

**Bodycote**

**Kolsterising®**  
(콜스터라이징)

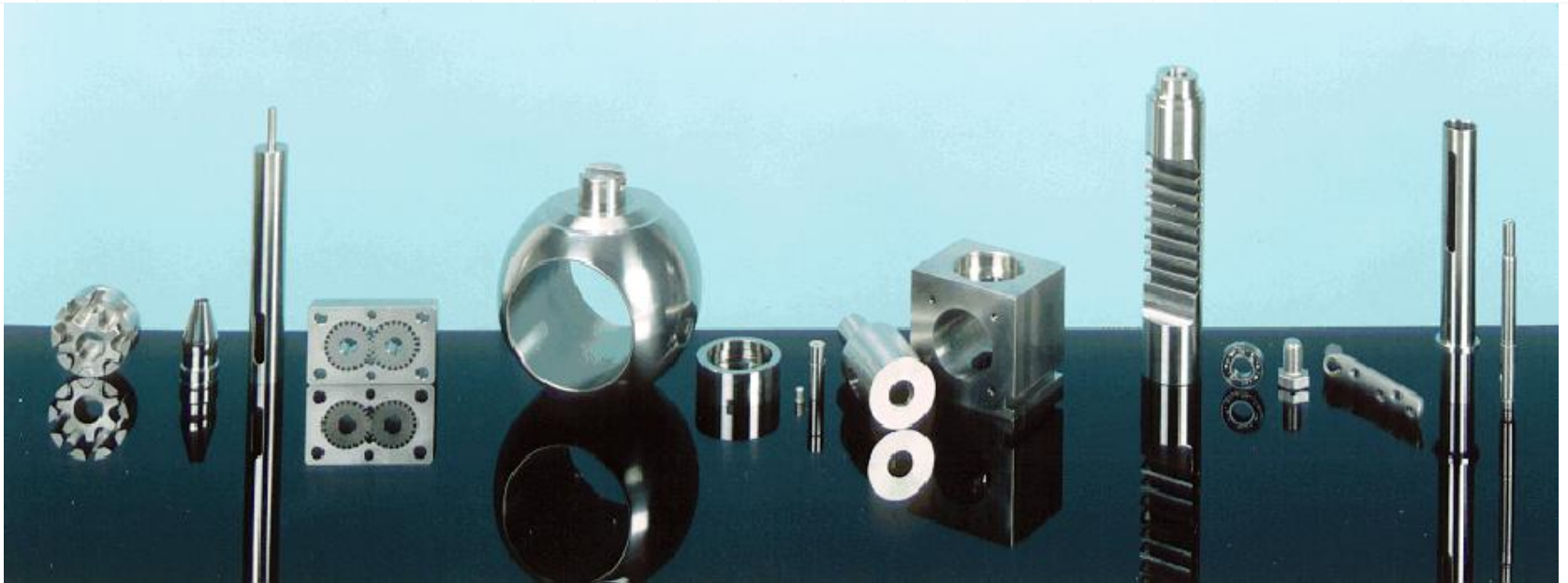
오스테나이트계 스테인레스鋼 전용 표면경화처리

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[www.kolsterising.info](http://www.kolsterising.info)

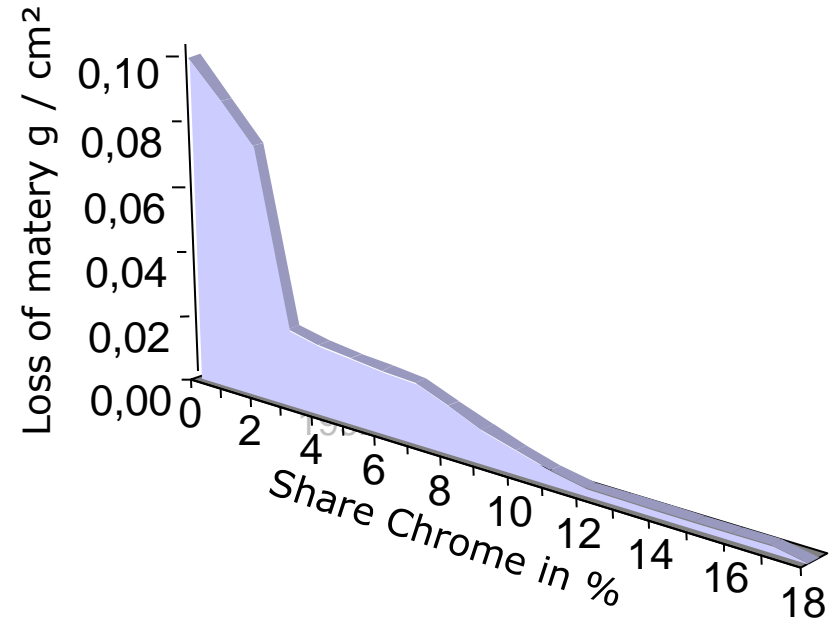
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- 미세조직 (Microstructure)
- 금속피로 (Fatigue strength)
- 내마모성 (Abrasive wear)
- 내식성 (Corrosion resistance)

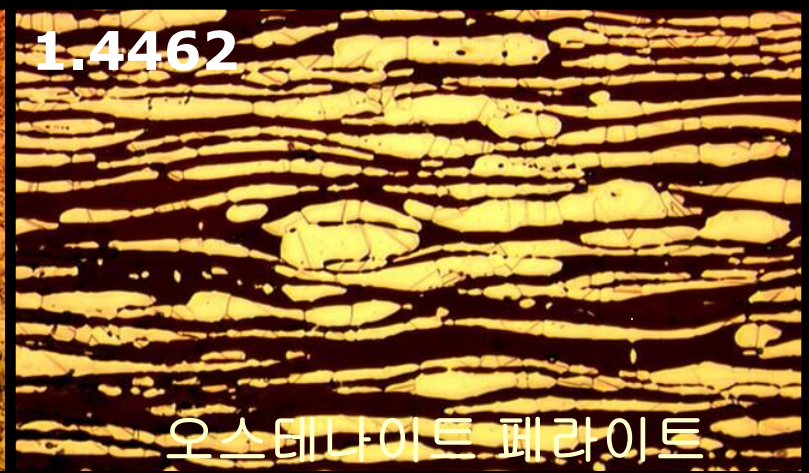
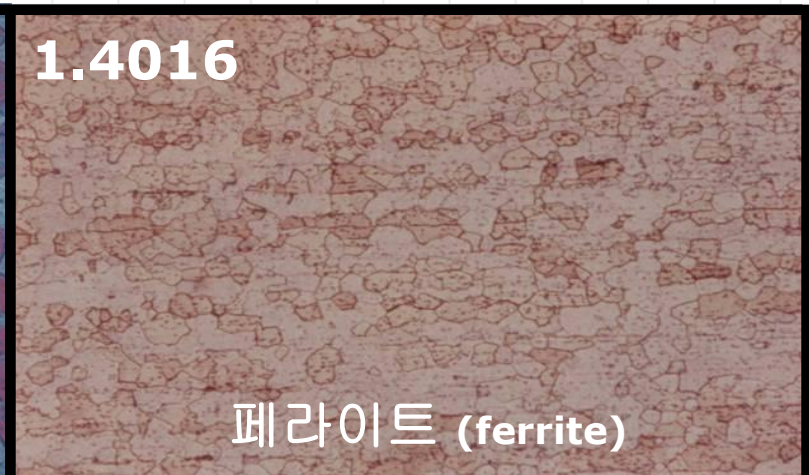
## 스테인레스강

- 크롬용량 **12% 이상**, 매트릭스에 분해되어 안정된 과학적 크롬산화물 산화물의 층이 생깁니다.(From a chromium content of >12%, dissolved in the matrix, formed an chemical stable chrome-oxide layer.)
- 철강에 **12% 이상**의 크롬이 있으면 내식성이 향상됩니다.(Steel with >12% Chrome applied as corrosion resistance)



## 미크로조직을 통해 본 스테인레스강의 분류

### Categories of stainless steel, based on their microstructure



## 오스테나이트계 스테인레스 타입 (Examples of austenitic stainless steel types)

Basis	Description by Norm EN 10088		AISI	examples applications
	Wst.-Nr.	Name - DIN		
18% Chrome, 8-12% Nickel	1.4301 1.4303 1.4306 1.4541	X 5 CrNi 18 10 X 4 CrNi 18 12 X 2 CrNi 19 11 X 6 CrNiTi 18 10	304 305 304L 321	Household apparatus machine- and fill in industries, pipeline equipment, electrical, steer components, Automotive industries
17% Chrome, 12-14% Nickel, 2-4% Molybdenum	1.4401 1.4404 1.4435 1.4571	X 5 CrNiMo 17 12 2 X 2 CrNiMo 17 12 2 X 2 CrNiMo 18 14 3 X 6 CrNiMoTi 17 12 2	316 316L 316L 316Ti	Food-, chemistry industries, pharmacy-, Medical- and, environment techniques
≤25% Chrome, ≤20% Nickel, ≤7% Molybdenum, Nitrogen, copper, manganese	1.3952 1.4406 1.4439 1.4539 1.4565	X 2 CrNiMoN 18 14 3 X 2 CrNiMoN 17 11 2 X 2 CrNiMoN 17 13 5 X 1 NiCrMoCu 25 20 5 X 2 CrNiMnMoN 25 18 6 5	316LN 317LMN 904L	Oil- and gas industry, chemical industry, Marine
22-27% Chrome, 5-7% Nickel, Nitrogen	1.4460 1.4462 1.4507	X 3 CrNiMoN 27 5 2 X 2 CrNiMoN 22 5 3 X 2 CrNiMoCuN 25 6 3	329	Duplex-Steel (austenite-ferrite) off-shore Industry, marine-, petrochemical-chemical Industry

## 오스테나이트 스테인레스 (Austenitic Stainless Steel)

### ➤ 장점 (Advantages)

- 뛰어난 내식성 (Corrosion resistance)
- 높은 인성 (High toughness)
- 높은 성질 전환성 (High transformable)
- 비자성 (Non-magnetic)

### ➤ 단점 (Disadvantages)

- 내마모성과 표면경도가 낮다 (Low wear resistance / surface hardness)
- 치핑이 잘 생긴다 (Big tent to friction (galling))

### ➤ 요구되는 특성 (Desired completion)

- 내마모성의 향상 (Improve wear resistance)
- 표면경도의 향상 (Higher surface hardness)
- 치핑방지 (Avoid galling)
- 내식성의 유지 (Preserve the good corrosion resistance)

오스테나이트系の 표면경화  
**Surface hardening of austenitic grades**



## 표면경도의 향상 (Increase in surface hardness)

### ▶ 오스테나이트계 스테인레스의 범용 열처리가 불가능

(Standard heat treatment of austenitic stainless steel not possible)

- ▶ 상전이가 없다(No phase transformation)
- ▶ 마르텐사이트 조직으로의 변화가 없다(No change to a martensite structure)

