Mathematics in Welding Design

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Abstract

The purpose of this paper is to show the importance of the welding calculations before the start in any projuct or making a ptroduct that involve a welding jop.

Intoductions

What is welding ?

Welding is a process of coalescence of metals with the use of heat and / or force with or without the use of additional welding metal.

Welding is known since long times from the time of old Egypt and Mesopotamia when they use it in fabricating weapons and tools . But we know it as we see it now since more than a hundred year at the time when electricity invented.MR. Slavianof invent the first arc welding process which is fusion welding and from that time welding as a manufacturing process is under development and modernization due to its importance in industry and fabrication .

Good weld means good welding joint with less heat input and less distortion and residual stresses. The ultimate weld joint has the same strength of the welded metal of the working piece .

Welding has many advantages over other joining processes and can be summarized as follows :

1- SUPERIOR STRENGTH
2- LACK OF BULK
3- VERSATILE
4- INEXPENSIVE
5- PORTABLE

Classification of welding processes :

Welding is versatile production process for which several methods has been developed .

Welding processes can be classified according to the process of welding. The 3 categories are :

1- Solid state welding (pressure welding)
2- Fusion welding
3- Soldering and brazing

The most commonly used welding process is arc welding and it has many types like MMA , MIG/MAG and TIGW .

We will describe in this research how to calculate mathematically the best thickness of welded joint to match the requirements of safe welding joint that can sustain the working load or applied stress during the functional use of it .we should make sure that the welded joint can sustain the working load during operation with safe margin , to be sure that the joint will not fail during use. The safety factors which can be used for engineering calculations in design of welds are as follows :

1- Static load $1.1 < SF < 1.6$
2- Dynamic load $1.6 < SF < 2.5$

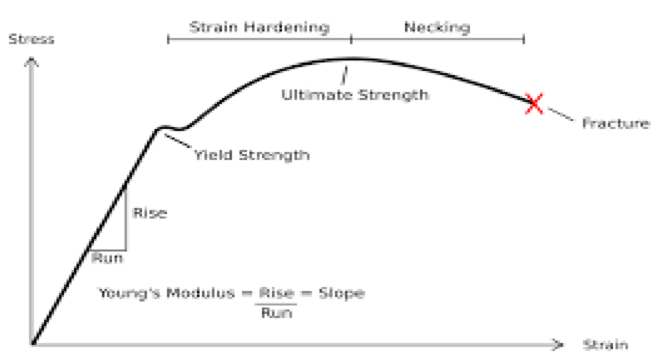
3- Extreme dynamics e.g., nuclear power plants parts $2.5 < SF < 4$

We know that metals has strength and can be appreviated as (Reh). For example steel S230 means this steel has a strength of Reh =235 N/mm2

S480 means Reh = 480 N/mm^2

S960 means Reh = 960 N/mm^2

Reh is the yield strength of a material and it is the maximum load the material can sustain in the elastic range of that material, Which means that the workpiece will return to its original dimensions after unloading .



We know that the perfect welded joint has a mechanical strength equal to yield strength of the welded parent metal , which means the safety factor is 1 since

δ adm = Reh/ SF   where δ : admissible stress

but we know in the real life we cannot achieve a perfect welded joint due to many reasons and circumstances , so we have to take a factor of safety in our design consideration to be on the safe side .

We mean that the applied load on the welded joint is less than its strength e.g. if the welded joint strength is 300 N/mm^2we apply at maximum working load 150 n/mm2

by taking a SF of 2 .

δ adm = Reh / SF = 300/ 2 = 150 N/mm^2

δ adm : admissible stress

In engineering design we always target safety and to be economical in using raw materials in order not to increase the cost .

I will solve some engineering mathematical problems to be as approach to calculate the perfect thickness and length of a welded joint for perfect engineering design.

