.73 \times 0.787 \times 10^{10} \times 1.98 \times 10^{-4} \right]$$

$$= \frac{0.521^2 \times 250^2 \times 0.787 \times 10^{10} \times 1.98 \times 10^{-4}}{24}$$

$T_2 = 10^3 [1.2 + 0.0i, (-0.3826 + 0.878i), (-0.3826 - 0.878i)]$

$T_2 = 1200 \, kg$

Taking true value

Sag can be calculated as

$$\delta_2 = \frac{w_2 \times l^2}{8 T_2} = \frac{0.521^3 \times 250^2}{8 \times 1200}$$

$\delta_2 = 3.984 \, m$

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3. for maximum sag condition

$w_2 = w_c$ (No wind) , $\theta_2 = 60^\circ C$

$w_2 = 0.521 \times 10^0$ Kgf/m

$\therefore$ Tension

$$t_2^2\left[T_2 - \left\{T_1 - \frac{w_1^2 l^2 EA}{24T_1^2}\right\} + (\theta_2 - \theta_1)\alpha EA\right] = \frac{w_2^2 l^2 EA}{24}$$

$$t_2^2\left[T_2 - \left\{2316 - \frac{250^2 \times 0.787\times10^{10} \times 1.98\times10^{-4}}{24 \times 2316^2}\right.\right. + (60-0)\,17.73\times 0.787\times10^{10}\times1.98\times10^{-4}$$

$$= \frac{0.521^2 \times 250^2 \times 0.787\times10^{10} \times 1.98\times10^{-4}}{24}$$

$$T_2 = 10^3\left[(-6.558+8.794i), (-6.558-8.794i) \\ (9.1712+0.00i)\right]$$

$T_2 = 9171.2$ Kg

Taking +ve value

sag can be calculated as

$$S_2 = \frac{w_2 l^2}{8T_2} = \frac{0.521 \times 250^2}{8 \times 9171.2\text{Kg}} = 4.438\text{m}$$

FOR COYOTE

Span Length	Initial condition (full wind) $\theta_1 = 0^\circ C$		Maximum Sag condition (no wind) $\theta_2 = 60^\circ C$		Erection condition (no wind) $\theta_2 = 30^\circ C$	
	T_1(Kg)	S_1(m)	T_2(Kg)	S_{max}(m)	T_2(Kg)	S_2(m)
250	2319	3.977	917.12	4.438	1200.8	3.98
275	2319	4.812	929.47	5.298	1177.4	5.02
300	2319	5.727	940.00	6.235	1157.6	5.98
325	2319	6.721	949	7.248	1141.0	6.99
350	2319	7.795	956.7	8.338	1127.0	7.98
375	2319	8.948	963.71	9.506	1115.1	9.103
400	2319	10.181	969.2	10.751	1105.1	10.99
425	2319	11.493	974.2	12.074	1096.6	11.98

for Tiger

① $UTS = 5758$

② $T_1 = \frac{UTS}{2} = \frac{5758}{2} = 2879$

③ $P = 100\ kg/m^2$

④ $W_c = 0.624\ kgf/m$

⑤ $d = 16.52 \times 10^{-3}\ m$

⑥ $W_P = \frac{2}{3} \times d \times P = 1.1013$

⑦ Young modulus, $E = 0.787 \times 10^{10}\ kg/m^2$

⑧ $Area = \frac{\pi d^2}{4} = \frac{\pi (16.52 \times 10^{-3})^2}{4}$

$= 2.14 \times 10^{-4}\ m^2$

⑨ Effective wt of conductor

$w_1 = \sqrt{w_c^2 + w_p^2} = \sqrt{0.624^2 + 1.1013^2}$

$w_1 = 1.1897\ kgf/m$

⑩ $\alpha = 17.73$

for span length 250m

sag at max. loading condition

$T_1 = \frac{UTS}{FOS} = 2879\ kg$

$\Rightarrow S_1 = \frac{w_1 l^2}{8T_1} = \frac{1.189 \times 250^2}{8 \times 2879}$

$$\delta_1 = 3.228\, m$$

(2) Sag at erection condition.