### ▶ 열과학적 확산처리에 의한 기존 프로세스

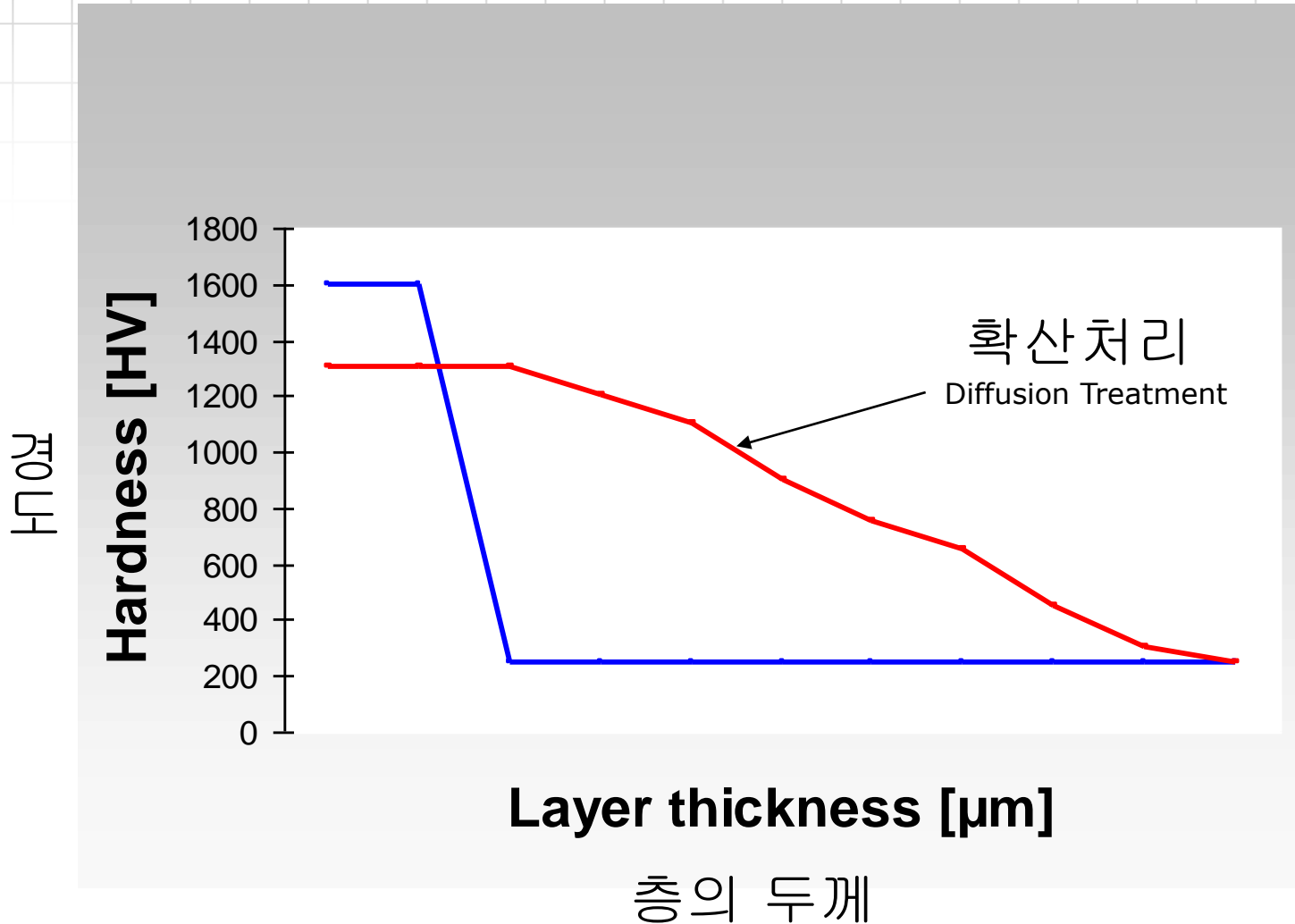
(Surface hardening with a thermo chemical diffusion process (Standard process))

- ▶ 질화처리(Nitriding / Nitrocarburising)
- ▶ 침탄(Carburising)
- ▶ 비평(Critical:
  - 침탄처리에 의한 크롬 산화피막에 방어막이 만들어지기 때문에 확산처리는 불가능하다(With conventional treatments the chromium oxide layer makes a barrier wherewith a diffusion process is almost not possible.)
  - 크롬이 질화나 탄소에 의해 복합 탄화물로 합쳐지는 것에 의해 질화물 혹은 카바이드가 만들어지는 결과, 치명적으로 내식성이 저하되는 양상을 띤다.(Because of the combination of chromium with nitrogen and/or carbon, nitrides or carbides are formed. This can give rise to a substantial loss of corrosion resistance.)

# 마모방지에 대한 일반적인 솔루션 (종래의 프로세스) **Common solution for wear protection**

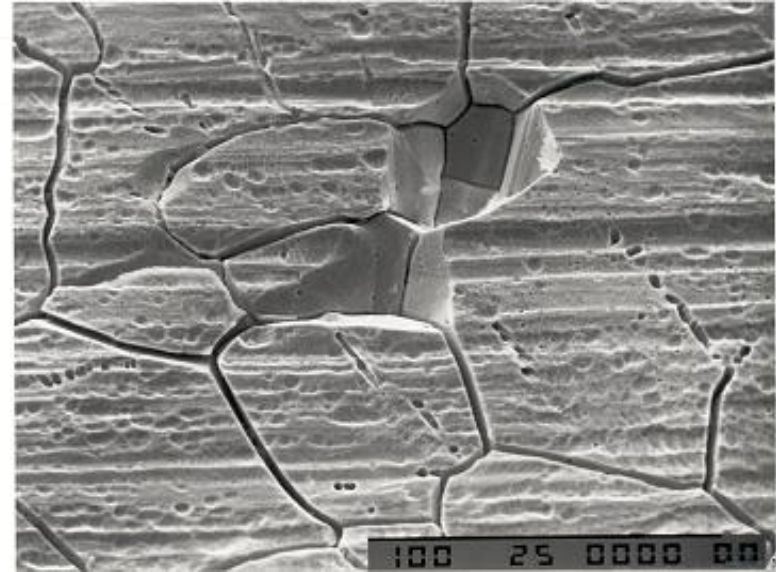
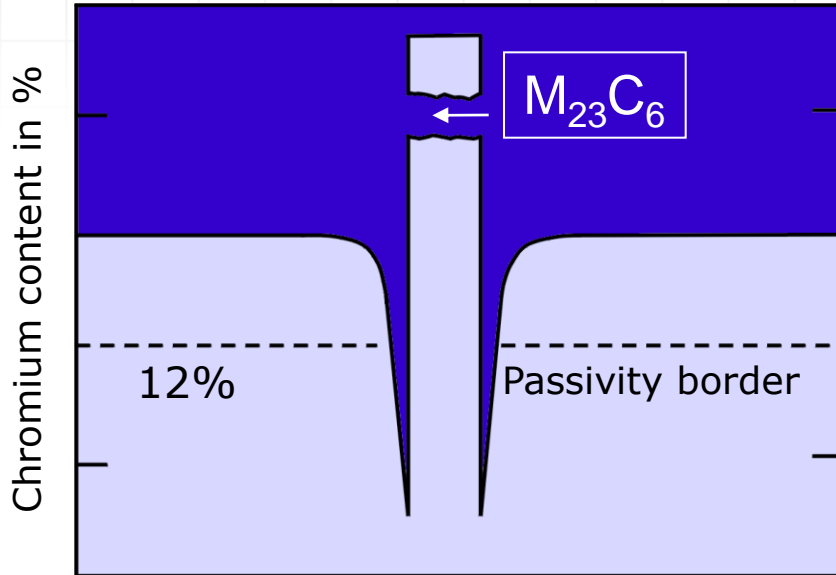
- ▶ 코팅 Coating
  - ▶ 박리(벗겨져 떨어져 나감) Adhesion failure
  - ▶ 기공 Porosity
  - ▶ 환경대응 Impact on environment

**코팅과 확산처리의 관계** Coatings vs. Diffusion Treatments



# 크롬카바이드( $M_{23}C_6$ )의 석출에 의한 크롬 감소의 영향

## Effect of chromium depletion due to precipitation of chromium carbides $M_{23}C_6$



표면상의 탄소 혹은 질소의 확산은 온도나 시간의 변화에 의해 크롬이 분비될 가능성이 있다. 크롬함유량이 **12%**이하의 경우 내식성이 저하하며, 이것은 부식이 진행되는 결과를 초래한다.

(Because the diffusion of carbon and/or nitrogen in the surface it is possible that there are chromium secretions, dependent upon temperature and time. Decrease in the chromium content below the 12% range, the alloy will have reduced corrosion resistance. This results in detrimental intergranular corrosion)

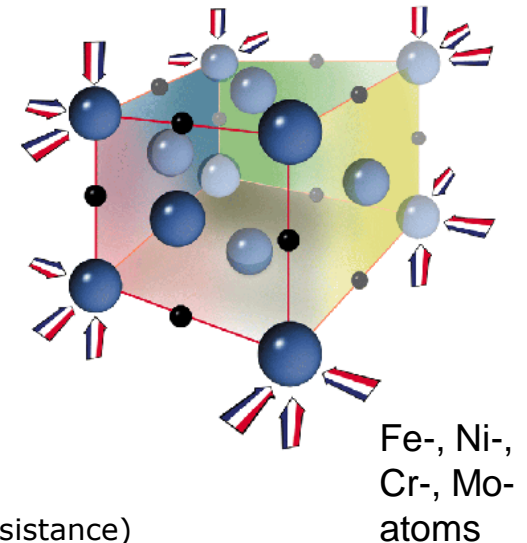
## 콜스터라이징 Kolsterising®

➤ 오스테나이트와 듀플렉스 스테인레스강의 저온 확산처리  
(Low temperature-diffusion process for austenite en duplex stainless steel)

- 열과학적 저온처리(Thermo-chemical low temperature process)
- 탄소원자의 침투, 확산(Diffusion of carbon)
- 원자와 원자간의 고용(固溶)(Interstitial solution of carbon atoms)
- 높은 압축응력의 발생(Forming of high compressive stresses)
- 크롬카바이드가 없다(No chromium carbides.)

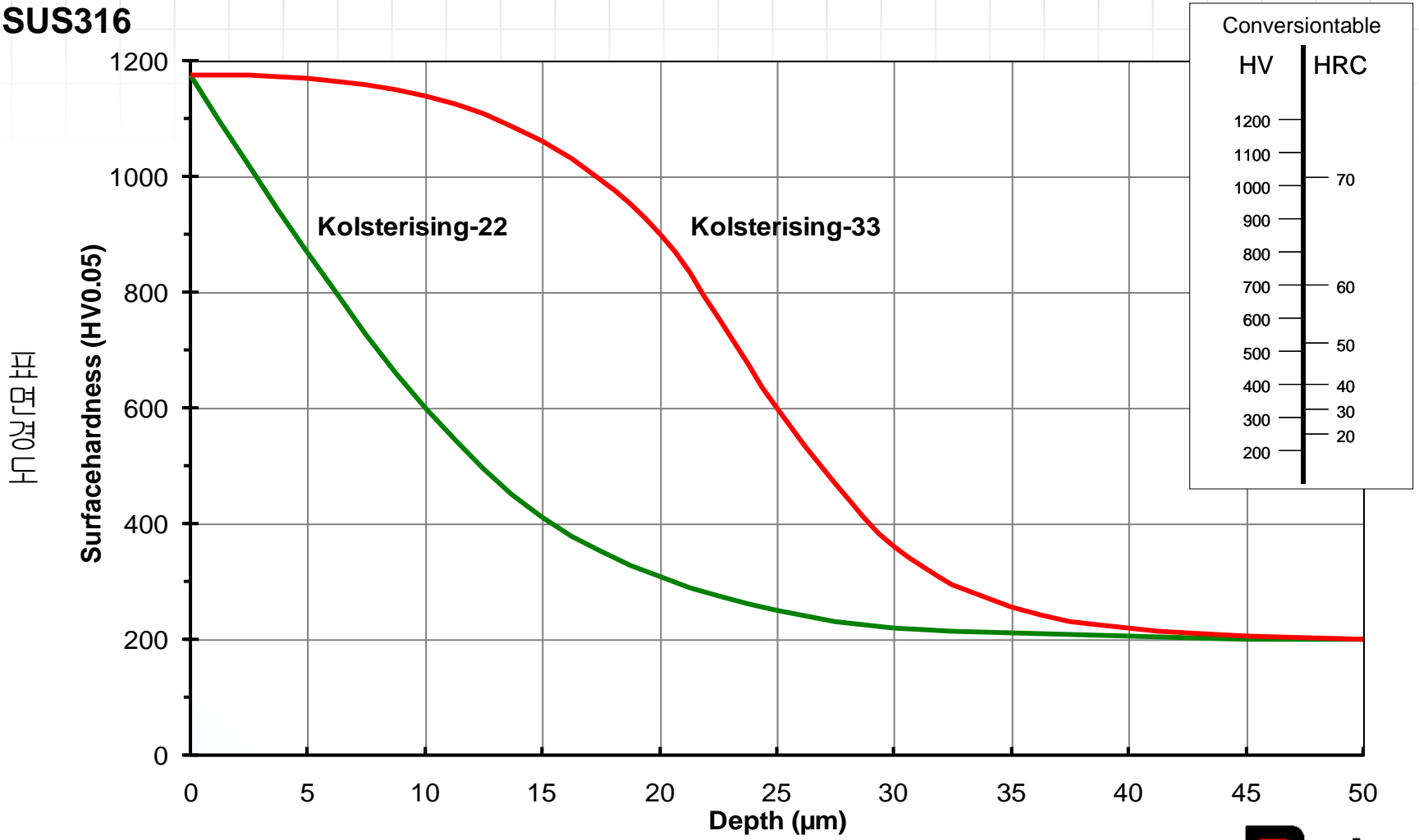
➤ 목적(Purpose)

- 표면경도의 향상(Increase of the surface hardness)
- 내식성의 향상(Improvement of the wear resistance)
- 치핑방지(Avoid galling)
- 내식성에 악영향이 없음(No negative influence on the corrosion resistance)
  - 모재에 의함(Depending of the base material!)



