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3rd International Conference and Exhibition on Mechanical & Aerospace Engineering, San Francisco, USA.

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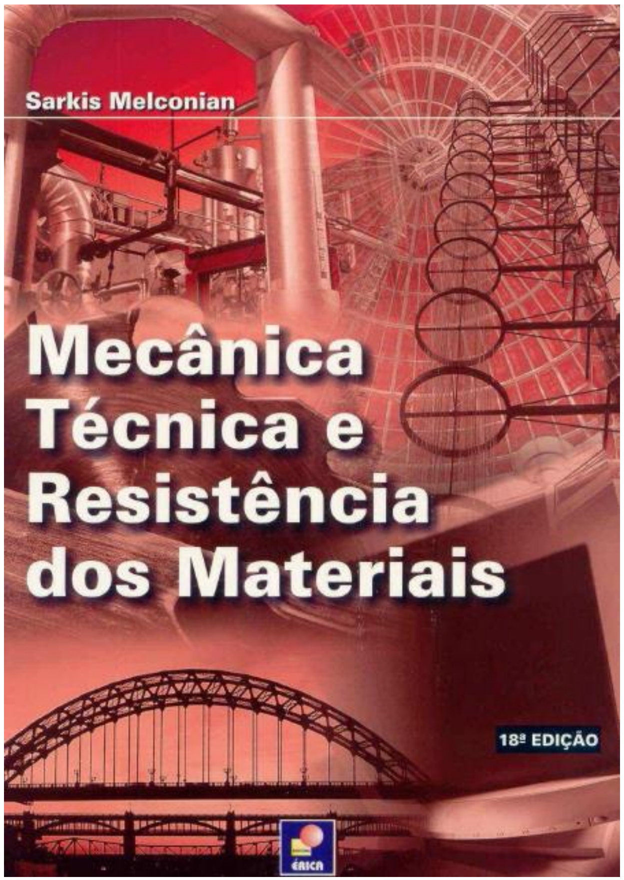
ANALYTICAL SOLUTION FOR WELDED JOINTS OF PERPENDICULAR PLATES SUBJECTED TO TORSIONAL MOMENT

What is the specific objective of this work?

Specifically, the objective of this work is to present an analytical solution based on shearing stress for welded joints of perpendicular plates subjected to torsional moment.

Solution of reference

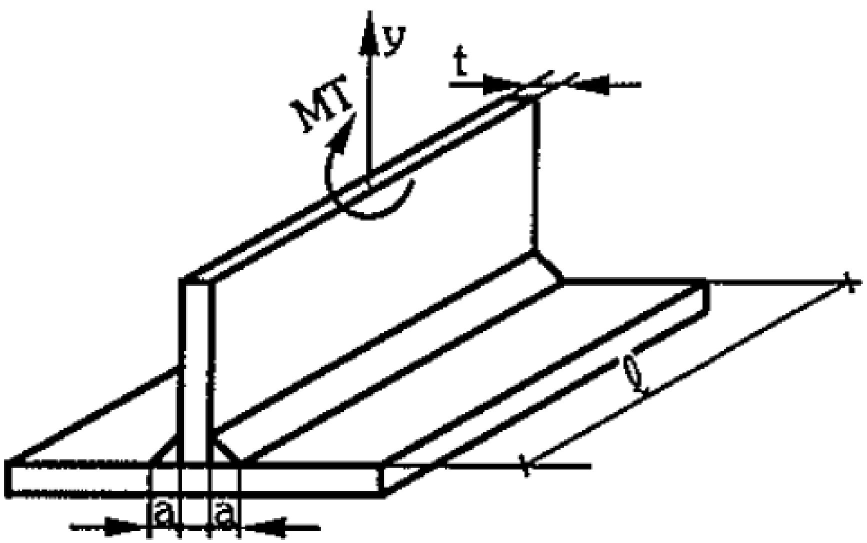


Technical Mechanic and Resistance of Materials

Melconian, Sarkis; Ed. 18, São Paulo, Brasil, 2008.

