School of Mechanical and Electrical Engineering,
Faculty of Health, Engineering and Science,
University of Southern Queensland

MEC3302 – Computational Mechanics in Design, S1 2017

Assignment 3 – Marks 300/1000

Due Date: 26th May 2017

Question 1 (90/300 marks)

Figure 1 (a) & (b) show preliminary drawings (arrangements) of a passenger railway carriage that was supplied to a design engineer to find out the appropriate Aluminium sheets needed to fabricate the superstructure walls of the carriage. The superstructure's side walls and roof will be manufactured entirely from thin Aluminium sheets.

Design Criteria:

(i) Optimize the weight
(ii) Optimized the maximum principal stress -The stress acting on the super structure needs to be kept at minimum levels as much as possible at 3.5g deceleration of a wagon. Keep stress level under 75 MPa as much as possible
(iii) Avoid stress raisers as much as possible by making minor design changes (to the sheet metal only).

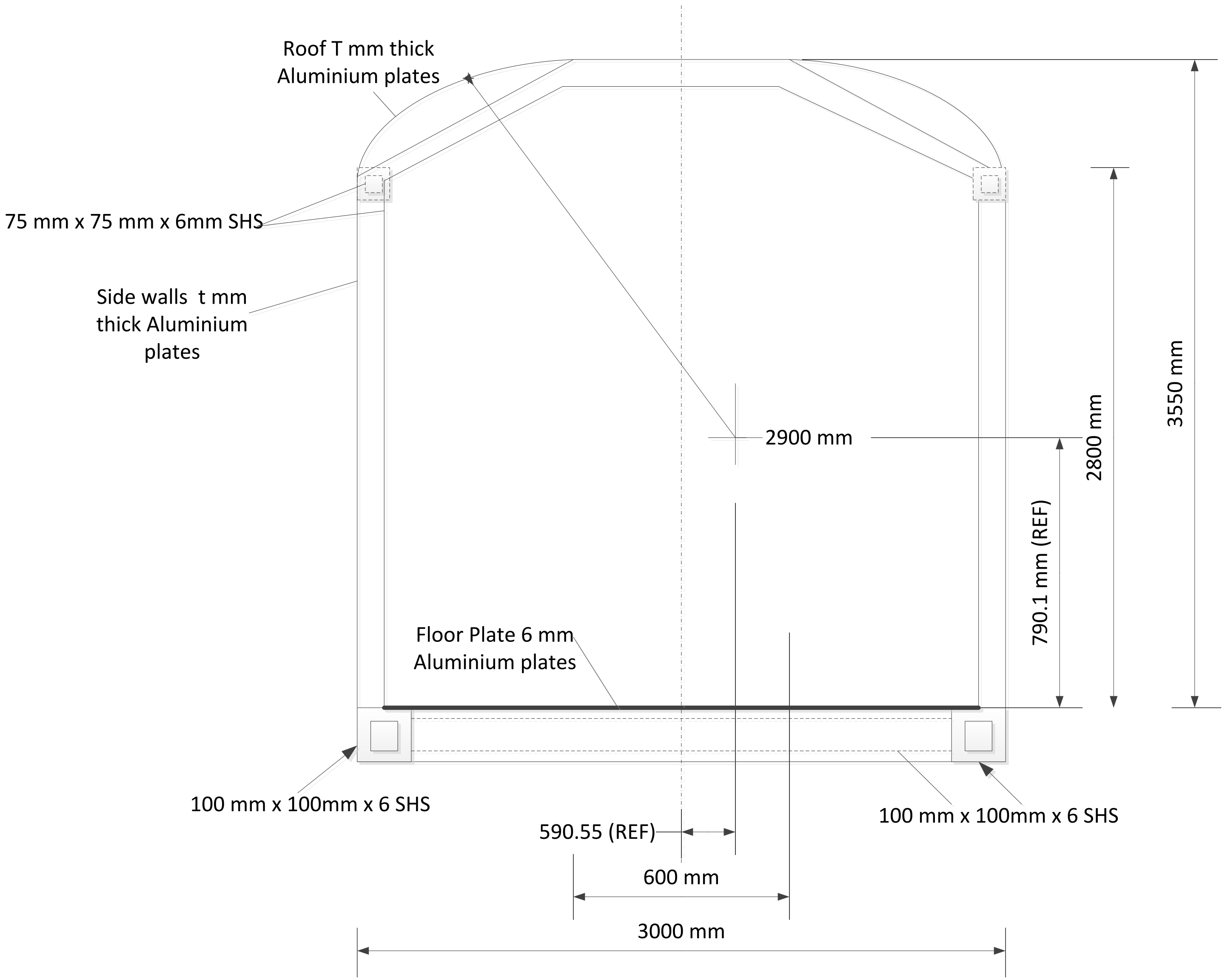
The following are some of the important details provided to the design engineer by the wagon designer. (you need to refer to appropriate Aluminium sheet data such as **Bluescope Aluminium Catalogue**)