**Kolsterising 22 (K22)**  
**Kolsterising 33 (K33)**

**SUS316**

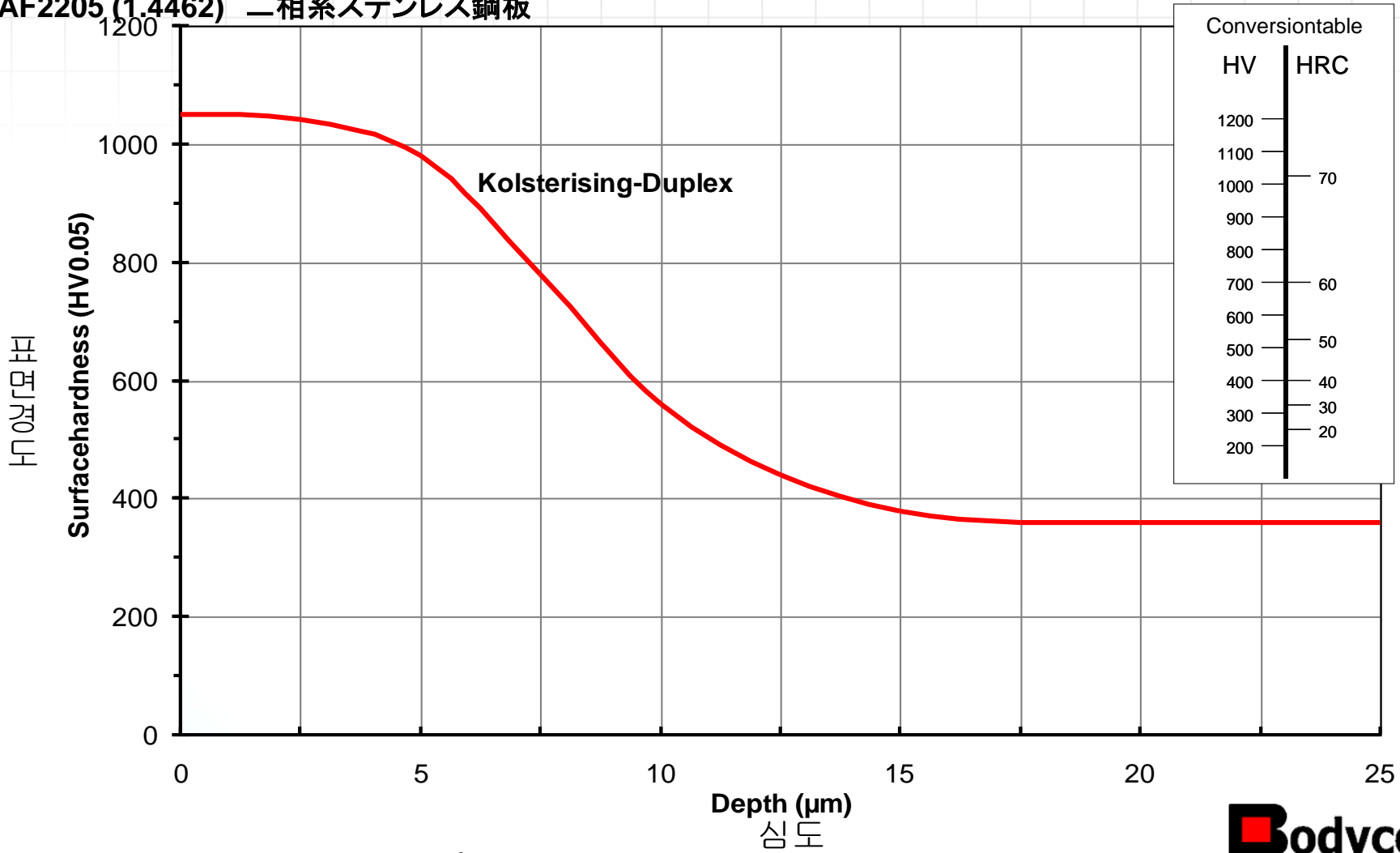


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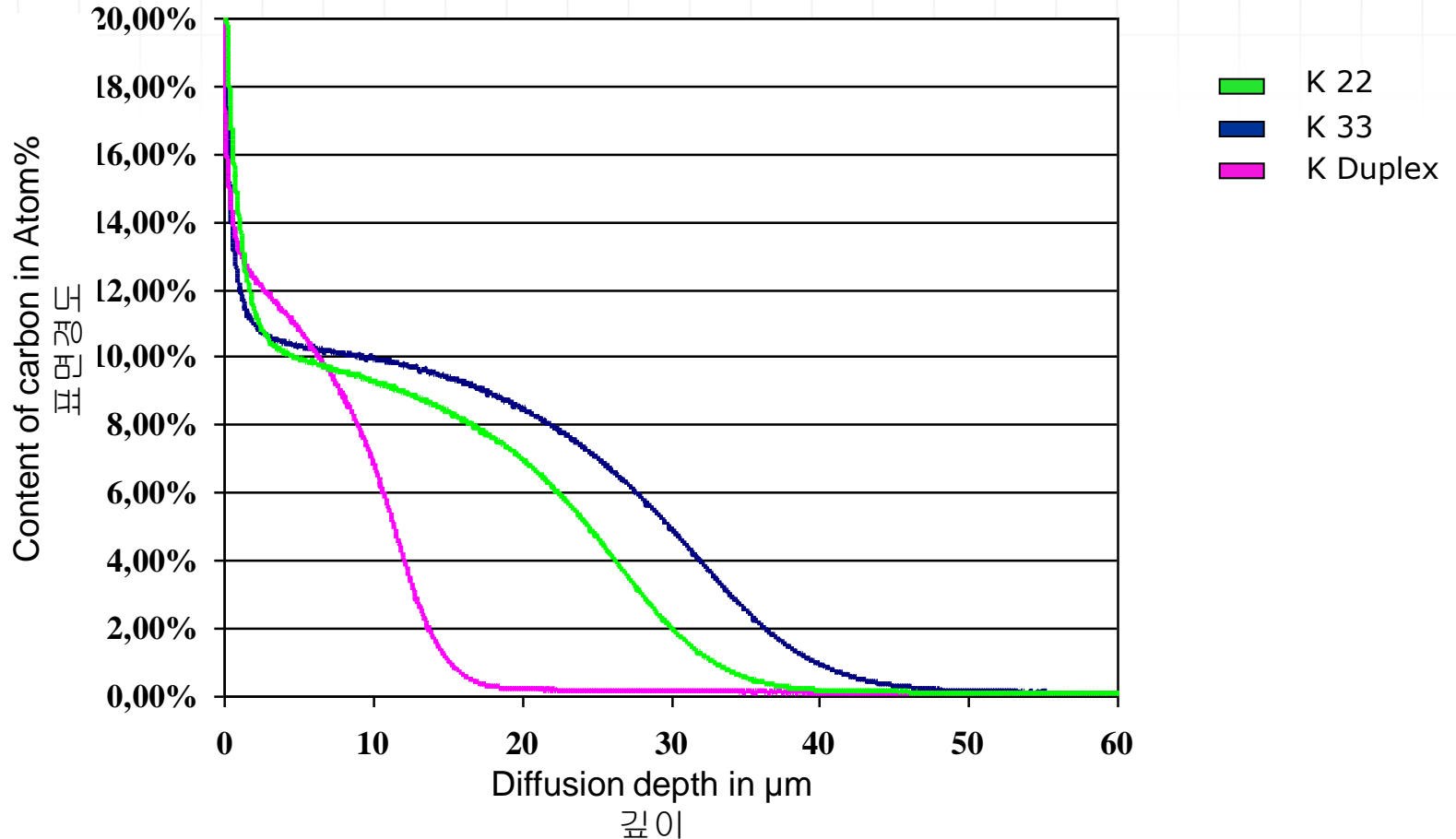


**콜스터라이징-듀플렉스 Kolsterising-Duplex**

**SAF2205 (1.4462) 二相系ステンレス鋼板**



# 표면의 탄소함유량 Content of carbon at the surface





## 콜스터라이징의 특성

### Characteristics of Kolsterising®

- 표면경도 증가(Increase surface hardness (ca. 900 – 1200 HV0,05))
- 피로강도의 향상(Improvement of fatigue strength)
- 내식성의 유지(Corrosion resistant diffusion zone)
- 비자성의 상태 유지(Non-Magnetic characteristics are not altered)
- 치핑방지(Reduce the risk of galling)
- 색, 형, 사이즈의 변화가 없음(Colour-, shape- and size stable)
- 날형태, 홀형태 등의 부분에도 균등히 확산  
(Evenly diffusion zone, also at sharp edges and inside bores and gaps)

미크로조직  
(Microstructure)

## 콜스터라이징 처리를 한 오스테나이트 스테인레스강의 조직 (Structure of Kolsterised austenitic stainless steel)



➤ 탄소(탄소)가 금속 조직안으로 용해(Carbon is dissolved in the metal matrix)

■ 높은 압축 응력에 의한 표면경화의 향상

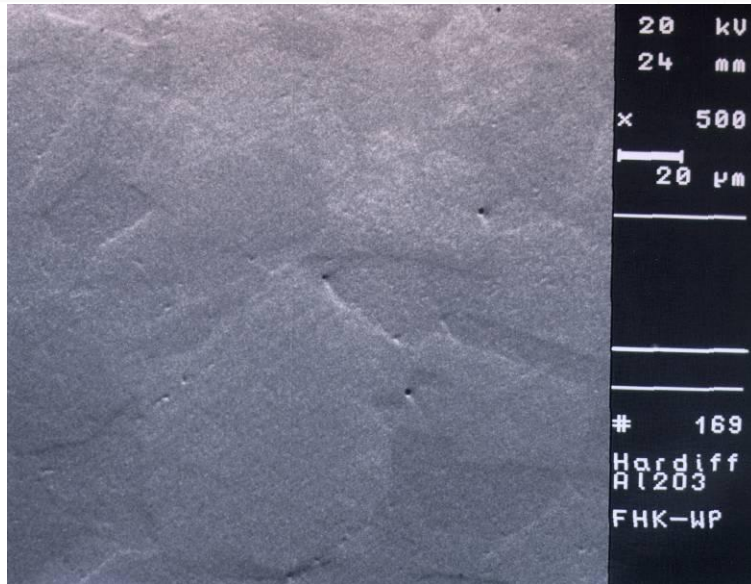
(Increase of surface hardness because of high compressive stresses)

➤ 카바이드 구조(결상)가 없음(No formation of carbides)

■ 내식성에 영향을 주지는 않음.(Corrosion resistance will not be influenced.)