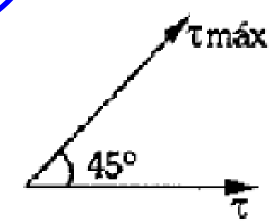
Solution of reference

It is based on normal stress from bending.



$$\tau = \frac{M}{J} Y_{max} = \frac{12Mt(\ell / 2)}{(2a)\ell^3} = \frac{3Mt}{a\ell^2}$$

$$\tau_{max} = \frac{\tau}{\cos 45°}$$



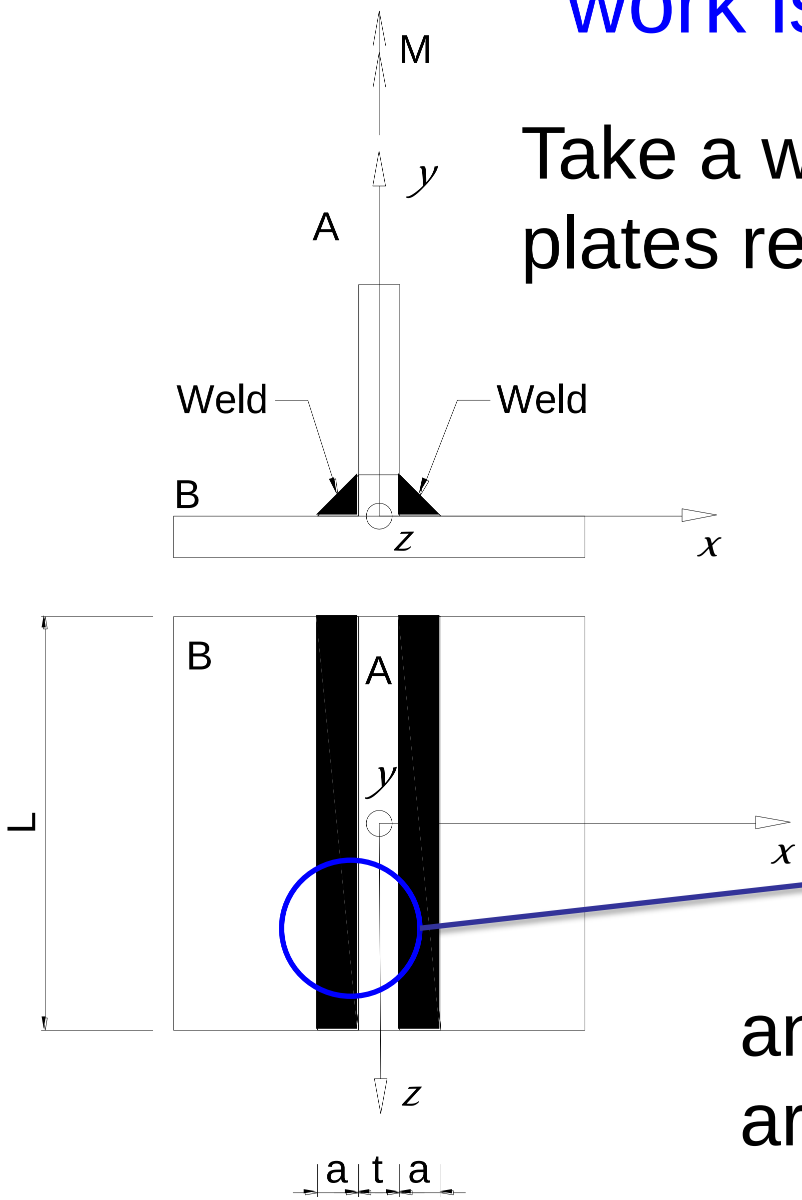
$$\tau_{max} = \frac{3Mt}{a.\ell^2 \cos 45°}$$

