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# Welding Solutions for Hot-dipped GI Steel & AHSS

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# Automotive Industry

## Trend in automotive industry

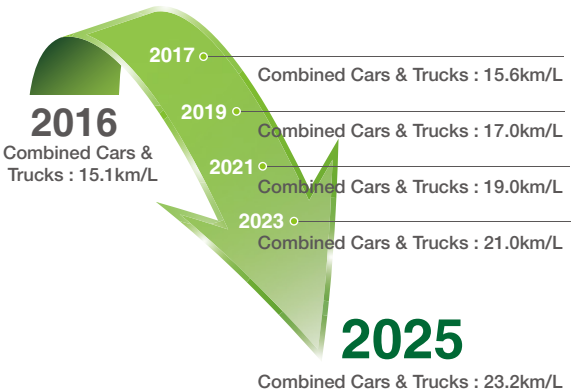
As part of the global CO2 reduction plan, regulations on vehicle fuel efficiency are being strengthened, and the application of advanced high strength steel plates is increasing.

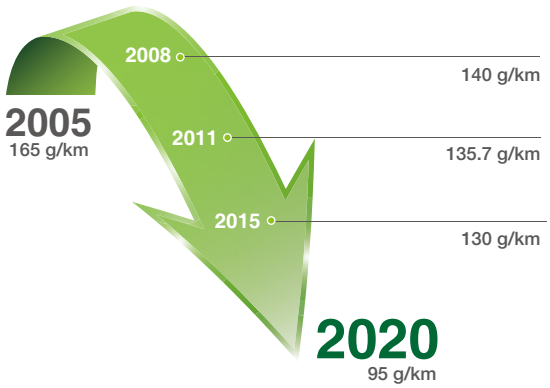
### USA

- Fuel efficiency regulation to be doubled by 2025
- About 5% improvement in fuel efficiency every year

### Europe

- Regulation of Greenhouse gas emission until 2020
- Cumulative penalty of 5 ~ 95 Euro per gram



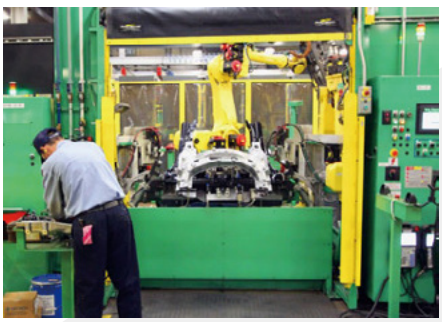

## Advanced high strength steel

The application of AHSS plates is expanded, the thickness of steel plates used in vehicles is decreasing. The thickness of the material becomes thinner due to the high strength of the material, and the demand for corrosion resistance increases further.

| Classification | Tensile strength (MPa) | Plate thickness (Mild Steel = 100) |
|---|---|---|
| Mild Steel | ≤ 340 | 100 |
| High Strength Steel | 340~780 | 80 |
| Advanced High Strength Steel | ≥ 780 | 62 |
| Ultra High Strength Steel | ≥ 1000 | - |

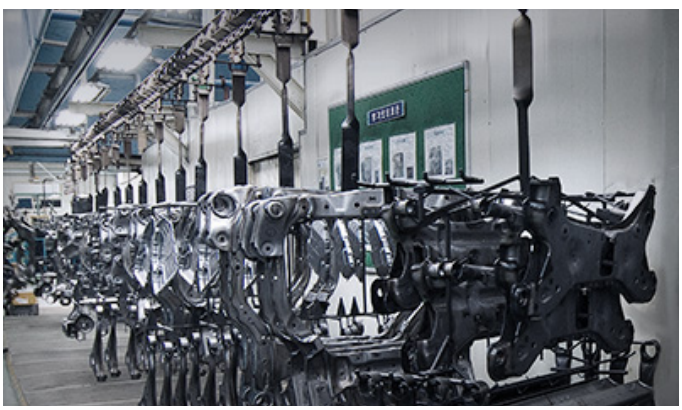
## Chassis - Welding

GMAW is implemented mainly as a robot in manufacturing car chassis parts.
One of the disadvantages of solid welding is the formation of glass slag.
Unless these slags are removed before painting, it will cause corrosion. It is being removed through grinding.

