Aalto University
School of Engineering

Exam type for
MEC-E6002 – Welding Technology and Design
MSc in Mechanical Engineering
Professor Pedro Vilaça
Spring 2019
Start XXh00; Duration: 3h00

Group I – Practical Application (55%) ☞ estimated time: 1h45 min

Description of the Case Study

Figures with captions supporting the description of the case study

Chemical composition of components:

Composition (%)	C	Mn	Si	Cr	N	Ni	S	P
ID of material								

In the role of responsible for the manufacturing of this component in everything that involves welding 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%)
   a) Characterize the case study, as follows: Series to produce; Total length of weld beads to manufacture; Overall quality level; Materials involved; Overall geometry (use a schematic representation of the pieces, with indication of the thickness of the sub-components); Local for manufacturing; Dimensional accuracy and surface finishing; Other features (e.g. accessibility, mobility).
   b) The positional clamping jig plays an important role in most of the welding application procedures. Considering the requirements of the present practical application, do you think a clamping jig would be important? If yes, what kind of clamping jig would you consider (use a schematic representation, if it helps)?

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.
e.g.

i. SAW (if applicable, indicate the type of current, polarity and flux)
ii. GMAW (if applicable, indicate the type of current, polarity and transference mode)
iii. Diffusion Welding (if applicable, indicate the temperature and compression load)
iv. Laser Welding (if applicable, indicate the type of laser, shielding gas and filler metal)
v. Electron Beam Welding (if applicable, indicate level of vacuum and filler metal)

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

4. (10%)
a) Represent and classify the type of joint and bevel to apply in the welding construction, considering the welding process, penetration level and overall conditions selected to perform the joint (e.g. accessibility and single or multipass weld).
b) Which thermal cutting technologies do you know? 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.

6. (10%)
a) Which typical residual deformation patterns do you know, resulting from welding thermal cycle and procedures?
b) From the previously identified residual deformation patterns which are more susceptible to occur, in the present case study, considering all the conditions established previously? Justify your answer and 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 3 (up to 5) questions, refer for each of the 3 (up to 5) answers given, its value: **T** (true) or **F** (false). The answer to a question involves / requires the answer to all the paragraphs a) to d). You can choose not to answer any of the questions.
Evaluation Criteria: +1.25 % for each correct and -1.25 % for each incorrect paragraph.

e.g.

1. (5%)

Considering the physics of electric arc in welding technology:

a) The efficiency considered in the estimation of the heat input has the lower value for the SAW process because the electric arc is submerged by the flux.
b) The arc blow effect improves the stability of the electric arc.
c) The arc blow is only relevant for high current values.
d) The arc start short-circuit technique should be only applied to electric arc based processes with consumable electrodes.

2. (5%)

Considering the Soldering and Brazing joining process:

a) The dilution rate (DR) is DR = 1 (one).
b) The main difference between brazing and soldering is the melting point of filler metal.
c) The capillary effect increases with the increase of the surface tension and wetting capability of the filler metal over the substrate of the base material.
d) The gap should be maximized to promote efficient capillary action.

3. (5%)

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

a) The projection welding is a variant of the resistance welding typically automatized and with high productivity.
b) The heat input generated by electric arc is mainly dissipated at the interface of the overlapped workpieces where the electrical resistance are higher.
c) To weld aluminium alloys by resistance welding it is used high weld current during low weld time.
d) Current shunting effect and electrode wear are common problems in resistance welding.

4. (5%)

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

a) The geometry of the probe and shoulder of the FSW tool plays a major role in the quality of the weld joint.
b) The aluminium alloys are difficult to weld due to the thick and stable oxide layer.
c) The correct application of stationary shoulder FSW tools result in smoother weld beads with lower heat input.
d) The FSW tools are non-consumables and have an infinite life.