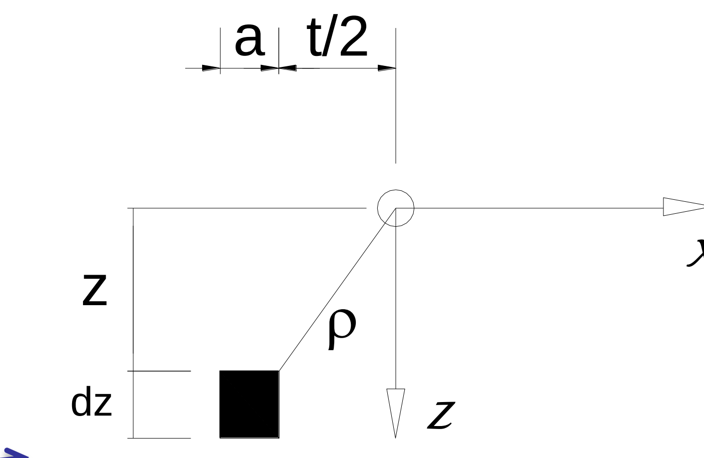
M = Bending Moment; t = Thickness of the perpendicular plate;

ℓ = Lenght of weld line; a = Base of the weld line.

The analytical solution of this work is based on shearing stress

Take a welded joint of perpendicular plates requested by torque *M*





and an infinitesimal element of area *dA* in weld. $dA = a\,dz$

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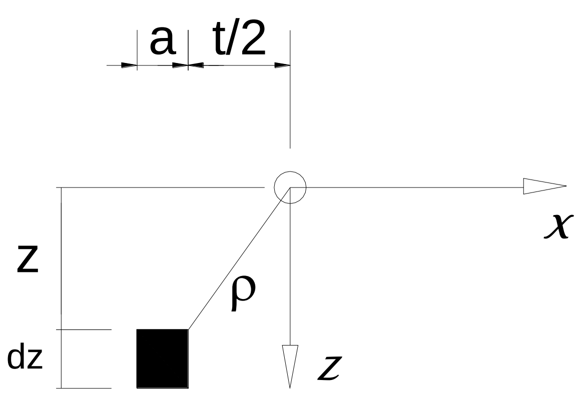
The analytical solution based on shearing stress

The distribution of the shearing stress obeys the law from Resistance of Materials, where "ρ" is the generic distance in relation to the center of joint and "*J*" is the polar moment of inertia.

$$\tau = \frac{M\rho}{J}$$

The polar moment of inertia to be determined by



$$\rho^2 = \left(a + t/2\right)^2 + z^2$$

The analytical solution based on shearing stress

The polar moment of inertia is obtained by the equation.

$$J = \int_A \rho^2 dA$$

Substituting the polar moment of inertia on that equation, with the integration limits appropriate to the problem, one has

$$J = \int_{-L/2}^{+L/2} \left[\left(a + t/2 \right)^2 + z^2 \right] a dz \longrightarrow J = La^3 + La^2 t + \frac{1}{4} aLt^2 + \frac{1}{12} aL^3$$

The analytical solution based on shearing stress

Replacing the polar moment of inertia obtained and knowing that the linear distribution of stresses requires that the maximum stress occurs at the end of the weld, we can approximate to ρ_{max} equals to L/2, and write the equation of maximum shear stress

$$\tau_{max} = \frac{M\,\dfrac{L}{2}}{La^3 + La^2t + \dfrac{1}{4}aLt^2 + \dfrac{1}{12}aL^3}$$

The analytical solution based on shearing stress

The prior expression can be used for the design of the base "a" of the bead weld. To this must be put it in the polynomial form

$$a^3 + a^2 t + a\xi - \eta = 0$$

Where $\xi = \dfrac{t^2}{4} + \dfrac{L^2}{12}$ and $\eta = \dfrac{M}{4\tau_{\max}}$

Whose real root is

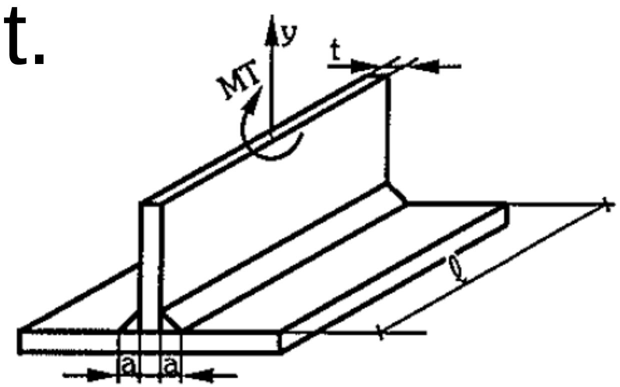
$$a = \frac{\Pi}{6} - \frac{2\xi - \dfrac{2t^2}{3}}{\Pi} - \frac{t}{3}$$

in which

$$\Pi = \sqrt[3]{36\xi t + 108\eta - 8t^3 + 12\sqrt{\left(12\xi^3 - 3\xi^2 t^2 + 54\xi t\eta + 81\eta^2 - 12\eta t^3\right)}}$$

