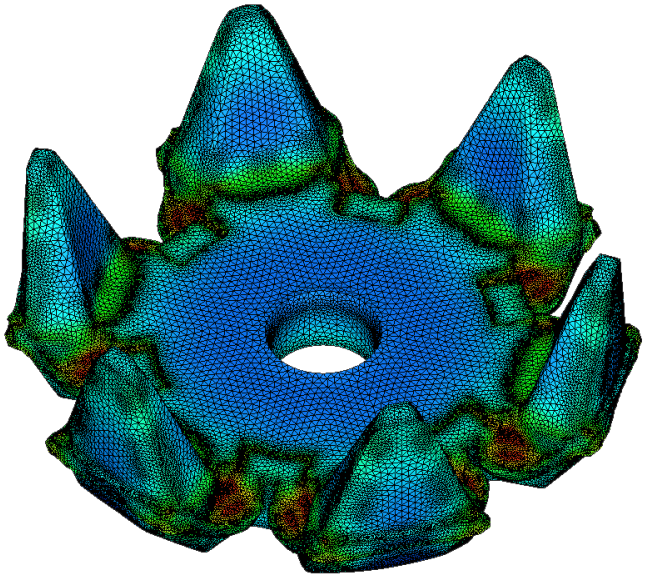
I. Metal Forming with emphasis on Forging

1.1 General consideration

1.2 Forgings

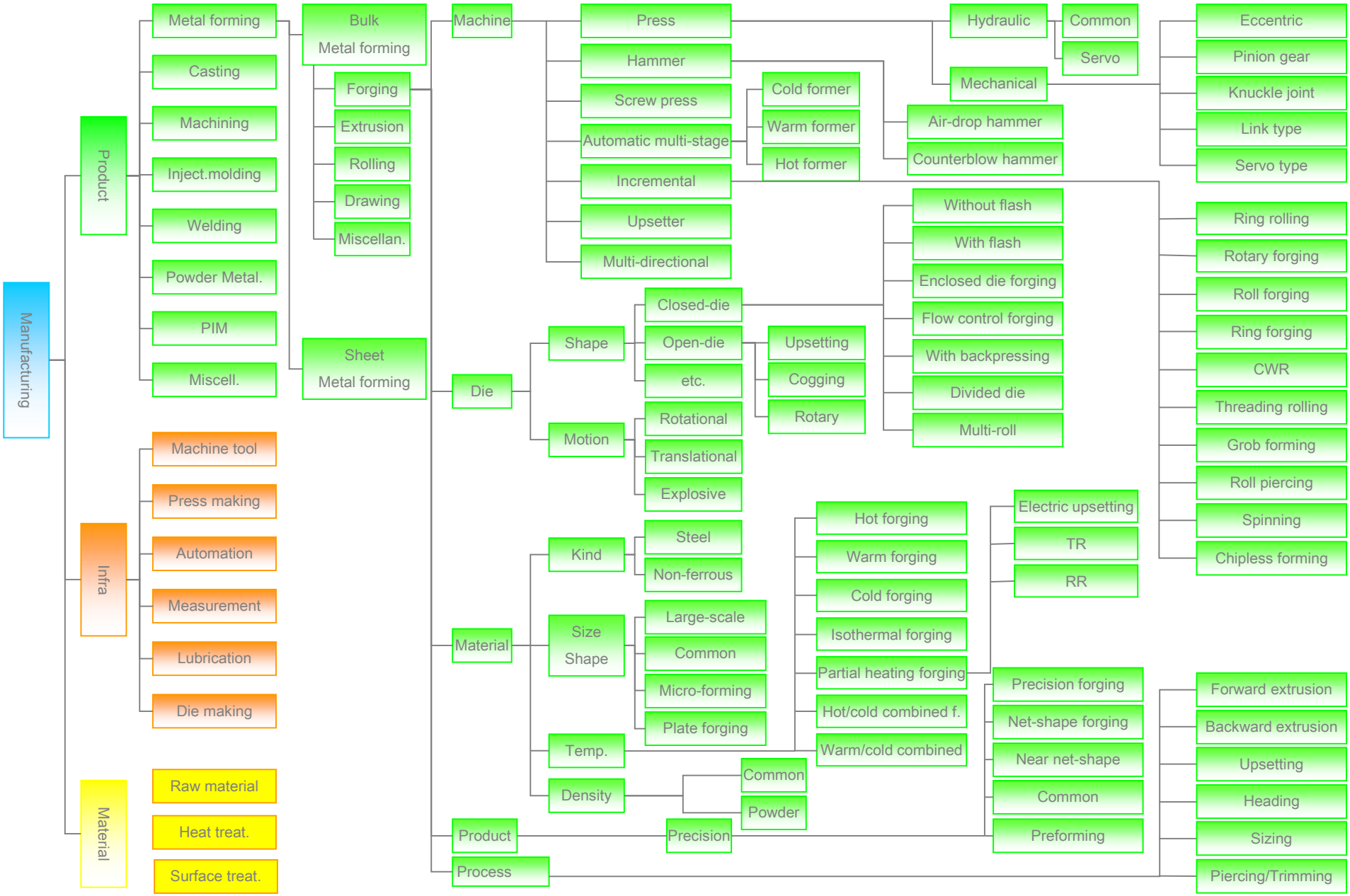
1.3 Important factors in forging industry

1.4 Process development

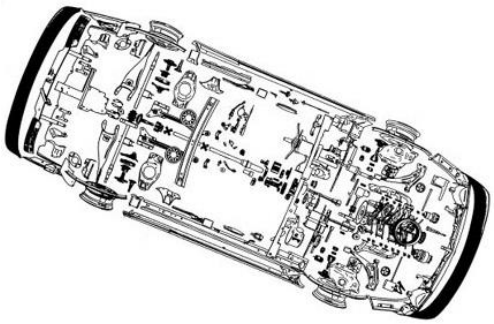


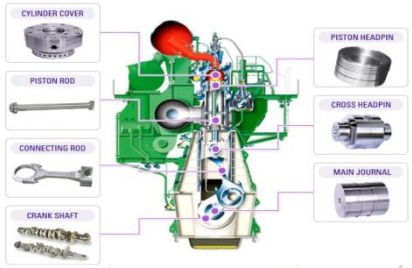
1.1 General considerations

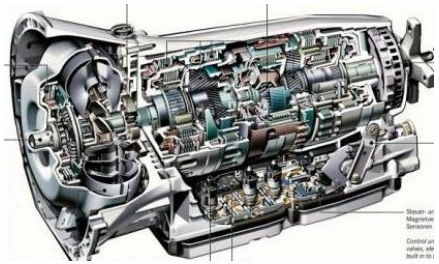
Manufacturing and Metal Forming

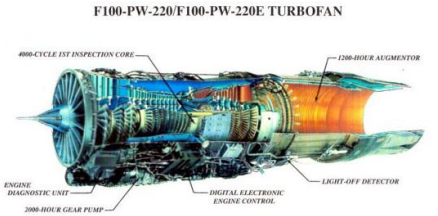


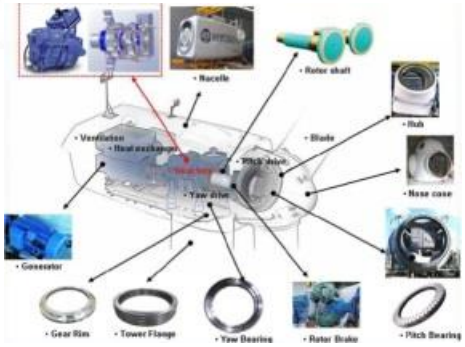
Forgings

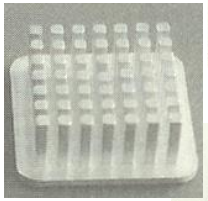


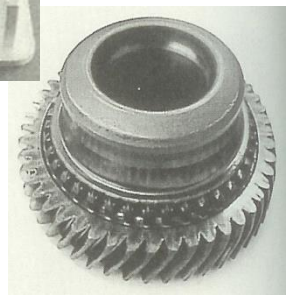

CYLINDER COVER
PISTON ROD
CONNECTING ROD
CRANK SHAFT
PISTON HEADPIN
CROSS HEADPIN
MAIN JOURNAL

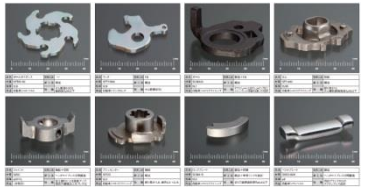



F100-PW-220/F100-PW-220E TURBOFAN
4000-CYCLE IST INSPECTION CORE
1200-HOUR AUGMENTOR
LIGHT-OFF DETECTOR
ENGINE DIAGNOSTIC UNIT
DIGITAL ELECTRONIC ENGINE CONTROL
2000-HOUR GEAR PUMP


Nacelle
Rotor shaft
Hub
Blade
Nose cose
Generator
Gear Rim
Tower Flange
Yaw Bearing
Rotor Brake
Pitch Bearing

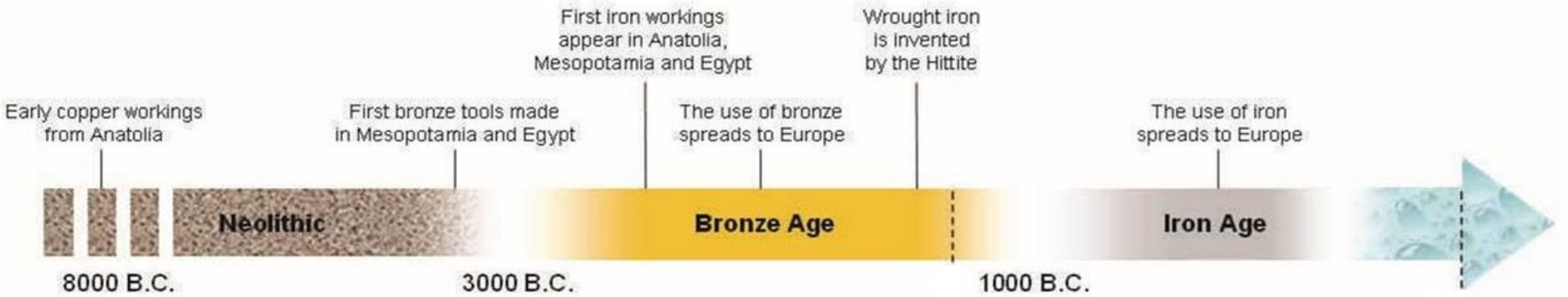




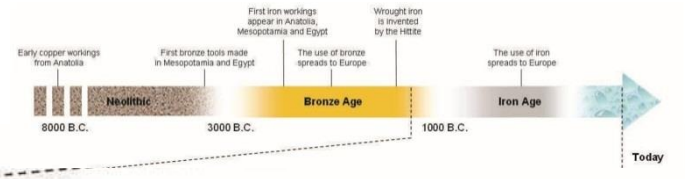



エンジン部品
デファレンシャル部品
ミッション部品
その他（車体部品等）

History of metal forming



History of metal forming



1000 B.C. | 500 | 1500 | Today

Ancient World | **Middle Ages** | **Modern Times**

The first anvils are used by the Egyptians, Greeks and Romans

Invention of the blast furnace by the Chinese

Development of crucible steel in India

Development of Damascus steel in Syria

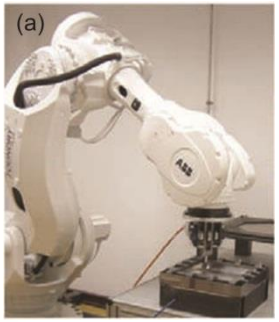
Development of first rolling mills

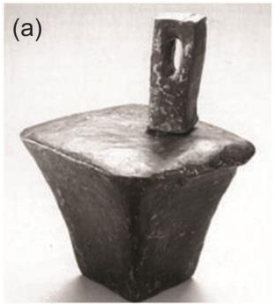
First usage of coke for iron making by Abraham Darby

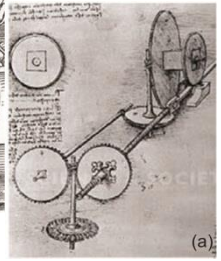
Invention of the steam hammer by James Nasmith

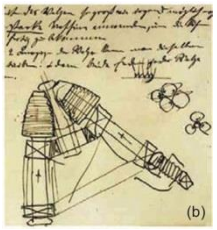
Development of the Bessemer converter by Henry Bessemer

