MANUFACTURING ENGINEERING TRIPOS PART I

Saturday 29 April 2006 9 to 12

PAPER P1

DESIGN AND MANUFACTURE

*Answer not more than **four** questions of which not more than **one** may be taken from each section **A, B, C** and **D**.*

*Answers to sections **A, B, C** and **D** must appear in four separate booklets.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

STATIONERY REQUIREMENTS

8 Page Answer Book x 4

Rough Work Pad

SPECIAL REQUIREMENTS

Engineering Data Book

P1 Data Book

ATTACHMENTS

If you choose to answer QUESTION THREE, the two attachments contained in this paper should be attached firmly to your answer booklet. Write your candidate number on each of the attachments and annotate them with your answer to the question.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

SECTION A

*Answer **one** question from this section.*

1 (a) Name the four characteristics of an optimised design. [10%]

(b) When designing for optimised assembly, explain what 'design efficiency' means. Outline how you might analyse an existing design in order to reduce the number of components and list the nine questions you might use to help you do this.

[15%]

(c) The design shown in Figure 1 is an old design for the front mechanism of a hand-held power saw. Not shown is the motor with a gear wheel on its shaft, which enters the hole at the right hand end of the housing, meshing with and turning the gear. The pin on the gear links with the connecting rod which links with the piston via another pin, converting the rotary motion of the gear to a reciprocating motion for the saw blade. Make a preliminary list of what you consider might be primary components and estimate the design efficiency. [25%]

(d) Sketch and explain a simplified design focusing on the primary functionality, adding features to the primary components and minimising the number of secondary components to reach a design efficiency of at least 60%.

[50%]

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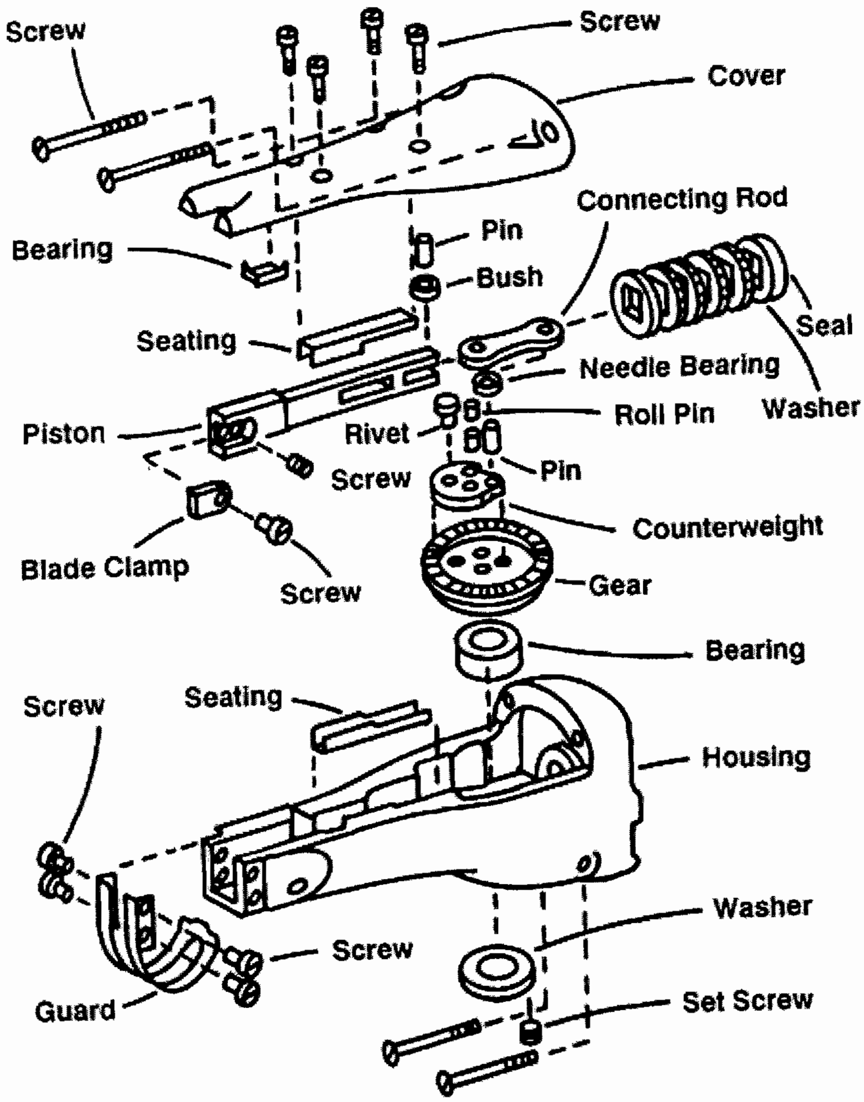

