

Turbine blade steels are critical materials in power generation, requiring exceptional high-temperature strength, creep resistance, and corrosion resistance. This guide provides a comprehensive technical analysis of three important grades: 1.4906 (X12CrMoWVNbN10-1-1), T505SC, and their equivalents.

Microstructural Requirements

- **Martensitic Structure:** Fully martensitic after heat treatment
- **Delta Ferrite:** <5% allowed
- **Grain Size:** ASTM 4 or finer (after all heat treatments)
- **Inclusions:** Controlled per ASTM E45
- **Homogeneity:** Must be free from porosity, excessive segregation

Equivalent Grades

Country/Standard	Equivalent Grade
Germany (DIN)	1.4906, X12CrMoWVNbN10-1-1
Japan (JIS)	T505SC
USA (ASTM/UNS)	S50490, S50491
China (GB)	1Cr11NiMoW2VNbN
Russia (GOST)	ЭП993
Europe (EN)	X12CrMoWVNbN10-1-1

Quality Control and Testing Requirements

- **Chemical Analysis:** Melt analysis required for all specified elements
- **Mechanical Testing:**
 - Tensile, impact, hardness testing required
 - 10% of bars (min. 10) tested for hardness uniformity
- **Non-Destructive Testing:**
 - Ultrasonic testing for bars ≥ 30 mm diameter (EN 10308)
 - Quality classes: Class 4 for ≤ 200 mm, Class 3 for > 200 mm
- **High-Temperature Testing:**
 - Elevated temperature tensile tests at 600°C
 - Creep rupture testing for qualification

Recent Developments and Modifications

Recent updates to specifications (as seen in the TLV document) include:

- Change from average to minimum value for impact energy requirements
- Updated heat treatment parameters
- Enhanced product and process qualification requirements
- More stringent documentation requirements

Applications

X12CrMoWVNbN10-1-1, 1.4906 Applications

- **Classification:** Martensitic stainless steel
- **Applications:** High-pressure steam turbine blades, rotors, and components in conventional and nuclear power plants
- **Key Features:**
 - Excellent high-temperature strength ($R_{p0.2} \geq 750 \text{ N/mm}^2$ at room temperature)
 - Good creep resistance at temperatures up to 600°C
 - Fully martensitic microstructure after heat treatment
 - Used in quenched and tempered condition (+QT)

T505SC Applications

- **Classification:** Martensitic stainless steel (Japanese standard)
- **Applications:** Steam turbine blades and rotors in thermal power plants
- **Key Features:**
 - Similar composition to 1.4906 with slight variations
 - Optimized for long-term creep resistance
 - Used in quenched and tempered condition

Equivalent or Similar Grades - Chemical Composition

Element	X12CrMoWVNbN10-1-1 / 1.4906	T505SC	Similar Grades
C	0.11-0.13	0.10-0.15	0.10-0.15
Si	≤0.12	≤0.50	≤0.50
Mn	0.40-0.50	0.30-0.80	0.30-1.00

Element	X12CrMoWVNbN10-1-1 / 1.4906	T505SC	Similar Grades
P	≤0.010	≤0.025	≤0.025
S	≤0.005	≤0.010	≤0.010
Cr	10.2-10.8	10.0-11.5	9.0-12.0
Mo	1.00-1.10	0.80-1.20	0.80-1.50
W	0.95-1.05	0.90-1.20	0.80-1.50
V	0.15-0.25	0.15-0.30	0.10-0.30
Nb	0.04-0.06	0.03-0.08	0.02-0.10
N	0.045-0.060	0.040-0.080	0.030-0.090
Ni	0.70-0.80	0.30-1.00	0.30-1.50

Note: Trace elements Cu, As, Sb, Sn, and Ti should be reported but are not specified in most standards.

Mechanical Properties

Room Temperature Mechanical Properties

Property	1.4906 / X12CrMoWVNbN10-1-1	T505SC
0.2% Proof Strength (MPa)	750-830	750-880
Tensile Strength (MPa)	870-1020	880-1080
Elongation A (%)	≥14 (d≤100mm), ≥13 (d>100mm)	≥15
Reduction of Area (%)	≥45 (d≤100mm), ≥40 (d>100mm)	≥50
Impact Energy (J)	≥55 (d≤100mm), ≥24 (d>100mm)	≥60
Hardness (HB)	270-310	270-320

High-Temperature Mechanical Properties (600°C)

Property	1.4906 / X12CrMoWVNbN10-1-1	T505SC
0.2% Proof Strength (MPa)	≥405	≥420
Tensile Strength (MPa)	≥420	≥440
Elongation A5 (%)	≥18	≥20
Reduction of Area (%)	≥65	≥70

Creep and Rupture Properties

1.4906 / X12CrMoWVNbN10-1-1 Creep Performance

Creep Rupture Strength at 600°C:

- 10,000 hours: ≥ 100 MPa (typical requirement)
- 100,000 hours: ≥ 80 MPa (estimated)

Creep Rate: Typically $< 1 \times 10^{-7}$ %/h at 600°C under 100 MPa stress

T505SC Creep Performance

- Generally shows slightly better creep resistance than 1.4906 at temperatures above 550°C
- 100,000 hour rupture strength at 600°C typically ≥ 85 MPa

Physical Properties

Property	1.4906 / X12CrMoWVNbN10-1-1
Density (g/cm ³)	7.8
Thermal Conductivity (W/m·K)	25 (at 20°C), 28 (at 600°C)
Specific Heat (J/kg·K)	460 (at 20°C), 600 (at 600°C)
Thermal Expansion (10 ⁻⁶ /K)	10.5 (20-100°C), 12.8 (20-600°C)
Electrical Resistivity (Ω·m)	0.85×10^{-6}
Elastic Modulus (GPa)	210 (at 20°C), 170 (at 600°C)

Heat Treatment

1.4906 / X12CrMoWVNbN10-1-1 Heat Treatment

Hardening

- Temperature: 1050-1100°C
- Quenching: Air or liquid cooling
- Must be cooled to $\leq 100^\circ\text{C}$ in the core to ensure complete martensitic transformation

Tempering

- First temper: 570-680°C
- Second temper: 680-720°C

- Stress relief (if straightening is required): 20-50K below tempering temperature with slow cooling

Final Condition: Quenched and Tempered (+QT)

T505SC Typical Heat Treatment

- **Hardening:** 1050-1100°C followed by air or oil quenching
- **Tempering:** Double tempering at 680-750°C
- **Final Condition:** Quenched and Tempered (+QT)

Processing Performance

Forging and Hot Working

- Recommended hot working temperature range: 1100-900°C
- Should be cooled slowly after hot working to prevent cracking
- Requires annealing if interrupted during hot working

Machinability

- Machinability rating: ~50% of free-cutting steels
- Recommended tools: Carbide tools with positive rake angles
- Cutting speeds: 30-50 m/min for turning operations
- Requires generous use of cutting fluids

Welding Characteristics

- **Weldability:** Fair to good with proper precautions
- **Recommended Processes:** GTAW (TIG), SMAW (shielded metal arc)
- **Preheat:** 200-300°C
- **Post-Weld Heat Treatment:** Full heat treatment cycle recommended
- **Filler Metals:** Matching composition or higher alloy grades