MECHANICAL STRENGTH OF ANCILLARY STRUCTURES

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SUMMARY

This document justifies the design for handling and transport of packaging ancillary structures as described in chapter O and in the drawings in Appendix 1 of chapter O.

For the TN-MTR packaging, these structures are limited to the shock absorbing cover. The verification applies to:

- the resistance to overpressure in the shock absorbing cover, due to a hypothetical release of gas from the wood under normal conditions of transport. This pressure is taken to be equal to 0.1 bars.

- The resistance of the cover to impact under normal transport conditions. The check is made for accelerations of 2g.

Considering the layout of the welds on the outer casing of the shock absorbing cover (butt welds) and the fact that the mechanical properties of weld filler materials are better than the properties of the assembled materials, the welds are not specifically verified.

Material properties are as given in chapter O; it is conservatively assumed that the temperature of the steel in the metal casing of the shock absorbing cover is 150°C.

The check is made by analytical calculations.

The results (maximum stress equal to 100 MPa) show that the yield stress of the stainless steel from which the outer casing of the shock absorbing cover is made is not reached and therefore the shock absorbing cover is neither deformed nor damaged under normal transport conditions. This guarantees that the shock absorbing cover complies with assumptions made for the analysis under accident conditions.

1. INTRODUCTION

This document justifies the design of packaging ancillary structures under normal handling and transport conditions as described in chapter O and in the drawings in Appendix 1 of chapter O.

For the TN-MTR packaging, these structures are limited to the shock absorbing cover. The verification applies to:

- resistance to overpressure in the shock absorbing cover,
- The resistance of the cover to impact under normal conditions of transport.

The design of securing and handling means is justified in Appendix 3 to Chapter 1 in the safety analysis report.

Considering the layout of the welds on the outer casing of the shock absorbing cover (butt welds) and the fact that the mechanical properties of weld filler materials are better than the properties of the assembled materials, the welds are not specifically verified.

2. SHOCK ABSORBING COVER RESISTANCE TO DIFFERENTIAL PRESSURE

2.1 Hypotheses

The shock absorbing cover consists of a casing made of stainless steel type A (see chapter O), filled with wood (oak and balsa). It is fixed to the body by 6 M42 screws. The metal casing contains radial stiffeners (711), also made of stainless steel.

Stresses are calculated for a differential pressure P = 0.1 bars = 0.01 MPa (internal overpressure) taking into account the low level of a hypothetical release of gas from the wood under normal conditions of transport.

The metal casing is fitted with meltable plugs (see description in chapter O) for good behaviour during a possible fire.

The check is made by comparing with the yield stress of steel type A (see chapter O), conservatively considered at 150°C. Chapter 2 shows that the maximum temperatures of contact surfaces between the body and the shock absorbing cover are actually less than this value.

σ_e = 130 MPa according to Table O.7

The calculation is performed only for the external metallic casing of the shock absorbing cover; the stiffeners (711) and the intermediate disks (725, 723) are not calculated because they are not subject to differential pressure (the pressure is the same on each side of the plates due to holes formed in these plates).

The sleeves are very strong due to their shape, their thickness (3.2 mm) and their small diameter (96.6 mm) and are not checked.

The diameter of the bottom inner shell (700) and the top inner shell (702) is smaller than that of the outer shell (701), therefore the check on their strength is covered by the calculation of the outer shell (701).

The shape of the disk under the shock absorbing cover (720) is similar to the shape of the upper disk of the shock absorbing cover (726), but the strength of this disk is covered by the calculation for the top disk (726) because it has a smaller free surface.

The verification therefore covers the following elements:

- Outer shell (701)
- Central lower disk (721)
- Central upper disk (724)
- Shock absorbing cover upper disk (726)
- Trunnion recess end plates (710)

2.2 Outer shell (701)

Considering that the outer shell is uniformly welded to radial stiffeners (711), the calculation is made assuming that the parts of shells between two stiffeners are flat plates, which is very conservative.

The longest section is calculated, namely the two sections centred on 0 and 180°.

The calculations are made according to case 1a in table 26 in <1>, corresponding to a rectangular plate supported on its 4 edges.

The maximum height is:

$b = 266 + 180 = 446$ mm.

The developed length of the arc of a circle is:

$a = \pi D /6 = \pi\ 2080 /6 \approx 1100$ mm.