NUMERICAL SIMULATIONS

Consider two steel plates welded perpendicularly through a weld bead length of $L = 500$ mm and weld base $a = 12$ mm. By the specifications of the American Welding Society, the allowable stress indicated is $\tau_{adm} = 70$ MPa. One wants to know the maximum torque that can act at the joint.



"M" is the torsional moment,
"a" is the base of bead weld and
"L" is the length of bead weld.

NUMERICAL SIMULATIONS

Solving the problem by the proposal for Sarkis, one has.

$$M = \frac{3\tau_{adm}}{aL^2}$$

and

$$M = \frac{3\tau_{adm}}{aL^2 \cos 45^o}$$

and by Wahrhaftig

$$M = \frac{\tau_{adm} \dfrac{L}{2}}{La^3 + La^2 t + \dfrac{1}{4} aLt^2 + \dfrac{1}{12} aL^3}$$

and

$$M = \frac{\tau_{adm} \dfrac{L}{2}}{\left(La^3 + La^2 t + \dfrac{1}{4} aLt^2 + \dfrac{1}{12} aL^3 \right) \cos 45^o}$$

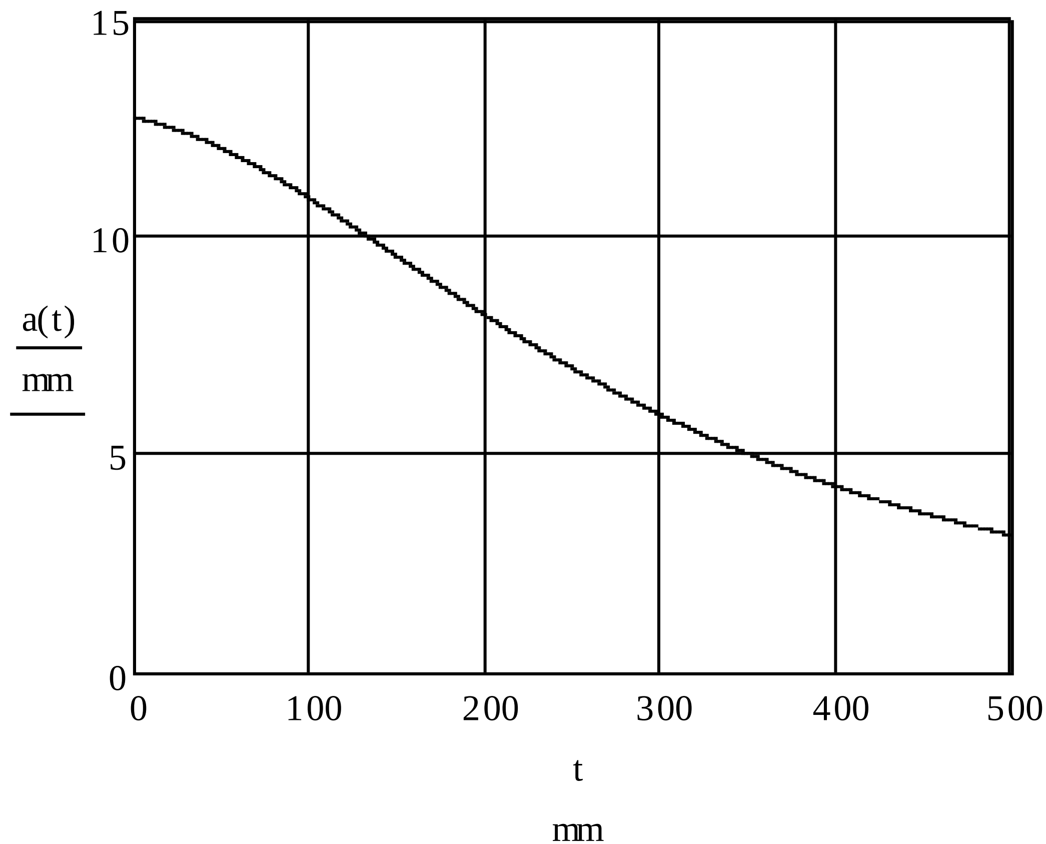
NUMERICAL SIMULATIONS

Results	M (Nm)	$Mcos45^o$ (Nm)	Difference
Wahrhaftig	70483.840	49839.601	342.127 (Nm)
Sarkis	70000.000	49497.475	0.686 (%)

NUMERICAL SIMULATIONS

$$\tau_{max} = \frac{M\frac{L}{2}}{La^3 + La^2t + \frac{1}{4}aLt^2 + \frac{1}{12}aL^3}$$

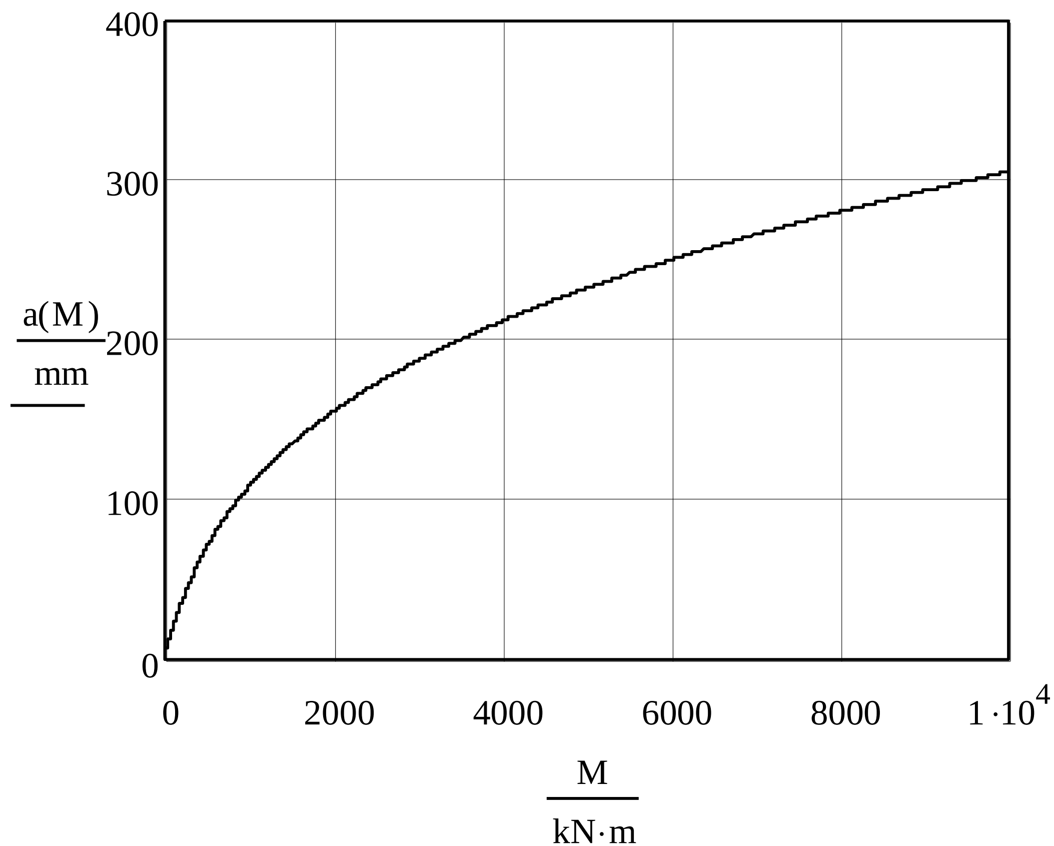
It allows performing to study the influence of the thickness of vertical plate over dimensions of the weld.



