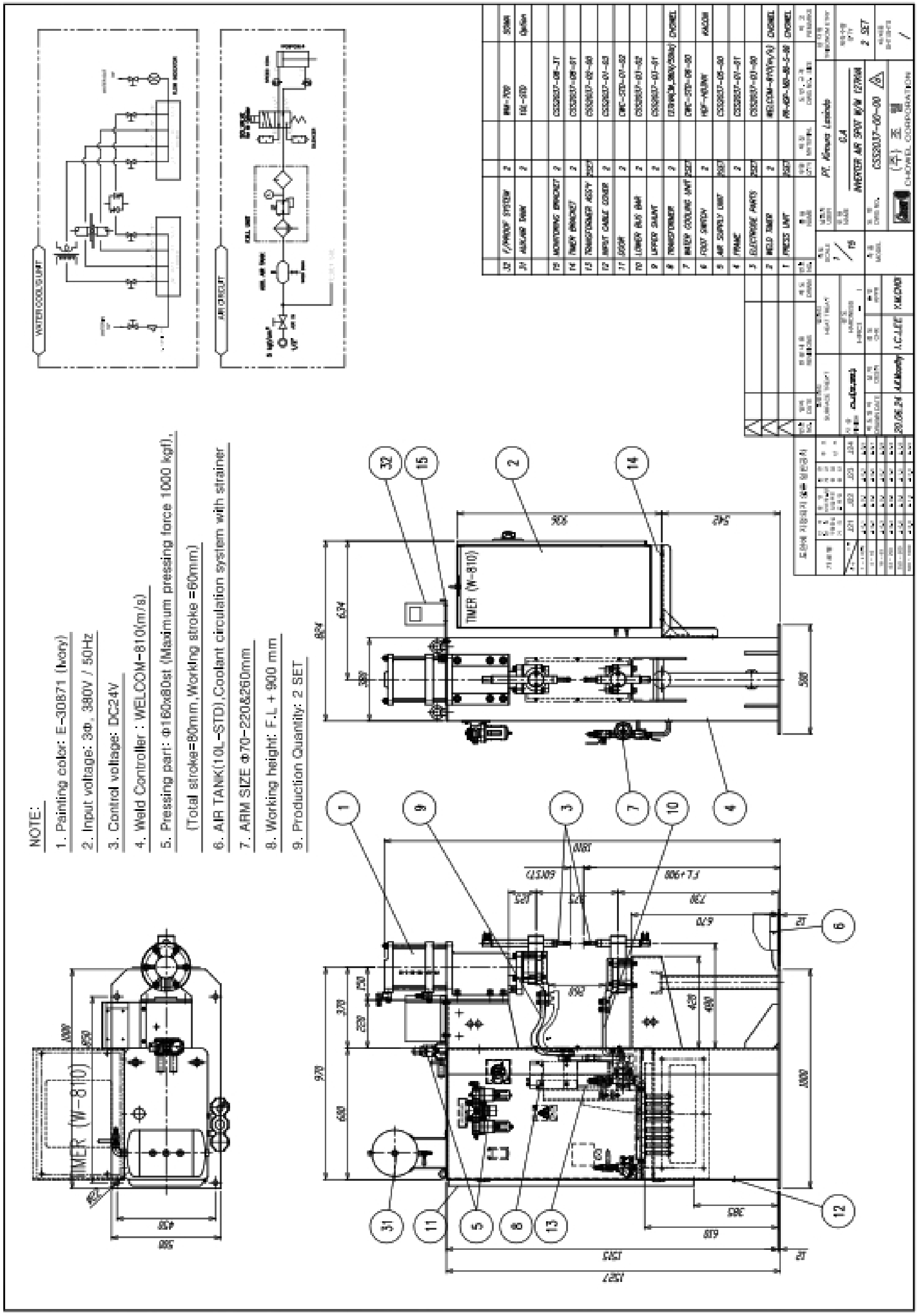