The ratio a/b is:

a/b = 1100 / 446 = 2.46

The coefficients corresponding to a/b = 3 for case 1a in Table 26 in <1> are chosen conservatively.

t: plate thickness = 4 mm

Therefore the maximum stress is:

$$\sigma = \frac{\beta q b^2}{t^2} = 0.7134 \times 0.01 \times 446^2 / 4^2 = 89 \text{ MPa}$$

This value is below the criterion of 130 MPa for steel type A.

2.3 Central lower disk (721)

This disk bears directly on the lid of the packaging body. Vertical displacement of the periphery of the disk is prevented by the screws fastening the shock absorbing cover to the packaging body. Therefore this disk transmits the force due to pressure directly to the lid:

$\sigma = p = 0.01$ MPa

2.4 Central upper disk (724)

We consider the free central disk (outside radius = 490 mm), fixed around the periphery, formula 10 b in table 24 in <1>.

The maximum bending moment is given by the following relation, corresponding to pressure applied to the total surface of the disk:

The maximum moment is:

$M_r = - q a^2 / 8$

and $\sigma = 6 M / t^2$

therefore $\sigma = - 6 q a^2 / (8 t^2)$

where:

q: pressure applied to the disk, q = 0.01 MPa

a: outside radius of the plate = 635/2 = 490 mm.

t: thickness of plate, t = 10 mm

$\sigma = - 6 \times 0.01 \times 490^2 / (8 \times 10^2) = - 18$ MPa

This value is below the criterion of 130 MPa for steel type A (see chapter O).

2.5 Shock absorbing cover upper disk (726)

We consider the free upper disk (inside radius = 490 mm, outside radius 1040 mm), fixed around the periphery, formula 2 h in table 24 in <1>.

The maximum bending moment is given by the following relation, corresponding to pressure applied to the total surface of the disk:

$M = K_M q a^2$

and $\sigma = 6 M / t^2$

therefore $\sigma = 6 K_M q a^2 / t^2$

where:

q: pressure applied to the disk, q = 0.01 MPa

a: outside radius of the plate = 635/2 = 1,040 mm.

t: thickness of plate, t = 4 mm

K_M: Coefficient defined in the introduction to case 2, and given in the table for case 2.h.

for b/a = 490 / 1040 ≈ 0.5

$K_{Mrb} = -0.0247$

$K_{Mra} = -0.0187$

$|K_{Mrb}| > |K_{Mra}|$, to calculate the worst case, we assume $K_M = K_{Mrb}$

$K_M = -0.0247$

$\sigma = - 6 \times 0.0247 \times 0.01 \times 1040^2 / 4^2 = 100$ MPa

This value is below the criterion of 130 MPa for steel type A.

2.6 Trunnion recess end plates (710)

We consider the rectangle in which the end plate is inscribed (width = 1040-740 = 300 mm, height= 658 mm), fixed around the periphery, formula 8.a in table 26 in <1>.

The maximum bending moment is given by the following relation, corresponding to a uniform pressure applied to the total surface of the disk:

$\sigma_{max} = - \beta_1 q b^2 / t^2$

where:

q: pressure applied to the disk, q = 0.01 MPa

b: smallest dimension of the plate = 635/2 = 300 mm

t: thickness of plate, t = 4 mm

β_1 : Coefficient given in the table for 8.a.

for a/b = 658 / 300 = 2.2

$\beta_1 = 0.5$

$\sigma = - 0.5 \times 0.01 \times 300^2 / 4^2 = - 28$ MPa

This value is below the criterion of 130 MPa for steel type A.

3. SHOCK ABSORBING COVER RESISTANCE TO TRANSPORT SHOCKS

3.1 Assumptions

The shock absorbing cover is made of a stainless steel casing filled with wood (oak and balsa), as defined in chapter O and on the drawings in Appendix 1 to chapter O.

We consider radial or axial shocks of 2 g likely to occur under routine transport conditions.

These shocks apply a load from the wood and steel to the faces of the casings opposing the movement. It is assumed that the corresponding force due to pressure is uniformly distributed to these faces.

3.2 2g axial shock

- Metal casing of the shock absorbing cover

  Only the verification of the most highly stressed zones is presented.

  The axial shock case causes maximum stresses on steel plates perpendicular to the direction of the shock. These plates work in bending and not only in tension.

  The most severe (resisting plate mass / thickness) ratio among these plates occurs on the disk under the shock absorbing cover (720) when it is loaded by the two oak rings, the balsa ring and the metal disks.