Invention of the electric motor by Johann Kravogl





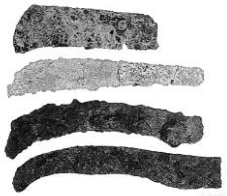




Past and present of metal forming in Korea

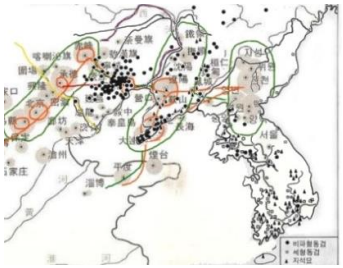
고조선 청동기

용연동 유물



삼한시대

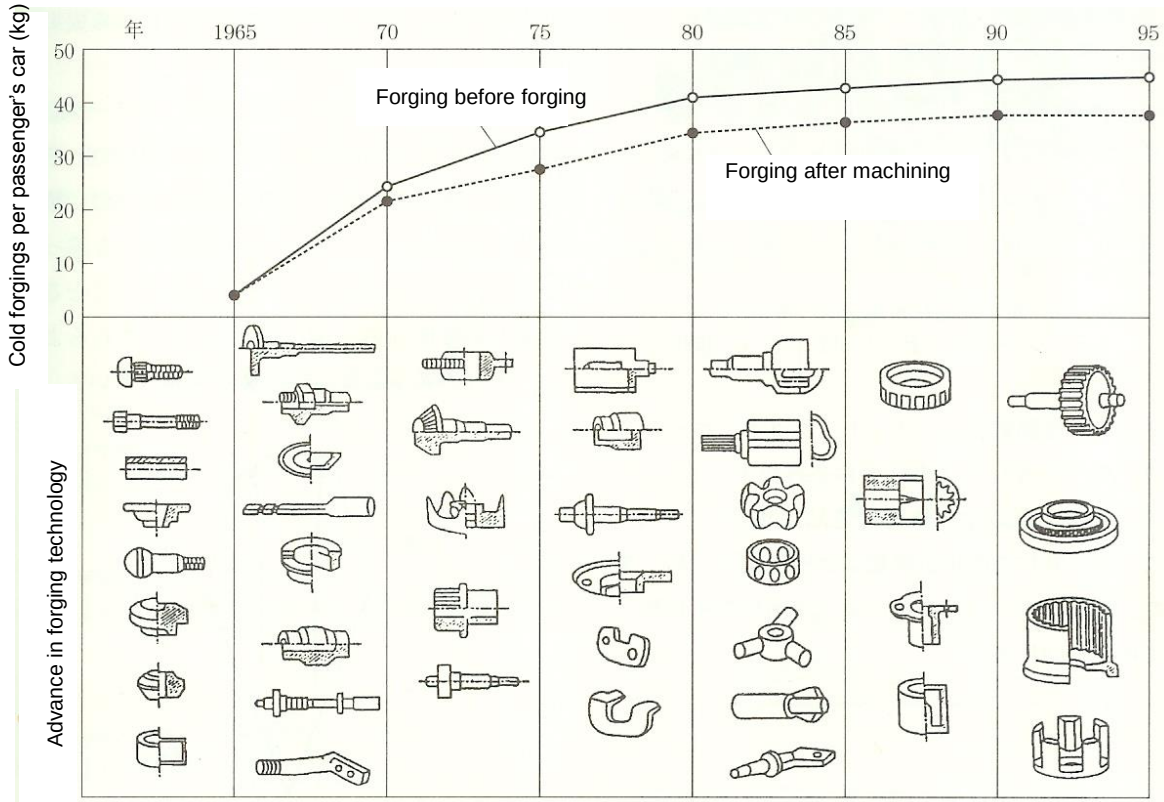
칠지도

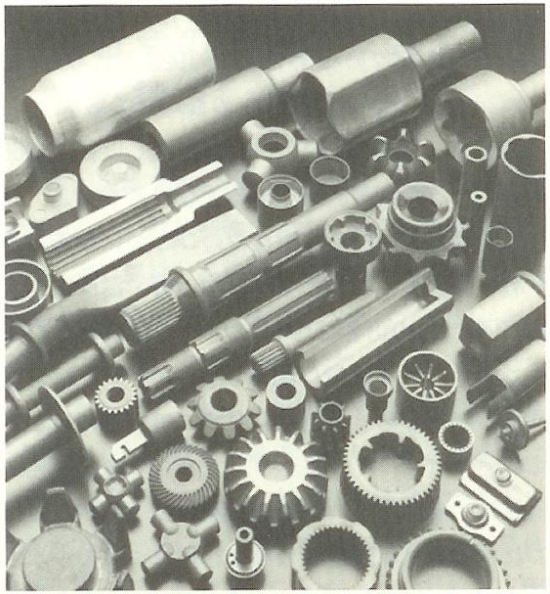


칠지도 명문

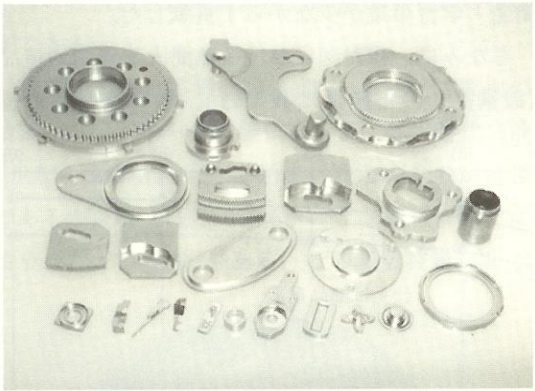
앞면〉 泰△四年五月十六日丙午正陽造百練銕七支刀出(生)辟百兵宜供供侯王△△△△祥(作)
뒷면〉 先世以來未有此刀百濟王世子奇生聖音故爲倭王旨造傳示後世

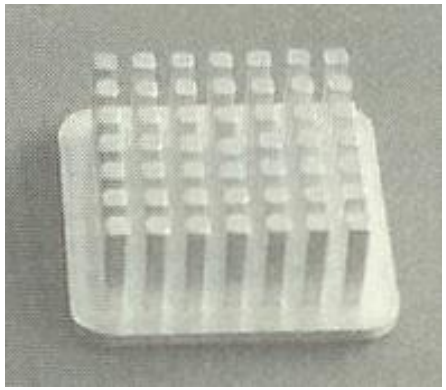
Evolution of forgings

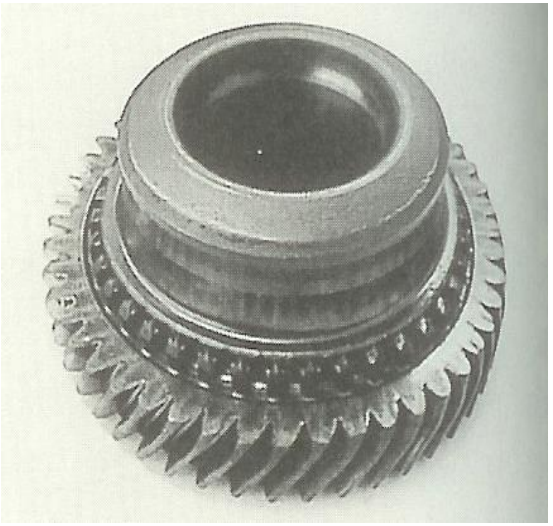




2000–

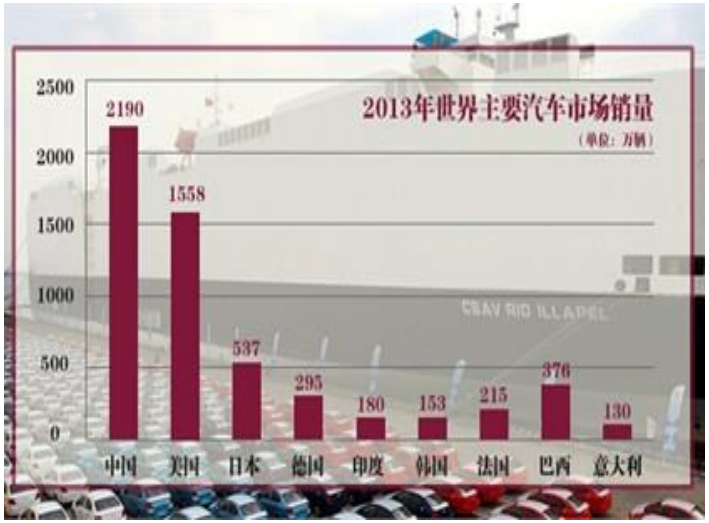




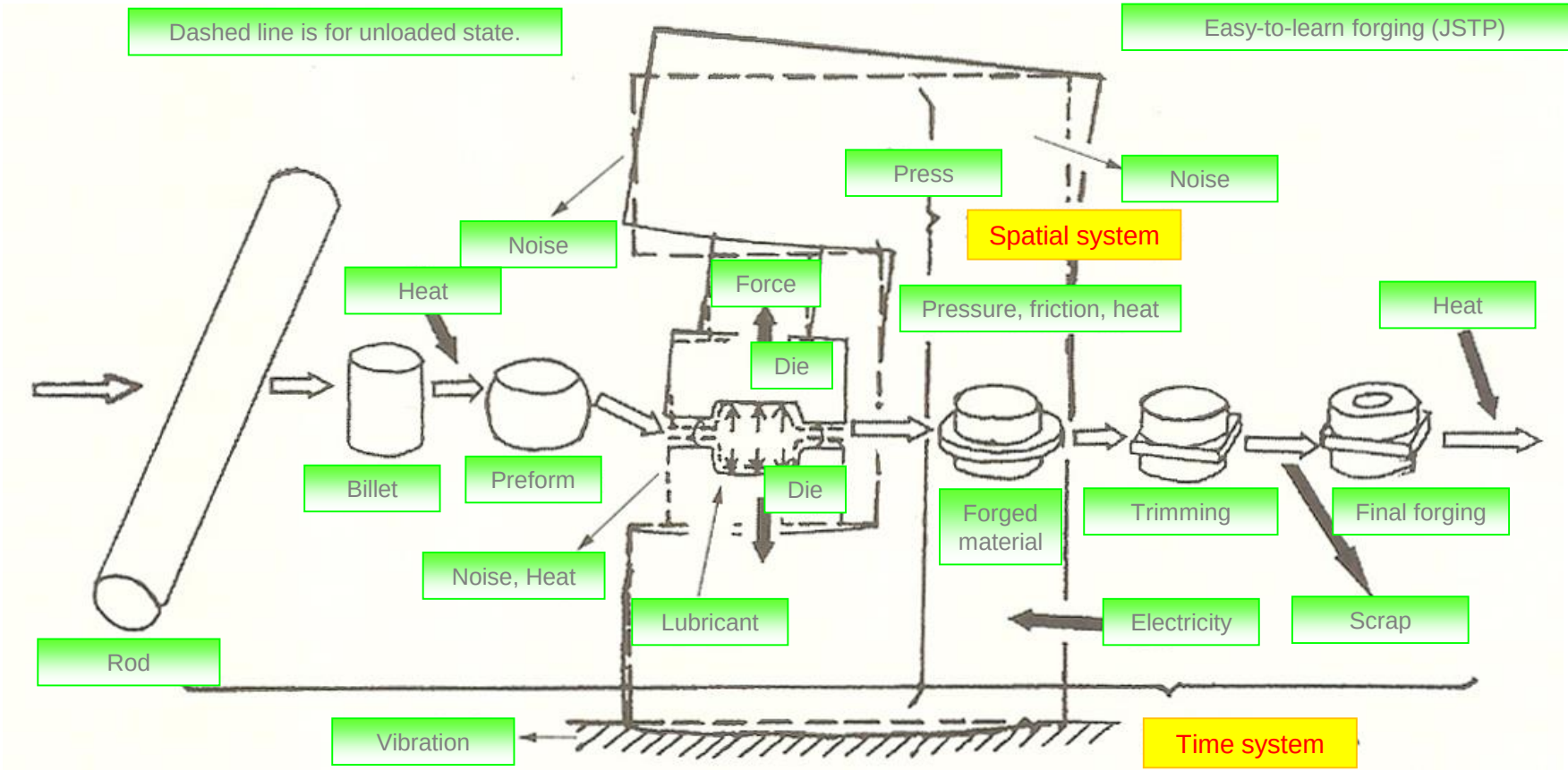


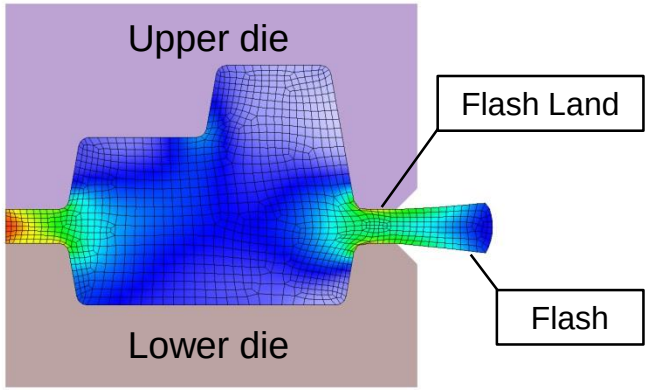
China forging market for auto parts

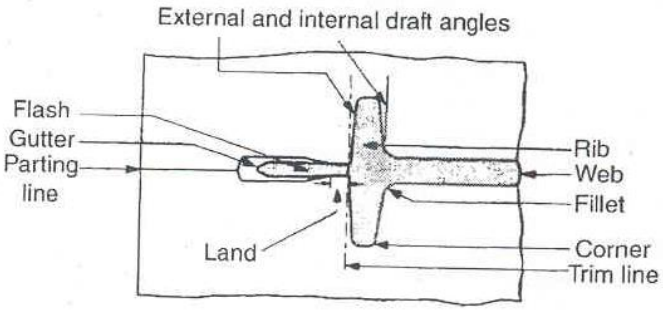
据中汽协统计，2013年中国汽车产量为2211.68万辆，同比增长14.76%。很多关键零件必须用冷锻或温锻工艺制造。在这些关键零部件本土化生产中，冷温锻造获得了新的发展机遇。