(iv) Weight of attachment on the roof surface (curved roof structure)of the superstructure can be considered as a 35 kg/m^2 weight load
(v) Weight of attachments on the side surface (walls above the floor)of the superstructure can be considered as a 15 kg/m^2 weight load
(vi) The super structure will be rigidly attached to the floor.
(vii) The floor is fabricated with 6 mm thick Aluminium plates.

Your task:

1. Create a suitable FEA model using Creo Parametric + Simulate 3.0
2. You can assume missing dimensions and methods of joining & connections of components which are essential for your analysis. You need to explain why you believe these assumptions are appropriate for the intended analysis.
3. **You need to minimize the size of your model as much as possible, using symmetry and sub-structuring for the analysis appropriately.** You need to perform appropriate analysis to investigate identified locations of stress concentrations such as corners of cut-outs (i.e. doors & windows)
4. **Determine suitable corner radii(s) of cut-outs** for doors and windows
5. Determine a suitable thickness, "T" and ***" t "*** of the Aluminium sheets for wall and roof structure of the railway carriage to satisfy the design criteria. (You need to consider excessive stresses and weight issues for your decision)
6. Using a suitable FEA model determine the first four natural frequencies of super structure and their mode shapes.
7. Provide an FEA report including appropriate stress, deflection, vibration mode plots and other necessary plots. Show results before and after your design changes highlighting the max stress and final weight.

(All dimensions in Figures 1 (a) and (b) show nominal values in millimetres unless otherwise stated. Do not scale from the drawings)


Roof T mm thick
Aluminium plates
75 mm x 75 mm x 6mm SHS
Side walls t mm
thick Aluminium
plates
2900 mm
2800 mm
3550 mm
790.1 mm (REF)
Floor Plate 6 mm
Aluminium plates
100 mm x 100mm x 6 SHS
100 mm x 100mm x 6 SHS
590.55 (REF)
600 mm
3000 mm

Do Not Scale

Figure 1 (a)