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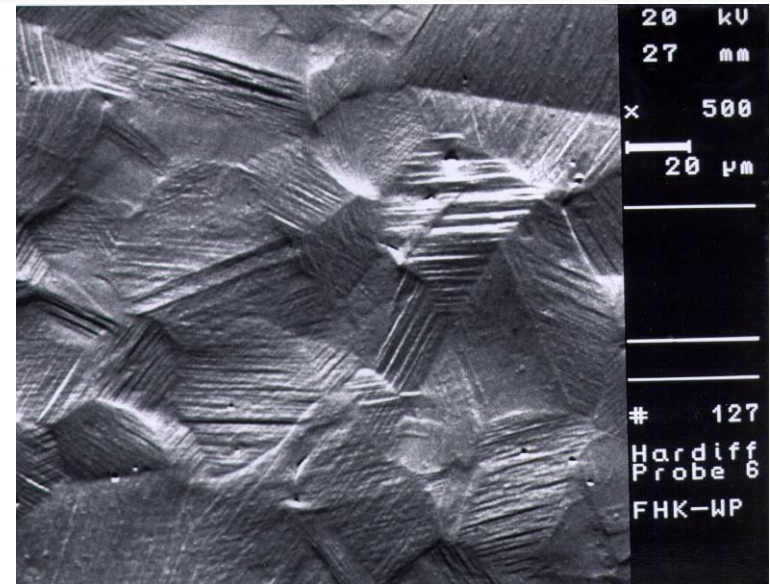
## 표면의 조밀도 (Surface roughness)



콜스터라이징 처리전

Before Kolsterising®

Ra: ca. 0,04 μm



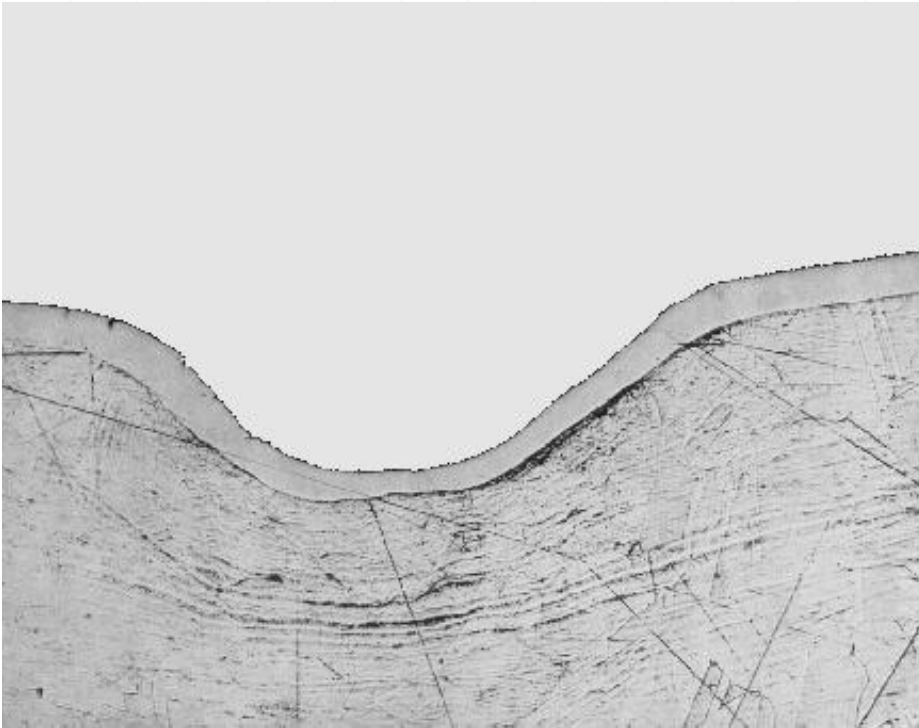
콜스터라이징 처리후(콜스터라이징**33**)

After Kolsterising® 33

(Slip lanes due to compressive stress)

Ra: ca. 0,08 μm

## 콜스터라이징 층(層)의 탄력성 (Elasticity of the Kolsterising layer)



표면에 높은 부하의 충격을 주었다.

원료물질(원자재)와 일체화 되어 있기 때문에 콜스터라이징층의 파손은 보이지 않는다.

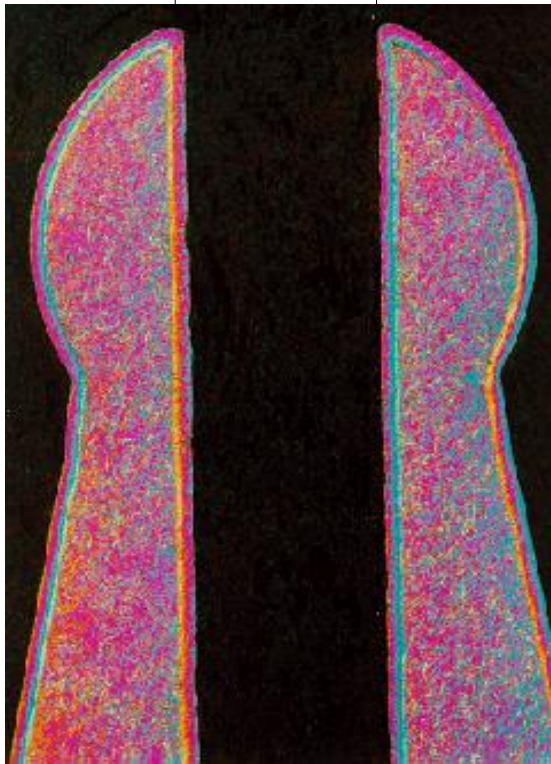
원료물질이 역성적으로 변형하고 있지만, 콜스터라이징 층은 변형에 본뜨는 모양으로 이동한다.

In this example, a high load impact hit the surface.

The Kolsterised layer did not break, because it is integrally joined with the base material. Nevertheless the base material plastically deformed. The Kolsterising zone followed the deformation.

## 개구부(開口部)내면 (Bores)

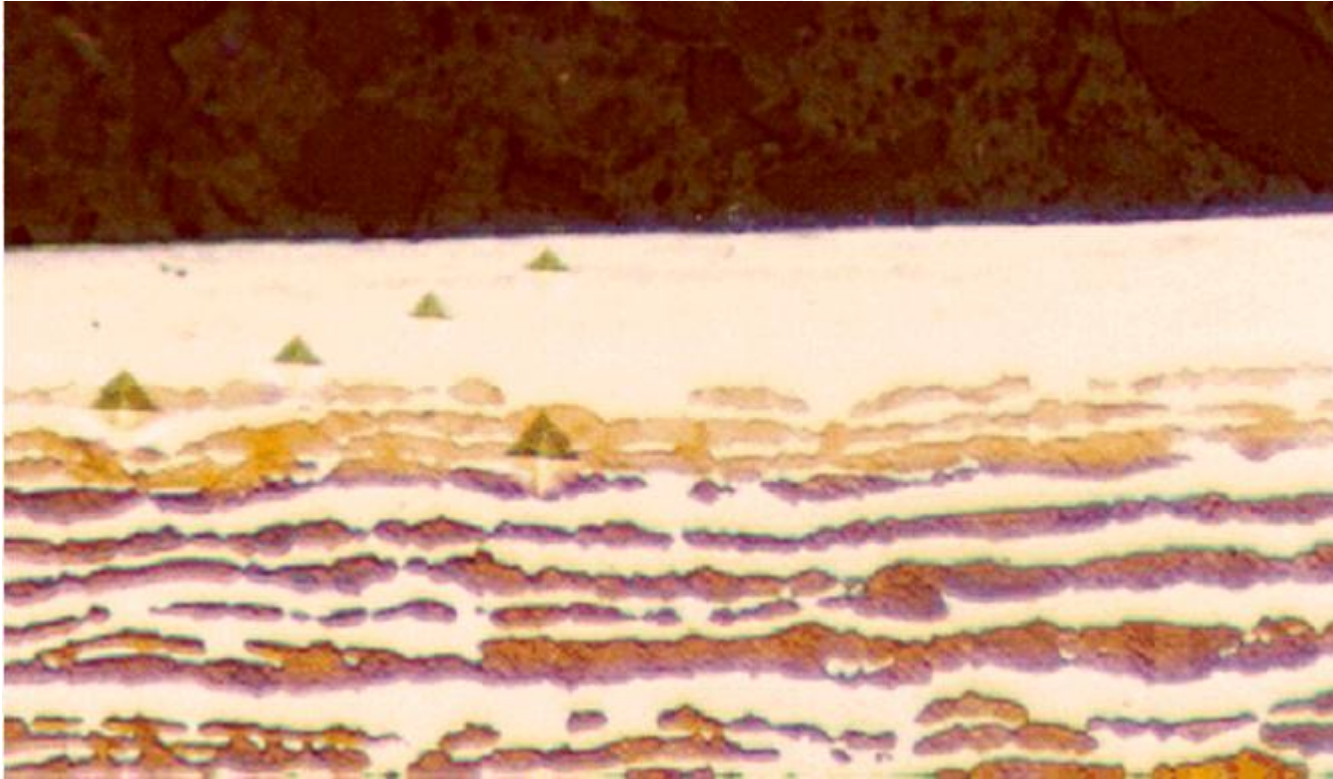
∅ 0.3 mm



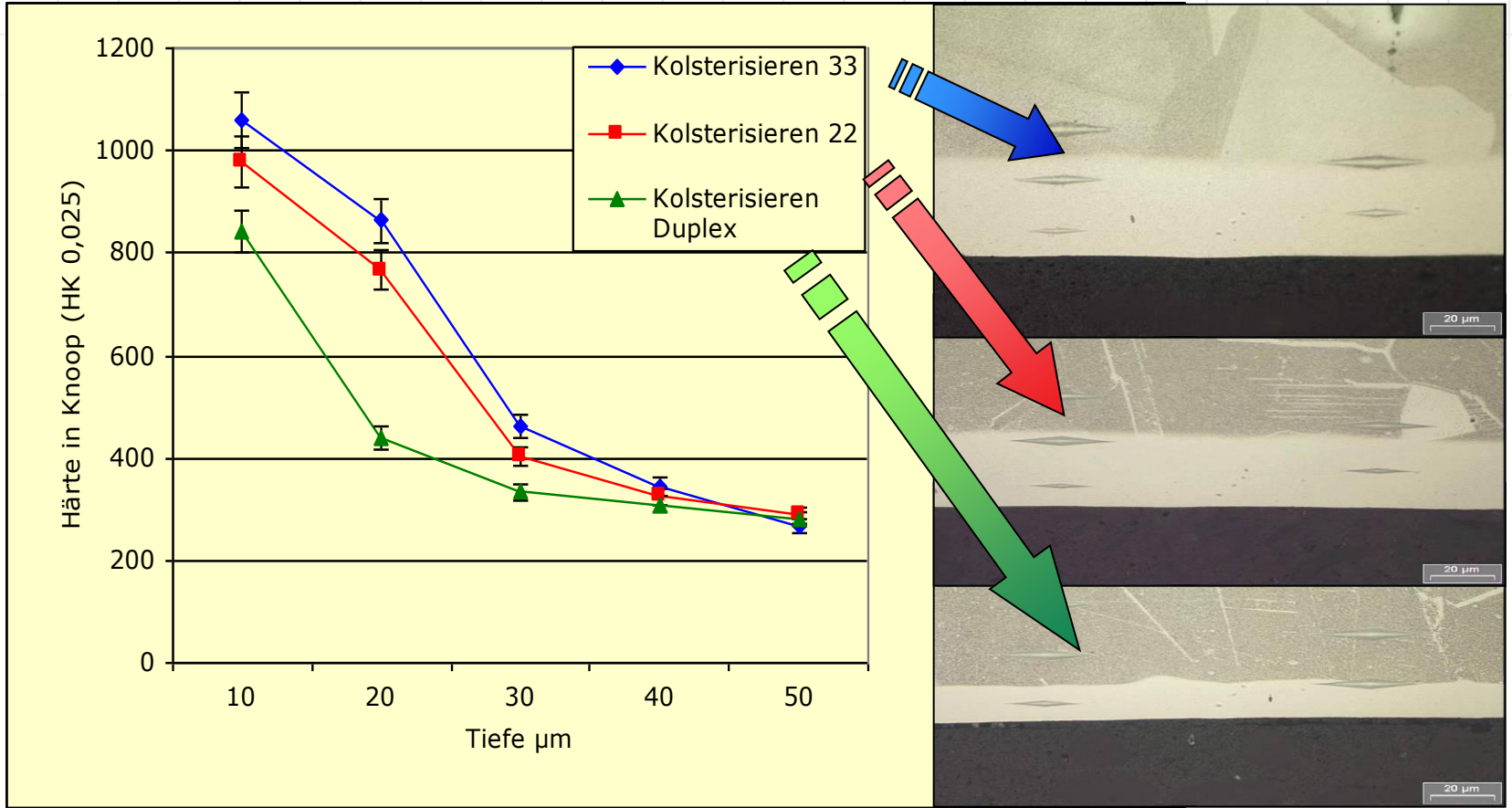
콜스터라이징에 의해 개구부 내면이나  
사이에는 균일한 확산층이 보인다.