Screw
Screw
Cover
Connecting Rod
Pin
Bearing
Bush
Seal
Seating
Needle Bearing
Washer
Roll Pin
Piston
Rivet
Screw
Pin
Counterweight
Blade Clamp
Screw
Gear
Bearing
Seating
Screw
Housing
Washer
Screw
Guard
Set Screw

Figure 1

2 (a) Briefly outline the Fisher/Deming/Taguchi story and explain the philosophy underlying the Taguchi approach to quality control. [15%]

(b) Explain the principle behind the design of a set of Taguchi experiments and outline how information on the effect of each parameter being investigated can be extracted from the results. [15%]

(c) In the commissioning of a poly-silicon deposition process, the settings of six out of the eight control parameters are being explored, with the intention of maximising the deposition rate whilst minimising the number of surface defects. The remaining two control parameters are considered to have a negligible effect but have been included as dummy parameters marked 'x' in the experiments. The six parameters being explored are each given three settings as outlined in Table 1. Eighteen tests are conducted and the settings for each parameter and the resulting levels of surface defects and rates of deposition are recorded in Table 2. Using the conventional quadratic loss function, the defect and deposition rates are converted into decibel levels, so that

Defect level (dB) $= -10 \log_{10} (\text{surface defect count})^2$
Deposition rate (dB) $= -10 \log_{10} (\text{deposition rate})^2$

Calculate and plot the effects of the settings of the six parameters being studied in these experiments. [50%]

(d) Discuss the effects of the different parameters and suggest a strategy for maximising overall production rate, given that significant surface defects cause rejection of the element produced before it is passed to the next process. [20%]

(cont

Factor	Levels		
	1	**2**	**3**
A. Deposition temperature (°C)	T_o - 25	T_o	T_o + 25
B. Deposition Pressure (mtorr)	P_o - 200	P_o	P_o + 200
C. Nitrogen flow (sccm)	N_o	N_o - 150	N_o - 75
D. Silane flow (sccm)	S_o - 100	S_o -50	S_o
E. Settling time (min)	t_o	t_o + 8	t_o + 16
F. Cleaning method	None	CM_2	CM_3

Table 1

Expt No.	Experiment settings								Defect Level (dB)	Deposition Rate (dB)
	x	**A**	**B**	**C**	**D**	**E**	**x**	**F**		
1	1	1	1	1	1	1	1	1	0.51	23.23
2	1	1	2	2	2	2	2	2	-37.30	31.27
3	1	1	3	3	3	3	3	3	-45.17	32.34
4	1	2	1	1	2	2	3	3	-25.76	31.15
5	1	2	2	2	3	3	1	1	-62.54	37.27
6	1	2	3	3	1	1	2	2	-62.23	33.89
7	1	3	1	2	1	3	2	3	-59.88	37.68
8	1	3	2	3	2	1	3	1	-71.69	40.46
9	1	3	3	1	3	2	1	2	-68.15	41.21
10	2	1	1	3	3	2	2	1	-3.47	27.89
11	2	1	2	1	1	3	3	2	-5.08	26.02
12	2	1	3	2	2	1	1	3	-54.85	31.82
13	2	2	1	2	3	1	3	2	-49.38	34.50
14	2	2	2	3	1	2	1	3	-36.54	33.20
15	2	2	3	1	2	3	2	1	-64.18	34.76
16	2	3	1	3	2	3	1	2	-27.31	37.71
17	2	3	2	1	3	1	2	3	-71.51	40.45
18	2	3	3	2	1	2	3	1	-72.00	39.22

Table 2

SECTION B

*Answer **one** question from this section.*

3 You are the chief engineer in a precision engineering firm. A trainee has given you a component drawing to check – the part is a spindle housing – and is named 'Exam 1'.