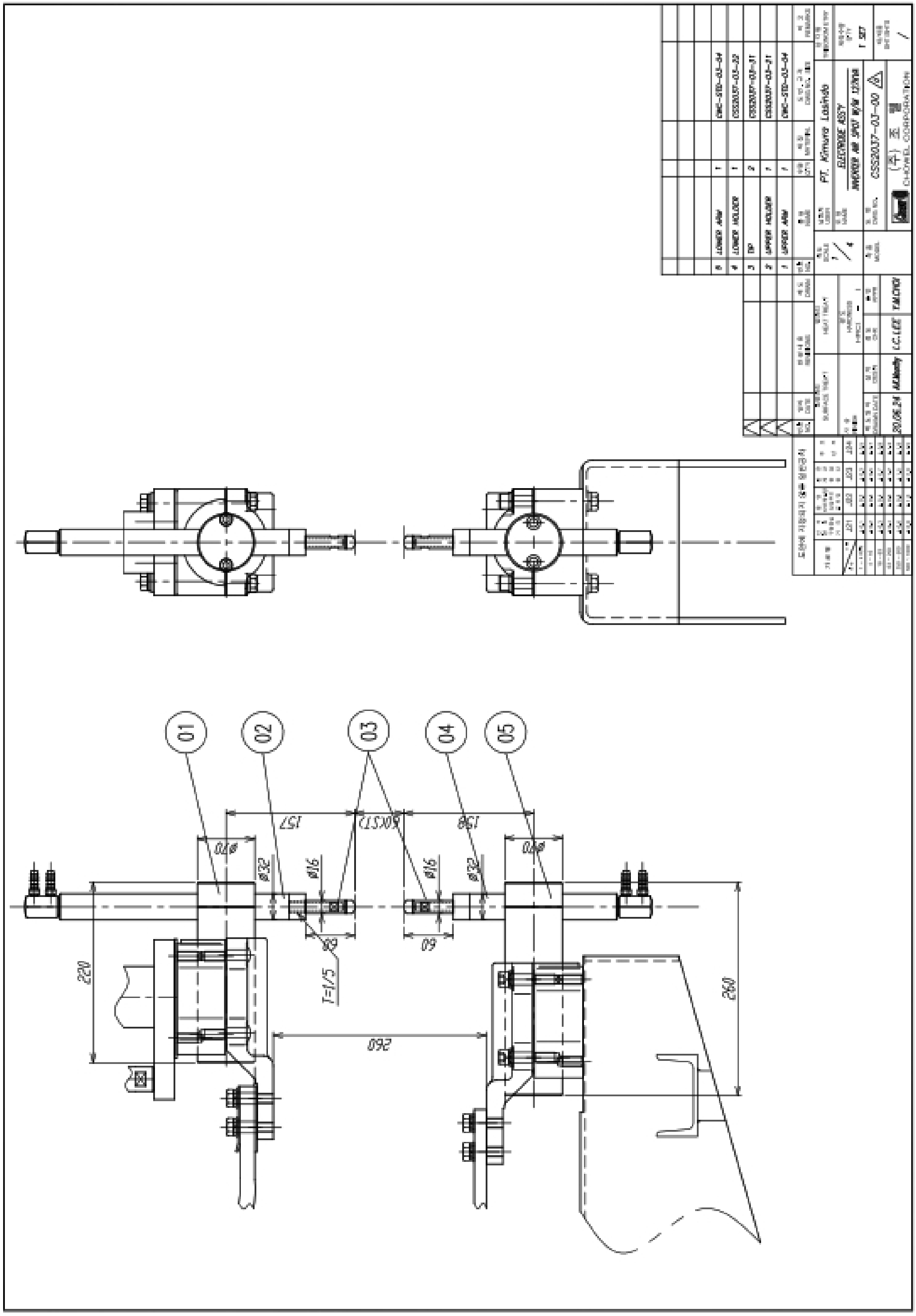
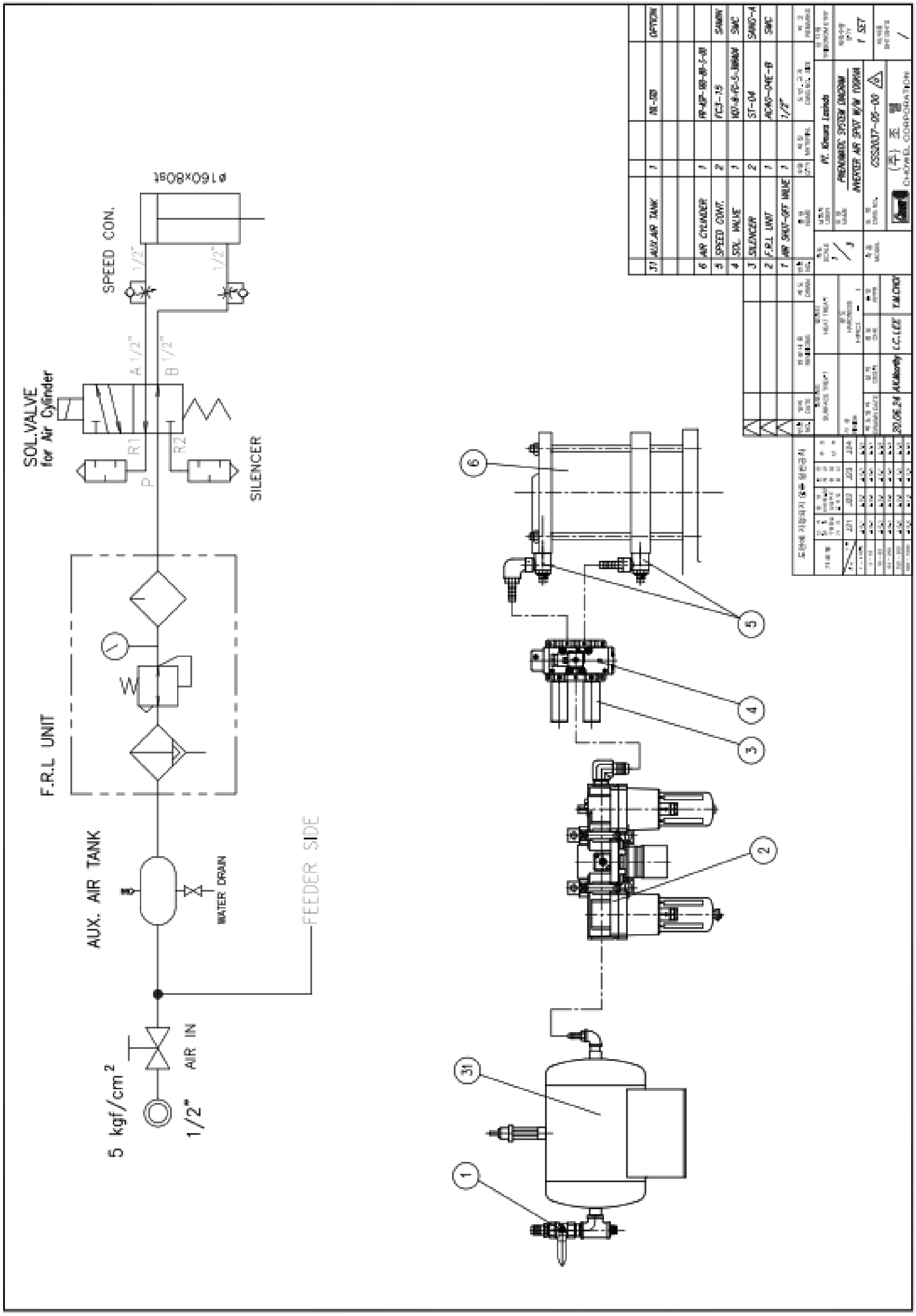