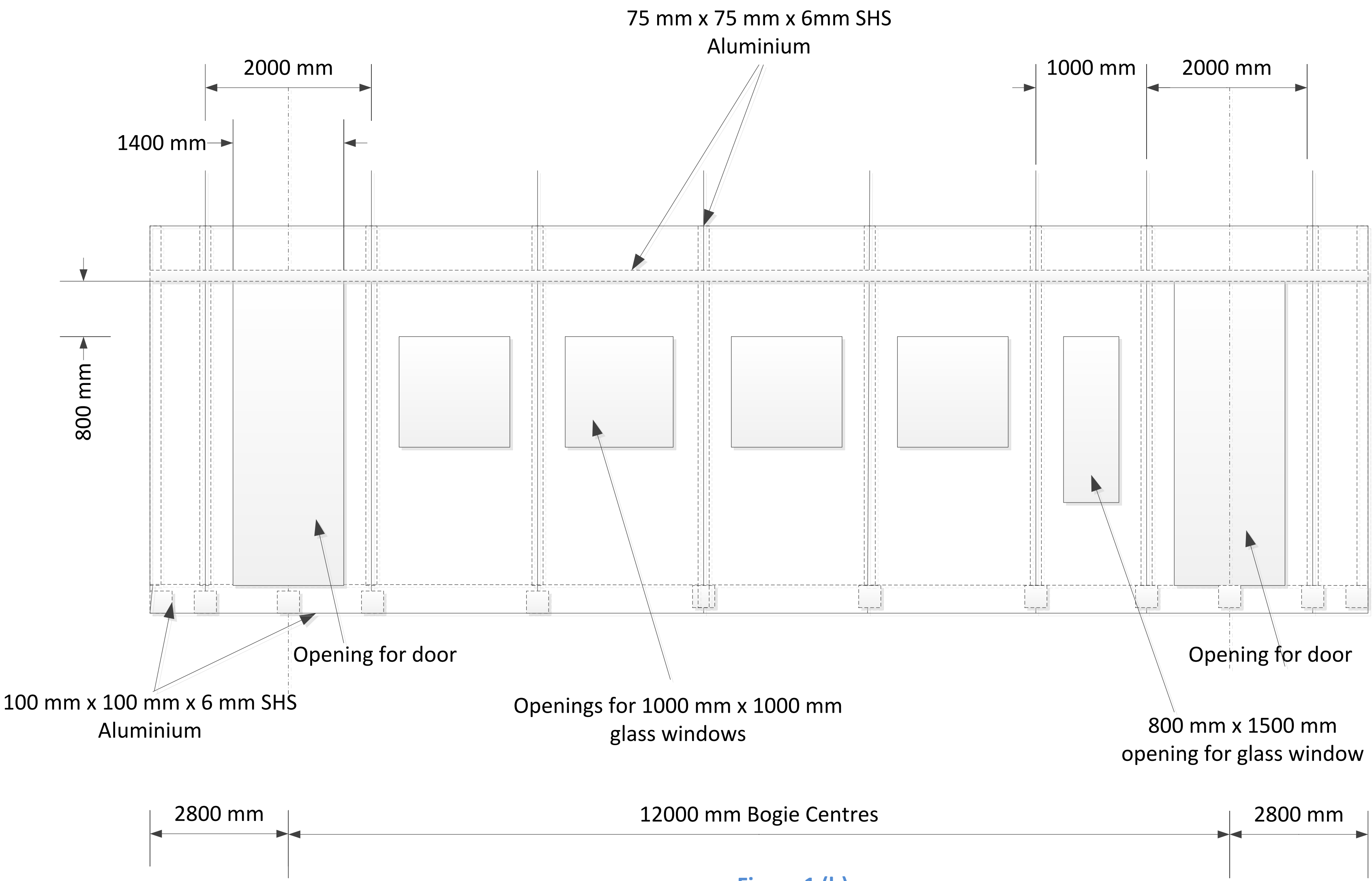
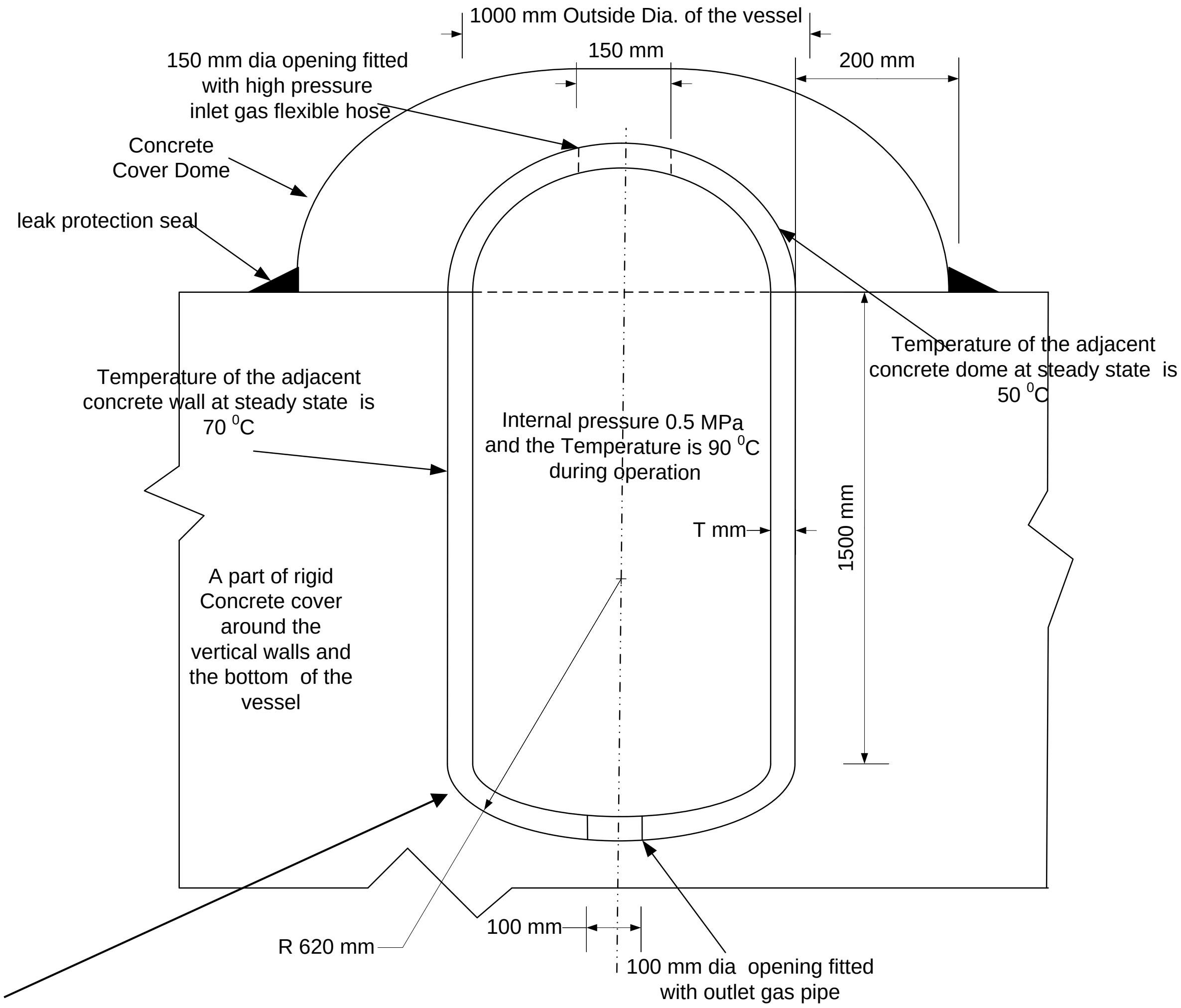