Concept of forging and terminologies

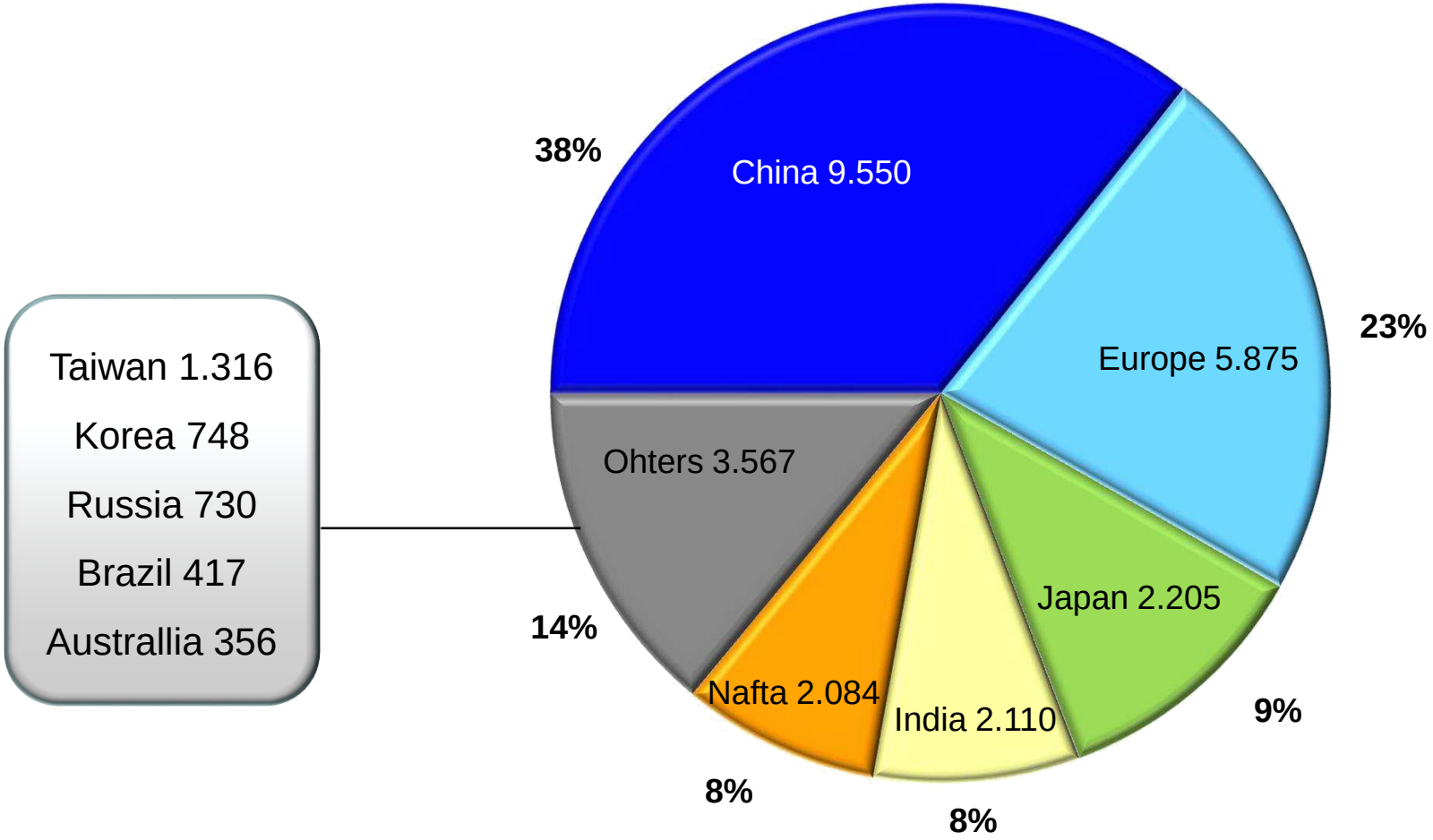






World market of forgings

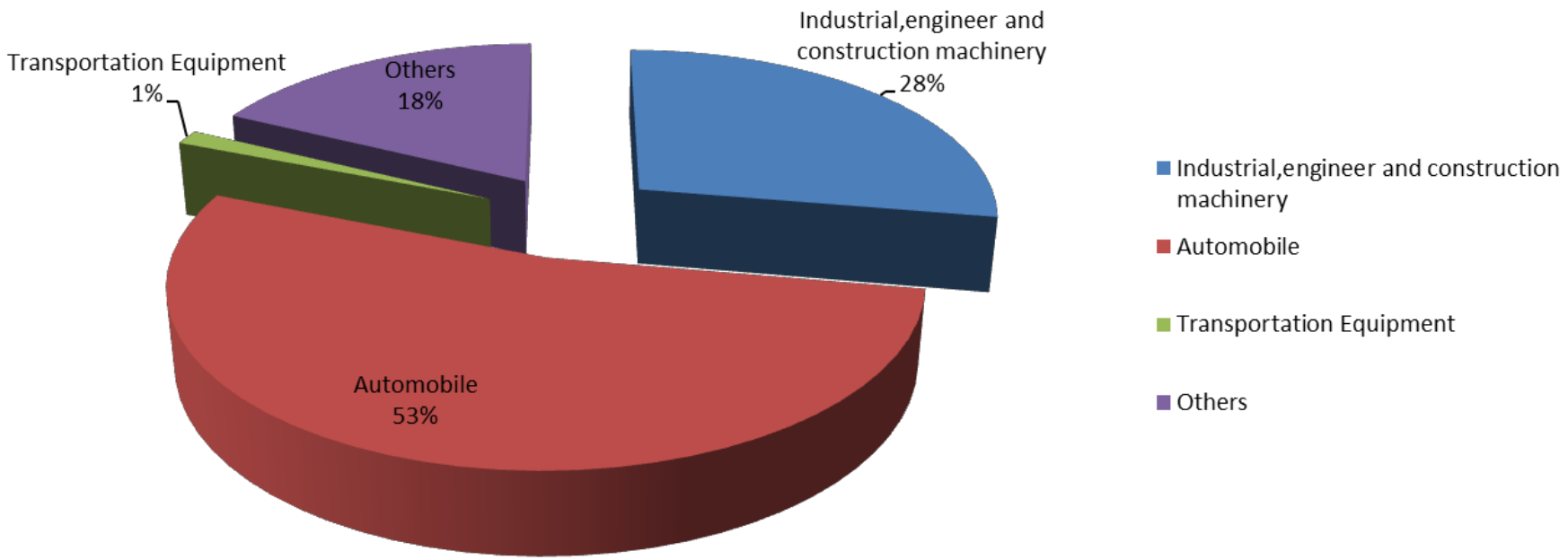
WORLDWIDE PRODUCTION PER REGION in ‘000 Tons in 2013
(From AFM 2014, Taiwan)



Customer segments in Asia

(unit: million tons)

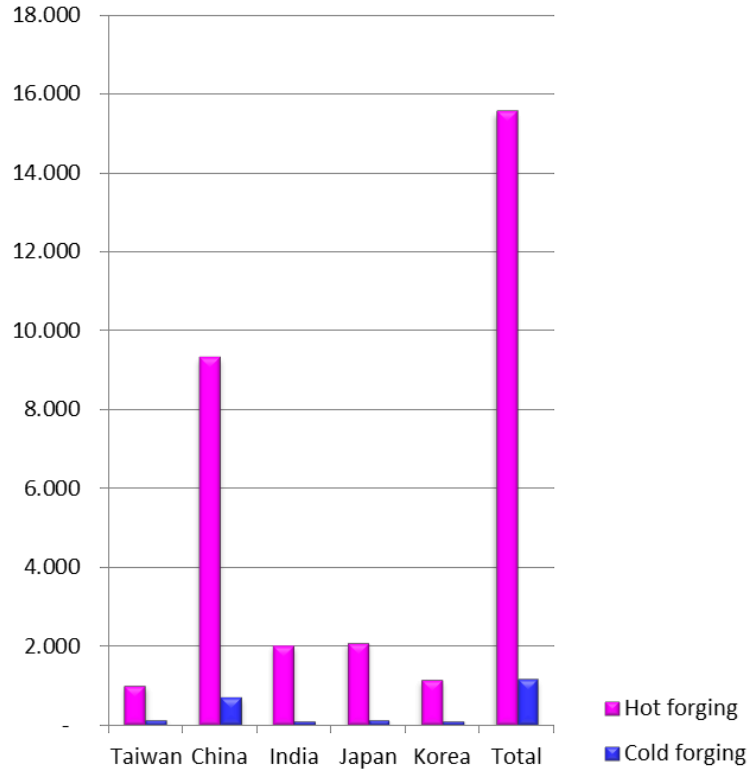
	China	India	Japan	Korea	Taiwan	Total
Automobile	4.645	1.239	1.577	0.679	0.691	8.832
Industrial, engineer and construction machinery	3.252	0.410	0.373	0.325	0.235	4.595
Transportation Equipment	0.110	0.086	0.022	0.008	0.006	0.226
Others	2.014	0.270	0.234	0.233	0.185	2.936

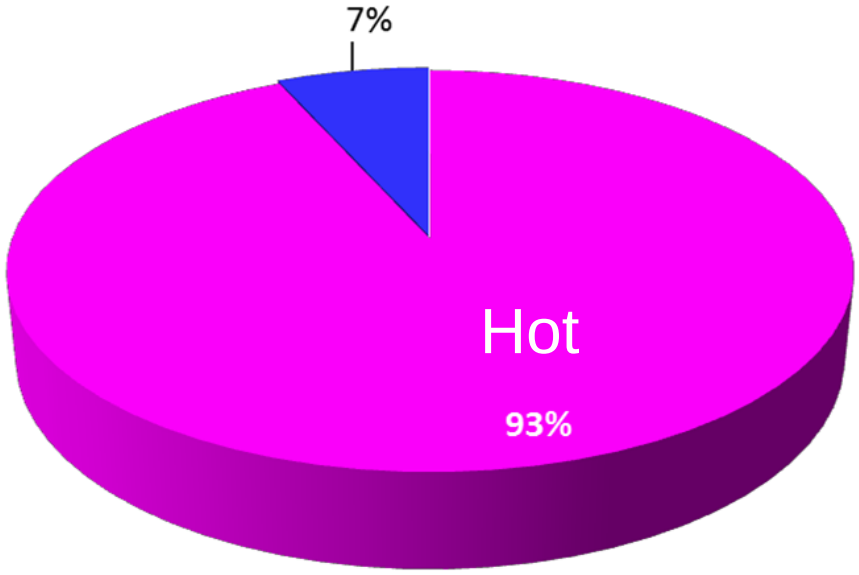


Forging process statistics in Asia

(unit: million tons)

	Taiwan	China	India	Japan	Korea	Total
Hot forging	0.995	9.319	2.008	2.089	1.144	15.555
Cold forging	0.122	0.696	0.096	0.118	0.101	1.133

