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Manufacturing Process of the SAV PALET Dacia Renault

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Abstract

The paper analyzes the technological workflow used to manufacture the welded SAV PALET G assembly intended for the Renault/Dacia application, starting with the procurement of semi-finished materials and continuing with cutting, machining on numerically controlled equipment, turning of the parts, welding, stress relieving, hot-dip galvanizing and final inspection. The study uses technical data from the attached technological documentation and focuses on the engineering interpretation of the manufacturing parameters. Calculations are presented for spindle speed, feed rate, theoretical machining time and an example of dimensional verification. The results show that the sequence of operations must be established so that geometric accuracy, welded-assembly stability and corrosion protection are maintained throughout the entire manufacturing cycle.

Keywords: SAV PALET G, Dacia Renault, manufacturing, stress relieving, hot-dip galvanizing, dimensional inspection.

2020 MSC: 74A20, 74K10, 90B25,, 90B30.

1. Introduction

In the manufacture of metal equipment and subassemblies, the quality of the finished product depends not only on the accuracy of a single operation, but on the coordination of all technological stages.

SAV pallets are used for assembling RENAULT front automotive seats (Front Seat = SAV), left (Left = G) or right (Right = D). This part is used on the RENAULT assembly line in Morocco-Somaca; these pallets help the human operator mount the seats on an automated assembly line.

For the SAV PALET G assembly, the analyzed documentation indicates a workflow that starts with material requirements planning and continues with cutting of semi-finished materials, machining on CNC centers, welding assembly, thermal stress relieving, galvanizing and dimensional inspection. This sequence is relevant because thermal and welding operations can modify the stress state and geometry of the part, while machining operations must be designed to ensure the functionality of the assembly.

For the analyzed order, the specified materials included, among others, $50 \times 50 \times 4$ mm square tube, 4 mm sheet, 8 mm sheet, $\varnothing 36$ mm round bar and $\varnothing 20$ mm round bar. The cutting plan indicates 242 pieces for the main semi-finished materials cut to 455 mm, 548 mm, 37×34 mm and 483 mm, as well as 50 pieces of $\varnothing 36 \times 100$ mm and 121 pieces of $\varnothing 20 \times 100$ mm.

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The main results of this paper were obtained by consulting following documents: International Organization for Standardization (2015), International Organization for Standardization (2021), International Organization for Standardization (2019) and International Organization for Standardization (2022), S.C. SPIACT CF ARAD S.A. (2024*a*), S.C. SPIACT CF ARAD S.A. (2024*b*).