  The mass per unit area of this assembly is:

  $m_S = \rho_{steel} \times h_{steel} + \rho_{oak} \times h_{oak} + \rho_{balsa} \times h_{balsa}$

  where:

  ρ_{steel}: density of steel = 7 850 kg/m^3 according to table O.8

  h_{steel}: steel height corresponding to the plates (720), (725) and (726)

  ρ_{oak}: density of oak = 600 ± 150 kg/m^3 according to chapter O

  h_{oak}: height of oak considered

  ρ_{balsa}: density of balsa = 140 ± 20 kg/m^3 according to chapter O

  h_{balsa}: height of balsa considered

  $m_S = 7850 \text{ x } 10^{-9} \times (4 + 4 + 4) + 750 \text{ x } 10^{-9} \times (256 + 190 - 4) + 160 \text{ x } 10^{-9} \times 200$

  $m_S = 458 \text{ x } 10^{-6}$ kg/mm²

  This mass per unit area to which an acceleration of 2g is applied generates a pressure p on the plate such that:

  $p = m_S\ 2\ g = 458 \text{ x } 10^{-6} \times 2 \times 9.81 = 0.009$ MPa.

  According to the assumptions used to calculate this value, this is the maximum pressure applicable to all the surfaces of the shock absorbing cover in the case of a 2 g axial shock.

This value is less than the calculation pressure (0.01 MPa) considered in the previous section. This section studies the strength of all plates of the metal casing combined. Therefore stresses generated in the metal casing of the shock absorbing cover due to a 2 g axial shock are also less than the yield stress of type A stainless steel.

- Attachment screws (151)

  The shock absorbing cover is fixed on the body of the packaging by 6 HM 42 class 10.9 screws (see table O.1 in chapter O).

  The force per screw for an axial acceleration equal to 2 g is:

  $F_{screws} = 2\ M_{cover}\ g\ /\ N_{screws}$

  M_{cover} :total mass of the shock absorbing cover, increased in relation to the value given in table O.9

  $M_{cover} = 1700$ kg

  N_{screws}: number of shock absorbing cover to body attachment screws (151) = 6

  $F_{screw} = 2 \times 1700 \times 9.81 / 6 = 5560$ N

  This force is very much lower than the preload in the screws (= 71 400 N) given in table O.6. This guarantees that the shock absorbing cover remains firmly in contact with the body of the packaging and that the screws are adequately sized.

3.3 2g radial shock

We will only describe the check on the cylindrical casing under an average radial pressure. The design and proportions of the shock absorbing cover are chosen such that mechanical loads in other zones are very low.

Considering the shape of the shock absorbing cover and the distribution of wood, the maximum wood pressure that can be applied to the outer shell is due to the oak ring placed above the lid (500, 501 or 502).

Conservatively, the upper inner metal shell (702) and the outer shell (701) are also considered.

For these components, the pressure applied to the outer casing at an acceleration of 2 g is:

$p = (\rho_{steel} \times e_{steel} + \rho_{oak} \times e_{oak})\ 2\ g$

where:

ρ_{steel}: density of steel = 7 850 kg/m^3 according to table O.8

e_{steel}: steel thickness corresponding to the shells (701) and (702)

ρ_{oak}: density of oak = 600 ± 150 kg/m^3 according to chapter O

h_{oak}: oak thickness considered = 1040 - 490 = 550 mm

$p = [\ 7850 \times 10^{-9} \times (4 + 4) + 750 \times 10^{-9} \times 550\ ] \times 2 \times 9.81 = 0.009$ MPa

According to the calculation assumption p = 0.009 MPa, this is the maximum pressure that can be applied to all the surfaces of the shock absorbing cover in the case of a 2 g radial shock.

This value is less than the calculation pressure (0.01 MPa) considered in the previous section. This section studies the strength of all plates of the metal casing combined. Therefore stresses generated in the metal casing of the shock absorbing cover due to a 2 g radial shock are also less than the yield stress of type A stainless steel.

4. CONCLUSION

The mechanical check on ancillary structures of the TN-MTR packaging only applies to the shock absorbing cover.

The calculations presented in this Appendix show that stresses due to an internal pressure of 0.1 bars are lower than the yield stress of the steel in the shock absorbing cover at 150°C.

It is also demonstrated that shocks with an acceleration of 2 g generate stresses in the metal casing that are less than the yield stress at 150°C.

5. REFERENCES

<1> Formulas for stress and strain
J. ROARK and Warren C. YOUNG fifth edition. McGraw Hill Book Company