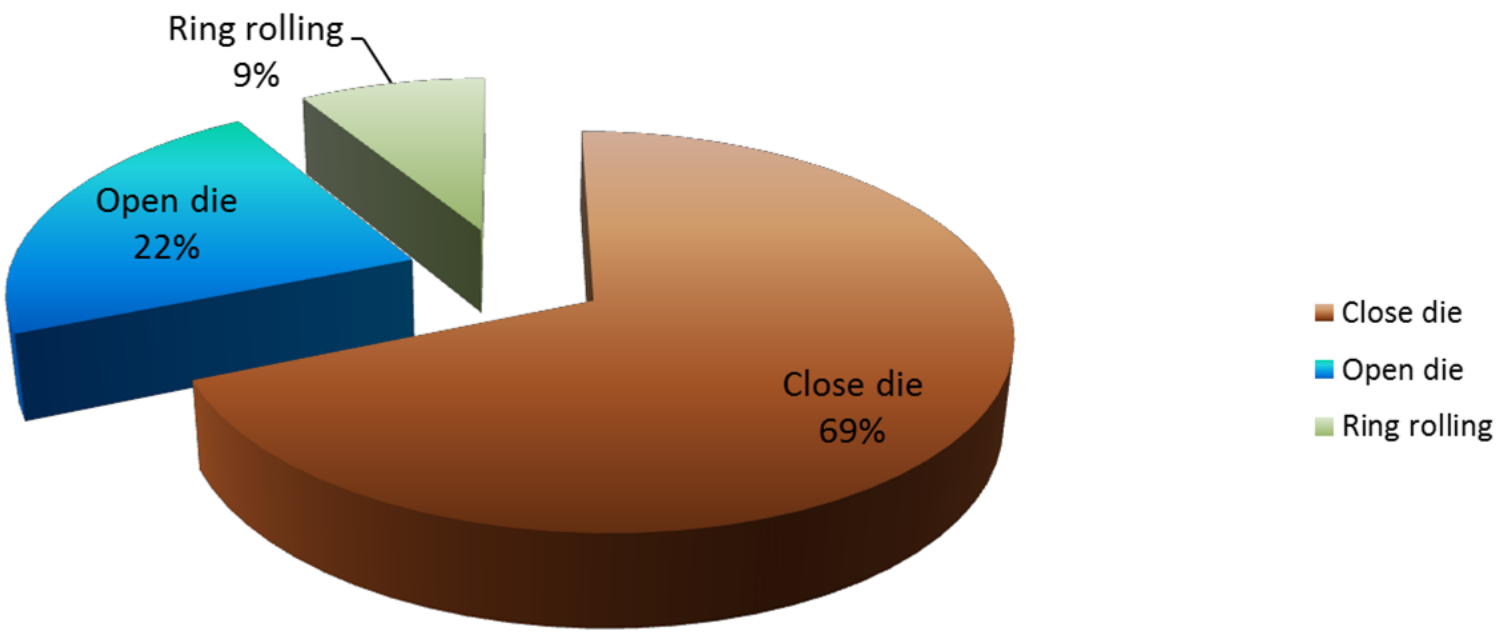




Hot Forging Statistics in Asia

(unit: million tons)

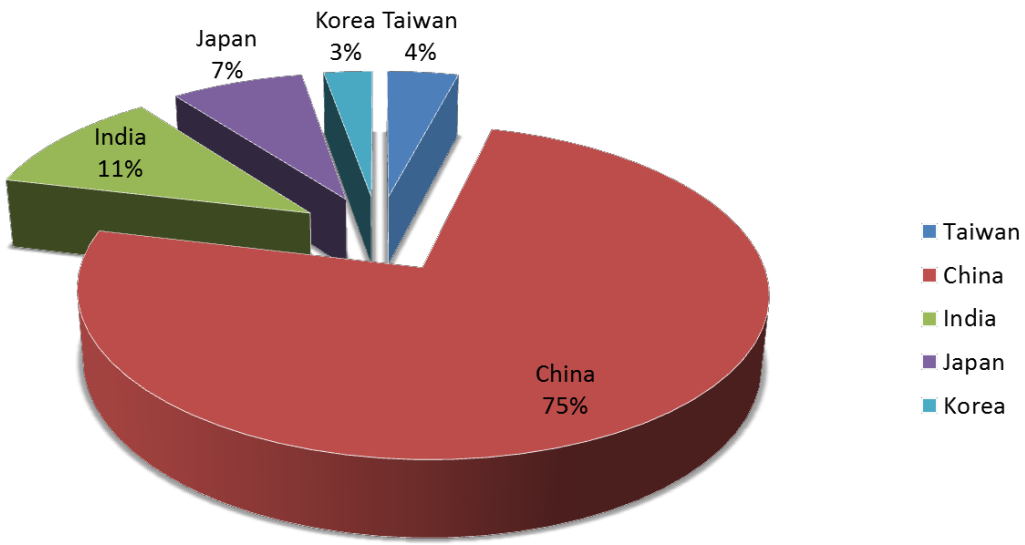
	China	India	Japan	Korea	Taiwan	Total
Close die	5.073	1.462	1.721	0.998	0.954	10.208
Open die	2.864	0.304	0.111	0.045	0.012	3.336
Ring rolling	0.901	0.077	0.234	0.079	0.010	1.301