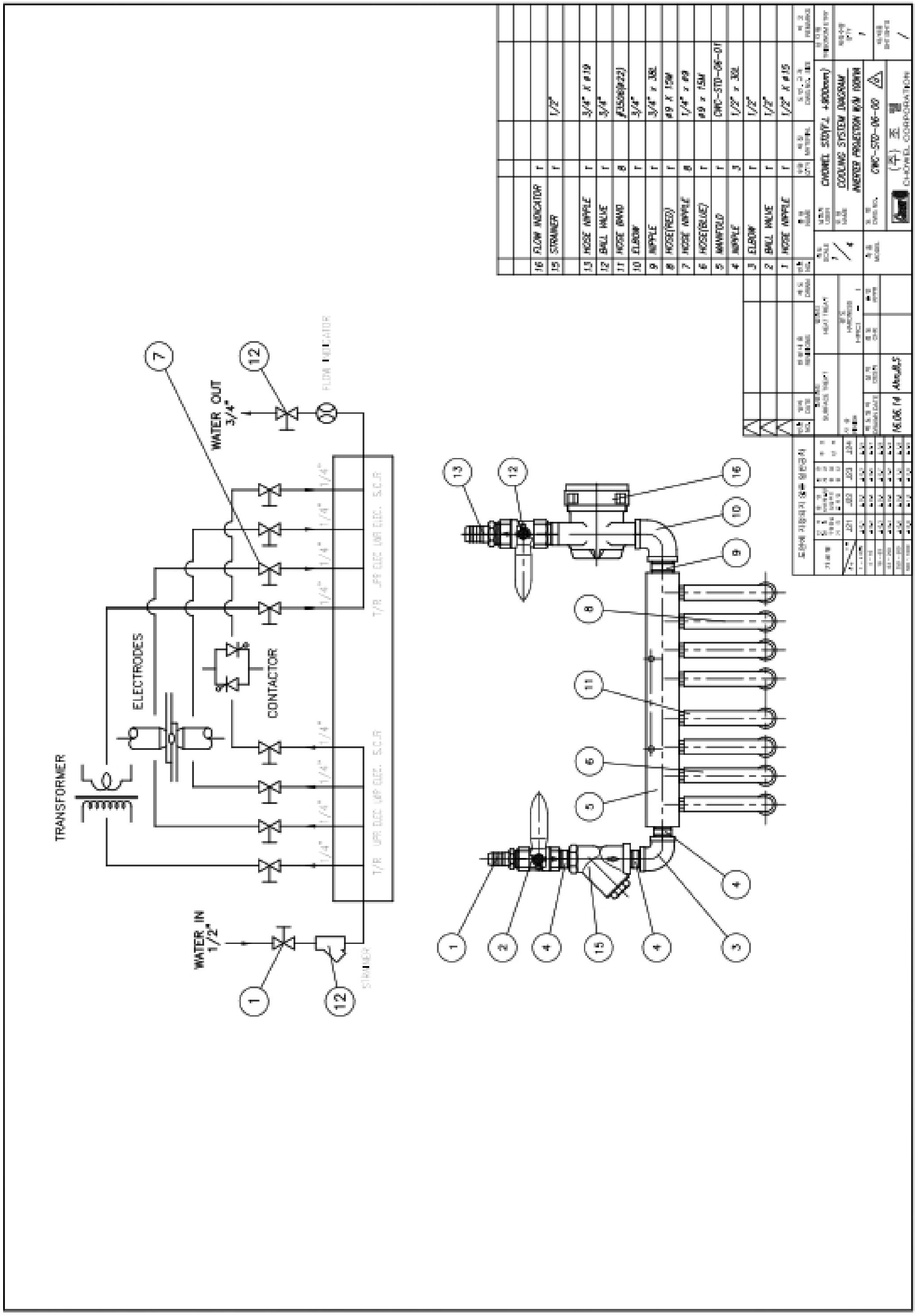
LAMPIRAN