Figure 1 (b)

Do Not Scale

Question 2 (80/300 marks)



Outer radius of transition is 25mm

Figure 2: A stainless steel pressure vessel.

A sectional impression of a stainless steel pressure vessel used in a nuclear material processing plant is shown in Figure 2. The pressure vessel needs to be installed in a rigid concrete (assume Grade 40) cover as shown and closed with a hemispherical cover dome. A flexible leak protection seal will be placed around the concrete dome. Assume there is no clearance between the vertical walls of the vessel and the concrete enclosure walls. The vessel is resting on the bottom concrete slab as shown. The initial conditions of the vessel estimated as ambient pressure, 1 bar and ambient temperature, 25 ^{0}C. Major design dimensions are shown and the thickness T needs to be determined by a FE Analysis. The vessel needs to withstand 0.5 MPa internal pressure and temperature increased up to 90^{0}C (at steady operational state). The vessel needs to be designed for 25% pressure surges and maximum stress in the vessel walls needs to be minimized as possible. You need to check your answers with appropriate manual calculations. (Assume the concrete cover adjacent to vessel's outer vertical walls reaches 70 ^{0}C and the interface at concrete dome and the vessels top dome is 50^{0}C at the steady state. Determine a suitable trial value for thickness "T ". Use the trial value for FEA and refine it until you meet the optimal design criteria. You need to (list all your assumptions):