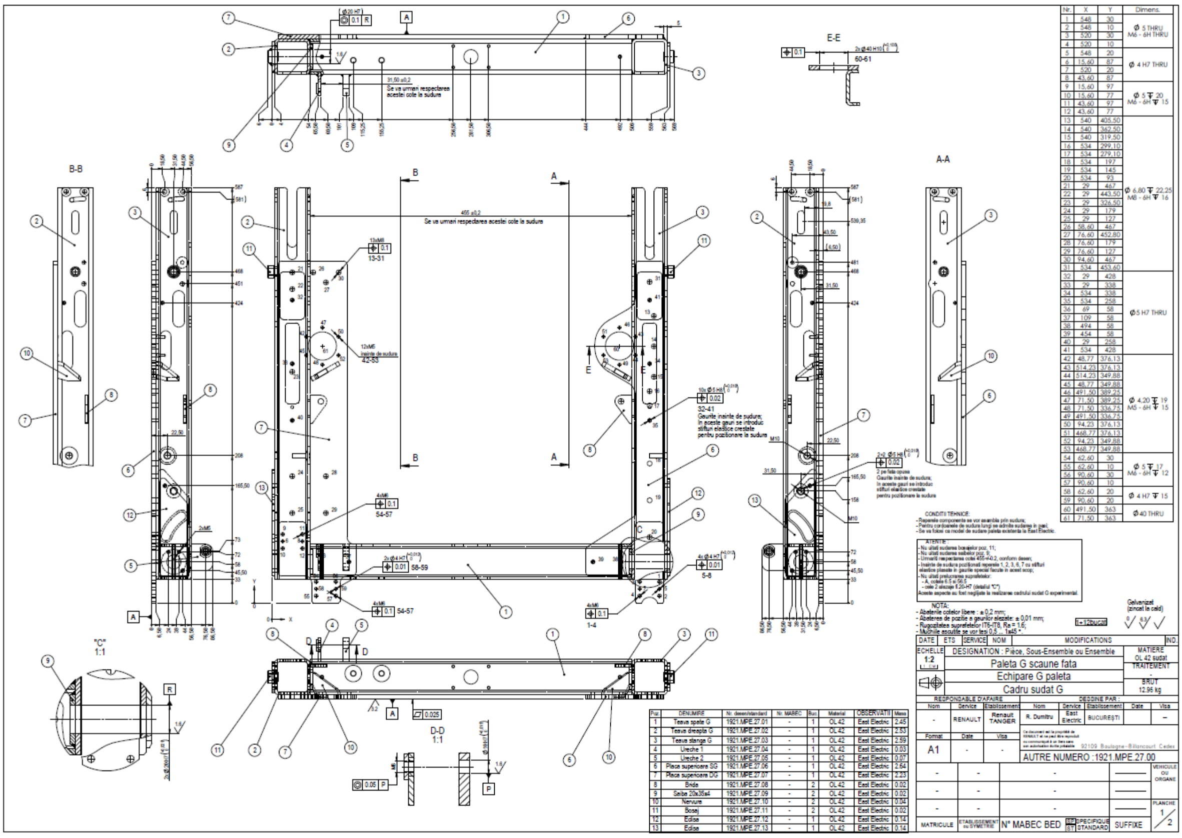

Figure 1. Manufacturing drawing of the SAV PALET G frame assembly ("Cadru sudat G").

2. Organization of the technological workflow

The workflow can be schematically represented by the following sequence:

procurement → inspection of semi-finished materials → cutting → CNC milling and drilling → turning →

welding → stress relieving → hot-dip galvanizing → dimensional inspection and conformity documentation.

An advantage of this organization is the separation of stages that generate geometric accuracy from those that generate thermal stresses.

For cutting, the Everesing S-250HA cutting machine is used, with a working capacity of 350 × 250 mm, a blade speed of 20–100 m/min and a 3.75 kW drive motor.

For sheet cutting, the Omnicut MGM machine is used, with a 12,000×4,500 mm table, a stated accuracy of ±0.3 mm and a maximum cutting thickness in the range of 10–150 mm.

Table 1. Overview of the technological stages.

Stage	Main operation	Equipment / resource	Purpose
1	Procurement	RNA / warehouse	Material supply
2	Cutting	Everesing S-250HA / Omnicut MGM	Obtaining semi-finished materials
3	CNC milling	AVIA VMC 1000	Surfaces, channels, holes
4	CNC turning	AVIAturn 35	Machining of bosses
5	Welding	ESAB TIG 2200i	Assembly formation
6	Stress relieving	UTTIS furnace	Reduction of residual stresses
7	Galvanizing	Zinc bath	Corrosion protection
8	Inspection	Measuring instruments	Conformity verification

3. Machining and calculation of cutting parameters

The component semi-finished materials are machined on the AVIA VMC 1000 milling center. According to the technical specifications, the machine has a maximum spindle speed of 10,000 rpm, a 14 kW motor and travels of 1,200 mm on X, 540 mm on Y and 620 mm on Z. The tool magazine holds 24 tools. Cutting parameters must be established according to the material, tool diameter, number of teeth and depth of cut.

3.1. Calculation of milling spindle speed

The basic relationship used for spindle speed is:

$$n = \frac{v_c \cdot 1000}{D \cdot \pi}$$

where n is the spindle speed [rpm], v_c is the cutting speed [m/min], and D is the tool diameter [mm]. For an engineering example, a HSS cutter with $D = 12$ mm and a cutting speed of 30 m/min is considered, a value selected for demonstration of the calculation.

$$n = \frac{30 \cdot 1000}{12 \cdot \pi} \approx \mathbf{796} \text{ rot/min}$$

The result must be compared with the machine limit and the tool manufacturer's recommendations. The calculated value is a starting value; in production, it is adjusted according to fixture rigidity, tool wear, cooling and material behavior.

3.2. Calculation of feed rate

For milling with a tool having z teeth, the feed rate can be estimated by:

$$v_f = f_z \cdot z_{\text{EFP}} \cdot n$$

where

- v_f – feed rate of the cutting tool;
- f_z – feed per tooth of the cutting tool;
- z_{EFP} – number of teeth of the cutting tool;

- n – cutting tool spindle speed.

If, for the calculation example, $f_z = 0.04$ mm/tooth, $z_{\mathrm{EFP}} = 4$ teeth and $n = 796$ rpm are adopted, the result is:

$$v_f = 0{,}04 \cdot 4 \cdot 796 \approx \mathbf{127{,}4} \text{ mm/min}$$

This value is compatible with a machining operation focused on stability and can be adjusted according to the radial and axial depth of cut.