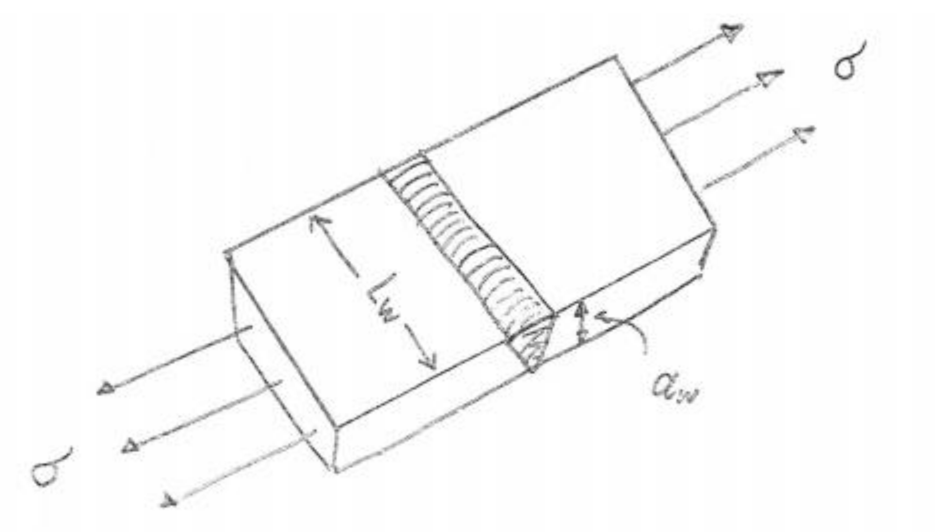
Calculations:

Problem # 1

We have a welded joint with dimensions :

Lw= 200mm , aw = 10mm   lw: weld length

aw: weld thickness or throat thickness



calculate which weld can sustain a load force of 360 KN, the tested weld or non-tested weld of SF=1.2 and SF=2 respectively?

The workpiece is made of Steel S270

solution :

tested δ adm = 270/1.2 = 225 N/mm^2

non-tested δ adm = 270/2 = 135 N/mm^2

δ = F/A = 360000/ (200 *100) = 180 N/mm^2

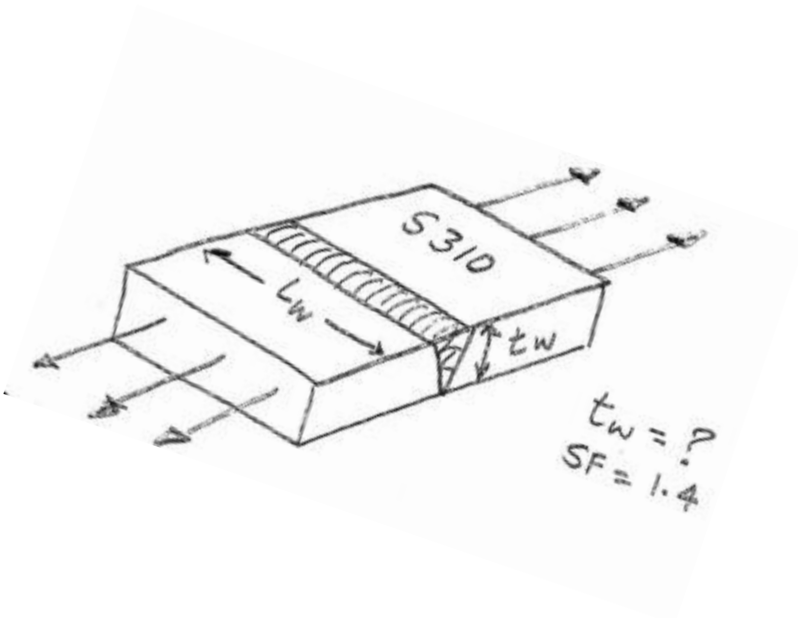
we find out from the mathematical calculations that the untested piece will not sustain the load where the tested one will sustain it.

Mathematical approach helped us to choose the proper welding procedure to make a safe workpiece and functional .