LAMPIRAN 1 Gambar Mesin Stationary Spot Welding

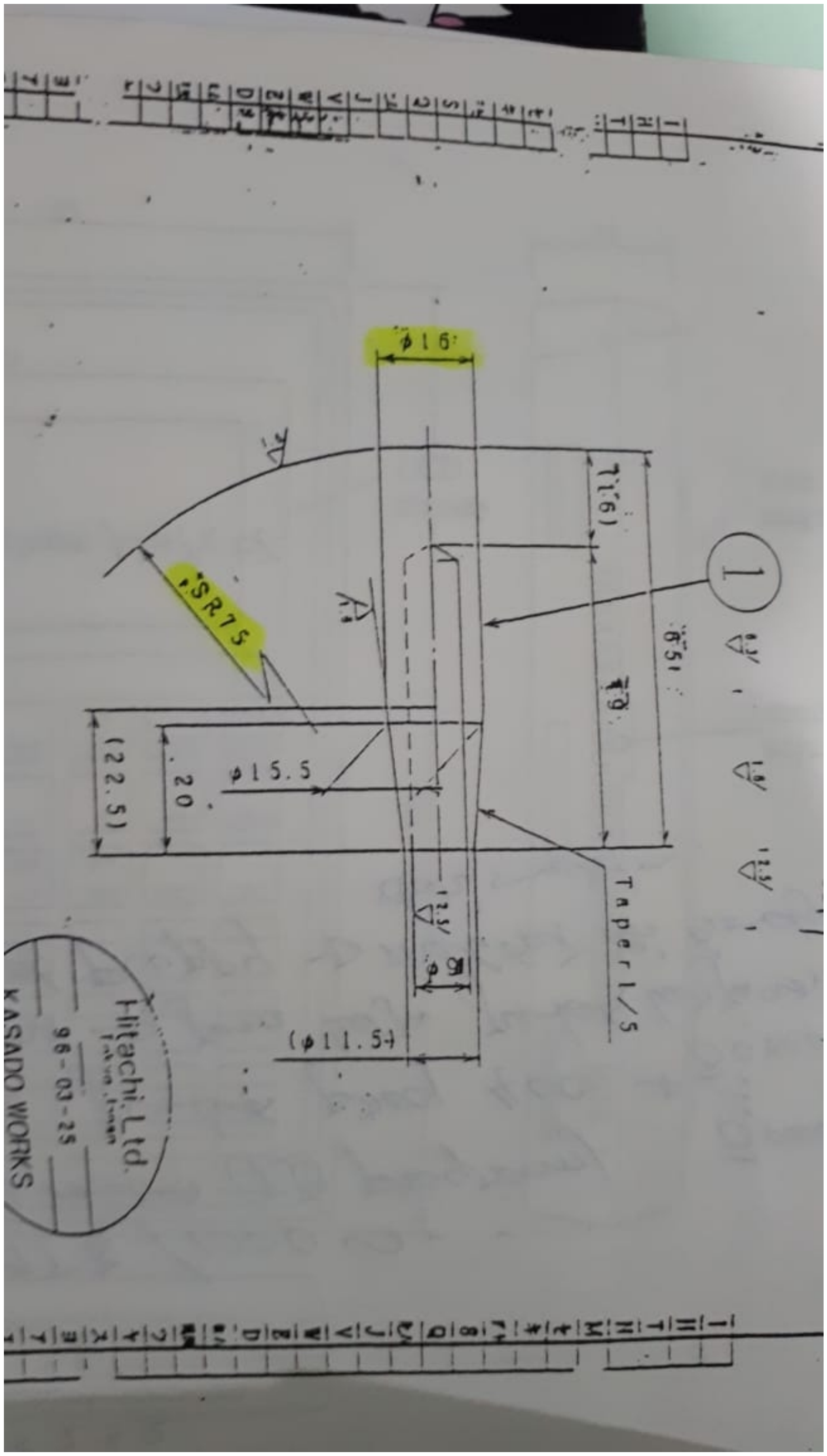





5 kgf/cm²
1/2"
AIR IN
AUX. AIR TANK
WATER DRAIN
FEEDER SIDE
F.R.L UNIT
SOL.VALVE
for Air Cylinder
SILENCER
SPEED CON.
ø160x80st


TRANSFORMER
ELECTRODES
CONTACTOR
WATER IN
1/2"
WATER OUT
3/4"
STRAINER
FLOW INDICATOR
16 FLOW INDICATOR
15 STRAINER
13 HOSE NIPPLE
12 BALL VALVE
11 HOSE BAND
10 ELBOW
9 NIPPLE
8 HOSE(RED)
7 HOSE NIPPLE
6 HOSE(BLUE)
5 MANIFOLD
4 NIPPLE
3 ELBOW
2 BALL VALVE
1 HOSE NIPPLE
COOLING SYSTEM DIAGRAM

LAMPIRAN 2 Elektroda Spot Ø16 R75



LAMPIRAN 3 Material Properties SUS 301

Stainless Steel - Grade 301 (UNS S30100)

Oct 19 2001

Chemical Formula

Fe, <0.15%C, 16-18%Cr, 6-8%Ni, <2%Mn, <1%Si, <0.045%P, <0.03%S

Introduction

Stainless steel grade 301 is usually supplied in the form of strips and wires, with a tensile strength of up to 1800 Mpa, to produce tempers ranging from 1/16 Hard to Full Hard. By subjecting grade 301 to controlled analysis it is capable of retaining sufficient ductility even in ½ hard conditions. This form of grade 301 may be used in aircraft, rail car components and architectural structures. Tempers of this grade, ranging from ¾ to full hard, may be used in applications requiring high wear resistance and spring features with simple form designs.

Grade 301L, which is the low carbon form of grade 301, is the ideal choice for applications that require good ductility. Grade 301LN is another variant. This contains a higher percentage of nitrogen and exhibits a higher work harden rate compared to standard 301. Only grade 301 is specified in ASTM A666. 301L and 301LN are represented by other conventions. Grade 301L is represented by JIS G4305 and 301LN by EN10088-2 as grade 1.4318.

Key Properties

The key properties listed in the below sections are for flat rolled products such as plate, sheet and coil - specified as Grade ASTM A666. For other grades, EN10088.2 and JISG4305, it is not necessary that the values and properties are identical.

Composition

Composition ranges of stainless steel grade 301 are tabulated below.

Table 1 *- Composition ranges for 301 grade stainless steel*

Grade	C	Mn	Si	P	S	Cr	Mo	Ni	N

301	min.	-	-	-	-	-	16.0	-	6.0	-
ASTM A666	max.	0.15	2.0	1.0	0.045	0.030	18.0		8.0	0.10
301L	min.	-	-	-	-	-	16.0	-	6.0	-
JIS G4305	max.	0.03	2.0	1.0	0.045	0.030	18.0		8.0	0.20
1.4318/301LN	min.	-	-	-	-	-	16.5	-	6.0	0.10
EN 10088-2	max.	0.03	2.0	1.0	0.045	0.015	18.5		8.0	0.20

Mechanical Properties

The mechanical properties of grade 301 stainless steels are listed in the table below. The bend test is obtained around a diameter of the bend factor multiplied by the steel thickness.