(a) Looking at the drawing provided in Figure 2, describe the way in which this part will be made in production, starting from raw material and including every subsequent processing step, describing any tooling, fixtures or gauging that may be required. [25%]

(b) The drawing in Figure 2 needs significant improvement. On *'Sheet 1' (provided as an attachment)*, mark up the drawing, identifying all of the errors, ambiguities and improvements needed. Your notes should be written *on* the attachment, along with your candidate number. [25%]

(c) The trainee has missed two important dimensions – diameter C and diameter D, but has described the type of fit needed. Diameter C requires a tight transition fit of nominal size ∅86.0 mm, and diameter D requires a loose clearance fit of nominal size ∅41.5 mm. Calculate the appropriate tolerances for these two features. [10%]

(d) As chief engineer, you have decided that Diameters C and D also require further geometric tolerances to ensure functionality. On *'Sheet 2' (provided as an attachment)*, add appropriate geometrical tolerances, to ensure that these two features are concentric to each other, and are perpendicular to the front surface of the component. Your answer should be written *on* the attachment, along with your candidate number. [20%]

(e) You also prefer to see all drilled holes dimensioned using positional tolerances. Also on *'Sheet 2'*, demonstrate how the 16 M5 holes and the 8 holes for M6 bolts should be specified using positional tolerancing. Your answer should be written *on* the attachment, along with your candidate number. [20%]