$w_2 = w_c$ (No wind), $\theta_2 = 30^\circ C$

$$w_2 = 0.624\ Kgf/m$$

∴ Tension

$$T_2^2\left[T_2 - \left\{T_1 - \frac{w_1^2 l^2 EA}{24 T_1^2}\right\} + (\theta_2 - \theta_1)\alpha EA\right] = \frac{w_2^2 l^2 EA}{24}$$

$$T_2^2\left\{T_2 - \left\{2879 - \frac{\times 250^2 \times 0.787\times10^{10} \times 2.14\times10^{-4}}{24 \times 2879^2}\right\} + [30^\circ - 0^\circ] \times 17.73 \times 0.787\times10^{10} \times 2.14\times10^{-4}\right.$$

$$= \frac{0.624 \times 250^2 \times 0.787\times10^{10} \times 2.58\times10^{-4}}{24}$$

$$T_2 = 10^3\left[(1.7145 + 0.00i), (-0.2910 + 0.9555i), (-0.2910 - 0.9555i)\right]$$

Taking +ve value

$$T_2 = 1714.5\ Kg$$

∴ Sag

$$S_{\cancel{max}_2} = \frac{0.624 \times 250^2}{8 \times 1714.5}$$

$$\delta_2 = 3.8094\ m$$

③ for maximum sag condition

$$w_2 = w_c \text{ (no wind)}, \ \theta_2 = 60^\circ C$$

$$w_2 = 0.624 \text{ kgf/m}$$

∴ tension

$$T_2^2 \left\{ T_2 - \left\{ T_1 - \frac{w_1^2 l^2 EA}{24 T_1^2} \right\} + (\theta_2 - \theta_1)\alpha EA \right] = \frac{w_2^2 l^2 EA}{24}$$

$$T_2^2 \left\{ T_2 - \left\{ 2879 - \frac{\times 250^2 \times 0.787 \times 10^{10} \times 2.14 \times 10^{-4}}{24 \times 2879^2} \right\} + \{60 - 0\} \times 17.73 \times 0.787 \times 10^{10} \times 2.14 \times 10^{-4}\right.$$

$$= \frac{0.624 \times 250^2 \times 0.787 \times 10^{10} \times 2.58 \times 10^{-4}}{24}$$

$$T_2 = 10^3 \left[(1.2797 + 0.0i), (-0.522 + 1.0315i), (-0.522 - 1.0315i) \right]$$

Taking the value

$$t_2 = 1279.7 \text{ kg}$$

∴ Sag

$$S_{max} = \frac{0.624 \times 250^2}{8 \times 1279.7} = 3.809 \text{ m}$$

$$= 3.809 \text{ m}$$

for TIGER

SPAN LENGTH	Initial condition full wind $\theta_1 = 0°C$		Maximum Sag condition (no wind) $\theta_2 = 60°C$		Erection condition $\theta_2 = 30°$	
	T_1 (Kg)	S_1 (m)	T_2 (Kg)	S_{max} (m)	T_2 (Kg)	S_2 (m)
250	2879	3.435	1279.7	3.809	1714.5	3.51
275	2879	4.156	1293.7	4.559	1684.0	4.32
300	2879	4.946	1305.9	5.375	1656.5	5.01
325	2879	5.805	1316.7	6.257	1632.0	5.91
350	2879	6.732	1326.2	7.204	1610.3	6.84
375	2879	7.728	1334.6	8.218	1591.2	7.81
400	2879	8.793	1342.0	9.299	1574.2	8.98
425	2879	9.927	1348.5	10.447	1559.2	10.001

