# 1.4906, X12CrMoWVNbN10-1-1, T505SC

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 ≥30mm diameter (EN 10308)
    - Quality classes: Class 4 for ≤200mm, Class 3 for >200mm
- **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 (Rp0.2 ≥ 750 N/mm² 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 $<1\times10^{-7}$ %/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/cm³) | 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) | $0.85 \times 10^{-6}$ |
| 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 ≤100°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