(cont

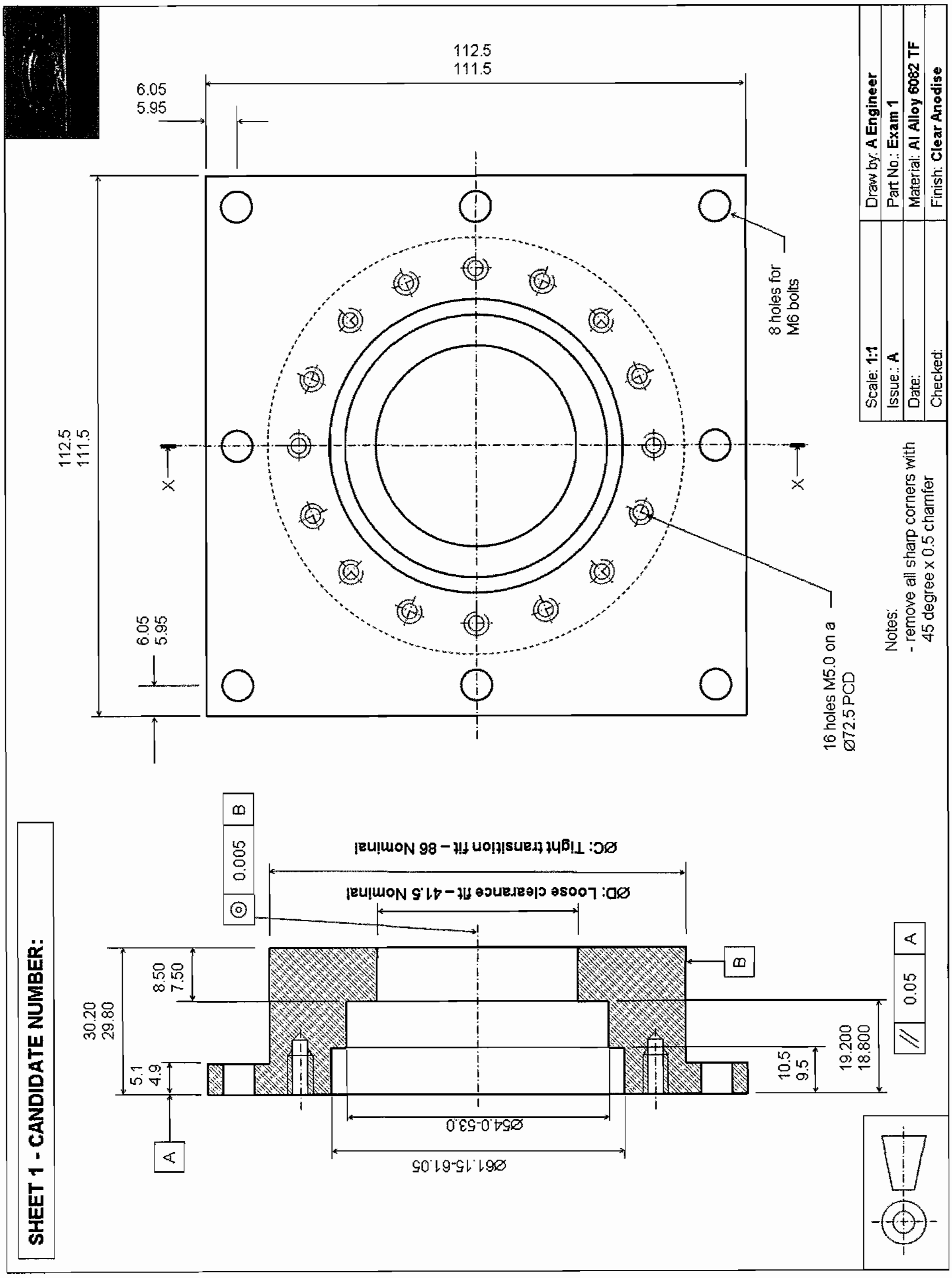

SHEET 1 - CANDIDATE NUMBER:
112.5
111.5
6.05
5.95
X
8 holes for M6 bolts
16 holes M5.0 on a Ø72.5 PCD
Notes:
- remove all sharp corners with 45 degree x 0.5 chamfer
Draw by: A Engineer
Part No.: Exam 1
Material: Al Alloy 6082 TF
Finish: Clear Anodise
Scale: 1:1
Issue.: A
Date:
Checked:
ØC: Tight transition fit – 86 Nominal
ØD: Loose clearance fit – 41.5 Nominal
0.005
B
0.05
A
30.20
29.80
8.50
7.50
5.1
4.9
10.5
9.5
19.200
18.800
Ø54.0-53.0
Ø61.15-61.05

Figure 2

4 You are a production manager in a firm that makes extruded components. To reduce waste and improve quality, the design office wishes to tighten the tolerance on the length of a critical component. 1000 parts from the first batch of the day have been measured, resulting in a mean length of 255.1 mm and a standard deviation of 0.7 mm.

(a) Calculate a sensible Upper Specification Limit (USL) and Lower Specification Limit (LSL) for a single component and explain your reasoning. [5%]

(b) Throughout the rest of the day, a further five batches of parts are measured. The mean and standard deviation are calculated for a sample of 1000 for each batch as shown in Table 3. For each batch, calculate the Cpk value, using your answers from part (a) for the LSL and USL values. [35%]

	Morning			Afternoon		
	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6
Mean values	μ_1=255.1	μ_2=256.3	μ_3=257.0	μ_4=255.0	μ_5=256.1	μ_6=256.8
Standard deviations	σ_1=0.7	σ_2=0.6	σ_3=0.4	σ_4=0.35	σ_5=0.3	σ_6=0.25

Table 3 Mean and standard deviation for each batch of 1000 components, all dimensions in mm

(c) Discuss, with sketches where appropriate, what the Cpk, mean and standard deviation values might indicate about the production process and how it might be improved. [35%]

(d) Based on evidence from the whole day's production, calculate a new LSL and a new USL to recommend to the design office. [10%]

(e) The design office has responded with a desired USL of 254.6 mm and a desired LSL of 253.4 mm. As production manager, how would you respond to their request? [10%]

(f) Briefly discuss how the underlying principles of six sigma develop the concept of process capability further. [5%]

SECTION C

*Answer **one** question from this section.*

5 (a) For a production facility discuss the differences between a functional layout and a cellular layout. Identify the advantages and disadvantages of each layout.