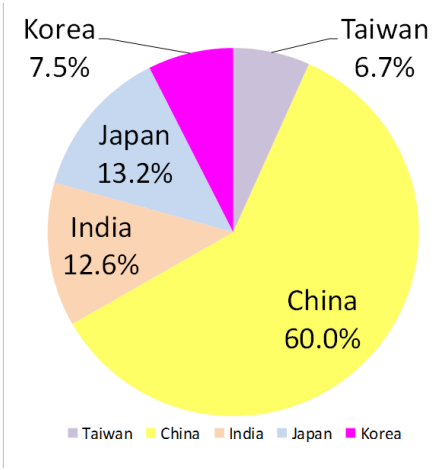
Labor statistics in Asia

China	India	Japan	Korea	Taiwan	Total
143,000	21,042	14,413	5,265	7,763	191,483

Labor



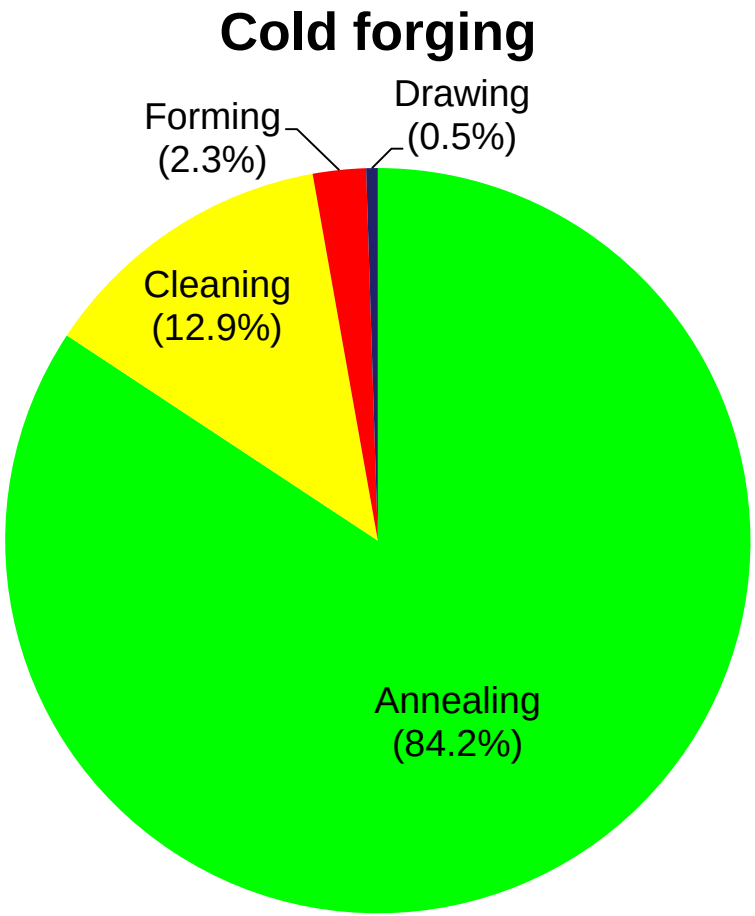
Production

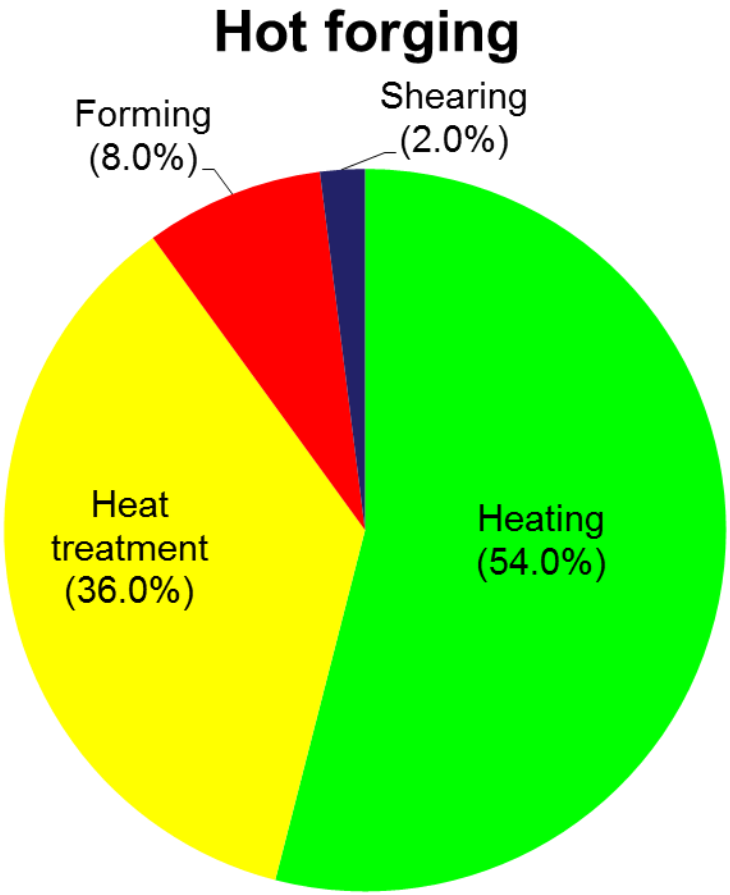


Japan 7%
Korea 3%

Japan 13.2%
Korea 7.5%

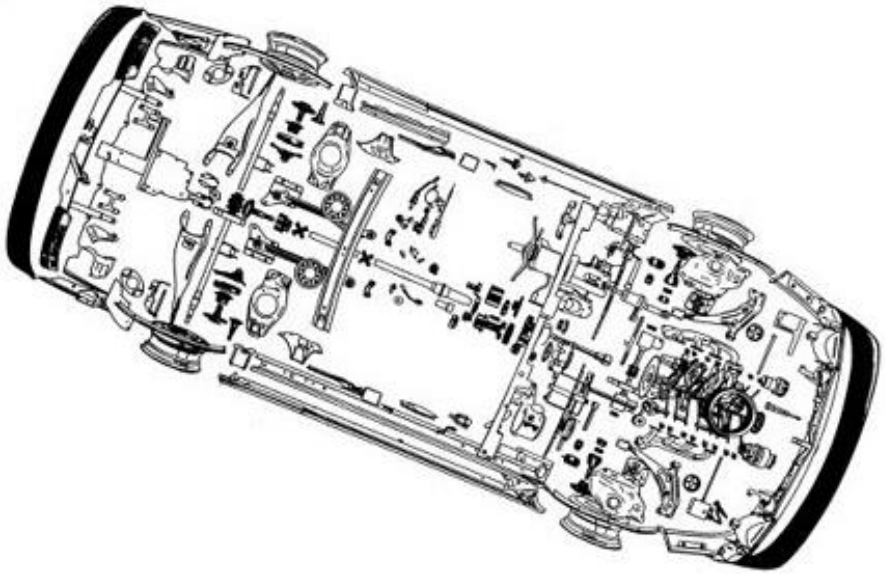
Energy consumption ratio

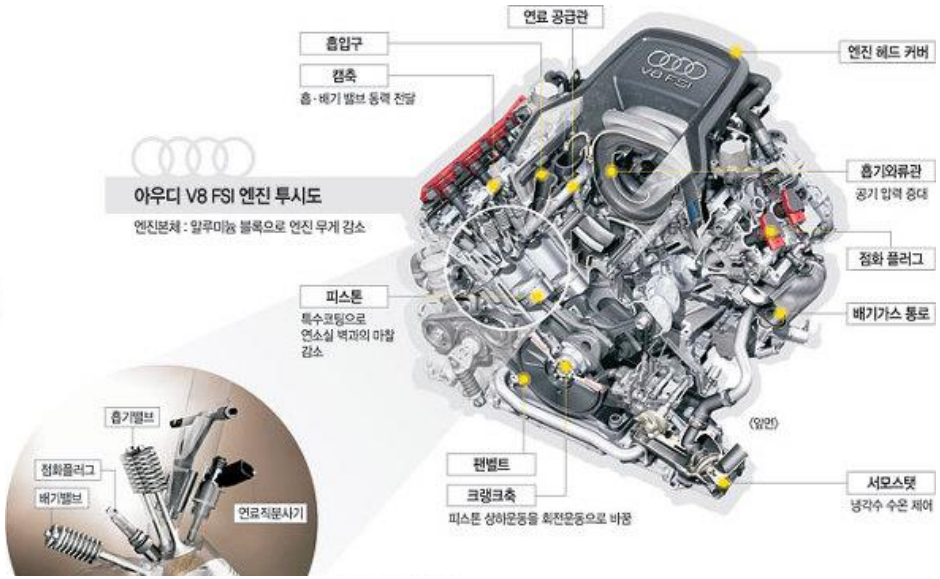


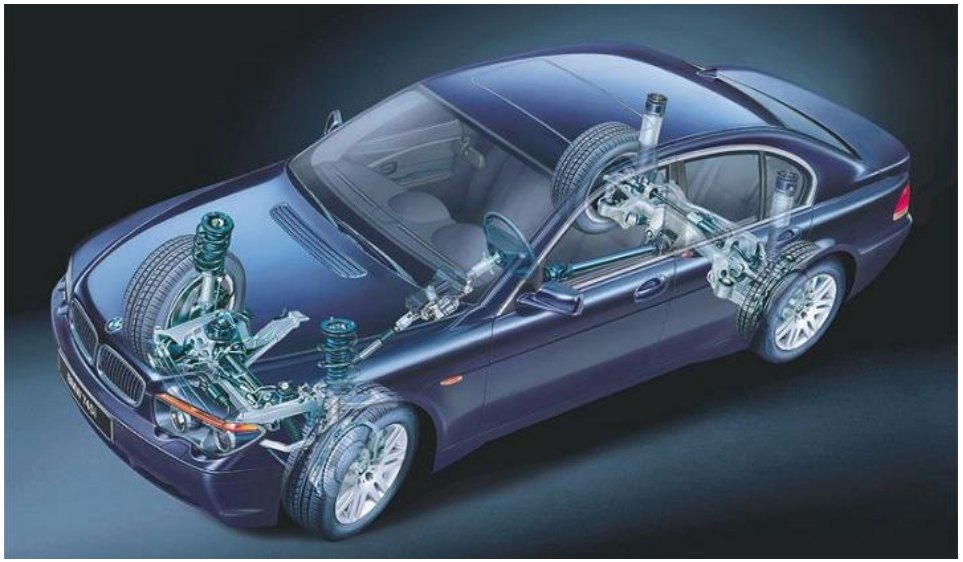


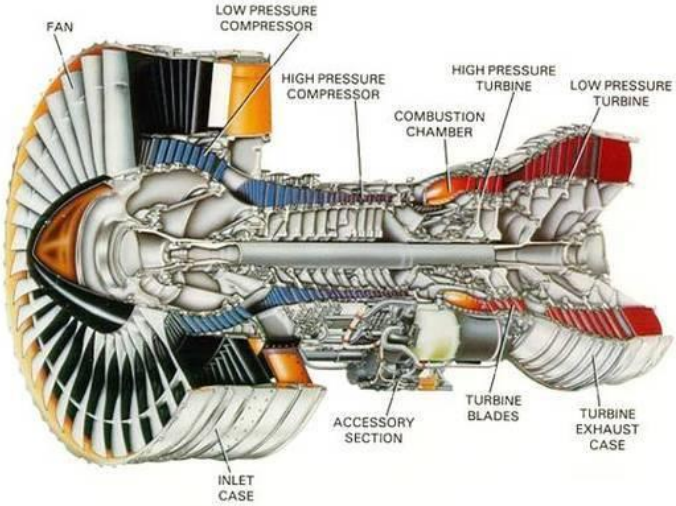
1.2 Forgings

Metal formed products

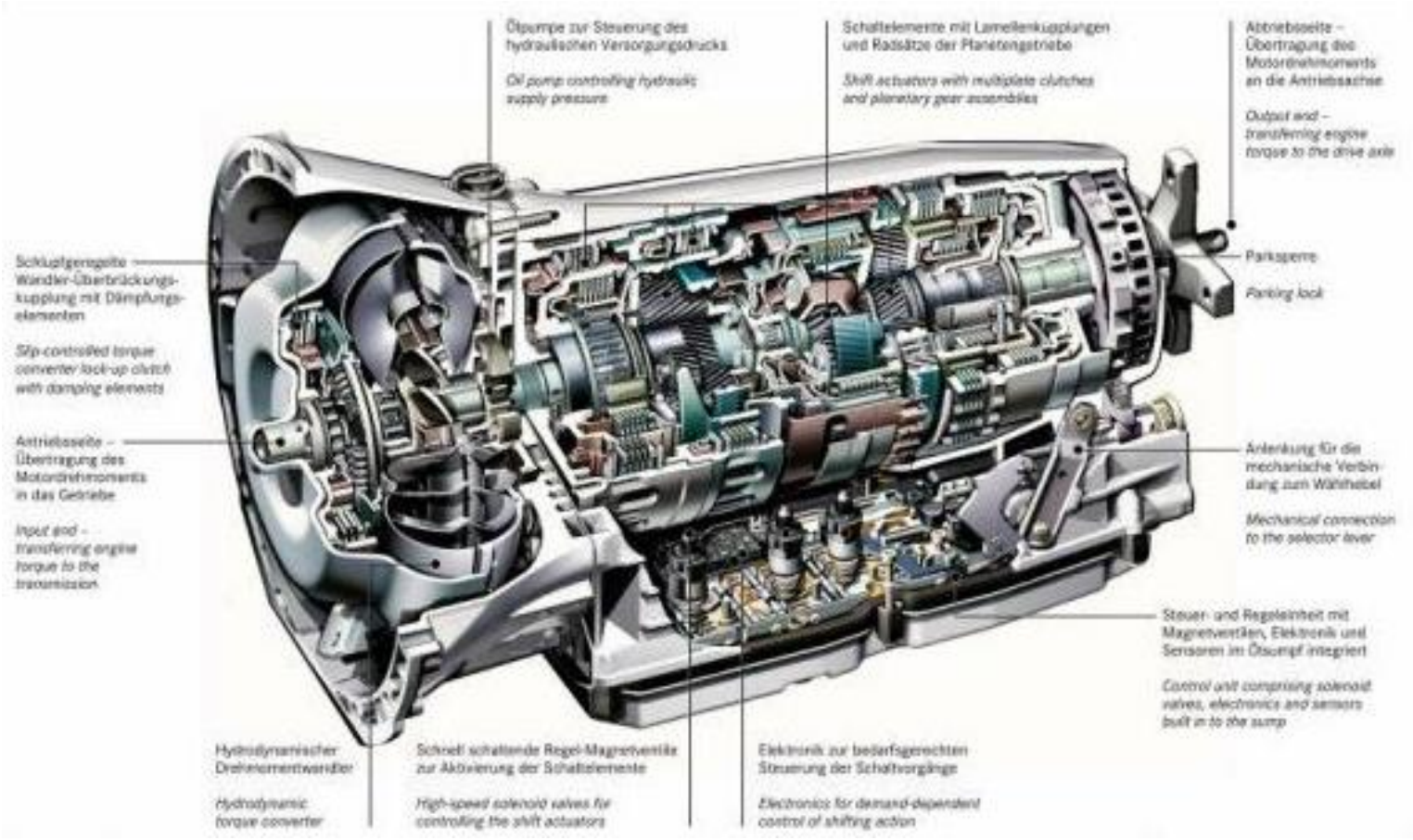








Auto-transmission



Mercedes Benz, 7 stage auto-transmission

Bearing parts



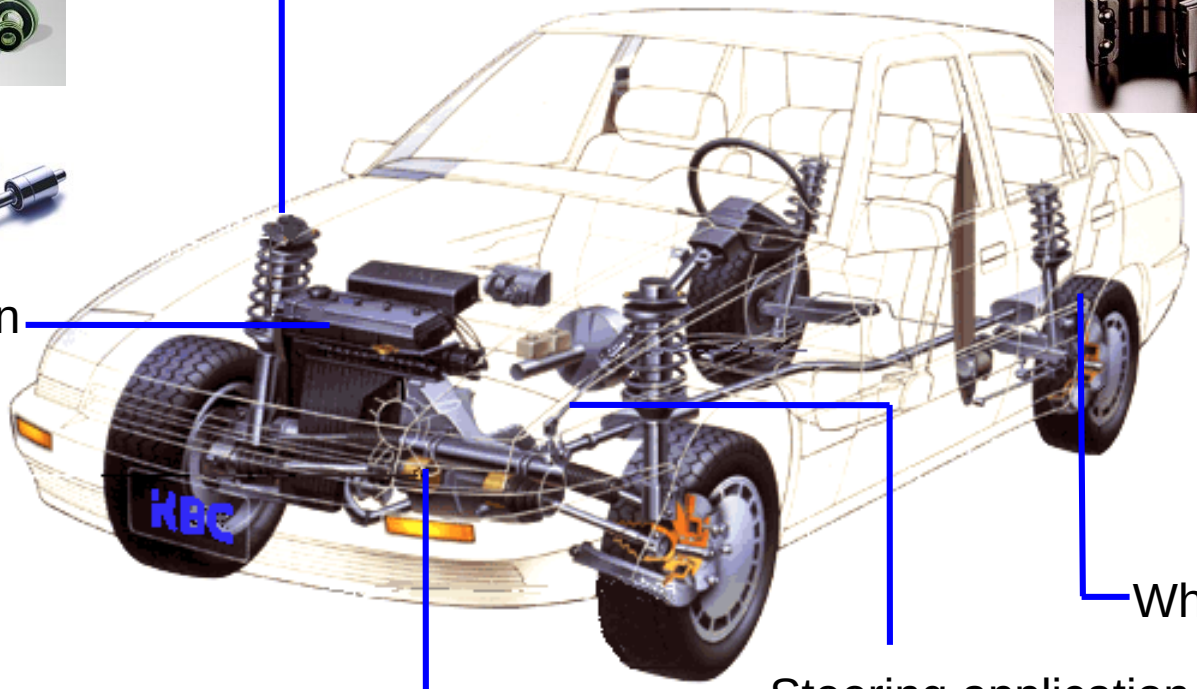


Suspension &
C.V Joint application






Engine application



Wheel application

Steering application

Powertrain application

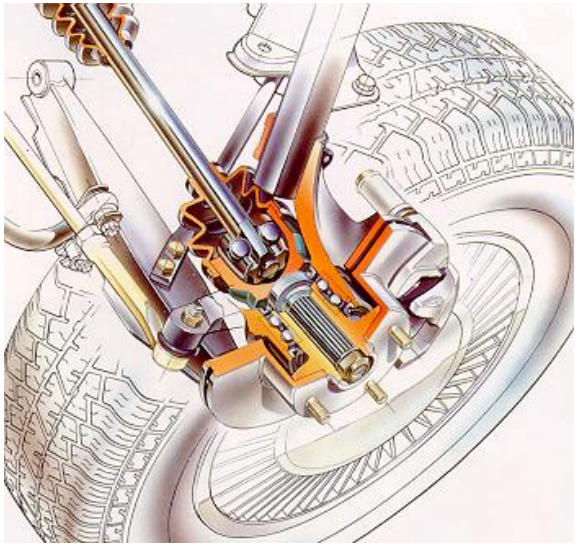


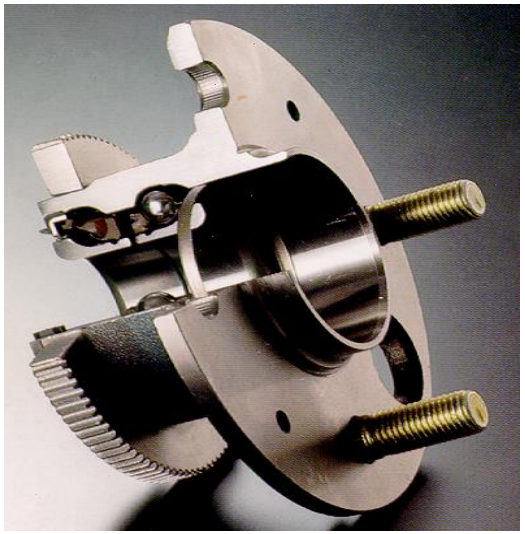




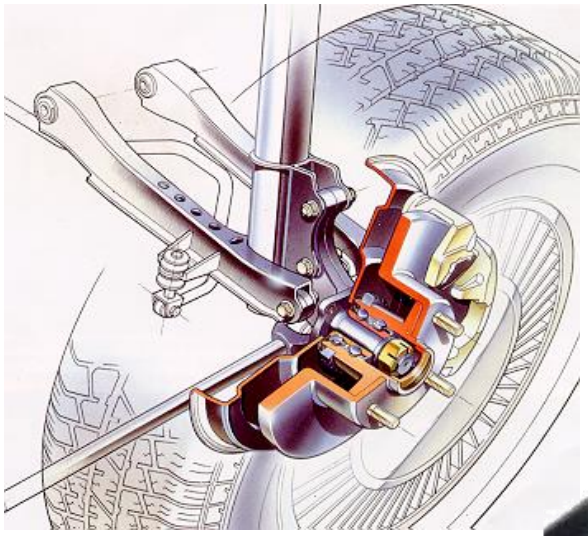
Detailed view of hub bearings, CV joint, etc.