When developing the CNC program, machining parameters are established according to the feed rate, spindle speed, diameter and number of teeth of the cutting tool, as well as the characteristics of the semi-finished material.

Drilling calculation example.. For the boss part, an 8.5 mm twist drill and subsequently an M10 tap are specified. The relationship for drilling spindle speed has the same general form:

$$n = \frac{v_c \cdot 1000}{d \cdot \pi}$$

Adopting, as an example, $v_c = 20$ m/min and $d = 8.5$ mm:

$$n = \frac{20 \cdot 1000}{8{,}5 \cdot \pi} \approx \mathbf{749} \text{ rot/min}$$

4. Welding and distortion control

After completion of machining operations, the parts are transported to the welding workshop. The assembly is produced by positioning the tubes and plates, using spring pins to maintain their position during welding. The welding operation is performed using the ESAB TIG 2200i machine, with a current range of 10–200 A. The assembly and tack-welding sequence is important because local heat input can produce shrinkage and dimensional deviations.

From an engineering standpoint, distortion control is achieved through a combination of measures: proper fixturing, controlled weld sequence, limitation of heat input and compliance with cooling times between operations when required by the technological documentation. For a multi-component assembly, checking the geometry after welding is important before placing it in the furnace.

5. Thermal stress relieving

The welded assembly is subsequently subjected to a stress-relieving operation in an industrial furnace. In general, stress relieving is carried out by setting the temperature to approximately 900 C, holding the assembly for about 20–30 minutes and then cooling it together with the furnace. The technological purpose is to reduce residual stresses associated with welding and decrease the risk of deformation or cracking during service.

From the thermal balance perspective, the amount of heat required to heat a mass m can be estimated using the relationship

$$Q = m \cdot c \cdot \Delta T$$

where c is the average specific heat.

For example, for a hypothetical mass of 500 kg, an average specific heat of 0.60 kJ/(kg·K) and a temperature increase from 20C to 900C, the result is:

$$Q \approx 500 \cdot 0{,}60 \cdot (900 - 20) = 264{,}000 \text{ kJ} = \mathbf{264} \text{ MJ}$$

The calculation is indicative and does not represent the actual furnace energy consumption, since this includes losses through the walls, exhaust-gas losses, heating of the equipment and burner efficiency. However, it highlights the order of magnitude of the energy associated with the heat treatment.

6. Dimensional inspection and evaluation of results

The final inspection is performed based on the dimensions specified in the manufacturing drawing and the internal measurement sheet.

Table 2. Dimensional inspection results for the analyzed batch.

Characteristic	Nominal [mm]	Tolerance [mm]	Measured [mm]	Deviation [mm]
Internal width	407,40	±0,20	407,42	+0,02
External width	521,40	±0,20	521,41	+0,01
Side plate thickness	6,50	±0,20	6,48	−0,02
Channel width	13,50	±0,20	13,49	−0,01
Part height	587,00	±1,00	586,80	−0,20

For each dimension, the condition $|x_m - x_{\text{nom}}| \leq T$ can be checked directly, where x_m is the measured value, x_{nom} is the nominal value, and T is the permitted tolerance. For the internal width, $|407.42 - 407.40| = 0.02$ mm ≤ 0.20 mm, therefore the measurement is within tolerance. The same check can be applied to the other characteristics.

7. Strength calculation of the part: Welded frame – SAV PALET G

7.1. Input data

Material: S235JR structural steel (EN 10025)

$$R_e = 235 \text{ MPa}; \quad R_m = 360 \text{ MPa}; \quad E = 210 \text{ GPa}; \quad \nu = 0{,}3$$

Construction type: welded frame made of rectangular tube and sheet.
Loads:

- Maximum useful load (equipment on pallet): 2000 N ($\approx$ 200 kg)
- Dynamic factor (shocks, handling): $\varphi = 1.5$
- Estimated self-weight of frame: $G \approx 120$ N

Total design load:

$$F_d = (2000 + 120) \cdot 1{,}5 = 3180 \text{ N} \approx \mathbf{3{,}18} \text{ kN}$$

Main geometry (according to drawing):

- External width B = 521.4 mm
- Internal width b = 407.4 mm
- Height $H \approx$ 587 mm (distance between cross-members)
- Side tubes: $50 \times 50 \times 4$ mm (OL 37)
- Upper and lower cross-members: $50 \times 50 \times 4$ mm tube
- Side plates and fastening elements: 6–8 mm sheet