for wolf

① $UTS = 6680$

② $T_1 = \frac{UTS}{2} = \frac{6680}{2} = 3340\ kg$

③ $P = 100\ kg/m^2$

④ $w_c = 0.724\ kgf/m$

⑤ $d = 18.13 \times 10^{-3}\ m$

⑥ $w_p = \frac{2}{3} \times d \times P = 1.2086\ kgf/m^2$

⑦ Young modulus $E_1 = 0.787 \times 10^{10}$

⑧ Area $= \frac{\pi d^2}{4} = \frac{\pi (18.13 \times 10^{-3})^2}{4}$

$= 2.58 \times 10^{-4}$

⑨ Effective wt of conductor

$w_1 = \sqrt{w_c^2 + w_p^2}$

$= \sqrt{0.724^2 + 1.2086^2}$

$w_1 = 1.4106$

⑩ $\alpha = 17.73\ {}^\circ C$

for span length 250 m

Sag at max loading condition

$T_1 = \frac{UTS}{FOS} = 3340\ kg$

$$\delta_1 = \frac{w_1 l^2}{8 T_1} = \frac{1.319 \times 250^2}{8 \times 3340}$$

$$\delta_1 = 3.2033\,m$$

(2) sag at erection condition

$w_2 = w_c$ (No wind), $\theta_2 = 30°C$

$w_2 = 0.724$ kgf/m

∴ tension

$$T_2^2 \left[T_2 - \left\{ T_1 - \frac{w_1^2 l^2 EA}{24 T_1^2} \right\} + (\theta_2 - \theta_1)\alpha EA \right] = \frac{w_2^2 l^2 EA}{24}$$

$$T_2^2 \left[T_2 - \left\{ 3340 - \frac{1.319^2 \times 250^2 \times 0.787 \times 10^{10} \times 2.58 \times 10^{-4}}{24 \times 3340^2} \right\} + [30 - 0] \times 17.73 \times 0.787 \times 10^{10} \times 2.58 \times 10^{-4} \right]$$

$$= \frac{0.724^2 \times 250^2 \times 0.787 \times 10^{10} \times 2.58 \times 10^{-4}}{24}$$

$T_2 = 10^3 [(1.551 + 0.0i), (-0.581 + 1.2105i), (-0.581 - 1.2105i)]$

Taking the value

$T_2 = 2102.6$

∴ sag

$$\delta_2 = \frac{0.724 \times 250^2}{8 \times 2102.6} = 3.3014\,m$$

3. for maximum sag condition.

$w_2 = w_c$ (no wind), $\theta_2 = 60^\circ C$

$\therefore T_2$

$$T_2^2\left[T_2 - \left\{T_1 - \frac{w_1^2 l^2 EA}{24 T_1^2}\right\} + (\theta_2 - \theta_1)\alpha EA\right] = \frac{w_2^2 l^2 EA}{24}$$

$$T_2^2\left[T_2 - \left\{3340 - \frac{1.9106^2 \times 250^2 \times 0.787\times10^{10} \times 2.58\times10^{-4}}{2.4 \times 3340^2}\right\}\right.$$

$$\left. + [60-0] \times 17.73 \times 0.787\times10^{10} \times 2.58\times10^{-4}\right]$$

$$= \frac{0.724^2 \times 250^2 \times 0.789\times10^{10} \times 2.58\times10^{-4}}{24}$$

$T_2 = 10^3 [(1.5538 + 0.i], (-0.587 + 1.286i),$
$(-0.5874 - 1.21697i)]$

Taking +ve value

$T_2 = 1553.8$ kg

$\therefore$ Sag

$$\delta_{max} = \frac{0.724 \times 250^2}{8 \times 1551.3} = 3.6614 m$$

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for WOLF

SPAN LENGTH (m)	INITIAL condition full wind $\theta_1 = 0^\circ C$		Maximum sag condition (No wind) $\theta_2 = 60^\circ C$		Erection condition (No wind) $\theta_2 = 30^\circ C$	
	T_1 (Kg)	S_1 (m)	T_2 (Kg)	S_{max} (m)	T_2 (Kg)	S_L (m)
250	3440	3.203	1551.3	3.6613	2102.5	3.301
275	3440	3.876	1571.9	4.3721	2071.6	3.91
300	3440	4.612	1590.2	5.1432	204316	4.71
325	3440	5.413	1606.5	5.9748	2017.4	5.58
350	3440	6.27	1621.0	6.867	1994.2	6.4754
375	3440	7.207	16340	7.821	1973.5	7.436
400	3440	8.2004	1645.5	8.836	1955.1	8.412
425	3440	9.257	1655.8	9.9133	1938.8	8.4663

we can conclude that, as the temperature increases. the corresponding sag increases & the tension decreases