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MARMON CLAMP

Analytical work on the Marmon Clamp has been limited to the development of some basic equations giving the relationship between mechanical loads and general parameters of the clamp. Thermal effects, exact design geometry, materials, and local details have not been considered.

The elementary equations that have been developed gives the relationship between the resultant holding force of the clamp (L) and the initial tightening tension force (T_1), tension force at any point (T) and the initial tightening tension force (T_1), and clamping force normal to wedge surface at any point (N) and the initial tightening tension force (T_1). These equations include the boundary conditions of friction and general idealized clamp geometry.

Examination of equation giving the relationship between the resultant holding force (L) and the initial tightening tension force (T_1) indicates the importance of the following items:

1. Number of tightening points.
2. Sequence of tightening (Sliding friction compared to static friction).
3. Local effects that influences the coefficient of friction.

For the first two items, expected results can be predicted by additional analytical development, but the last item could depend on design and manufacturing details requiring extensive study. However, a practical approach to overcome this uncertainty is by monitoring the installation of the clamp in a manner that is frictionally dependent.

MARMON CLAMP

Definition of Symbols

T_1	=	Initial tangential tension force at tightening clamp points ~lbs.
P	=	Radial clamp forces from tension force - lbs.
F	=	Tangential friction forces resulting from tension force - lbs.
Δ	=	Angle between tightening points of clamp ~radians
σ	=	Variable angle $0 \leq \sigma \leq \Delta$ ~radians
γ	=	Typical angle
R	=	Radius ~tension band ~inches
F'	=	Radial friction forces ~lbs.
N	=	Clamping force normal to wedge surface at any point ~lbs.
$\tan \mu$	=	Coefficient of friction
α	=	Face angle of clamp
A	=	$\frac{\tan \mu}{\sin \alpha + \cos \alpha \tan \mu}$
T	=	Tangential tension force at any point ~lbs.
dT	=	Tangential tension differential force at any point ~lbs.
N_T	=	Total clamping force normal to wedge surface ~lbs.
L	=	Resultant reactive force of Marmon Clamp before complete separation of mating parts ~lbs.
R_1	=	Radius ~contact surface ~inches

Derivation of Equations

General Force Balance Equations

Summation Radial Forces

$$\frac{P}{2} = (N \sin \alpha + F' \cos \alpha) \left(\frac{R}{R_1} \right) \quad (1)$$

Coefficient of Friction Equation

$$\tan \mu = \frac{F'}{N} \quad (2)$$

$$N = \frac{F'}{\tan \mu}$$

Radial Friction & Radial Clamp Force Balance

$$\frac{P}{2} = \left[\left(\frac{F'}{\tan \mu} \right) \sin \alpha + F' \cos \alpha \right] \left(\frac{R}{R_1} \right) \quad (3)$$

Radial & Tangential Friction Force Relation

(Normal Force "N" Is Identical For Each)

$$F = F \quad (4)$$

Radial Clamp Force & Tangential Friction Force Relation

$$P = 2F \left(\frac{\sin \alpha}{\tan \mu} + \cos \alpha \right) \left(\frac{R}{R_1} \right) \quad (5)$$

Tangential Clamp Force & Radial Clamp Force Relation

$$T = PR$$

$$P = \frac{T}{R} \quad (6)$$

Tangential Clamp Force & Tangential Friction Force Relation

$$\frac{T}{R} = 2F \left(\frac{\sin \alpha}{\tan \mu} + \cos \alpha \right) \left(\frac{R}{R_1} \right)$$

$$F = \frac{T}{2R} \left(\frac{\tan \mu}{\sin \alpha + \cos \alpha \tan \mu} \right) \left(\frac{R}{R_1} \right) \quad (7)$$