NUMERICAL SIMULATIONS

$$\tau_{max} = \frac{M\,\frac{L}{2}}{La^3 + La^2 t + \frac{1}{4} aLt^2 + \frac{1}{12} aL^3}$$

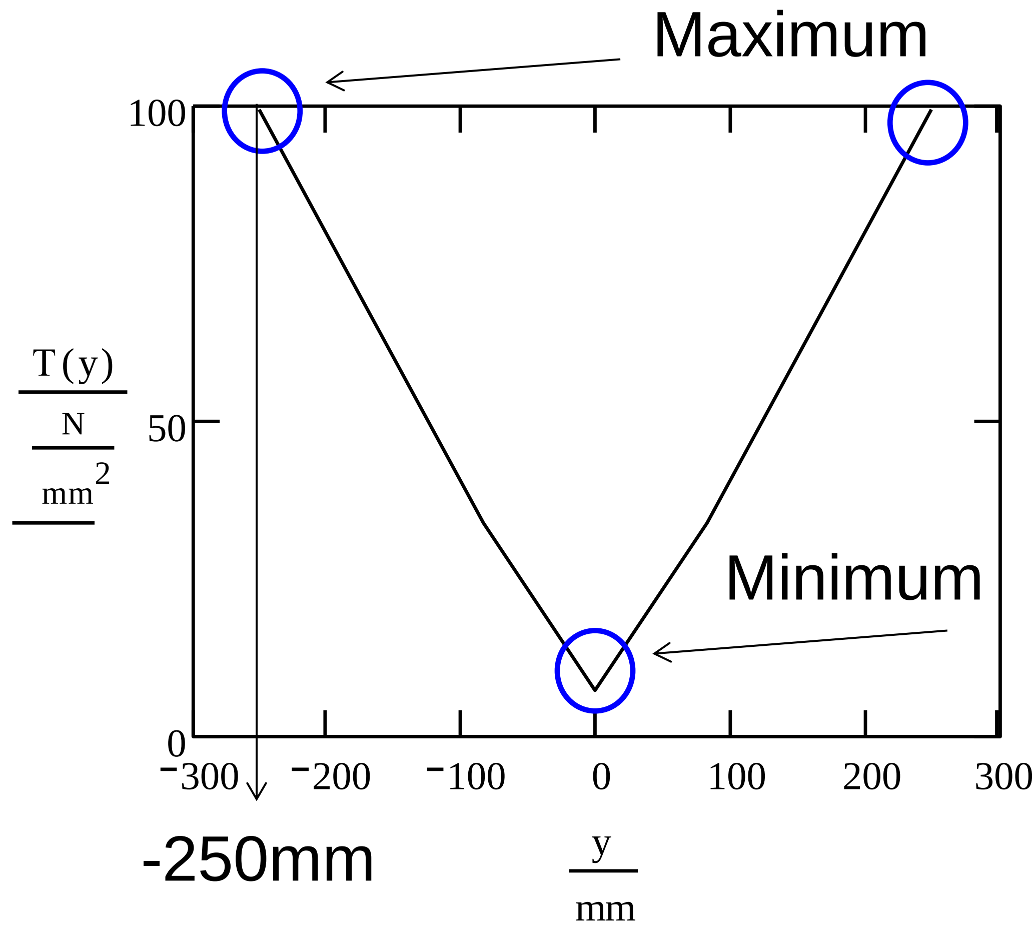
It allows to obtain the weld dimensions in function of the torsional moment acting.



NUMERICAL SIMULATIONS

$$\tau = \frac{M\rho}{La^3 + La^2 t + \frac{1}{4} aLt^2 + \frac{1}{12} aL^3}$$

Shearing stress distribution on weld line to t = 12 mm.



CONCLUSIONS

- Analytical solution presented in this work (Wahrhaftig) is appropriate for the design and verification of bead weld to joints of perpendicular plates subjected to torsional moment;

- It allows evaluating of the horizontal shearing stresses induced in the way that it really occurs;

CONCLUSIONS

- Difference of the polar moment of inertia between Sarkis and Wahrhaftig is 1.51%;
- Results by Wahrhaftig and Sarkis are consistent in order of magnitude; but
- Sarkis, considers the bending theory, while Wahrhaftig the torsion theory.

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Thank you very much!