Group III – Quantitative Analysis (25% val.) ☞ estimated time: 50 min

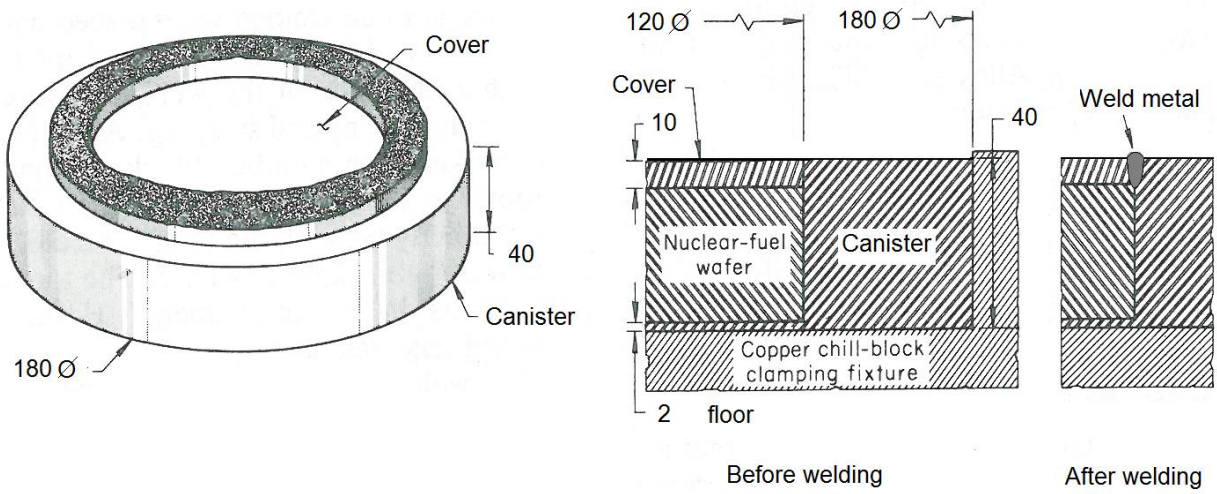
One or Two questions involving mostly quantitative analysis in one or more of the following welding related fields: (Typically, it is related with the case study of Group I, but not necessarily)

- welding technology;
- welding metallurgy;
- welding design.

e.g.

Consider the welded construction of the container for the nuclear fuel wafer presented in Group I (Attention: the dimensions have been modified from Group I condition). This joint was produced with 1 full penetration pass by advanced A-TIG process with filler metal in butt joint with no bevel and strong clamping (high constrain). The welding parameters and conditions are:

- Travel speed, V_{weld} = 144 mm/min;
- Weld position: Flat but joint
- Voltage, V = 30 V;
- Current, I=160 A;
- Absorption efficiency of electric arc energy: η=50%;
- Dilution rate, DR = 0.75.



Note: All dimensions in "*mm*".

Chemical composition and properties of base material (Stainless Steel 304L):

Composition (%)	C	Mn	Si	Cr	N	Ni	S	P
SS 304L	0.03	2.0	0.7	19.0	0.10	10.1	≤0.030	≤0.045

Physical properties	Yield strength: 241 MPa	Ultimate strength: 586 MPa
Young modulus: 193 GPa	Fusion temperature: 1427 ºC	Density: 8000 kg/m^3
Thermal expansion: 17.3 μm/(m.K)	Specific heat: 510 J/(kg.K)	Thermal cond.: 16.3 W/(m.K)

Group III (Continuation) – Quantitative Analysis

Answer the following questions:

a. Determine the heat input associated with the parameters of the A-TIG process.

b. Considering that only 20% of the heat input is delivered into the Cover, determine the total heat energy delivered to the Cover.

c. Considering the Cover in adiabatic condition, determine:
   c1) The uniform temperature of the Cover, long time after welding.
   c2) The correspondent final diameter of the Cover due to radial thermal expansion, if the cover was free to expand.
   c3) The residual compressive stress in the Cover if the Canister would not undergo any thermal expansion.

d. Select among the following 3 filler metals available in the market, the one to use as filler metal for this application. Include a detailed justification of the selection.

Note: Consider the WRC-92 Diagram (that is included in the formulae support). Mark clear indications of the keypoints and procedures supporting the answer and submit this diagram for evaluation along with your resolution of the exam. Do not forget your identification.

Composition (%)	C	N	Si	Mn	Cr	Ni	Ti	Nb	Mo	Cu	Co
Filler Metal A	0.05	0.1	3	3	12	10	0	0	1.5	0	0
Filler Metal B	0.1	0	4	2	18	5	1.5	1	2.5	1	1
Filler Metal C	0.15	0	4	5	17	7	1	0	0	2	2