[40%]

(b) A company manufactures five product groups as shown in Table 4, (A, B, C, D, E, and F are functional departments).

Product Group	Production Sequence	Production/Week
Hays	ABCDEF	2000
Bees	DBCAF	3500
Sees	CADAFA	6000
Dees	FECDBC	2500
Ease	CBDECAB	500

Table 4

i) Using this data, create an activity relationship diagram. [30%]

ii) Describe in detail what other data you would require to enable you to develop a factory layout, and discuss the stages that you would go through to do this.

[30%]

6 (a) Define the term ‘method study’. Briefly outline the main stages of method study. [30%]

(b) As part of a study into the machining operations in a production department you wish to know the utilisation of five machines. The foreman has estimated that three machines have a utilisation of 80%, one has a utilisation of 70% and one a utilisation of 50%. You decide to verify his estimates by means of an activity sampling study. Describe in detail how you would design and carry out the study, assuming that you wish to be 90% confident that the error in the values you determine would be no greater than +/- 5% in absolute terms (e.g. if the estimate were 78%, you wish to be 90% certain the true value lies between 73% and 83%). [50%]

(c) Discuss the advantages and disadvantages of activity sampling compared to time study. [20%]

SECTION D

Answer ***one*** *question from this section.*

7 (a) High accuracy mould tools are critical for the production of precision plastic mouldings. Name three materials that could be used for injection mould tooling and state the reasons for choosing them. [15%]

(b) Electric Discharge Machining (EDM) is an advanced machining process used for the production of complex mould tools.

(i) Describe in detail the physical principles of the EDM process and its practical implications with regard to the following:

- electrode materials;
- user selectable process parameters;
- the types of materials that can be machined;
- the importance of fluid delivery.

[50%]

(ii) What influence does energy density have on the quality of the machining?

[15%]

(c) Briefly describe two processes that are not based on mechanical cutting and can compete with EDM for the production of precision tooling. [20%]

8 (a) Machining is a general term used to describe the removal of material from a workpiece. It covers several processes which can be divided into the following categories:

(i) cutting;

(ii) abrasive processes;

(iii) advanced machining processes.

List four machining processes for each category. [12%]

(b) Describe the basic model of chip formation in an orthogonal cutting operation. Support your description with a diagram and highlight the important features of the chip formation process. [30%]

(c) The types of chip produced in a cutting operation significantly influence surface condition, machining integrity and the overall cutting operation. There are some deviations from the ideal model. Describe the four basic chips produced in metal-cutting operations, and discuss the conditions under which they are likely to occur. Use diagrams to support your answer. [28%]

(d) Consider the face milling example shown in Figure 3. The workpiece moves into the cutter at a velocity, v; the width of the cut, w, is 25 mm; the depth of cut, d, is 2.5 mm; the diameter of the cutter, D, is 50 mm; the number of cutting teeth, N, is 4; the feed per tooth is 0.175 mm; the cutter's tangential surface speed is 12,500 mm/s; and the specific cutting energy of the material is 1.1 J mm^{-3}. Calculate the following:

(i) Material Removal Rate MMR ($mm^3\ s^{-1}$)

(ii) Power requirement P (W) [30%]

