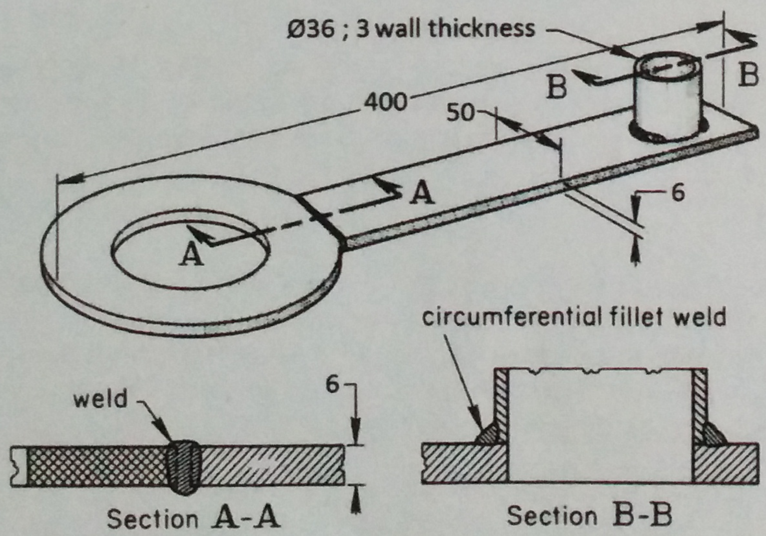
17th December 2014
Kon-67.4200 - Hitsaustekniikka
MSc in Mechanical Engineering
Professor Pedro Vilaça
Autumn 2014
Start 9h00; Duration: 3h00

Aalto University
School of Engineering

Group I – Practical Application (60%) ☞ estimated time: 1h45

Your company received an order to produce 1000 components in AISI 316 that will serve as *Guides* for the drying cylinders in paper machinery, where high productivity (long operation periods with minimum maintenance) and heavy-duty industrial conditions (mechanical fatigue and impact, thermal and chemical loading) are expected. The schematic representation of one *Guide* unit is shown in the figure below. Each *Guide* unit is constituted by 3 components: 1 ring plate + 1 strip plate + 1 tube. The tube is welded to the strip plate in 2 circumferential segments of 120° each, equally spaced by 60° (i.e. no welds near the 2 long sides of the strip plate). The geometrical requirements for the Guide are very strict and thus very low residual deformation is demanded (≤ 0.1 %).
Besides the high dimensional accuracy, an absolutely flat exterior surface for the joint between the ring and strip plates is demanded.



Note: All dimensions are in "*mm*" and manufacturing and quality inspection are performed indoors. The type of joint and bevel represented in the schematic drawing are only representative, i.e. any other more convenient should be adopted.

Chemical composition of all sub-components:

Composition (%)	C	Mn	Si	Cr	Mo	Ni	S	P
AISI 316	0.08	2.00	1.00	17.5	2.50	12.0	≤0.1	≤0.1

Group I (Continuation) – Practical Application

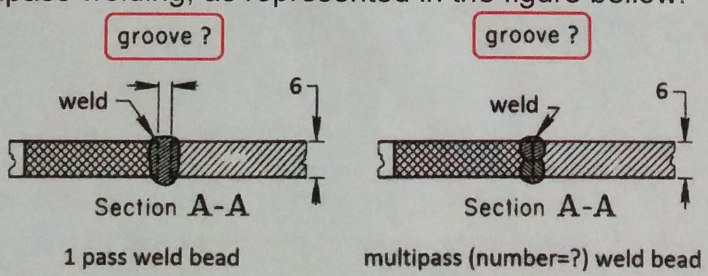
In the role of responsible for the manufacturing of this component in everything that involves welding and NDT technology it is your task to develop a complete and effective solution taking into consideration the client's specifications. Please, answer the following questions:

1. (10%)
Characterize the case study, as follows: Series to produce; Total length of weld beads to manufacture; Overall quality level; Materials involved; Overall geometry (including the scheme of the pieces, with indication of the thickness of the sub-components, respecting the basic rules of technical drawing); Local for manufacturing; Dimensional accuracy; Surface finishing; Other features (e.g. accessibility, mobility).

2. (20%)
Establish a Weldability Analysis considering the potential to apply each of the following welding processes. Justify in detail considering all the conditions and establish the final selection.
Note: no description of the processes is required.
   i. GTAW (also indicate type of shielding gas, current, polarity and filler metal, if required)
   ii. Brasing (also indicate the level of operating temperature, type of filler metal and flux)
   iii. Electron Beam Welding (also indicate the level of vacuum)
   iv. GMAW (also indicate the type of shielding gas, current, polarity and filler metal)

3. (5%)
Describe in detail, the joining process selected for the application. Namely, address the process fundaments, parameters, special features, variants, advantages, disadvantages and application field. Note: if relevant, you may use schematic drawings with legend.