First generation





Second generation

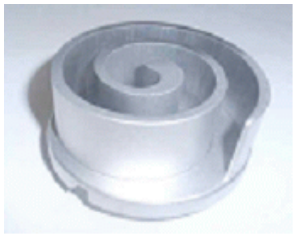


Aluminum forgings for automobile parts

Precision forgings for automobile parts

<Spider>

<CVJ-Inner Race>



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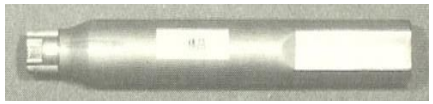
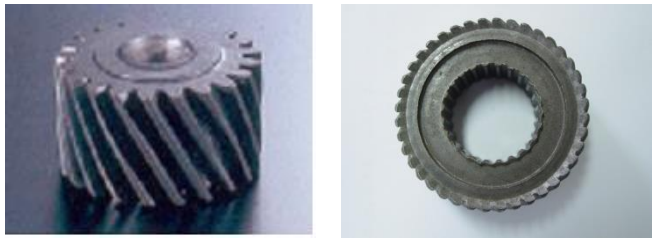




<Helical Gear>

<Diff Side Gear>

<Outer Cone>

Hot forgings for automobile parts

Steering parts

Hub/spindle parts

Bevel gear parts

Trans mission parts

Hinge parts

Hot forgings

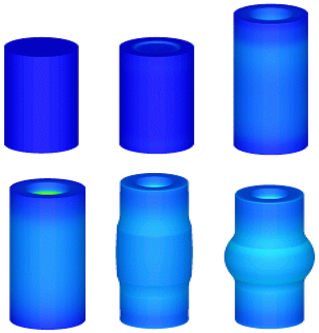
Axi-symmetric hot forgings and variants

CV joint outer race

Gear blank

Combined warm and cold forgings

Cold former forgings for automobile parts

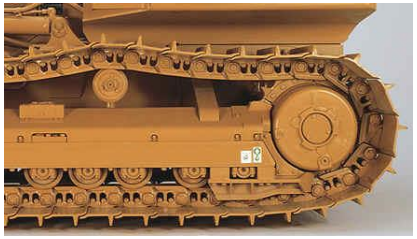


Fasteners

Engine or chassis

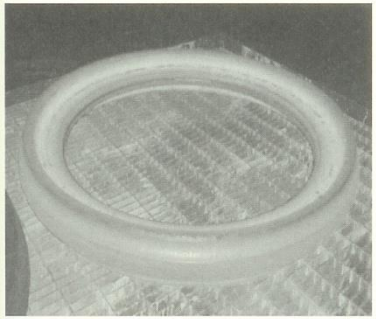
Steering & function bolt

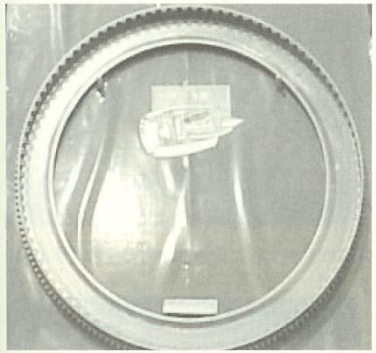
Special bolt



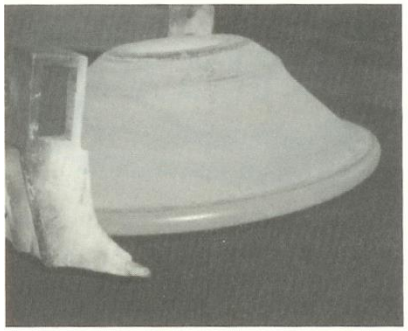
Construction vehicle, agricultural or defense vehicle

Aircraft forgings



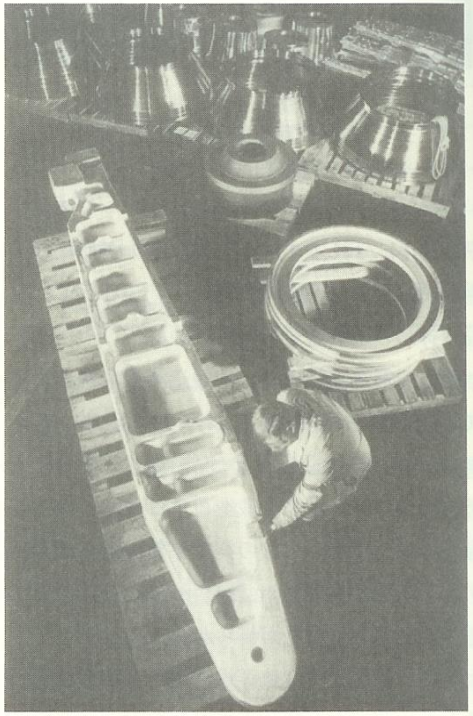


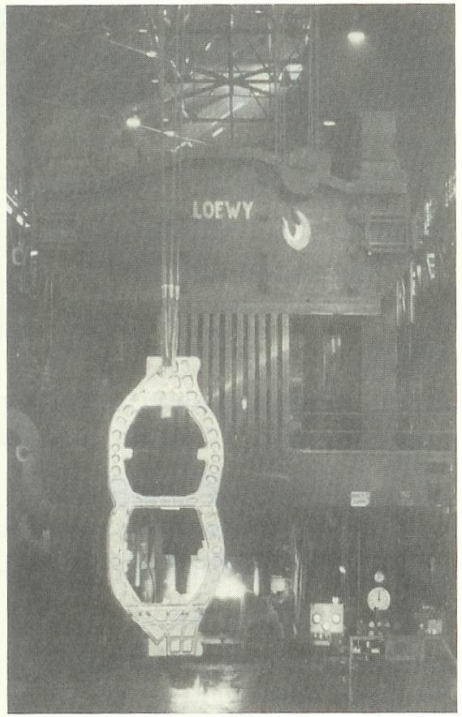
Ring disk of large aircraft engine (600kg)



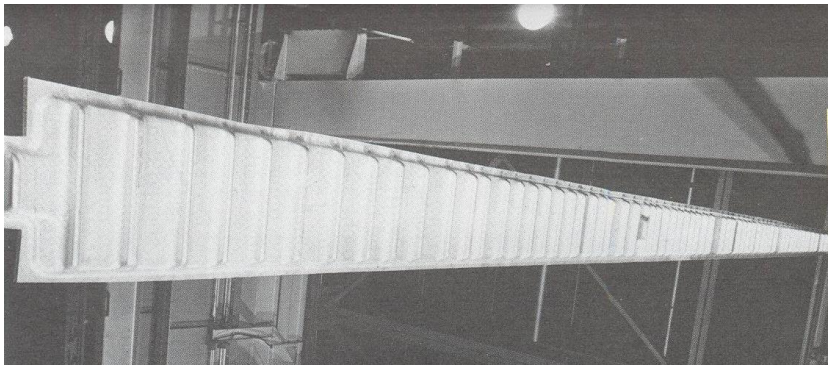
Disk shaft of large aircraft engine

Boeing 777, Support beam of landing gear, Al forging



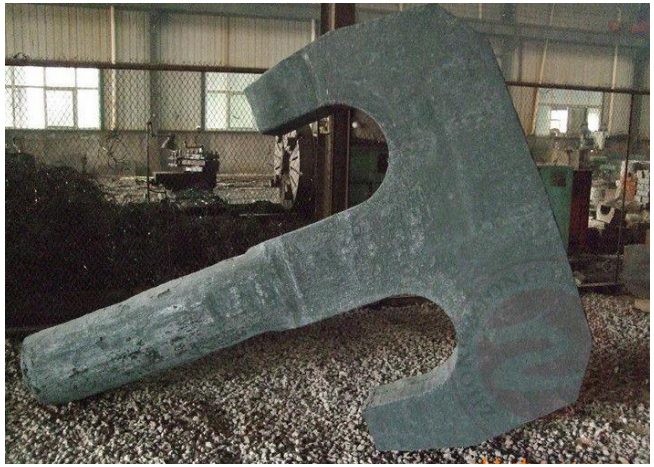


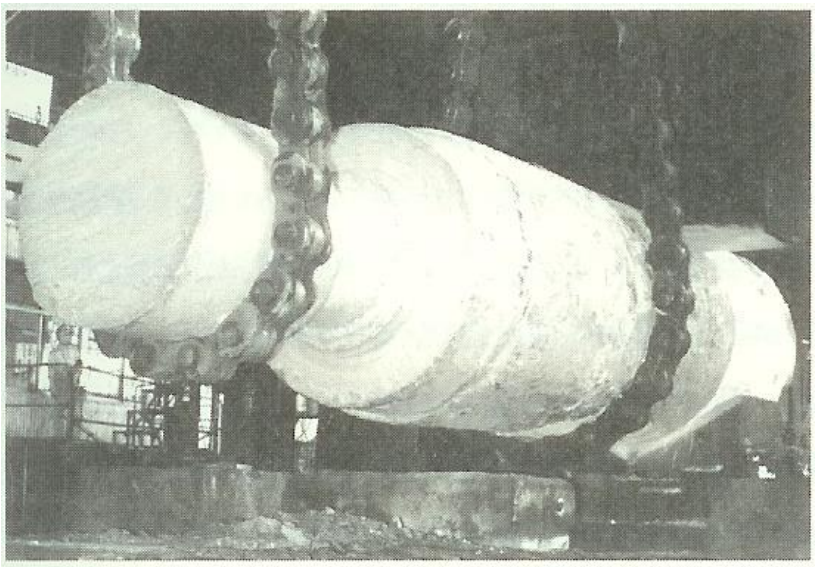
Ti alloy forging, Boeing 747, Support beam of landing gear (50,000ton press)