1. Assume a trial thickness and perform simple manual calculations for a pressure vessel i.e. hoop and axial stresses at ambient conditions. Compare your manual calcs with axi-symmetric FEA (2D Static FEA). Then perform with axi-symmetric FEA (2D Static + thermal FEA). You need to continue trial values of plate thickness until you find an optimized condition according to your judgment. You should not go beyond the thickness of 35 mm.
2. Provide stress/strain/deflection/Temperature plots as necessary.
3. Perform an appropriate 3D analysis for final design of the vessel (Combined static & steady state thermal) and compare your 2D FEA results with 3D FEA results in a table.
4. Provide your comments on the FEA analysis. Include your suggestions for improved design (geometry, materials of the vessel and the concrete dome) if the operational conditions cause higher stresses than allowable stresses.

Question 3 (65/300 marks)

Figure 3 shows a typical brake disk of an automobile for your understanding. Your task is to develop a suitable and optimized FEA model on your choice of a brake disk. You need to evaluate the structural response and dynamic behaviour (forces, temperatures, natural frequencies and centrifugal forces) according to its operational conditions. You are required to do your own research and determine realistic/actual geometry/dimensions, the functionality/real-life use and the materials for your analysis. The functionality/real-life use must be clearly detailed in your report. You need to perform an essential analysis and provide the detail of significance of the analysis to the functionality. In your report, you must clearly show your estimate of input forces and the appropriateness of applied constraints. You may use sub-structuring, symmetry as required. Include clear details of modelling, assumptions and modelling techniques (2D/3D analysis, mesh refinement, etc.) that you have used for your analysis. Include comments on the results and any potential design issues.

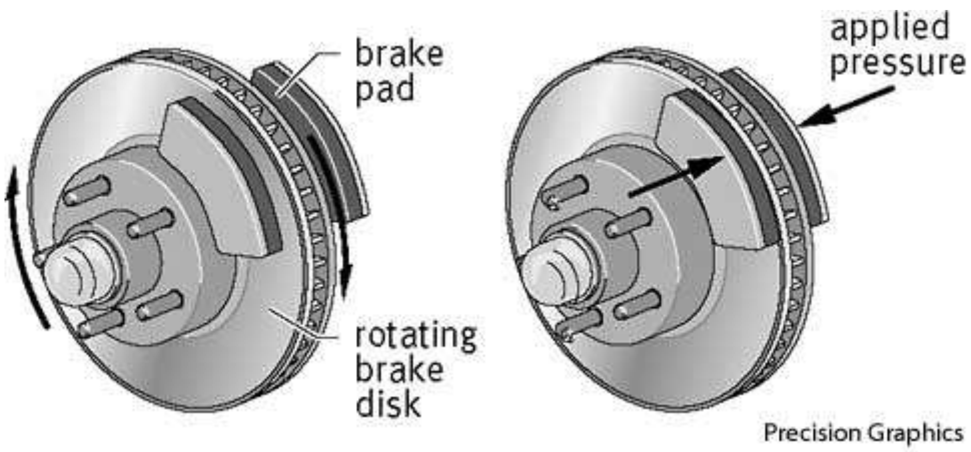


Figure 3. Brake Disc Rotor

Question 4 (65/300 marks)

Figure 4 shows an engineer's sketch of a proposed horizontal stainless steel shaft which will drive a mixer of a chemical plant. It will be directly coupled to a 5kW, 1500 rpm electrical induction motor and the smaller end coupled to the shaft of the mixer. The length of bearing surfaces can be assumed as indicated in the drawing. Bearing A and the connection at mixer do not allow axial movements. The estimated thrust created on the shaft by the mixer P = 2kN. Please note an additional block bearing C is only necessary depending on the outcomes of your FEA analysis. Block bearings allowed small axial movements. The surface of the smaller diameter shaft is fully insulated to avoid heating by insulating safety covers (not shown here) The portion of bigger diameter of the shaft will be exposed to ambient air (convection coefficient can be taken as 60 $W/m^2/^0C$) .