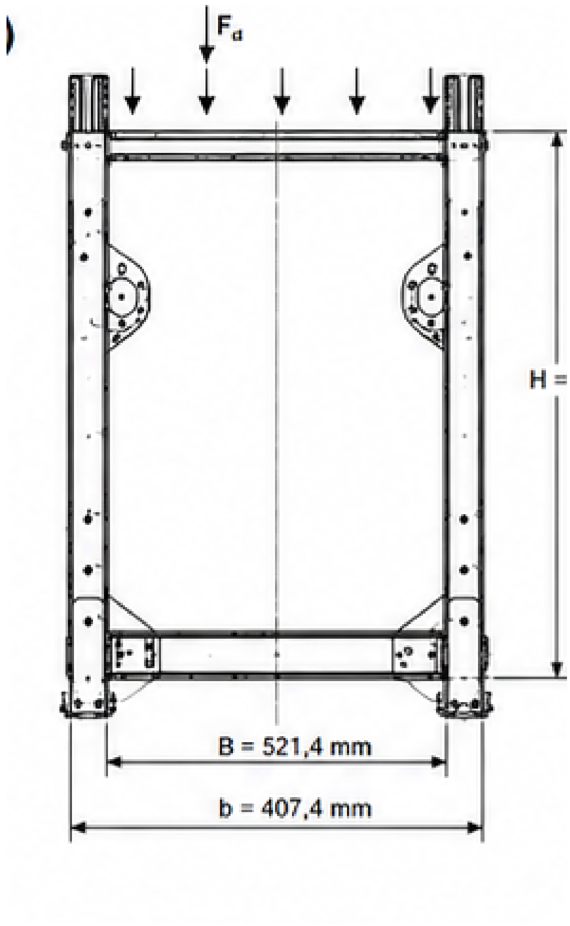

Figure 2. Loading scheme of the welded frame (F_d applied at the top cross-member).

7.2. *Calculation scheme*

The frame is considered as a beam on two supports (lower ends), loaded vertically at the center of the upper cross-member.

Model: simply supported beam, concentrated load at mid-span.

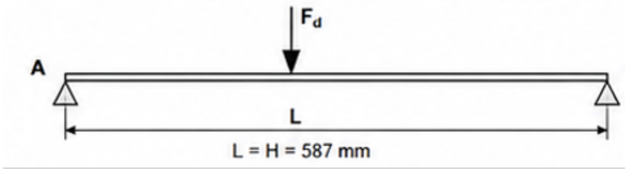

Figure 3. Simply supported beam model with concentrated load at mid-span.

7.3. Support reactions

$$R_A = R_B = \frac{F_d}{2} = \frac{3{,}18}{2} = \mathbf{1{,}59}\ \text{kN}$$

7.4. Maximum bending moment

$$M_{\max} = \frac{F_d \cdot L}{4} = \frac{3{,}18 \cdot 0{,}587}{4} = 0{,}466\ \text{kN} \cdot \text{m} = \mathbf{466}\ \text{N} \cdot \text{m}$$

7.5. Verification of cross-members ($50 \times 50 \times 4$ *tube)*

Properties of the $50 \times 50 \times 4$ mm square tube section:

$$A = 50^2 - 42^2 = 2500 - 1764 = \mathbf{736}\ \text{mm}^{\mathbf{2}} \tag{7.1}$$

$$I = \frac{50^4 - 42^4}{12} = 1{,}04 \cdot 10^5\ \text{mm}^4 \tag{7.2}$$

$$W = \frac{I}{y_{\max}} = \frac{1{,}04 \cdot 10^5}{25} = \mathbf{4160}\ \text{mm}^{\mathbf{3}} \tag{7.3}$$

$$i = \sqrt{\frac{I}{A}} = \sqrt{\frac{1{,}04 \cdot 10^5}{736}} = \mathbf{11{,}9}\ \text{mm} \tag{7.4}$$

7.5.1. Bending stress

$$\sigma_b = \frac{M_{\max}}{W} = \frac{466 \cdot 10^3}{4160} = \mathbf{112}\ \text{MPa}$$

Strength condition:

$$\sigma_b \leq \sigma_{\text{adm}} = \frac{R_e}{\gamma_M}, \quad \text{with } \gamma_M = 1{,}1$$

$$\sigma_{\text{adm}} = \frac{235}{1{,}1} = \mathbf{213{,}6}\ \text{MPa}$$

$$112\ \text{MPa} < 213.6\ \text{MPa} \quad \rightarrow \quad \textbf{Condition satisfied}$$