Problem 2 :

Calculate the thickness of the weld (Tw) we need to insure the welded joint will sustain the applied load of a force F= 400 KN

With factor of safety of SF = 1.4 and steel S310 and the length of weld is Lw = 300 mm



Solution :

δadm= Reh/ SF = 310/1.4 = 221.43 N/mm^2

weld area Aw= F/δadm= 400000/221.43=1806.4 mm^2

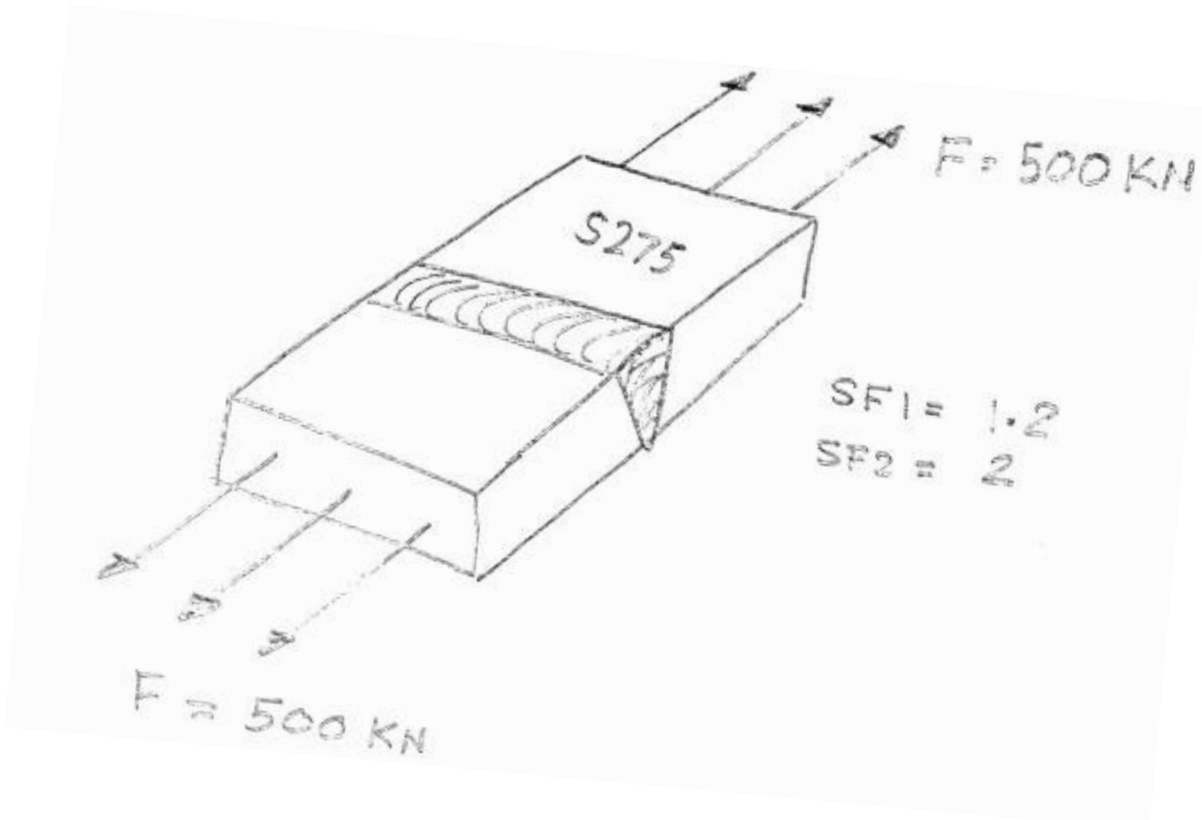
weld thickness aw= Aw/Lw= 1806.4/ 300 = 6 mm

conclusion : the most suitable thickness of weld is 6mm to sustain the load safely.

In the next problem we will explain the difference between the tested and the untested welded joints in sustaining a special load .

<u>Problem 3 :</u>

A welded workpiece of S275 as shown in the figure determine the thickness of weld (Tw) if the welded joint is tested SF1=1.2 and non-tested SF2 = 2 ?



<u>solution :</u>

1- <u>Tested weld SF1= 1.2 :</u>

δadm=Reh/SF1= 275/1.2= 229.16N/mm^2

Aw= F/δadm=500000/229.16=2182mm^2

Tw=Aw/Lw= 2182/400=5.45mm

We can say we will choose a steel plate of 6mm thickness to sustain the load .

