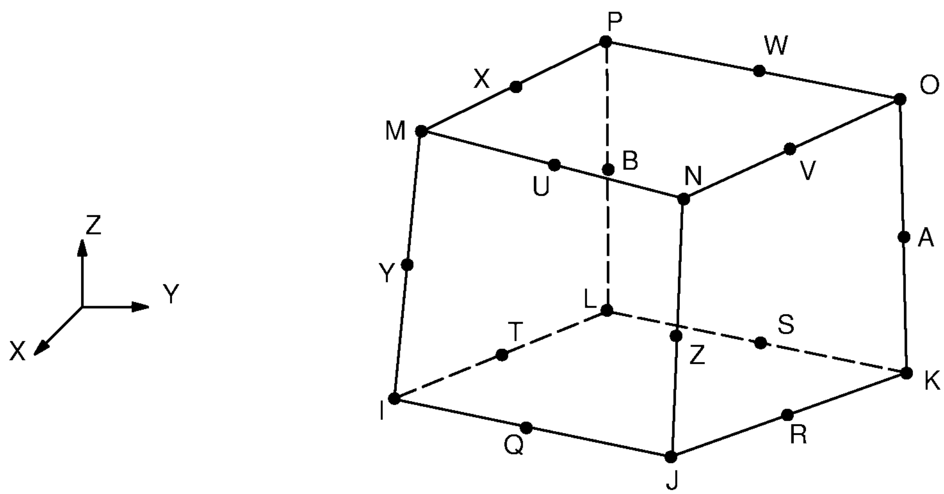
# 14.117 SOLID117 — 3–D Magnetic Edge




| Matrix or Vector | Shape Functions | Integration Points |
|---|---|---|
| Edge Formulation of Magnetic Vector Potential Coefficient Matrix | Equations (12.8.18–7), (12.8.18–8), and (12.8.18–9) for magnetic vector potential; Equations (12.9–26) thru (12.9–37) for edge–flux | 2 x 2 x 2 |
| Electric Potential Coefficient Matrix | Equations (12.9–18) thru (12.9–25) | 2 x 2 x 2 |
| Load Vector of Magnetism due to Source Currents, Permanent Magnets, and Applied Currents | Same as coefficient matrix | 2 x 2 x 2 |

| Load Type | Distribution |
|---|---|
| Current Density, Voltage Load and Phase Angle Distribution | Trilinearly varying over the thru element |

References: Biro et al(120), Gyimesi and Ostergaard(201), Gyimesi and Ostergaard (221), Ostergaard and Gyimesi(222), Ostergaard and Gyimesi(223), Preis(203), Nedelec(204), Kameari(206), Jin(207)

## 14.117.1 Other Applicable Sections

The following sections describe the theorem of the magnetic edge element using edge flux DOF:

- 5.1.2 Magnetic Vector Potential
- 5.1.4 Edge Flux Degrees of Freedom
- 5.1.5 Harmonic Analysis Using Complex Formalism
- 5.2.2 Magnetic Vector Potential
- 12.9 Electromagnetic Edge Elements
- 13.1 Integration Point Locations

Section 4.117 of the *Elements Reference* serves as a reference user guide and is provided in the Electromagnetic Field Analysis Part of the Analysis Guides. Chaper 6, 7 and 8 describe respectively static, harmonic and transient analyses by magnetic element SOLID117.

## 14.117.2 Matrix formulation of low frequency edge element and tree gauging

This low frequency electromagnetic element eliminates the shortcomings of nodal vector potential formulation discussed in section 5.1.5. The pertinent shape functions are presented in section 12.9.

The column vector of nodal vector potential components in SOLID97 is denoted by $\{A_e\}$, that of time integrated scalar potentials by $\{\nu_e\}$. (See definitions in section 5.2.2.) The vector potential, {A}, can be expressed by linear combinations of both corner node vector potential DOFs, $\{A_e\}$, as in SOLID97, and side node edge–flux DOFs, {AZ}. For this reason there is a linear relationship between $\{A_e\}$ and {AZ}.

$$\{A_e\} = [T^R]\ \{A^Z\} \tag{14.117–1}$$

where: $[T^R]$ = transformation matrix. Relationship (14.117–1) allows to compute the stiffness and damping matrices as well as load vectors of SOLID117 in terms of SOLID97.

Substituting (14.117–1) into (5.2–25) and (5.2–26) provides

$$\{A^Z\}^T\Big([K^{ZZ}]\{A_z\} + [K^{ZV}]\{\nu_e\} + [C^{ZZ}]d/dt\{A_z\} + [C^{ZV}]d/dt\{\nu_e\} - \{J^Z\}\Big) = 0 \quad (14.117\text{–}2)$$

$$\{\nu_e\}^T\Big([K^{VZ}]\{A_z\} + [K^{VV}]\{\nu_e\} + [C^{VZ}]d/dt\{A_z\} + [C^{VV}]d/dt\{\nu_e\} - \{I^t\}\Big) = 0 \quad (14.117\text{–}3)$$

where:

$$[K^{ZZ}] = [T^R]^T\ [K^{\Lambda\Lambda}]\ [T^R] \quad (14.117\text{–}4)$$

$$[C^{ZZ}] = [T^R]^T\ [C^{\Lambda\Lambda}]\ [T^R] \quad (14.117\text{–}5)$$

$$[K^{ZV}] = [T^R]^T\ [K^{\Lambda\Lambda}]\ [T^R] \quad (14.117\text{–}6)$$

$$[C^{ZV}] = [T^R]^T\ [C^{\Lambda V}]\ [T^R] \quad (14.117\text{–}7)$$

$$[J^Z] = [T^R]^T\ [J^\Lambda] \quad (14.117\text{–}8)$$

$$[K^{VZ}] = [K^{V\Lambda}]\ [T^R] \quad (14.117\text{–}9)$$

$$[C^{VZ}] = [C^{V\Lambda}]\ [T^R] \quad (14.117\text{–}10)$$

Equations (14.117–2) and (14.117–3) need to be properly gauged to obtain uniqueness. For more on this topic see for example Preiss et al(203). SOLID117 applies a tree gauging algorithm. It considers the relationship between nodes and edges by a topological graph. A fundamental tree of a graph is an assemly of edges constituting a path over which there is one and only one way between different nodes. It can be shown that the edge–flux DOFs over the fundamental tree can be set to zero providing uniqueness without violating generality.

The tree gauging applied is transparent to most users. At the solution phase the extra constraints are automatically supplied over the tree edges on top of the set of constraints provided by users. After equation solution, the extra constraints are removed. This method is good for most of the practical problems. However, expert users may apply their own gauging for specific problems by turning the tree gauging off by the command, GAUGE,OFF.