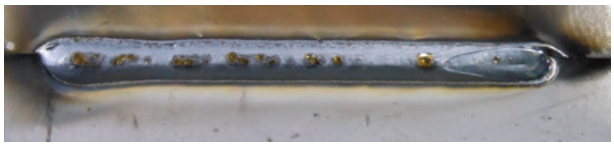


## Chassis - Painting

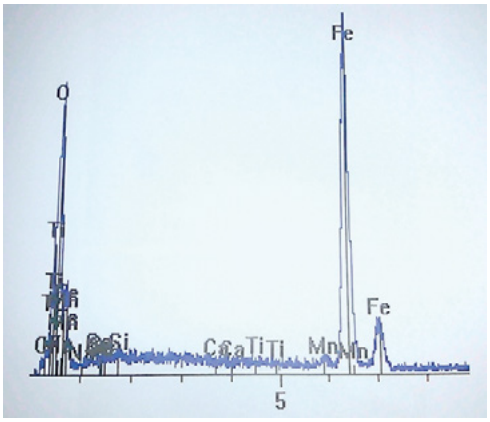
Chassis parts will be protected with paint to prevent deterioration of durability due to corrosion.
If the unremoved slag remains in the weld, the slag will fall with the paint due to differences in the level of thermal expansion of the parent metal and slag.
As paintwork is destroyed, corrosion occurs first in areas exposed to the atmosphere.




# Slag in Welding



| | | |
|---|---|---|
| $SiO_2$ | CaO | $TiO_2$ |
| MgO | $Al_2O_3$ | $Na_2O$ |
| FeO | MnO | Other Oxides |




## Role of Deoxidize

CO2 (Shielding Gas) → CO + [O]
Fe (Base metal) + [O] → FeO
☞ Oxygen removal required to prevent porosity formation
FeO + C (Base metal) → Fe + CO (Main cause of porosity)

※ Deoxidizing component of welding wire

2FeO + Si (Deoxidizing) → 2Fe + SiO2 (Slag)
FeO + Mn (Deoxidizing) → Fe + MnO (Slag)
2FeO + Ti (Deoxidizing) → 2Fe + TiO2 (Slag)
* De-oxidation : Ti > Si > Mn

# Related Key Products

## KC-35 Low Slag Solid Wire

The amount of slag generated is reduced by more than 50% compared to conventional products.
The slag is moved along the arc to reduce the area of occurrence.
It is recommended to use high Ar content in order to minimize slag from oxygen in shielding gas.

## Chemical composition of KC-35 wire

| Section | C | Si | Mn | P | S |
|---|---|---|---|---|---|
| AWS ER70S-3 | 0.06-0.15 | 0.45-0.75 | 0.90-1.40 | ≤0.025 | ≤0.035 |
| AWS ER70S-6 | 0.06-0.15 | 0.80-1.15 | 1.40-1.85 | ≤0.025 | ≤0.035 |
| KC-35 (ER70S-G) | 0.06 | 0.51 | 1.15 | 0.014 | 0.030 |

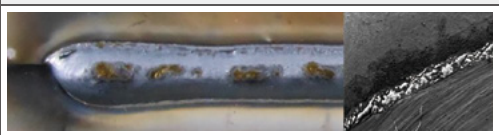
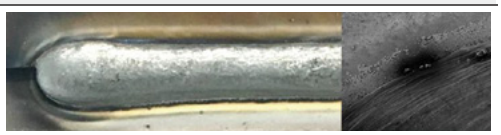
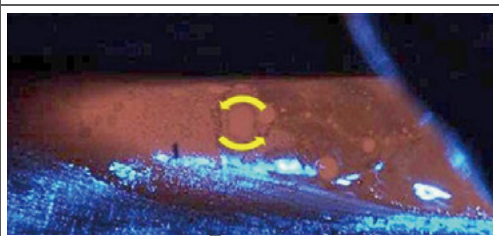
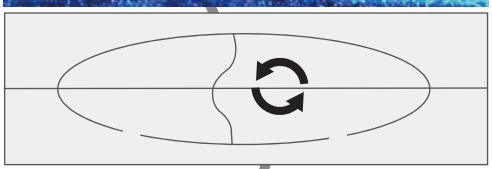
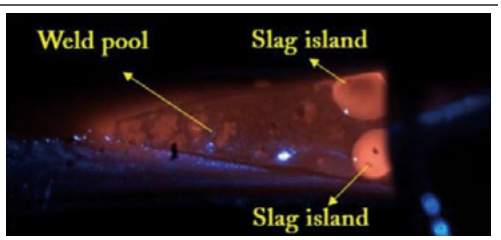
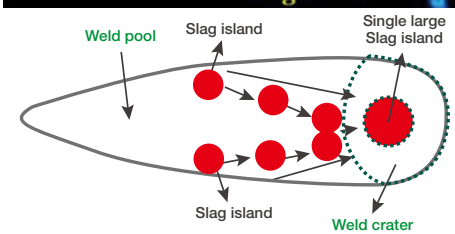
※ S : Decrease surface tension and Increase flow rate of molten weld metal
※ Si : Reduce silicate island