2- <u>Non –Tested SF2= 2 :</u>

δadm=Reh/SF1= 275/2= 137.5 N/mm^2

Aw= F/δadm=500000/137.5=3636 mm^2

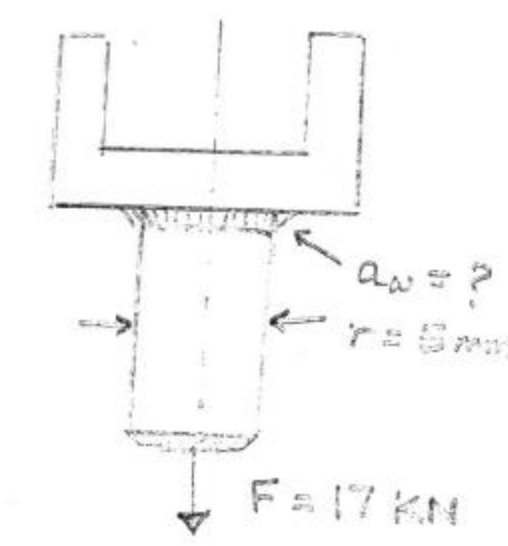
Tw=Aw/Lw= 3636/400=9.09mm

We can say we will choose a steel plate of 10 mm thickness to sustain the load

Conclusion :We have always test the welds in order to save material and control the weight and cost of the mechanical workpiece.

<u>Problem 4:</u>

We want to design this workpiece by calculating the proper and safe weld thickness aw by knowing the applied force F=17KN and d=10mm,SF=2 and it is made of steel S270



Solution:

δadm=Reh/SF = 270/2= 135 N/mm^2

Aw= F/δadm=17000/135=126mm^2

Since Aw = $2 \times \pi \times r \times aw$

$aw = \frac{Aw}{2\times\pi\times r} = \frac{126}{2\times\pi\times 5} = 4$mm

Thickness of the weld required = 4mm

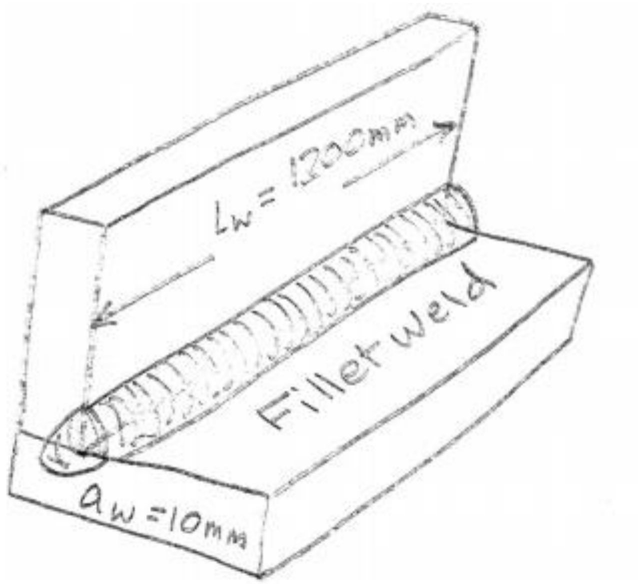
<u>Weld cost calculations:</u>

When we design a welded joints in a workpiece we have to estimate the cost of these welds for engineering purposes to control the cost. Math help us estimate the cost which is essential factor in welding industry.

We will derive a problem in calculating the number of electrodes we need to weld a joint in MMA process then we can predict the cost of weld.

<u>Problem5:</u>

Calculate the number of electrodes needed to complete a fillet weld with length of weld lw = 1200mm and throat thickness of aw =10mm knowing the electrode of mass me =35gm and density of $\rho = 0.00786\ gm/mm^3$



Solution:

$Aw = aw \times aw = 10 \times 10 = 100mm^2$

$Vw = Aw \times Lw = 100 \times 1200 = 120000mm^3$

Then we can calculate the weld mass $Mw =$
$Vw \times \rho = 120000 \times 0.00786 = 943.2gm$

No. of electrodes $n = \frac{Mw}{me} = \frac{943.2}{35} = 27electrodes$

Now, if every electrode take 2 minutes of time to weld.

Total time of weld this joint tw

$tw = n \times te = 27 \times 2 = 54min = 1\ hour$

Conclusion:

We find that the mathematical approach in calculating proper weld dimensions, proper materials for weld and most economical materials, consumables and time is important to reach the most economical and perfect weld which effect on the cost and quality of the engineering workpieces.

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