23 ft aircraft wing spa

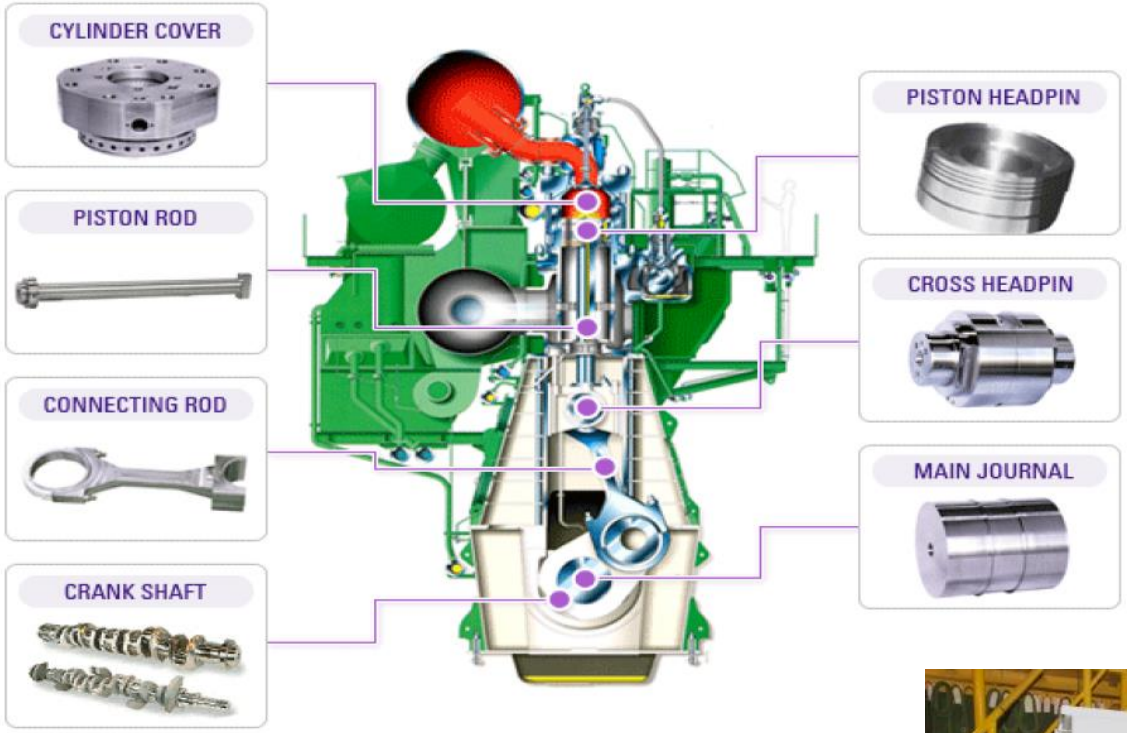
Very large open die forgings





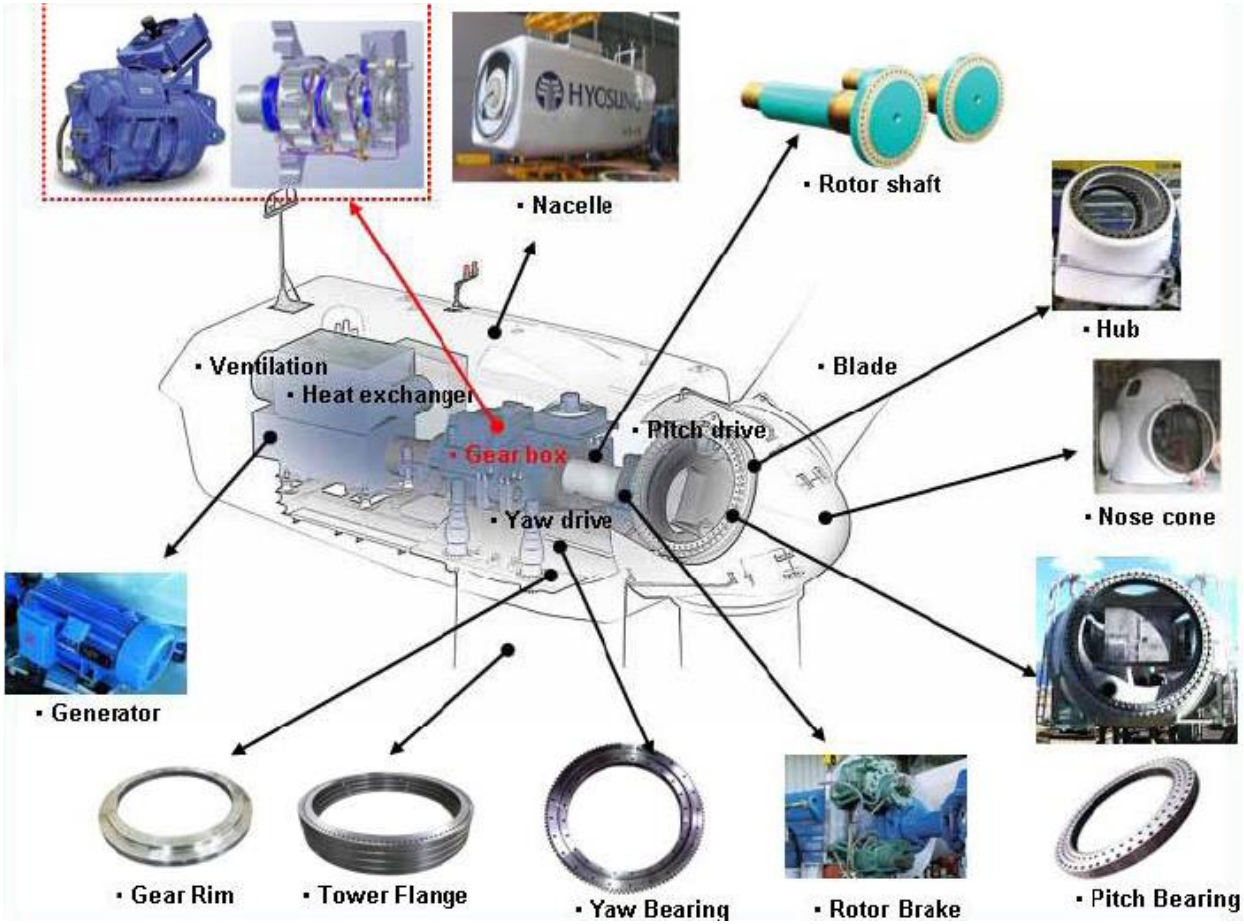
1992, low pressure turbine rotor, 25 ton, open die forged by 10000ton press

Ship engine or power generation engine

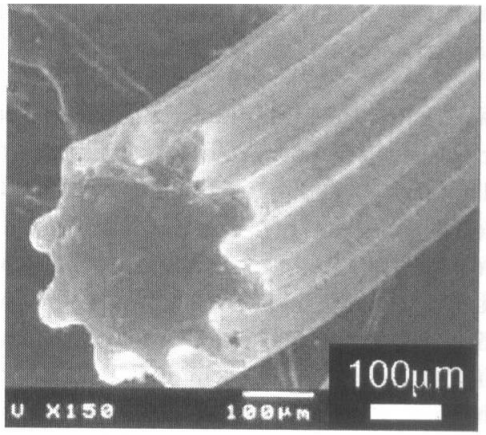


Himsen engine

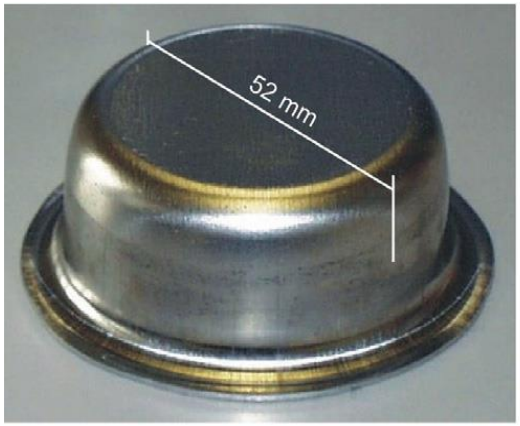
Wind power generator

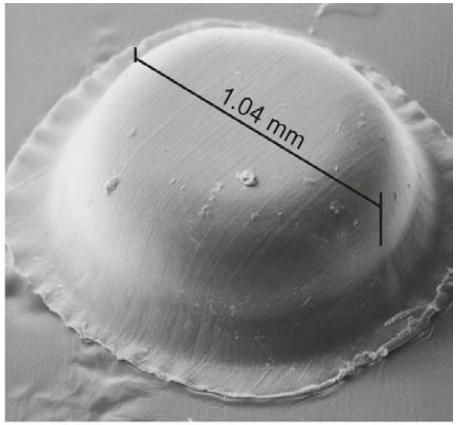


Micro-forming

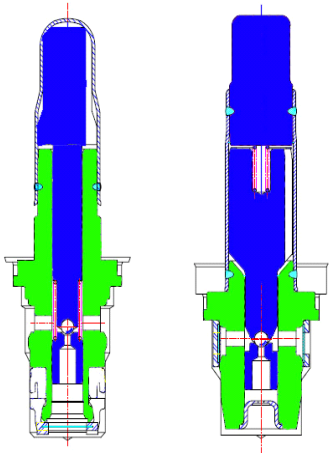


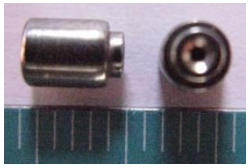
<Forward-extruded micro gear shaft>





<Comparison of macro and micro deep drawing cups >



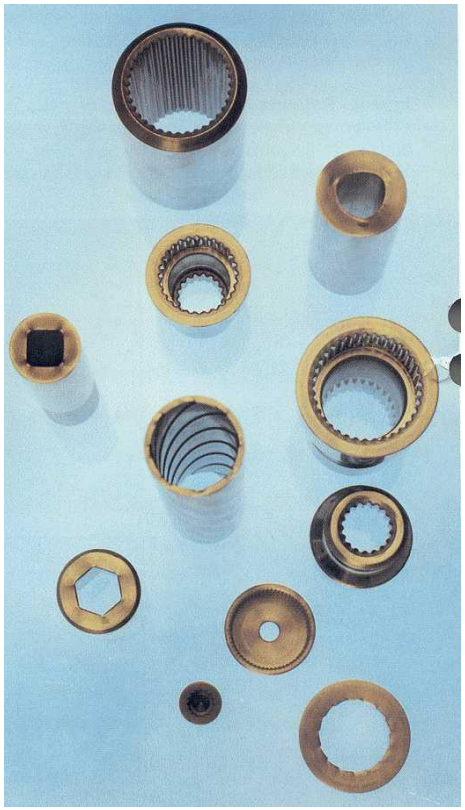


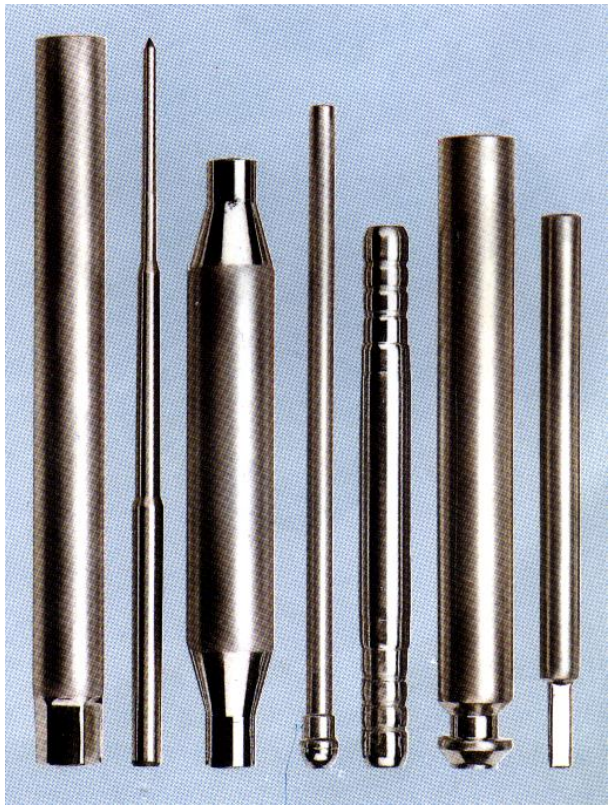
<Cold headed micro parts>

Tools

Coin and medal, accessory

Swaged parts





Flow formed parts



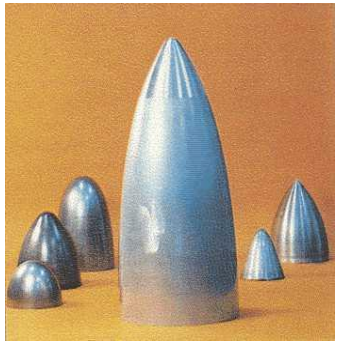


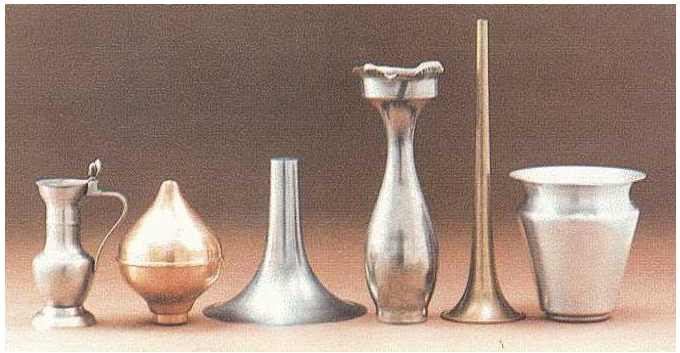


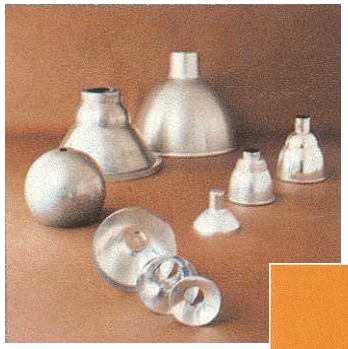





Spun parts





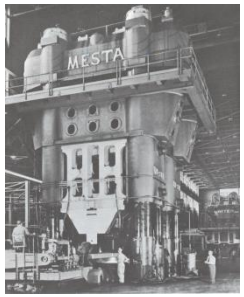



Wheel (2-pieces)
Wheel (3-pieces)
Rim for buggy
Motor cycle rim
Disk for truck
Front shaft cover
Fender mirror
Muffler
Poly-V-pulley
V-pulley