With Kolsterising® there is a uniform diffusion  
zone (layer), also inside bores and gaps

콜스터라이징 처리를 행한 듀플렉스 스테인레스강  
**Kolsterised duplex RVS (1.4462)**



## 경도와 층깊이 통계 데이터 (Hardness vs. case depth profiles)

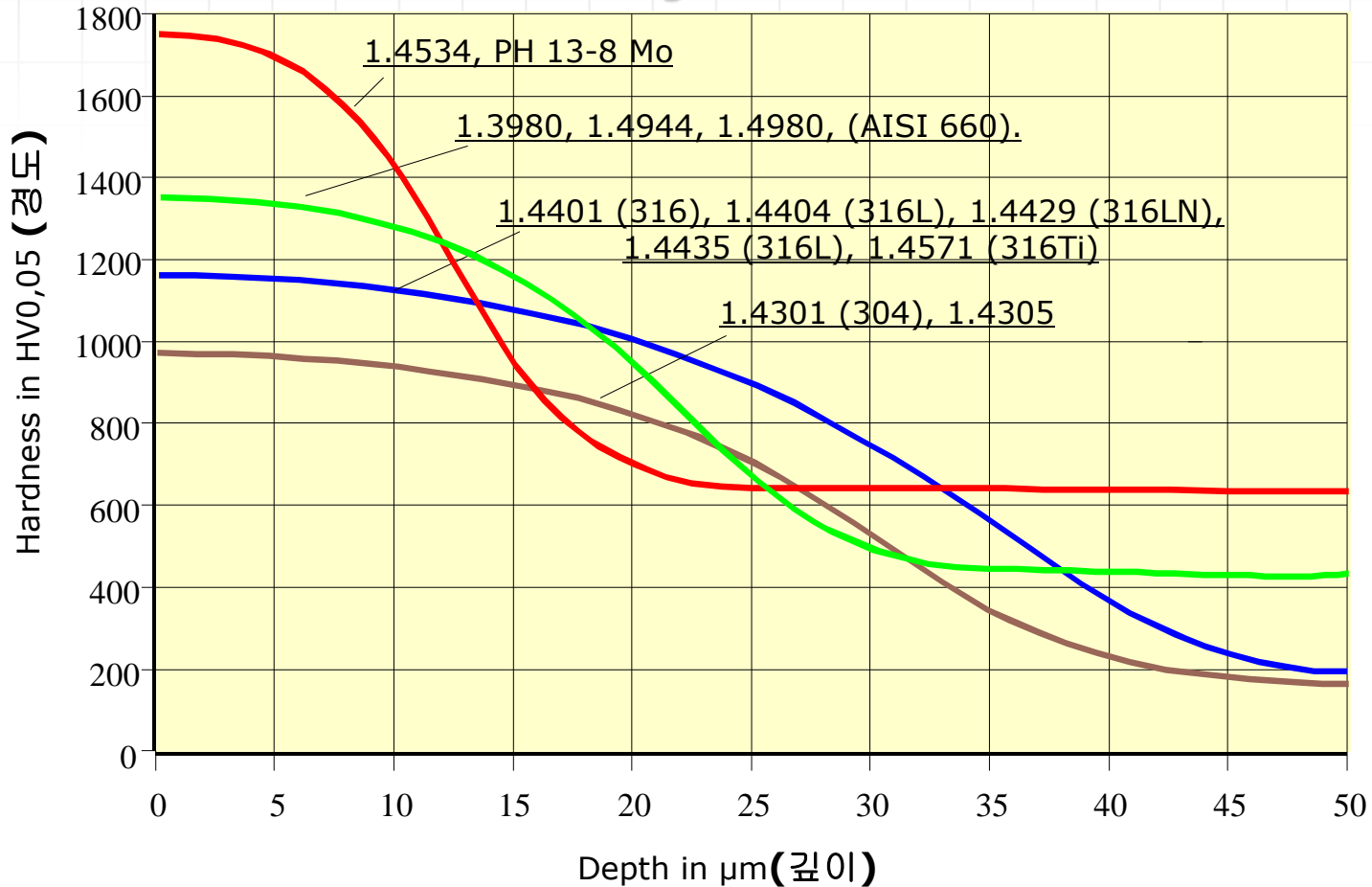


재질 : 용해, 소둔된 **SUS316**  
Material 1.4404 solution annealed, or 1.4462



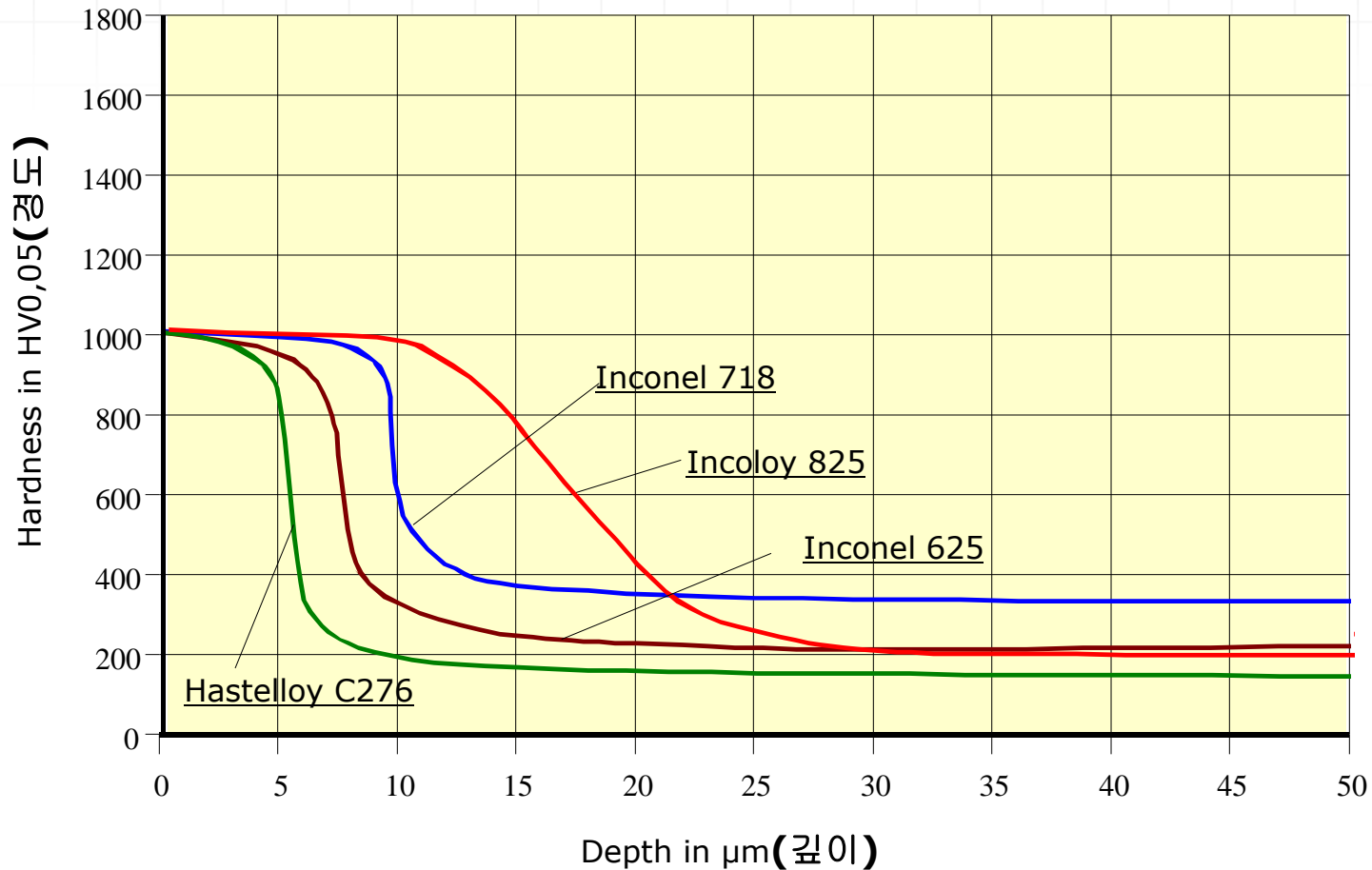
## 경도데이터 (처리방법 : 콜스터라이징33)

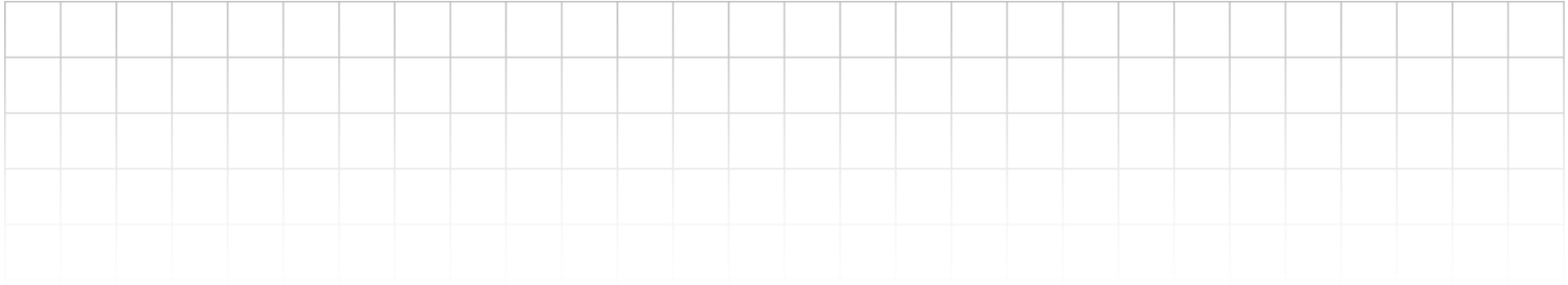
**Examples of hardness profiles for various grades, Kolsterising® 33 Treatment**



# 니켈합금의 경도데이터(처리방법 : 콜스터라이징33)

**Examples of hardness profiles of nickel-base alloys, Kolsterising® 33 treatment**

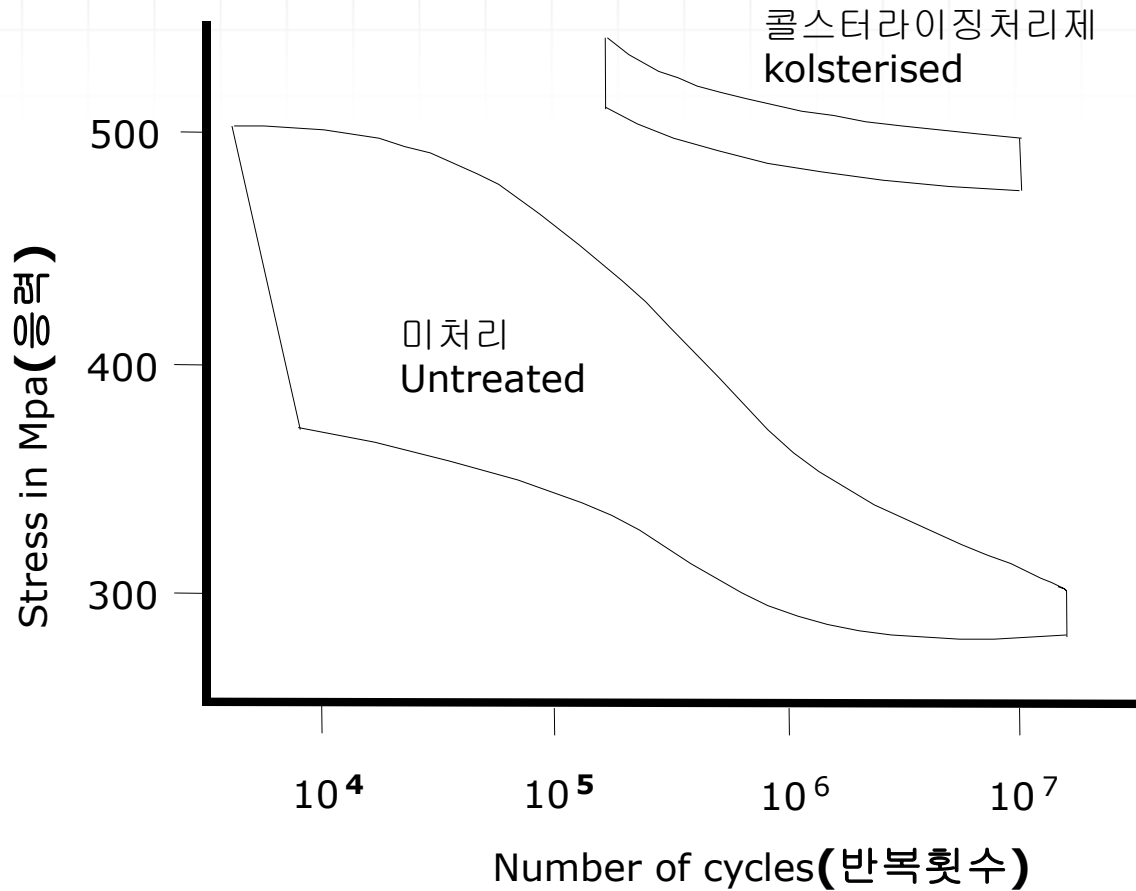




피로강도  
**Fatigue strength**

# 피로강도, 실험결과

## Fatigue strength, test



## 캐비테이션에 의한 부식 Cavitation erosion

➤ 콜스터라이징 처리를 행하면 캐비테이션 부식에 대하여 내성이 개선된다.(Kolsterising® improves the resistance against cavitation erosion.)