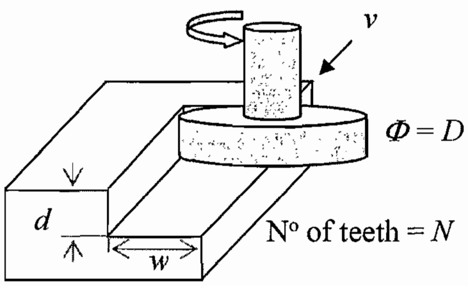
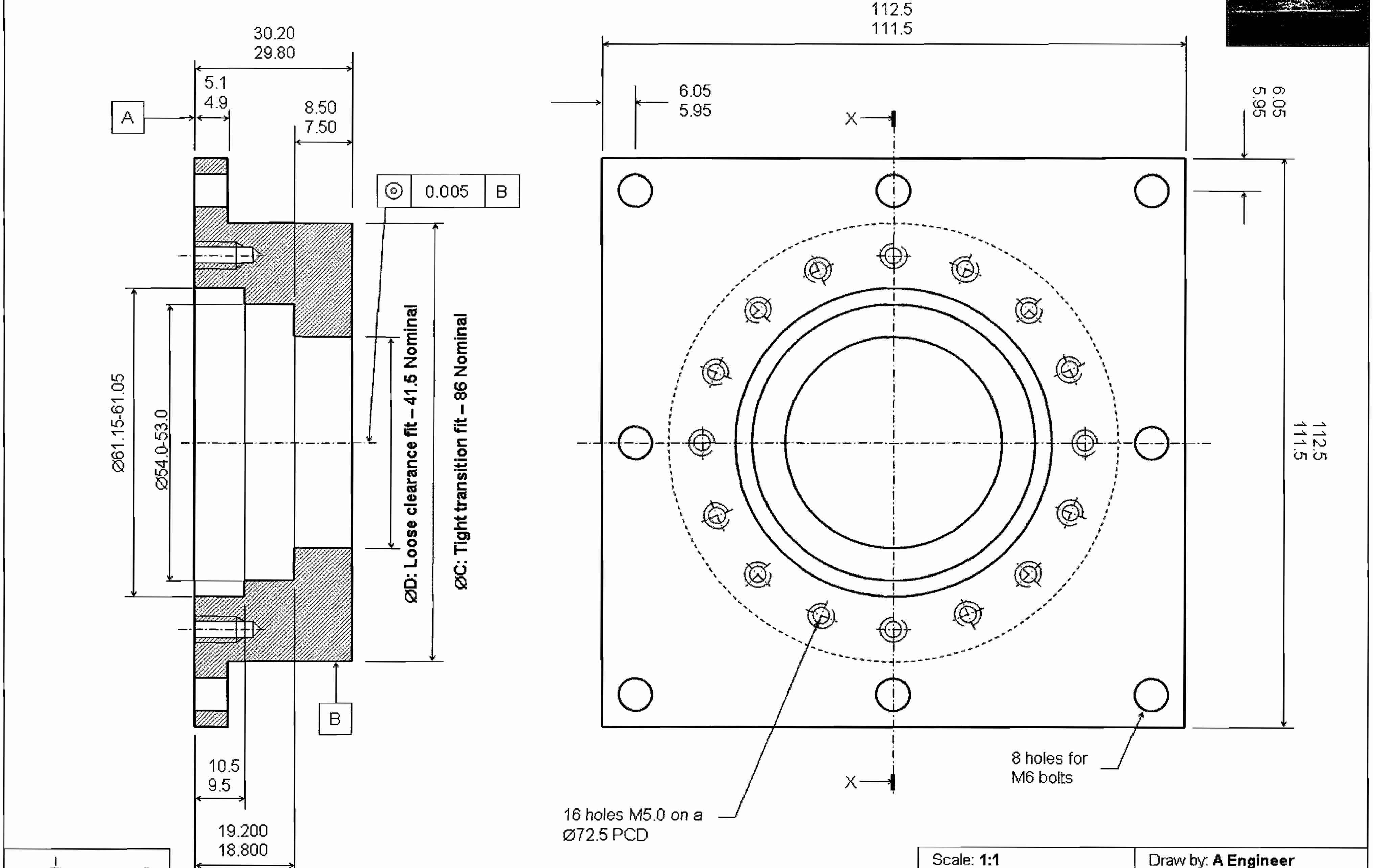