# Surface tension in weld pool

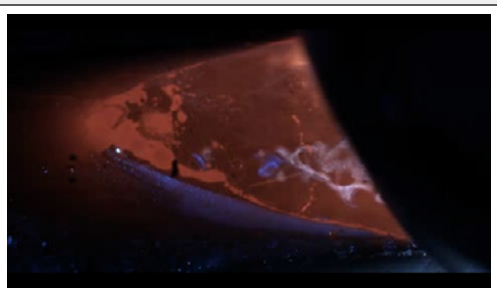
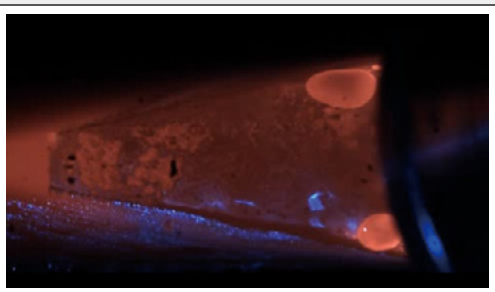
## Marangoni effect

This refers to the phenomenon of material transfer due to differences in surface tension between two liquids.
If you put water in a plate on the left, sprinkle pepper on the surface, and drop a bubble of soap in the center, pepper powder moves to edge with high surface tension.
This is because the surface tension at the center has been reduced by surfactants.

# Bead appearance

| Results | Conventional Wire | KC-35 |
|---|---|---|
| Bead appearance |  |  |
| EDS |  |  |
| Slag behavior |  <br>  <br>Both flows merge and create single spin |  <br>  |

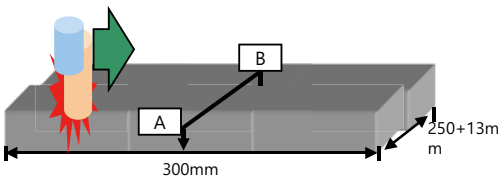
# Slag behavior

| Conventional wire | KC-35 |
|---|---|
|  |  |
| Most of the slag moves from center to edge of the weld metal | Because of less surface tension of molten pool, slag is flowed in crater part |

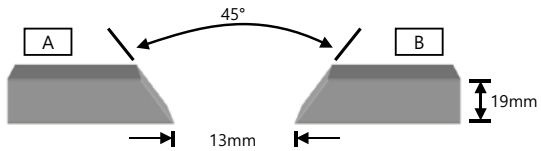
# Mechanical Properties

## Test specimen according to AWS A5.18

| Current(A) | Votage(V) | PASS (LAYER) | Shield Gas | Position | ROOT(mm) | Angle | Welding Machine | Base metal |
|---|---|---|---|---|---|---|---|---|
| 300 | 32 | 1~14 PASS (5 LAYER) | Ar+10%$CO_2$ Ar+20%$CO_2$ | Flat | 13 | 45° | Daihen 500P | SM-490 |



<Welding geometry>



<A-B cross section >

## Mechanical properties from test specimen

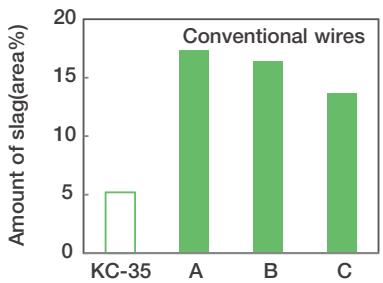
| Section | Y.S. ( MPa ) | T.S. ( MPa ) | E.l. (%) | I.V (J) at- 20℃ | Shielding Gas |
|---|---|---|---|---|---|
| AWS ER70S-G | ≥ 400 | ≥ 480 | ≥ 22 | - | |
| KC - 35 ( Φ 1.2mm ) | 480 | 550 | 25.4 | 80 | Ar+10%$CO_2$ |
| | 485 | 560 | 25.0 | 70 | Ar+20%$CO_2$ |

# Slag formation

## Bead Appearance and Slag amount on galvanized steel

Conventional

KC-35




## Slag Distribution by Mix Gas type

Conventional Ar+20%CO2 (Slag 11.81%)

KC-35 Ar+20%CO2 (Slag 5.30%)

KC-35 Ar+15%CO2 (Slag 2.59%)

KC-35 Ar+10%CO2 (Slag 2.22%)

# Related Key Products

## KC-37 Improve paint durability

Slag generation is reduced compared to conventional products, resulting in fine dispersion.
By replacing the Si component, with other components, the glass slag are extremely reduced.
Reduction of slag removal work and prevention of gradation of corrosion resistance due to slag peel off after painting.