➤ 이유 : 콜스터라이징층에 높은 압축응력이 발생한다.

Explanation: High compressive stresses in the kolsterised layer.

➤ 예 : SUS316 스테인레스 제 (고압)균질기

Example: (High) pressure homogenizer made out of material AISI 316 (1.4401)

➤ 미처리할 경우의 수명 : 3주

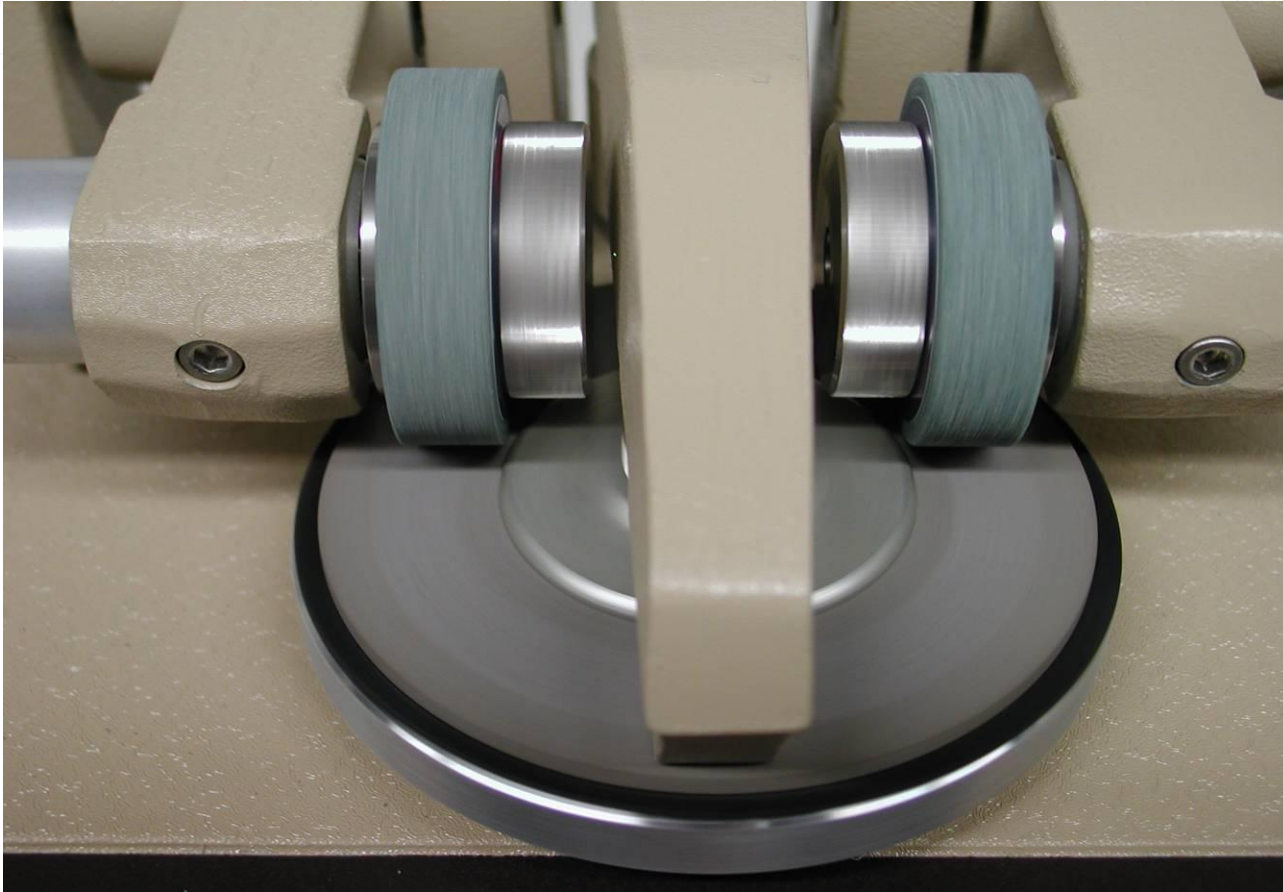
Operational life untreated: 3 weeks

➤ 콜스터라이징 처리할 경우의 수명 : 4년

Operational life Kolsterised: > 4 years

연마마모  
(Abrasive wear)

테이버 식 마모시험  
(Wear Taber Abraser test)

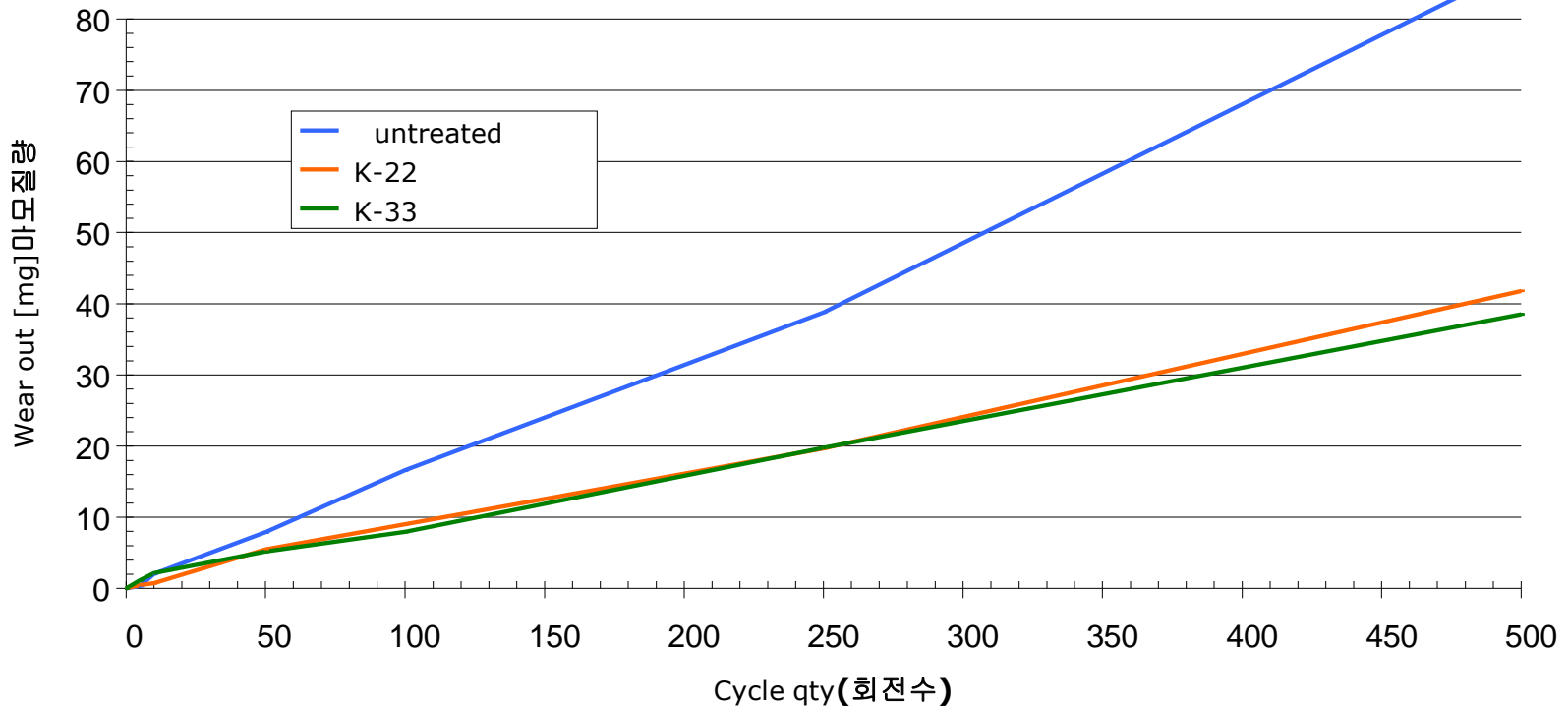


# 마모시험 측정데이터

## Wear test measurements

테이버 식 마모시험  
TABER Abrader wear test  
1.4404 kolsterised

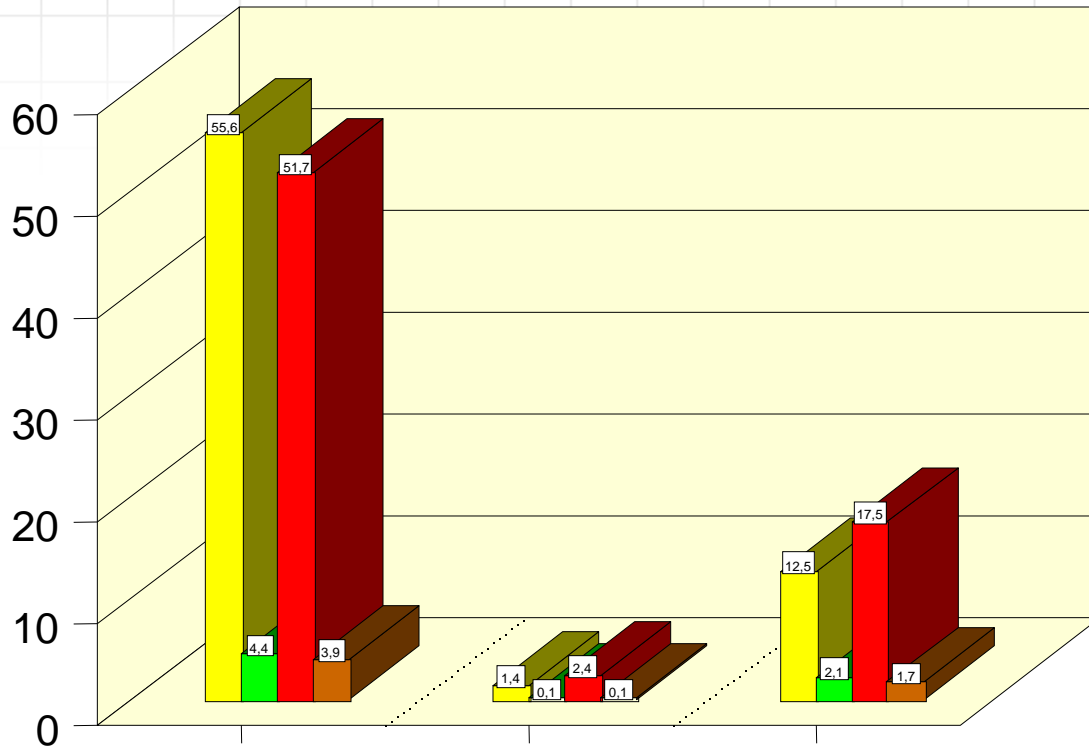
Graze rol: H -10 Load: 500 g extractor: 100 %