$$F = \frac{TA}{2R} \left(\frac{R}{R_1} \right) = \frac{TA}{2R_1}$$

Equations For Variable Forces Relation

Change of Tension Force dT Over the Arc Length of Rdθ

$$dT = -FRd\theta \quad (8)$$

$$dT = -\frac{TA}{2} d\theta \quad (9) \text{ (From 7 \& 8)}$$

Tangential Clamp Force at any Angle σ

$$\int \frac{dT}{T} = - \frac{TA}{2} \int_0^\sigma d\theta$$

$$T = ce^{-\frac{A\sigma}{2}} \quad (10)$$

Expression (10) Only Includes One Point of Tightening of Clamp. When There Are More Points of Tightening, Which Are Δ Degrees Apart, The Tangential Clamp Force

$$T = c \left(e^{-\frac{A\sigma}{2}} + e^{-\frac{A(\sigma - \Delta)}{2}} \right) \quad (11)$$

From The Boundary Conditions When

$$\sigma = 0 \quad T = T_1$$

$$T_1 = c \left(1 + e^{-\frac{A\Delta}{2}} \right)$$

$$c = \frac{T_1}{\left(1 + e^{-\frac{A\Delta}{2}} \right)}$$

$$T = \left[\frac{T_1}{\left(1 + e^{-\frac{A\Delta}{2}} \right)} \right] \times \left[e^{-\frac{A\sigma}{2}} + e^{-\frac{A(\sigma - \Delta)}{2}} \right] \quad (12)$$

Equations For Resultant Clamping Force

Summation Radial Forces

$$\frac{P}{2} = (N \sin \alpha + F' \cos \alpha) \left(\frac{R}{R_1} \right) \quad (1)$$

Coefficient of Friction Equation

$$\tan \mu = \frac{F'}{N}$$

$$F' = \frac{N}{\tan \mu} \quad (2)$$

Normal Clamping Force & Radial Clamp Force Relation

$$\frac{P}{2} = (N \sin \alpha + N \cos \alpha \tan \mu) \left(\frac{R}{R_1} \right) \quad (13)$$

Tangential Tension Force & Radial Clamp Force Balance

$$T = PR \quad (14)$$

Tangential Clamp Force & Normal Clamping Force Balance

$$T = 2RN(\sin \alpha + \cos \alpha \tan \mu) \left(\frac{R}{R_1} \right)$$

$$T = \frac{2R^2 N \tan \mu}{R_1 A} \quad (15)$$

Normal Clamping Force at any Angle σ

$$\frac{2RN \tan \mu}{A} = \frac{T_1}{\left(1 + e^{-\frac{A\Delta}{2}} \right)} \times \left(e^{-\frac{A\sigma}{2}} + e^{\frac{A(\sigma - \Delta)}{2}} \right)$$

$$N = \left[\frac{R_1 A T_1}{2R^2 \tan \mu \left(1 + e^{-\frac{A\Delta}{2}} \right)} \right] \times \left[e^{-\frac{A\sigma}{2}} + e^{\frac{A(\sigma - \Delta)}{2}} \right] \quad (16)$$

Equations For Resultant Clamping Force

Total Normal Clamping Force

$$N_T = \frac{2\pi R_1 A T_1}{2R^2 \Delta \tan \mu \left(1 + e^{-\frac{A\Delta}{2}} \right)} \int_0^\Delta \left(e^{-\frac{A\sigma}{2}} + e^{\frac{A(\sigma - \Delta)}{2}} \right) R d\sigma$$

$$N_T = \frac{4\pi R_1 T_1}{R \Delta \tan \mu \left(1 + e^{-\frac{A\Delta}{2}} \right)} \times \left(e^{\frac{A\Delta}{2}} - 1 \right) \quad (17)$$

Resultant Clamping Force

$$L = N_T \times \cos \alpha$$

$$L = \left[\frac{4\pi R_1 T_1 \cos \alpha}{R\Delta \tan \mu \left(1 + e^{\frac{A\Delta}{2}} \right)} \right] \times \left[e^{\frac{A\Delta}{2}} - 1 \right] \quad (18)$$