***Table 2 -** Mechanical properties of 301 grade stainless steel*

Grade 301 Temper ASTM A666	Tensile Strength (MPa) min.	Yield Strength 0.2% Proof (MPa) min.	Elongation (% in 50mm) (thick.>0.76mm) min.	Bend Test (thickness > 1.27mm)	
				Bend Angle (°)	Factor
Annealed	758	276	60	-	-
1/16 Hard	620	310	40	180	1
1/8 Hard	690	380	40	180	1
1/4 Hard	862	514	25	90	2
1/2 Hard	1034	758	18	90	2
3/4 Hard	1205	930	12	90	3

Full Hard	1276	965	9	90	5

Physical Properties

Physical properties of grade 301 stainless steels are listed in the table below.

Table 3 *- Physical properties of 301 grade stainless steel*

Grade	Density (kg/m^3)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion (μm/m/°C)			Thermal Conductivity (W/m.K)		Specific Heat 0-100˚C (J/kg.K)	Electrical Resistivity (nΩ.m)
			0-100°C	0-315°C	0-538°C	at 100°C	at 500°C		
301	7880	193	16.9	17.2	18.2	16.2	21.4	500	695

Grade Specification Comparison

Table 4 provides an approximate grade comparison for 301 stainless steels. The comparisons given in the table are of functionally similar materials. (For exact equivalents, the original specifications must be referred to).

Table 4 *- Grade comparison for grade 301 stainless steel*

Grade	UNS No	Old British		Euronorm		Swedish SS	Japanese JIS
		BS	En	No	Name		
301	S30100	301S21	-	1.4310	X10CrNi18-8	2331	SUS 301

Possible Alternative Grades

A list of the possible alternatives to grade 301 stainless steels is given in Table 5.

Table 5 *- Possible alternative grades to 301 grade stainless steel*

Grade	Reason for choosing the alternate grade

LAMPIRAN 3 Material Properties DIN 1.4003

Utility Ferritic Stainless Steel: Grade 1.4003

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Stainless steel grade 1.4003 is a utility ferritic stainless steel and an alternative for mild steel. It is supplied in the form of plate, sheet, and tube. Due to its numerous benefits, 1.4003 stainless steel can be used in several applications across a wide range of industries. It corresponds to designations 3CR12 and Nirosta 4003, but may not be a direct equivalent.

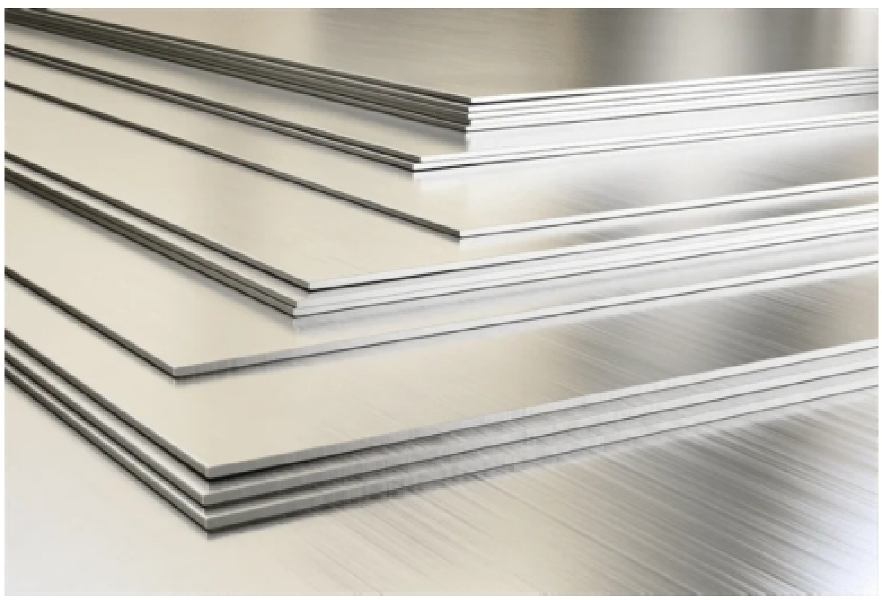


Image Credit: Shutterstock/SimoneN

It is a fact that 1.4003 stainless steel provides lower life-cycle costs than conventional materials, where service conditions involve abrasion and/or corrosion. Compared to conventional materials, there are options to minimize initial cost by excluding protective coatings and corrosion allowances. Costs are further reduced as a result of less maintenance, better productivity, and a considerably longer life. This stainless steel does not contain major quantities of costly alloying elements, such as molybdenum and nickel, so the cost of the material is lower than austenitic stainless steel and can be used as an alternative to these grades.

In damp or wet conditions where abrasive conditions exist, stainless steel grade 1.4003 provides superior performance by resisting corrosion, maintaining good flow and slideability, compared to low-alloy or non-alloyed steels, including abrasion resistant grades.

Benefits

The other benefits of using type 1.4003 stainless steel are listed below:

- High strength
- 250 times greater corrosion resistance than mild steel
- Exceptional impact resistance
- Can be welded by traditional techniques
- Can eliminate the need for protective coating
- Better performance at high temperatures
- Proven success in several applications across numerous industries

Chemical Composition

1.4003 Steel	Spec: EN 10088-2:2005
Chemical Element	**% Present**
Carbon (C)	0.0 - 0.03
Chromium (Cr)	10.50 - 12.50
Manganese (Mn)	0.0 - 1.50
Silicon (Si)	0.0 - 1.00
Phosphorous (P)	0.0 - 0.04
Sulphur (S)	0.0 - 0.02
Nickel (Ni)	0.30 - 1.00
Nitrogen (N)	0.0 - 0.03
Iron (Fe)	Balance