# 내마모성 실험

## Wear resistance test



공기air

기름oil

해수Sea water

- 미처리 304 untreated
- 콜스터라이징 처리제 304 kolsterised
- 미처리 316 untreated
- 콜스터라이징 처리제 316 kolsterised

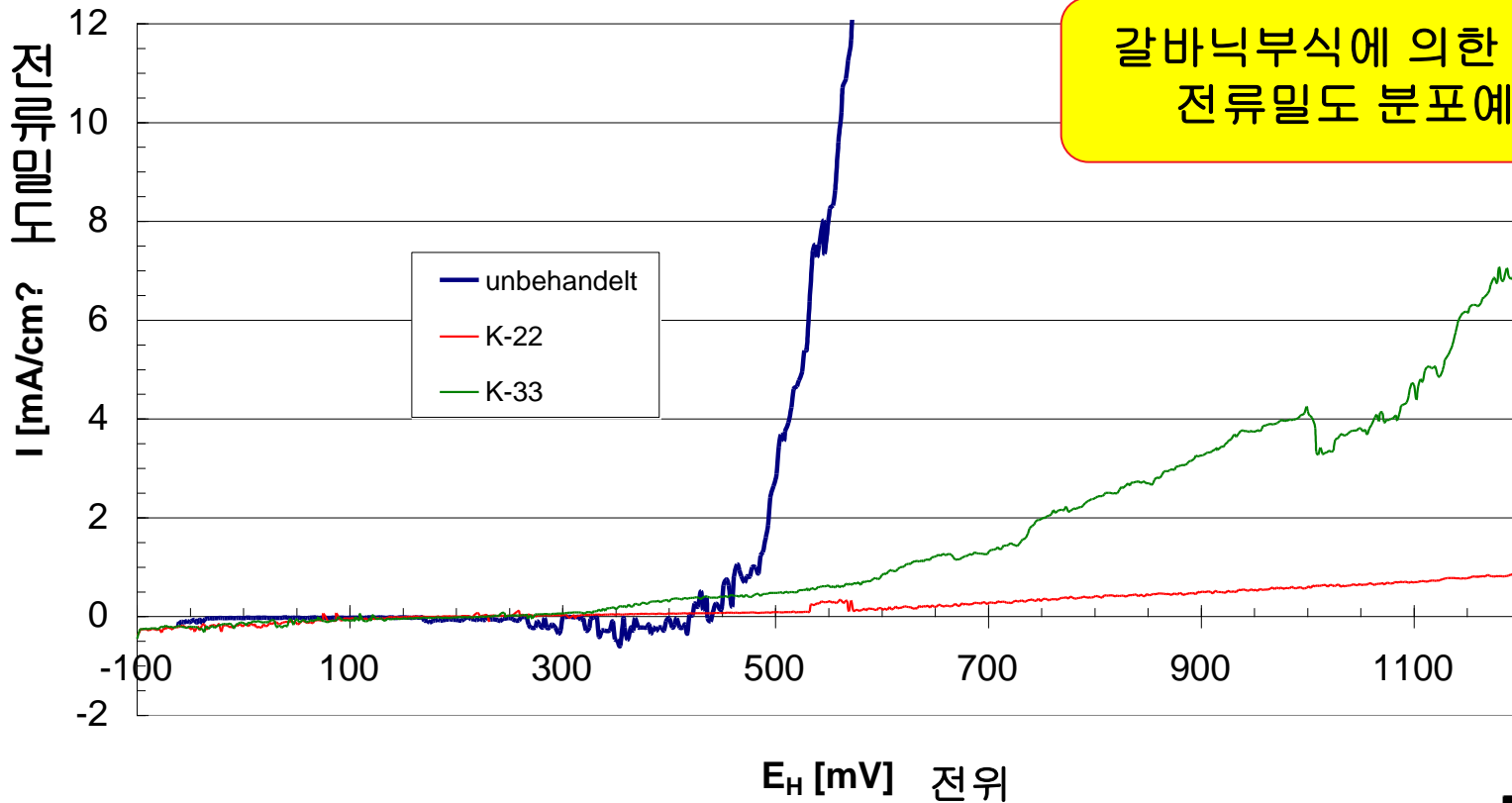
부식저항  
(Corrosion resistance)

# 내공식성 측정

## (Measurements of galvanic corrosion)

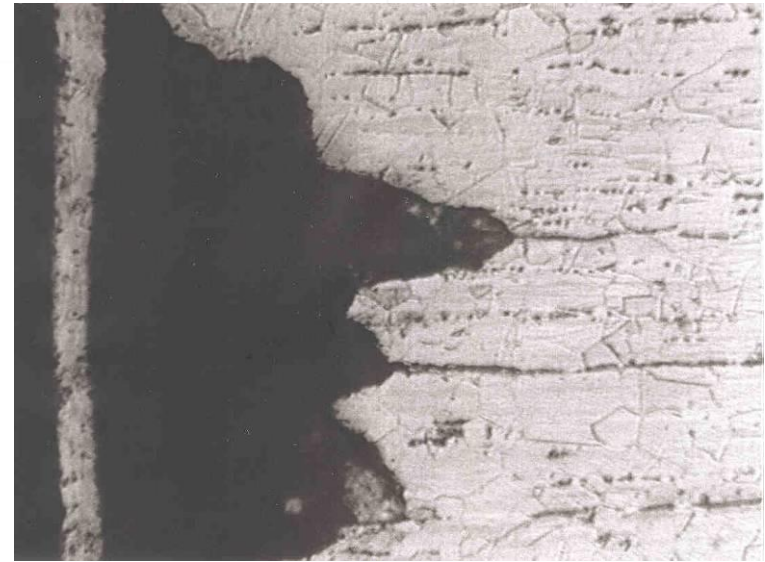
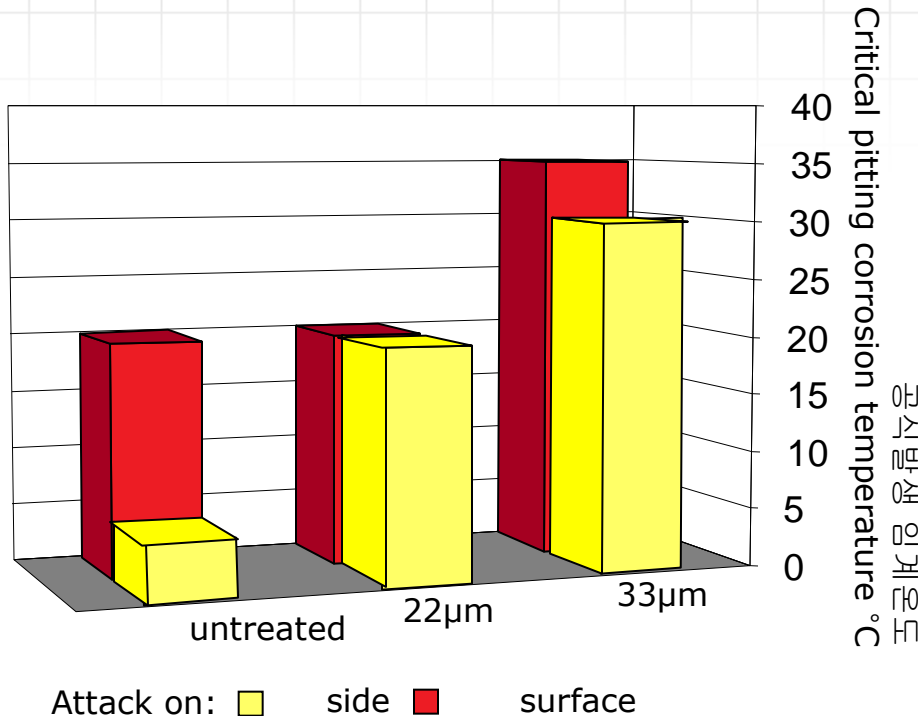
Stromdichte - Spannungskurven