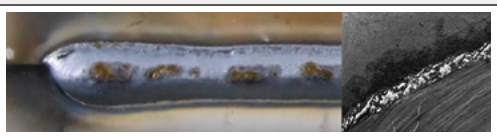
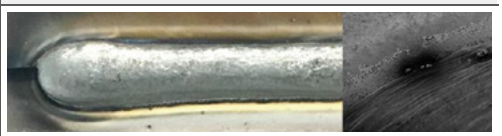
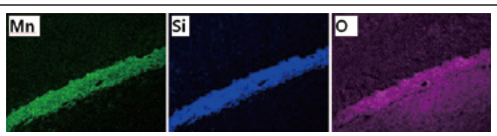
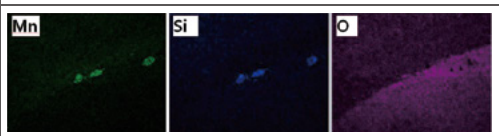
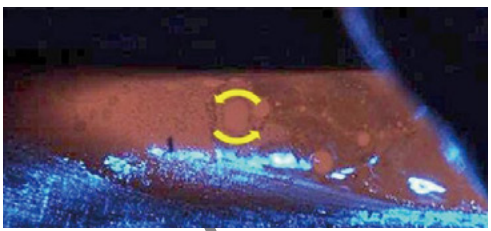
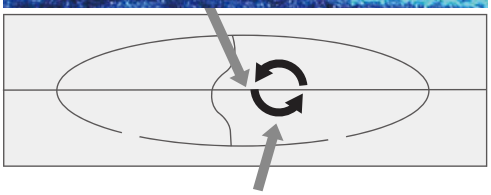
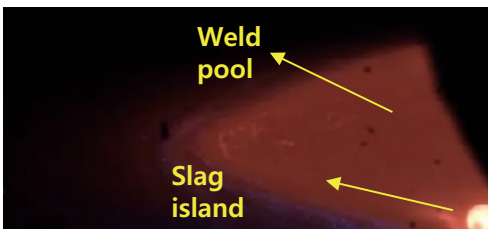
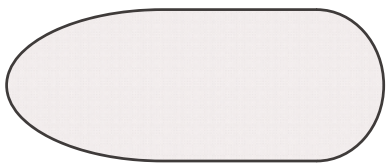
## Chemical composition of KC-37 wire

| Section | C | Si | Mn | P | S |
|---|---|---|---|---|---|
| **AWS ER70S - 3** | 0.06 - 0.15 | 0.45 - 0.75 | 0.90 - 1.40 | ≤0.025 | ≤0.035 |
| **AWS ER70S - 6** | 0.06 - 0.15 | 0.80 - 1.15 | 1.40 - 1.85 | ≤0.025 | ≤0.035 |
| **KC - 37 (ER70S - G)** | 0.08 | 0.06 | 1.73 | 0.011 | 0.001 |

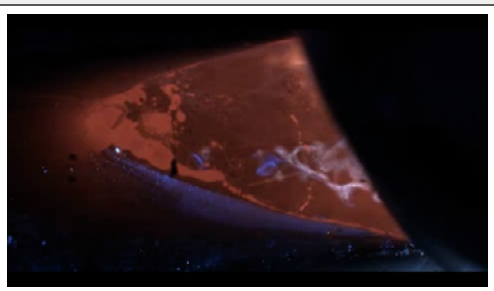
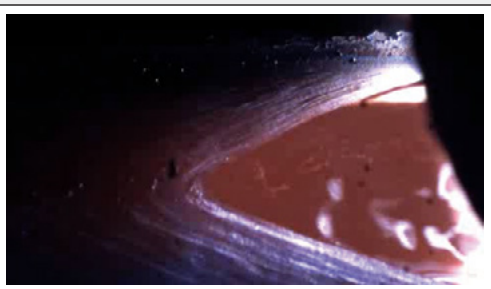
※ Si : Minimize content to reduce glass slag

※ Mn : Increased content to supplement insufficient Si content

# Bead appearance

| Results | Conventional Wire | KC-37 |
|---|---|---|
| Bead appearance |  |  |
| EDS |  |  |
| Slag behavior |  <br>  <br>Both flows merge and create single spin |  <br>  <br>Slag dispersed widely and thinly |