Properties

Physical Property	Value
Density	7.74 g/cm³
Melting Point	1430-1510°C
Thermal Expansion	11.1-12.3 x 10^{-6}/K
Modulus of Elasticity	200 GPa

Thermal Conductivity	30.5 W/m.K
Electrical Resistivity	0.678 x 10^{-6} Ω.m

Sheet & Plate - Up to 13.5mm Thick	Spec: EN 10088-2:2005
Mechanical Property	**Value**
Proof Stress	280 Min MPa
Tensile Strength	450-650 MPa
Elongation A	20 Min %

Plate - Over 13.5mm to 25mm Thick	Spec: EN 10088-2:2005
Mechanical Property	**Value**
Proof Stress	250 Min MPa
Tensile Strength	450 - 650 MPa
Elongation A	18 Min %

Fabrication

Weldability - The fine-grained microstructure of type 1.4003 limits grain growth in the heat-affected zone (HAZ) and allows highly reliable welds in section thicknesses up to 30 mm. Ideal weld methods include GTAW, FCAW, SMAW, PAW, Spot, Laser, and Seam.

Strength and stiffness – It offers better strength, but equal structural stiffness to mild steels, such as BSEN10113 Grade Fe430A (ASTM A36). Compared to aluminium, it offers better impact and energy resistance. It acts similar to austenitic steel as it gradually yields and does not reveal a clear yield point.

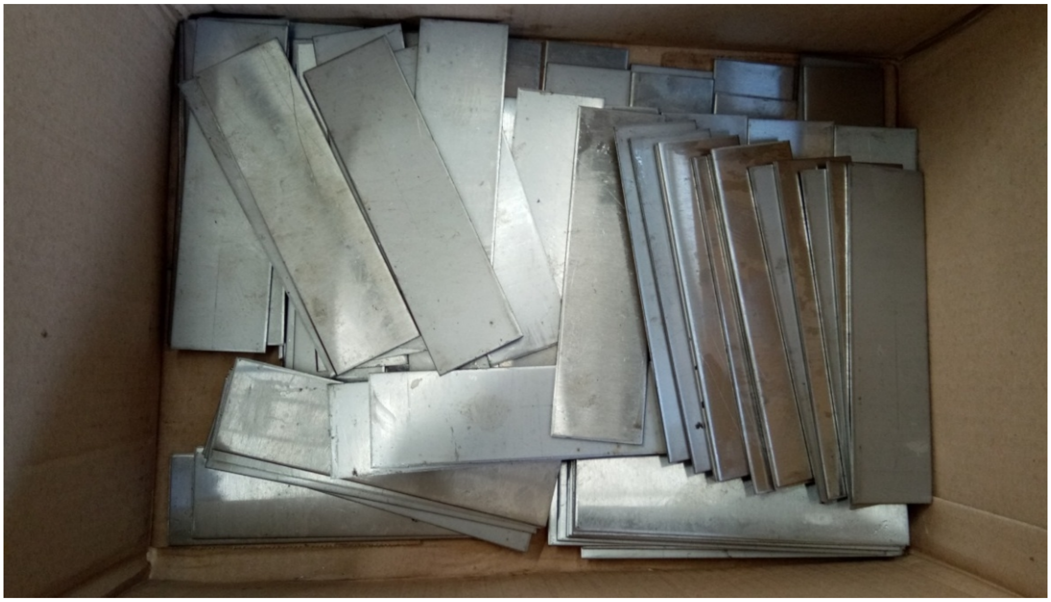
Coating and painting – As stainless steel type 1.4003 provides superior corrosion resistance and exceptional abrasion resistance, it does not require coating or painting systems to be applied to enhance performance. Painting may be desired only for aesthetic reasons in some applications. The metal can resist corrosion even if the paint wears off. A clean surface free of grease and other contamination is recommended before starting the paint job. A primer coat is recommended for cold-rolled material, as it has a smoother surface. In the case of hot rolled 1D finish material a single coat of paint will suffice.

Applications

1.4003 stainless steel can be used in the following scenarios:

- Cable trays

LAMPIRAN 4 Material SUS dan DIN Setelah Dilakukan Pemotongan



LAMPIRAN 5 Journal Tentang Setting Awal

ROTASI Jurnal Teknik Mesin
Available online at Website http://ejournal.undip.ac.id/index.php/rotasi

STUDI LITERATUR PENGARUH PARAMETER PENGELASAN TERHADAP SIFAT FISIK DAN MEKANIK PADA LAS TITIK (*RESISTANCE SPOT WELDING*)

***Haikal[1], Triyono[2]**
Mahasiswa Jurusan Teknik Mesin, Fakultas Teknik, Universitas Sebelas Maret
Dosen Jurusan Teknik Mesin, Fakultas Teknik, Universitas Sebelas Maret
Jl. Ir. Sutami 36 A Kentingan Surakarta 57126
*E-mail: haikal_kalkal@yahoo.co.id

ABSTRACT

Resistance spot welding (RSW) is the most widely used for joining thin sheet metals in automotive industry. Various applications of dissimilar materials and thicknesses were commonly found in many spot welding processes especially in the manufacture of car body. The resistance spot welding of dissimilar materials are generally more challenge than similar materials due to differences in the physical, chemical, and mechanical properties of the base metals. Differences of materials have an impact on heat input generated at the spot welding. Diameter of the weld nugget size is influenced by several parameters such as electric current, welding time, different types of material, and the thickness of the plate. Nugget diameter will influence on physical and mechanical properties weld such as microstructure, shear strength and hardness. For practical use, various industrial standards have recommended a minimum weld size for a given sheet thickness, mostly in the form of tables. For example the American Welding Society (AWS), Society of Automotive Engineering (SAE) and the American National Standards Institute (ANSI). They were only suitable to be apllied on the similar metal and thickness joint because in this joint, symetrical nugget will be formed. Meanwhile a type of dissimilar metal that joined by spot welding method will result in the asymetrical nugget. This paper aims to review the results of researchs on the similar and dissimilar resistance spot welded joint to evaluate the use of similar metals weld parameters and standards on the dissimilar metals weld. It was determined that parameters welding such as electric current, welding time, and the standard for similar metals weld can not be applied on the dissimilar metals weld. The asymetrical nugget shape decreased shear strength on the weld nugget. The most important factor that was considered on the dissimilar metals weld to make high quality weld joint was nugget diameter. If the nugget diameter weld increased the strength of welding will increase.