1.4404 ( X 2 CrNiMo 17 13 2) kolsterisiert in 3% NaCl, 30꺼



갈바닉부식에 의한 전위, 전류밀도 분포예측

# 내공식성 실험데이터 (Resistance against pitting corrosion)

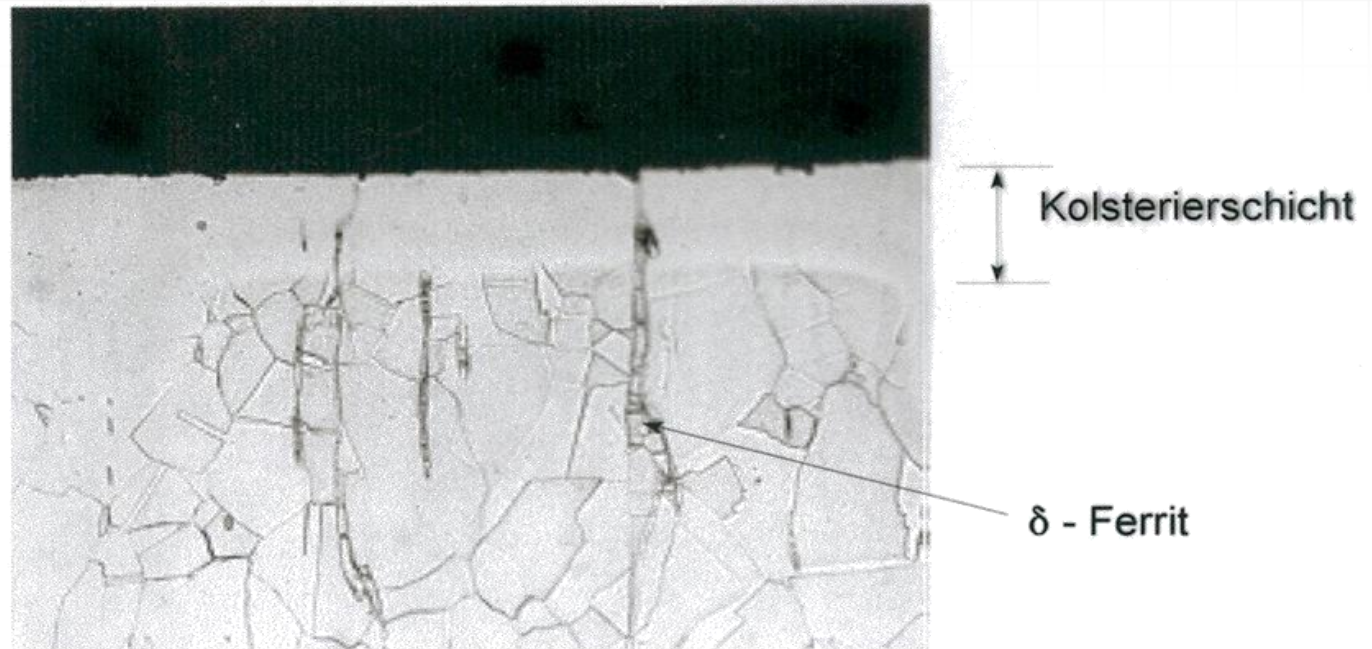


Material: 1.4404

Test with 10% FeCl<sub>3</sub> solution, by ASTM G-48

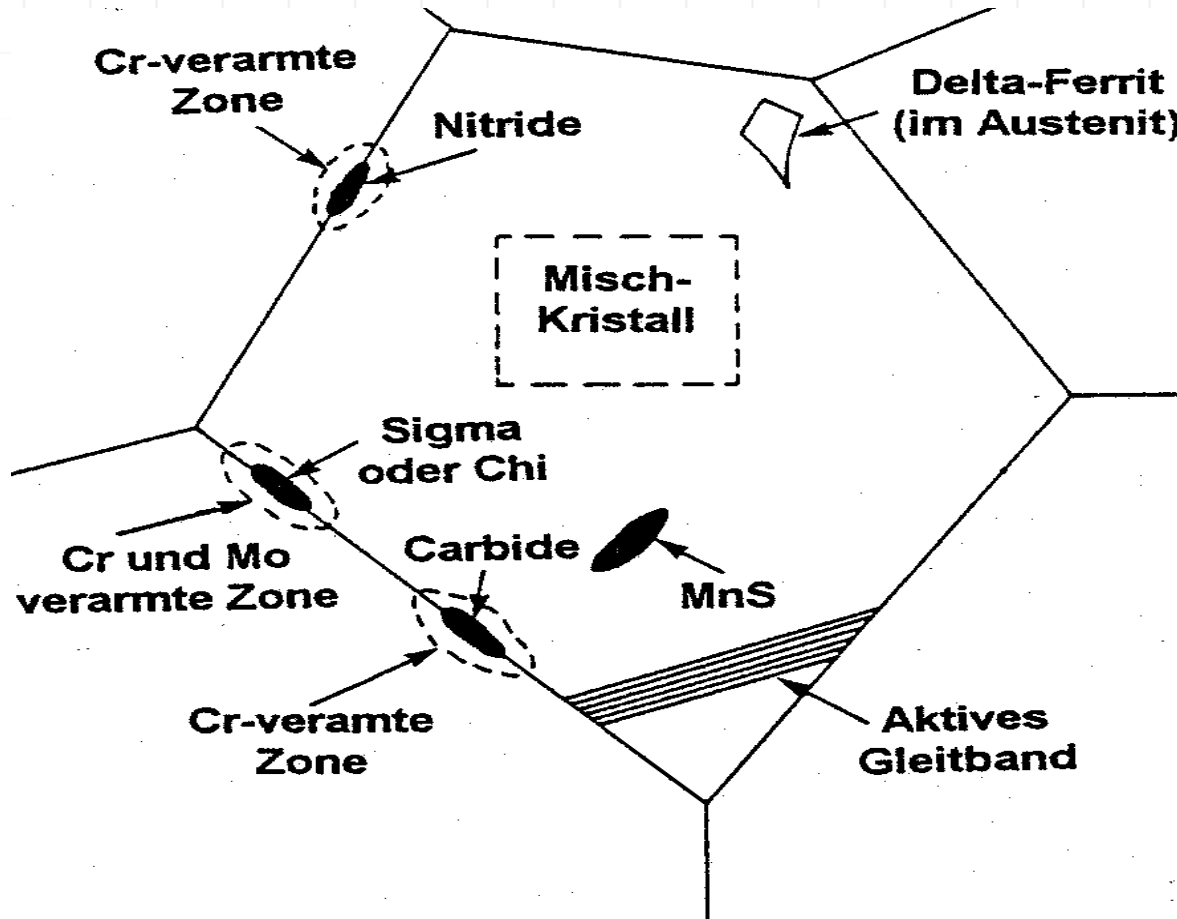
*Remark: structure particles likes delta ferrite, deformation martensite  
Having a negative influence on the corrosion resistance*

**델타페라이트의 악영향**  
**(Negative effect of delta-ferrite)**



## 내식성의 악영향

(Negative impact on corrosion resistance)



# 콜스터라이징 처리

Example of Kolsterising®



양산 나사, 너트, 왓셔 등  
Bulk, screws, nuts, washers, etc.

# 콜스터라이징 처리

Example of Kolsterising®

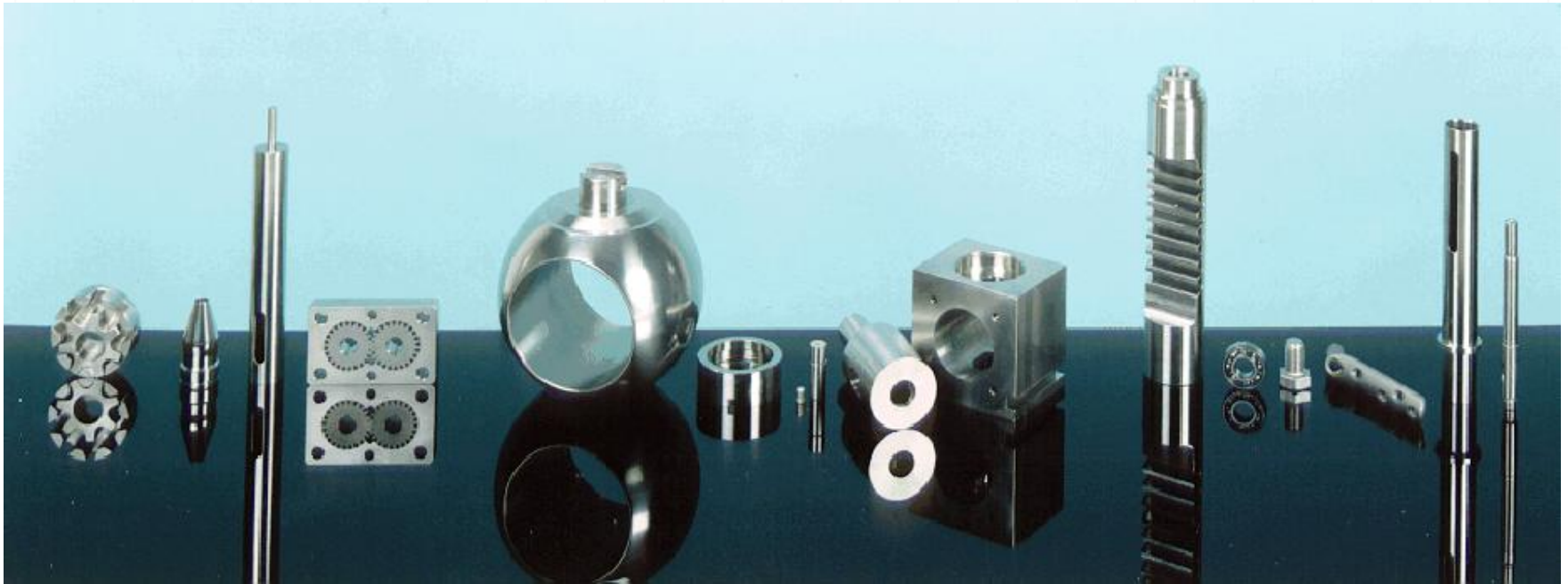


중량부품  
Heavy parts



# 성공례의 소개

Applications for Kolsterising®



# 성공례의 소개

Applications for Kolsterising®



자동차산업:

오토매틱트랜스 미션

부품내 자성압력제 벨브

A magnetic pressure control valve part in automatic transmissions used in the automobile industry

재질: W.-Nr. 1.4301(SUS304) 등  
1.4305 (SUS303)

- 요구조건 Requirements
- 내마모성 Wear resistance
- 치수의 안정성 Dimensionally stable
- 비자성 Non-magnetic
- 표면품질 Surface quality

# 성공례의 소개

Applications for Kolsterising®



## 수무(액체,기체)생성노즐

Nozzles for water automatization

재질: W-Nr. 1.4404 (SUS316L)

요구조건 Requirements

- 내마모성(캐비테이션, 부식) Wear resistance (cavitation erosion)
- 내식성 Corrosion resistance
- 치핑방지 Prevention of galling

# 성공례의 소개

Applications for Kolsterising®



자동차산업:디젤엔진,  
커먼레일분사용 댐핑 비품

Damping device for diesel fuel common rail injectors used  
in the automotive industry

재질: SUS316LA

요구조건 Requirements

- 내마모성 Wear resistance
- 치수의 안정성 Dimensionally stable
- 비자성 Non-magnetic

# 성공례의 소개

Applications for Kolsterising®



## 제약산업용 펌프부품

Pump parts used in the pharmaceutical industry

재질: W.-Nr. 1.4435 (SUS316L)

요구조건 Requirements

- 내마모성 (캐비테이션부식)

Wear resistance (cavitation erosion)

- 내식성 Corrosion resistance

- 표면품질 Surface quality

# 성공례의 소개

Applications for Kolsterising®



## 전자산업용 에어베어링

Air bearings used for electronics

재질: W.Nr. 1.4404 (SUS316L)

인베스트먼트주조품

Investment casting

요구조건 Requirements

- 내마모성 Wear resistance
- 치수의 안정성 Dimensionally stable
- 비자성 Non-magnetic
- 표면품질 Surface quality

# 성공례의 소개

Applications for Kolsterising®



## 화학산업용 볼밸브용 볼

Ball for a ball valve, used in the chemical industry

재질: W.-Nr. 1.4404 (SUS316L)

요구조건 Requirements

- 내마모성 Wear resistance
- 내식성 Corrosion resistance
- 치수의 안정성 Dimensionally stable

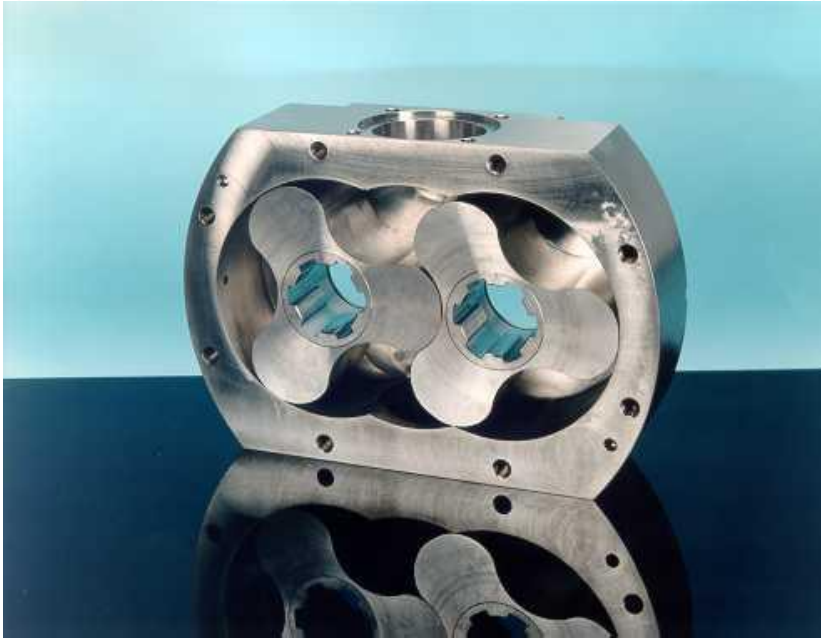
# 성공례의 소개

**Applications for Kolsterising®**

식품가공산업:

오물처리용용량펌프

Aseptic positive displacement pump for food processing industry



재질: W.-Nr. 1.4404 and  
1.4435 (SUS316L)

요구조건 Requirements

- 내마모성 Wear resistance
- 치수안정성 Dimensionally stable
- 비자성 Non-magnetic
- 표면품질 Surface quality



# 성공례의 소개

Applications for Kolsterising®



## 화학산업용 버터플라이 밸브

Butterfly valves for the chemical industry

재질: W.-Nr. 1.4401 (SUS316)

요구조건 Requirements

- 내마모성 Wear resistance
- 내식성 Corrosion resistance
- 표면품질 Surface quality

# 성공례의 소개

Applications for Kolsterising®



## 제약산업:투약호일

Dosing wheel for the pharmaceutical industry

재질: W.-Nr. 1.4401 (SUS316)

요구조건 Requirements

- 내마모성 Wear resistance
- 마모감소 Friction reduction
- 치수안정화 Dimensionally stable
- 내식성 Corrosion resistance

콜스터라이징 처리공장  
**Production plants Kolsterising®**

## Production plants Kolsterising®



### Netherlands

Bodycote Hardiff bv  
Paramariboweg 45  
7333PA Apeldoorn  
Tel.: +31 55 542 63 92  
Fax: +31 55 542 31 16



### Germany

Bodycote Hardiff GmbH  
Max-Planck-Strasse 9  
86899 Landsberg  
Tel.: +49 8191 91 79 30  
Fax: +49 8191 91 79 13



### France

Bodycote Chanteloup  
ZI des Garennes II  
78570 Chanteloup les Vignes  
Tel.: +33 1 39 70 21 70  
Fax: +33 1 39 70 21 71



### USA

Bodycote Kolsterising North America  
443 E. High Street  
Ohio, 43140 London  
Tel.: +1 740 852 49 65  
Fax: +1 740 852 49 56

**한국 대리점 안내**  
**(Korean agent)**



서울특별시 금천구 시흥동 966 중앙철재상가 (주)일강상사

Tel : 02)808-4354~5, 02)807-0882~3

Fax : 02)805-5687

E-mail : [ilkangtrading@gmail.com](mailto:ilkangtrading@gmail.com)

Homepage : [www.ilkangtrading.com](http://www.ilkangtrading.com)