Figure 3

END OF PAPER

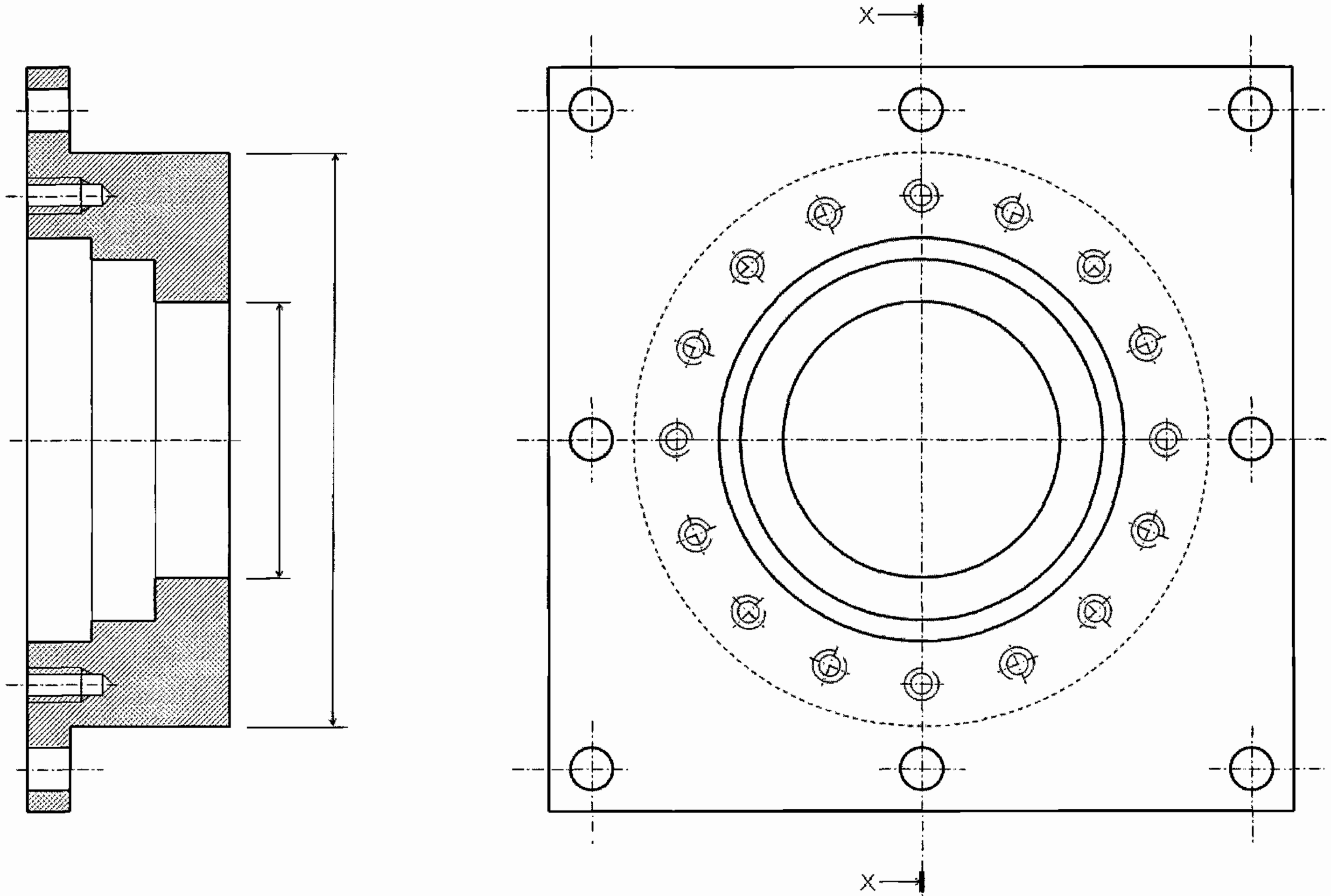
SHEET 1 - CANDIDATE NUMBER:

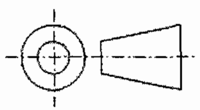


Notes:
- remove all sharp corners with 45 degree x 0.5 chamfer

Scale: **1:1**	Draw by: **A Engineer**
Issue.: **A**	Part No.: **Exam 1**
Date:	Material: **Al Alloy 6082 TF**
Checked:	Finish: **Clear Anodise**

SHEET 2 - CANDIDATE NUMBER:





Scale: **1:1**	Draw by: **A Engineer**
Issue.: **A**	Part No.: **Exam 1**
Date:	Material: **Al Alloy 6082 TF**
Checked:	Finish: **Clear Anodise**