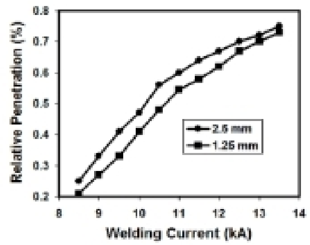
Keywords: *resistance spot welding, welding joint, similar metals, dissimilar metals*

1. PENDAHULUAN

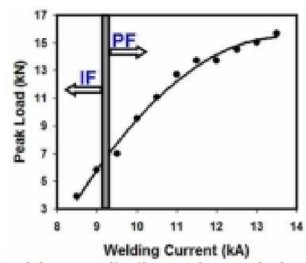
Resistance spot welding (RSW) merupakan proses pengelasan yang banyak digunakan di industri otomotif seperti pembuatan bodi kendaraan. Selain itu, proses las titik ini juga banyak digunakan di industri elektronik, penerbangan, dan sektor nuklir. Pouranvari [1] mengatakan bahwa kendaraan modern mengandung 2000 sampai 5000 sambungan las titik. Proses RSW dipilih, karena sebagian besar bahan yang dipakai dalam proses perakitan bodi kendaraan adalah plat tipis, sehingga apabila menggunakan proses las yang biasa (SAW, SMAW, dan lain sebagainya), maka material tersebut akan mengalami penurunan sifat mekanik. Keuntungan lainnya adalah proses pengerjaannya membutuhkan waktu yang singkat dan permukaan yang akan dilas biasanya tidak perlu dibersihkan sebelum pengelasan. Pengelasan titik juga dapat dimodifikasi dengan menambahkan aplikasi robotik sehingga sangat efektif untuk industri yang menggunakan jalur produksi otomatis dan produksi secara massal. Metode las ini juga cocok untuk produksi kecil, karena fleksibel, peralatan proses sederhana, biaya relatif murah dan pengelasan mudah untuk dikontrol.

Kualitas dan kekuatan hasil sambungan las titik sangat penting dalam kelayakan dan keamanan alat transportasi sehingga perlu dilakukan penelitian lebih dalam. Penelitian tentang las titik telah banyak dilakukan oleh peneliti terdahulu yang bertujuan untuk mengetahui parameter yang dapat mempengaruhi hasil las. Parameter las titik sangat berpengaruh terhadap sifat fisik dan mekaniknya yang meliputi kemampuan menahan beban geser, kekerasan, dan perubahan strukturmikro. Parameter yang mempengaruhi hasil pengelasan titik berdasarkan hasil berbagai penelitian adalah kuat arus listrik, lama waktu pengelasan, jenis material, dan ketebalan plat.

Kegagalan pada las titik dibagi menjadi 2 tipe yaitu *Interfacial failure* (IF) dan *Pull out failure* (PF). *Interfacial failure* merupakan kegagalan dalam pengelasan titik dimana terjadi kerusakan atau keretakan pada zona fusi. *Pull out failure* merupakan kegagalan dimana terjadi kerusakan pada daerah sekitar zona fusi sehingga plat mengalami kerusakan yaitu plat sobek. *Pull out failure* merupakan tipe kegagalan yang diharapkan oleh *engineer* karena memiliki kemampuan menahan beban geser lebih besar dibandingkan *Interfacial failure*. Parameter terpenting dalam mencari tipe kegagalan RSW adalah ukuran *nugget* las. Industri telah merekomendasikan berbagai macam standar ukuran minimal nugget las untuk ketebalan plat tertentu agar memudahkan dalam pengelasan. Standar tersebut antara lain ditunjukkan pada Gambar 3. Umumnya kegagalan pada las titik dibagi menjadi 2 tipe yaitu *Interfacial failure* (IF) dan *Pull out failure* (PF). *Interfacial failure* merupakan kegagalan dalam pengelasan titik dimana terjadi kerusakan atau keretakan pada zona fusi. Sedangkan *Pull out failure* merupakan kegagalan dimana terjadi kerusakan pada daerah sekitar zona fusi sehingga plat mengalami kerusakan yaitu plat sobek seperti pada Gambar 4. *Pull out failure* merupakan tipe kegagalan yang dibutuhkan dalam *design of manufacture*. Hal ini dikarenakan tipe *Pull out failure* memiliki deformasi plastik yang tinggi.



Gambar 2. Pengaruh kuat arus listrik terhadap kedalaman las [1].



Gambar 3. Pengaruh kuat arus listrik pengelasan terhadap beban puncak [1].