4. (15%)
   a) When the quality requirements are high the positional "jigs" and constrains are relevant. Discuss and represent the type of "jig" to implement.
   b) Represent and classify the type of joint and bevel to apply in the weld bead identified by Section A-A, if the GMAW process was to be applied. Present a solution for 1 pass welding and multipass welding, as represented in the figure bellow.



   c) Which thermal cutting technologies do you know? Please select and justify which one would you apply to produce the bevels for the welding joint.

5. (10%)
   a) Discuss the susceptibility for welding defects (technological and metallurgical), considering all the previous conditions established.
   b) For the defects more susceptible to occur, address how you could act in order to reduce the probability to occur.

Group II – Diverse Questions (20%) ☞ estimated time: 25 min

Rules: In the following 4 questions, refer for each of the 4 answers given, its value: **T** (true) or **F** (false). The answer to a question involves / requires the answer to all the paragraphs. You can choose not to answer any of the questions.
Evaluation Criteria: +1.25 % for each correct and -1.25 % for each incorrect paragraph.

1. (5%)

Considering the physics of electric arc in welding technology:

a) For the same technological conditions and parameters in SAW, the DC+ promotes higher penetration and less deposition rate than DC-. T
b) The electric arc efficiency of PAW is lower than of GMAW. T
c) The electric arc start is easier with Argon than with Helium shielding gas. T
d) The shape of the penetration of the weld bead with Ar shielding gas is uniform. F

2. (5%)

Considering the submerged electric arc welding (SAW) process:

a) The electric arc efficiency is the highest of all the conventional electric arc processes. T
b) It is easy to weld all the thicknesses. F
c) The existence of flux does not enable to weld in overhead position. T
d) With multiple-electrodes connected to multiple-power sources, the first electrode is in AC and all the others in DC. T

3. (5%)

Considering the resistance welding (RW) process, it is possible to state that:

a) During seam welding variant the electrode discs are aligned and the current is continuous and constant. F
b) The control of the distance between consecutive spot welds is important to control the current shunting effect. T
c) Projection welding is the same as spot welding with multi-electrodes. F
d) Spot welding of aluminium alloys demands low current and short weld period. F

4. (5%)

Considering the friction stir welding process (FSW), it is possible to state that:

a) The clamping of the base materials plays an important role in the quality of the welds. T
b) The robotic application of the FSW is easy because the process is in solid-state. F
c) The main difficulty in welding steels is the high hardness of the consumable tools. T
d) The heat is generated inside the base materials. T

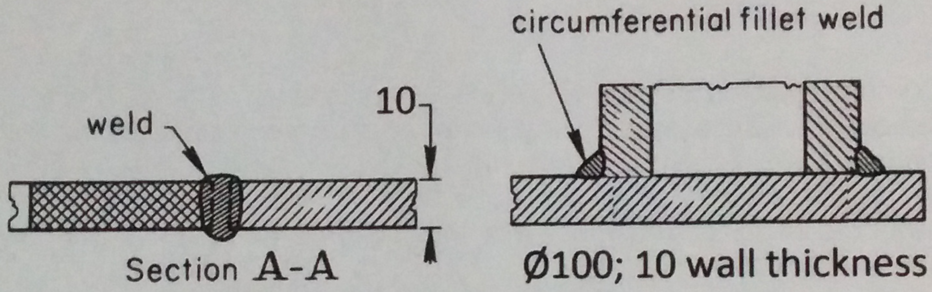
Group III – Quantitative Analysis (20% val.) ☞ estimated time: 50 min

Consider the welded construction of the guide units presented in Group I (<u>Attention</u>: the design, dimensions and material have been modified from Group I condition). The joints were produced with one pass by conventional GMAW process. Component includes corner joint (consider as fillet weld) with no bevel and butt-joint and clamping for both is strong (high restrain). The welding parameters and conditions for both welds are as follows:

- Travel speed, V_{weld} = 480 mm/min and wire diameter 2.0 mm;
- Voltage, U = 30 V;
- Current, I = 290 A;

Consider also that:

- Electric arc efficiency: η = 77%.
- Shielding gas Mison 8 (Ar + 8 % CO_2)



Note: All dimensions in "*mm*". Assume that the tube has circular section with infinite axial length and that the in-plane dimensions of the strip plate are infinite.

Answer the following questions:

a) Determine the heat input associated with the parameters of the GMAW process.
b) Estimate the recommended pre-heat temperature, T_0, for the technological conditions established for both welds (butt and fillet)
c) Determine the extension of the heat affected zone in <u>butt-joint</u> if the critical transformation temperature is 540 °C. Comment the resulting values considering the thickness of the components.
d) Represent and identity the typical main sub-zones of a Heat Affected Zone in a fusion welding of a similar butt-joint of structural steel?

Note: Consider the following physical and chemical properties for the base materials:

Physical properties	Fusion temperature: 1590 °C	Density: 7860 kg/m^3	Specific heat: 510 J/(kg.K)	Thermal cond.: 46.0 W/(m.K)

Composition	C	Si	Mn	S	Cr	Mo	V	Ni	Cu
Structural steel	0.35	0.36	1.40	0.035	0	0	0	0	0