7.5.2. Lateral-torsional buckling verification (simplified)

Slenderness ratio:

$$\lambda = \frac{L_{\text{ef}}}{i} = \frac{587}{11{,}9} = \mathbf{49{,}3}$$

For square tube, the usual limit is $\lambda_{\text{lim}} \approx 80 \ \rightarrow\ 49.3 < 80$ **OK**

7.6. Verification of side columns (50 × 50 × 4 tube)

Each column is considered to be subjected to compression by the support reaction:

$$N = R_A = \mathbf{1{,}59}\ \text{kN}$$

7.6.1. Compression verification (stability)

Effective length: $L_{\text{ef}} = 587$ mm
Slenderness ratio: $\lambda = 49.3$ (same as for the cross-member)
Reduction factor (Euler, approximate): $\chi \approx 0.92$ (for S235, $\lambda \approx 50$)
Design compression resistance:

$$N_{b,Rd} = \chi \cdot \frac{A \cdot R_e}{\gamma_{M1}} = 0{,}92 \cdot \frac{736 \cdot 235}{1{,}1} = \mathbf{137{,}1}\ \text{kN}$$

Condition:

$$N = 1{,}59\ \text{kN} < 137{,}1\ \text{kN} \quad \rightarrow \quad \mathbf{OK}$$

7.7. Verification of side plates (6 mm sheet)

A side plate subjected to local bending is considered. Conservative assumption: the load is uniformly distributed over the height of the plate ($h = 300$ mm).

Uniformly distributed load:

$$q = \frac{F_d}{h} = \frac{3180}{300} = \mathbf{10{,}6}\ \text{N/mm}$$

Maximum moment in a plate fixed at both ends (active width ∼ 200 mm):

$$M_{pl} = \frac{q \cdot l^2}{8} = \frac{10{,}6 \cdot 200^2}{8} = \mathbf{53{,}0}\ \text{N} \cdot \text{m}$$

$$W_p = \frac{t \cdot l^2}{6} = \frac{6 \cdot 200^2}{6} = \mathbf{40{,}000}\ \text{mm}^{\mathbf{3}}$$

$$\sigma_{pl} = \frac{M_{pl}}{W_p} = \frac{53 \cdot 10^3}{40 \cdot 10^3} = \mathbf{1{,}3}\ \text{MPa} \ll 213{,}6\ \text{MPa} \quad \rightarrow \quad \mathbf{OK}$$

7.8. Weld verification (example: fillet weld a = 5 mm)

Design shear resistance of the weld (EN ISO 5817):

$$\tau_{\text{adm}} = \frac{f_u}{\sqrt{3} \cdot \gamma_{M2}} = \frac{360}{1{,}732 \cdot 1{,}25} = \mathbf{166}\ \text{MPa}$$

Effective area of a fillet weld: $A_w = 0.7 \cdot a \cdot l$
Assume total length of critical welds: $l_{\text{tot}} = 400$ mm

$$A_w = 0{,}7 \cdot 5 \cdot 400 = \mathbf{1400}\ \text{mm}^{\mathbf{2}}$$

Shear stress in the weld:

$$\tau = \frac{F_d}{A_w} = \frac{3180}{1400} = \mathbf{2{,}27}\ \text{MPa} < 166\ \text{MPa} \quad \rightarrow \quad \mathbf{OK}$$

Table 3. Summary of strength verifications for the welded frame.

Verified element	**Loading**	**Calc. stress**	**Allow. stress**	**Result**
Cross-members ($50 \times 50 \times 4$)	Bending	112 MPa	213,6 MPa	OK
Side columns ($50 \times 50 \times 4$)	Compression	1,59 kN	137,1 kN	OK
Side plates (6 mm)	Local bending	1,3 MPa	213,6 MPa	OK
Fillet welds (a = 5 mm)	Shear	2,27 MPa	166 MPa	OK

7.9. Summary of verifications

Under the considered loading conditions (3.18 kN) and for S235JR material, the welded frame meets the strength and stability requirements according to the verifications performed.

Overall safety factor $\approx 2.0 \ldots 2.5$

8. Conclusions

The analysis of the SAV PALET G manufacturing process highlights the integrated nature of the technology: the accuracy achieved during cutting and CNC machining must be maintained through controlled welding, while subsequent thermal effects must be managed through stress relieving and appropriate cooling. The calculation of cutting parameters provides a basis for CNC programming; however, the final values must be confirmed experimentally and against the tool manufacturer's recommendations.

The dimensional inspection data available for the analyzed product indicate small deviations from the nominal values, with all presented characteristics falling within the specified tolerances.

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