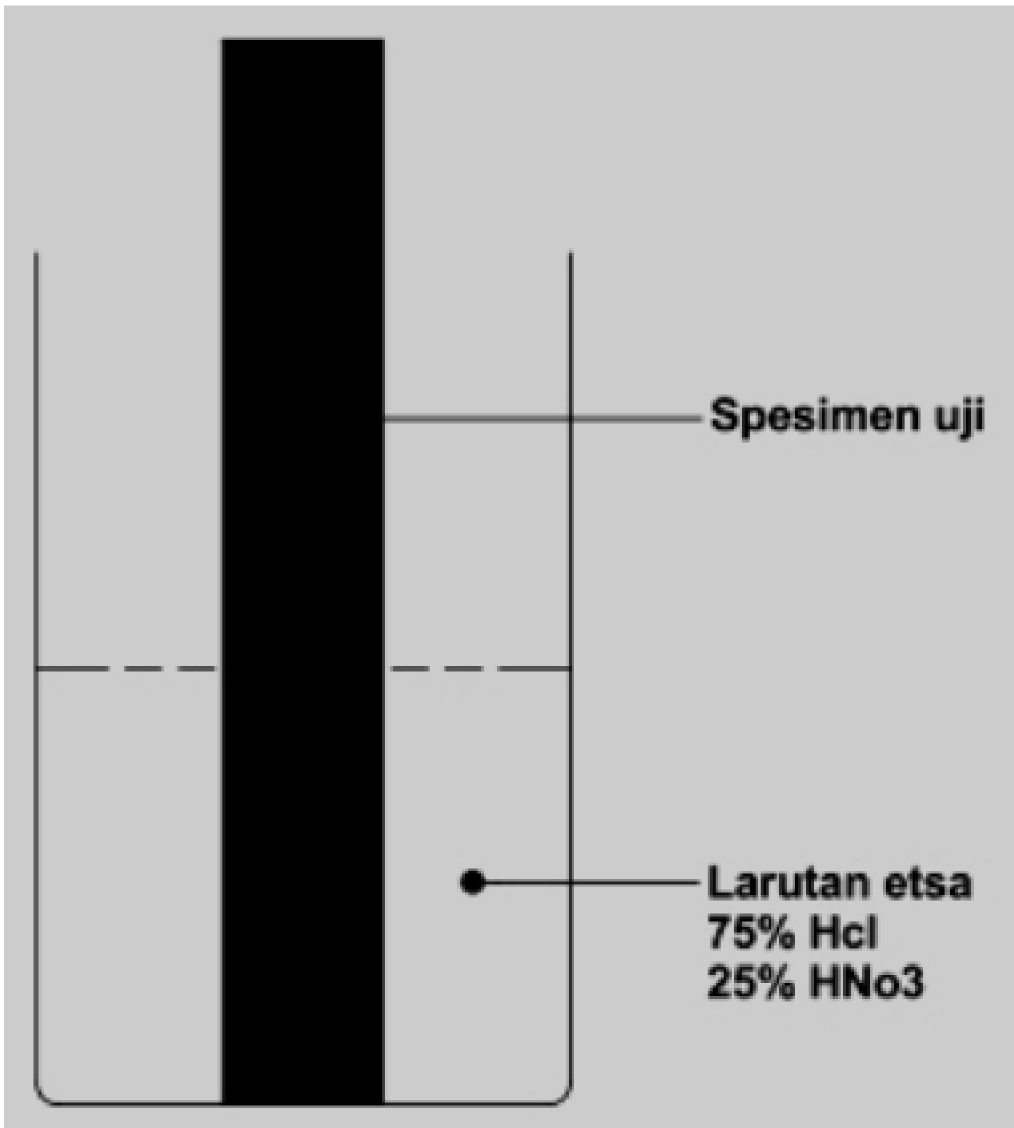
Penelitian terhadap metode pengelasan titik tidak hanya dilakukan dengan percobaan tetapi juga dapat menggunakan *software*. Penelitian tentang pengelasan titik menggunakan *software* telah dilakukan oleh Ninshu dan Hidekazu [2] yang melakukan penelitian tentang pengaruh kuat arus listrik dan waktu pengelasan terhadap ukuran *nugget* pada proses las titik secara *numerical* dan *experiment*. Penelitian ini bertujuan membandingkan hasil analisa menggunakan *software* FEM (*Finite Element Method*) dengan hasil percobaan. Pengelasan menggunakan plat tipe baja karbon tinggi dengan ketebalan 0.7, 1.4, 1.8 mm. Pengelasan dilakukan dengan susunan plat 3 lapis dan gaya penekanan elektroda konstan. Variasi arus listrik yang digunakan dalam pengelasan yaitu 5, 6, dan 7 kA, sedangkan variasi waktu yang digunakan yaitu 4, 5, 7, 10, 13, dan 17 detik. Dari hasil hasil penelitian menunjukkan bahwa *nugget* tidak terbentuk sebelum 4 detik dan ukuran *nugget* mulai meningkat setelah 5 detik. Berikut adalah data yang dihasilkan dari *software* FEM disajikan seperti terlihat pada Gambar 4. Gambar tersebut menunjukkan kuat arus listrik dan waktu pengelasan sangat berpengaruh terhadap ukuran nugget hasil las titik. *Nugget* hasil las akan berdampak pada sifat mekaniknya yaitu kekuatan geser.

Penelitian menggunakan *software* juga pernah dilakukan oleh Kong dkk [3] yang melakukan penelitian tentang numerical untuk kekuatan hasil las titik pada baja karbon rendah. Hasil penelitian menunjukkan bahwa meningkatnya diameter *nugget* untuk dua plat sejenis berdampak terhadap meningkatnya kekuatan geser sambungan las titik. Ketebalan plat juga berpengaruh terhadap meningkatnya kekuatan geser hasil las untuk plat dengan ketebalan yang sama seperti ditunjukkan pada Gambar 5.

LAMPIRAN 6 Spesimen Uji Setelah Dilakukan Pengelasan Resistansi Titik

LAMPIRAN 7 Spesimen Uji Macro

LAMPIRAN 8 Proses Etsa Dengan Metode Pencelupan



LAMPIRAN 9. Cairan HCl dan HNO_3 yang Digunakan Untuk Etsa

LAMPIRAN 10. Proses Pengujian Tarik Spesimen