# Slag behavior

| Conventional wire | KC-37 |
|---|---|
|  |  |
| Most of the slag moves from center to edge of the weld metal | Low Si content produces less slag |

# Slag formation

### Welding machine and base metal

| Base Metal | Welding joint | Welding machine | Robot | Shielding Gas |
|---|---|---|---|---|
| Galvanized (2.3T) | Lap | Lincoln | Fanuc R-30iA | Ar + 8% $CO_2$ |

### Conventional ER70S-3

| Current (A) | Voltage(V) | Travel speed (CPM) | Torch Angle(°) |
|---|---|---|---|
| 238 | 24 | 80 | 90 |

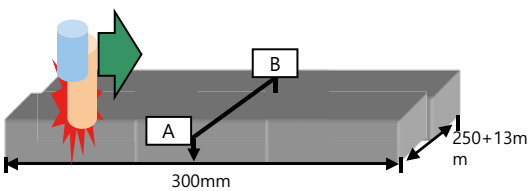
### KC-37 after welding (Without grinding)

| Current (A) | Voltage(V) | Travel speed (CPM) | Torch Angle(°) |
|---|---|---|---|
| 257 | 24 | 80 | 90 |

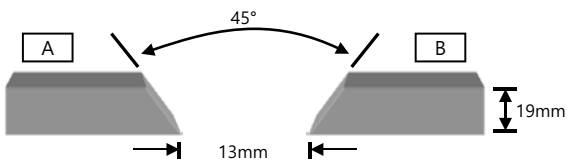
# Mechanical properties

### Test specimen according to AWS A5.18

| Current(A) | Votage(V) | PASS(LAYER) | Shielding Gas | Position | ROOT(mm) | Angle | Welding Machine | Base metal |
|---|---|---|---|---|---|---|---|---|
| 300 | 32 | 1~14 PASS (5 LAYER) | Ar+10%$CO_2$ Ar+20%$CO_2$ | Flat | 13 | 45° | Daihen 500P | SM-490 |




<Welding geometry>



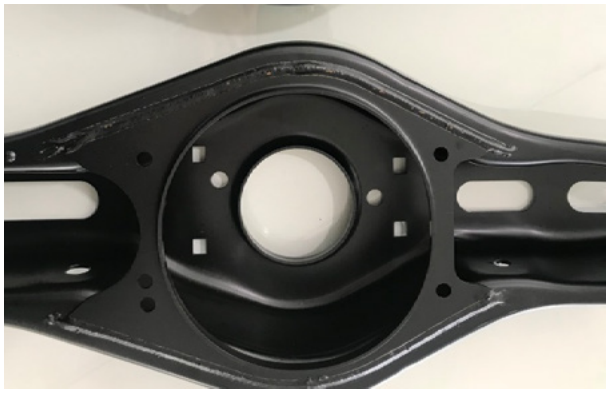

<A-B cross section >

| Section | Y.S. ( MPa ) | T.S. ( MPa ) | E.l. (%) | I.V (J) at-20℃ | Shielding Gas |
|---|---|---|---|---|---|
| AWS ER70S-G | ≥ 400 | ≥ 480 | ≥ 22 | - | |
| KC-35 ( ϕ 1.2mm ) | 450 | 553 | 32.1 | 100 | Ar+10%$CO_2$ |
| | 485 | 570 | 30.8 | 80 | Ar+20%$CO_2$ |

# Cyclic corrosion test

Welding bead of conventional one galvanized steel

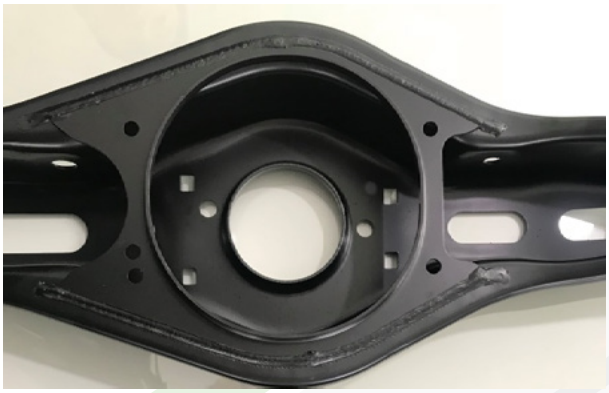
After Welding & Painting



After CCT Test

Welding bead of KC-37 galvanized steel

After Welding & Painting



After CCT Test