Your task:

1. Create an appropriate FEA model on Creo 3.0. Assume and justify any missing details you required. You need to list assumptions with your justification in the report.
2. Perform static, thermal and static +thermal and dynamic analysis.
3. Show necessary results including 3 natural frequencies and mode shapes of the shaft. Perform an analysis to determine the suitability of proposed arrangement using your FEA results. Check some of these results against some hand calculations.
4. Using a modification to your FEA model by adding Bearing C at an appropriate position with your engineering judgement, check whether you can improve the structural performances of the shaft (i.e. reduced stresses, reduced risk of buckling, change of natural frequencies and mode shapes etc.
5. Provide your engineering judgement using FEA results.

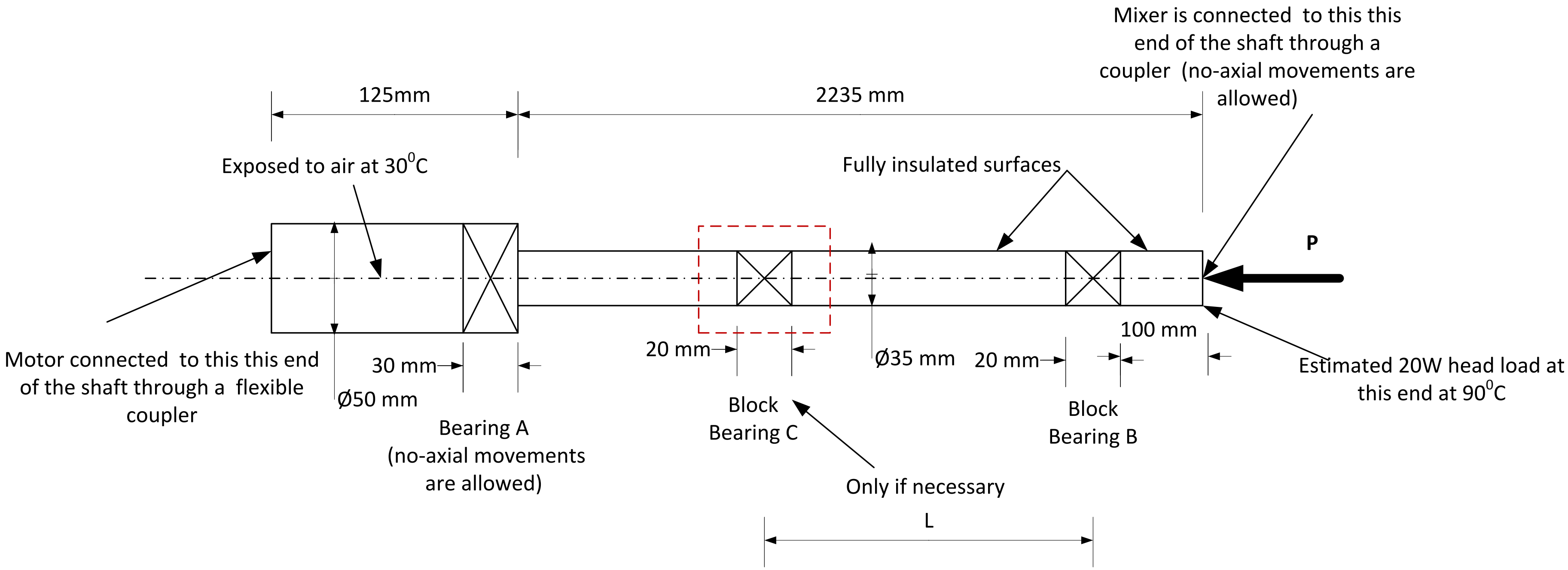


Figure 4: Shaft for a mixer