Miscellaneous parts

1.3 Important factors in forging industry

Various forging machines

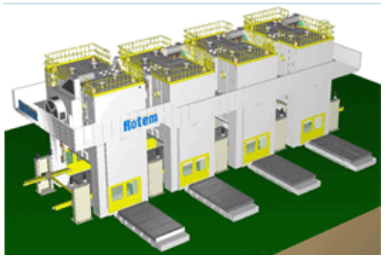


Hydraulic press

Hot forging press

Cold forging press

Servo press



High speed tendum press

Bolt part former

Part former

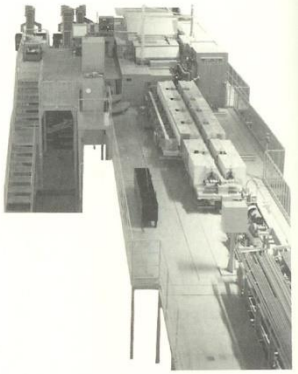
Transfer press

Blanking press I

Open die forging m/c

Micro-former

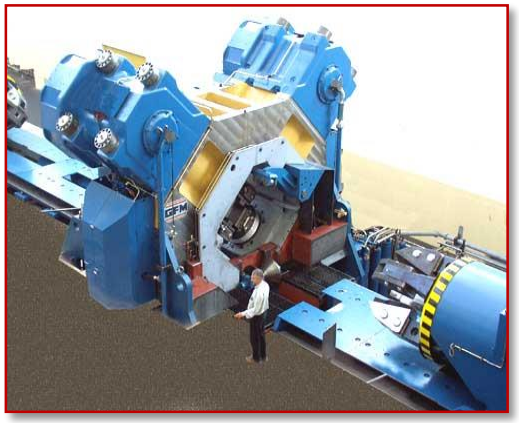
Counter-blow hammer m/c



Hot former

Ring rolling mill

Various forging machines



Radial forging m/c

Chipless forging m/c

Roll forging m/c

Small ring rolling m/c

Cross-wedge rolling m/c

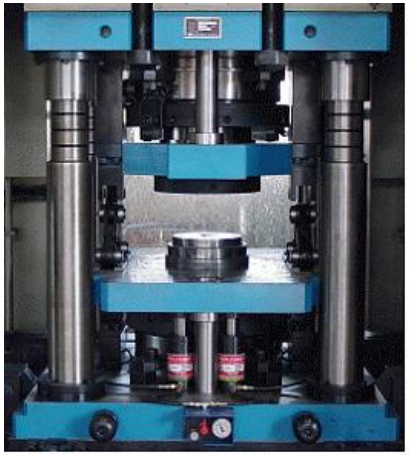
Upsetter

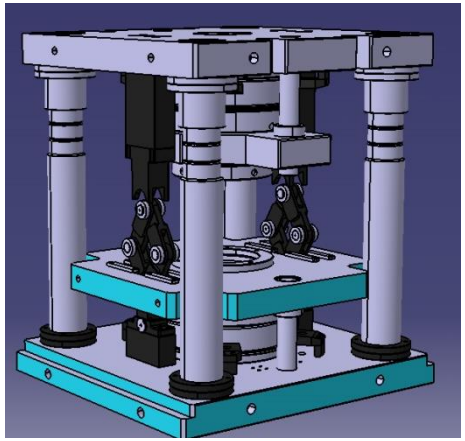
Air drop hammer

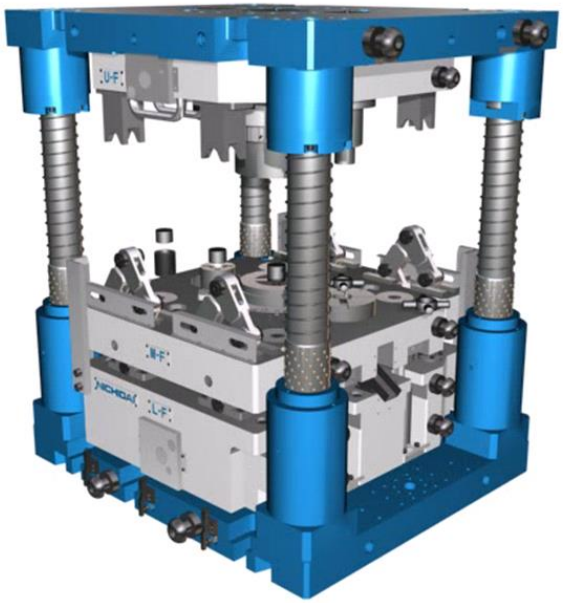
Swaging m/c

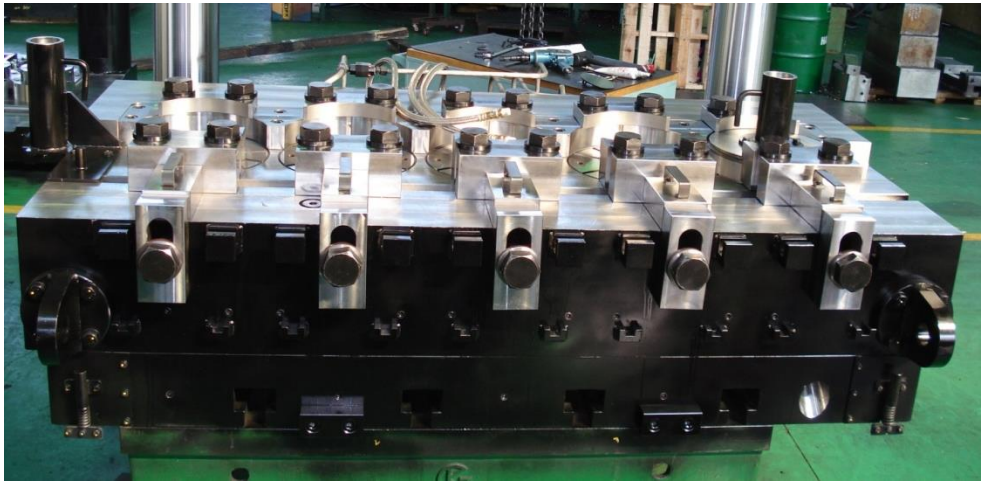
Roll piercing m/c

Die set





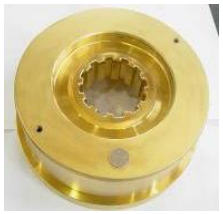




Die



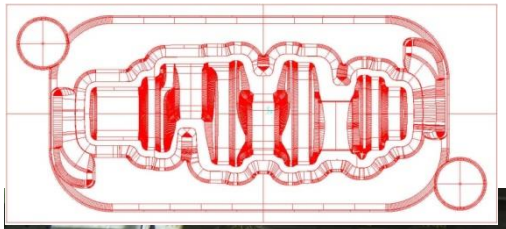


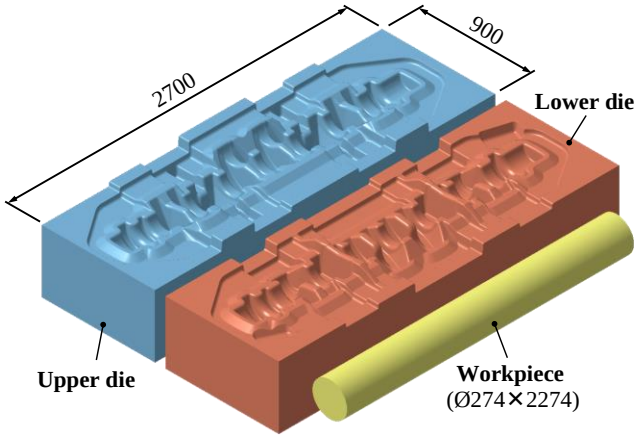




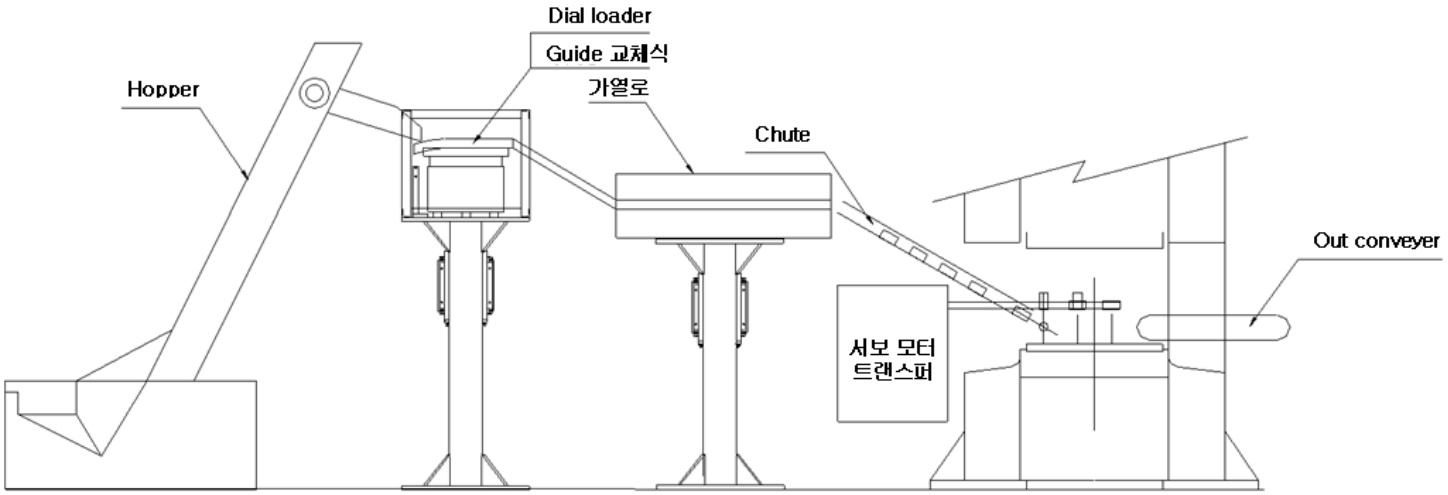




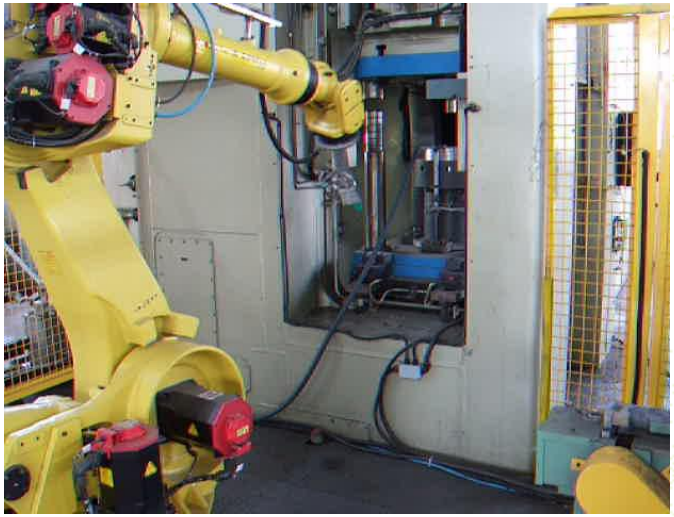


Automation

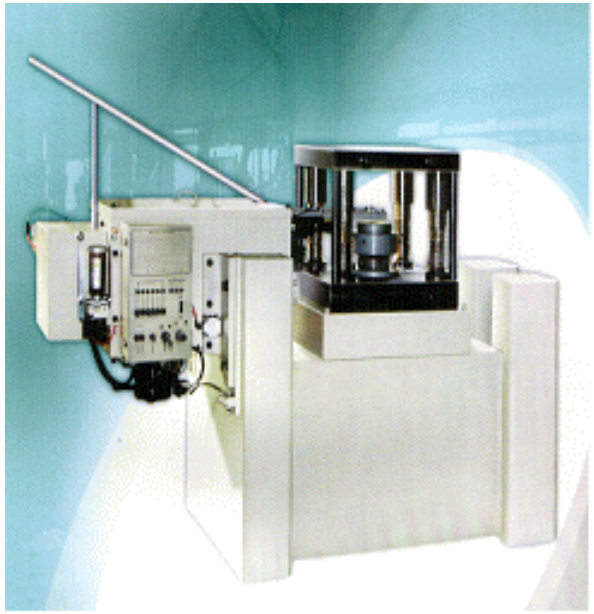


○ Multi-linkage robot



○ Servo transfer

○ Mechanical transfer



Die making machines

Vertical Machining Center

Vertical Machining Center

E.D.M

WireE.D.M D/Machime

Milling

Die making machines

1	선반 (현대위아 NARA 6020) (Ø620×2000L)	2	선반 (ONG-IL) (Ø850×1500L)
			
3	선반 (SEL6LL KO KI) (Ø1200×2500L)	4	밀링 (BONG SHIN BM-U6N) (1000×300×450)
			
5	밀링 (KITAMURA KMU-5) (1600×360×600)	6	머시닝센터 (BONG SHIN ON-3V) (1200×400×500)
			

7	머시닝센터(현대위아(KV75)) (1700×650×600)	8	머시닝센터(BONG SHIN(1100 VNC)) (2200×1100×900)
			
9	고속가공기(KITAMURA 3XIF) (950×400×500)	10	고속가공기(현대위아 HI-V560M) (1200×500×600)
			
11	고속가공기(현대위아 F660M) (1400×660×635)	12	CNC보링(현대위아 KBN 135CL) (4000×2000×2000)
			

13	방전기(XERMAC XHC-240) (1200×700×700)	14	방전기(XERMAC X40B) (2600×1400×1100)
			

15	방전기(XERMAC X20) (1200×500×1000)	16	머시닝센터(현대 AJU 25/405) (1400×600×600)
			

Measurement and test equipments

- Magnetic Particles Inspector
- Spectrometer
- Universal Testing Machine
- Co-ordinate Measurement Machine
- Contracer
- Spot Thermometer
- Metal Microscope
- Ultrasonic Tester
- Brinell, Rockwell & Equo–Tip Hardness Tester
- Polishing & Cutting Machine

Spectrometer

U.T.M

C.M.M

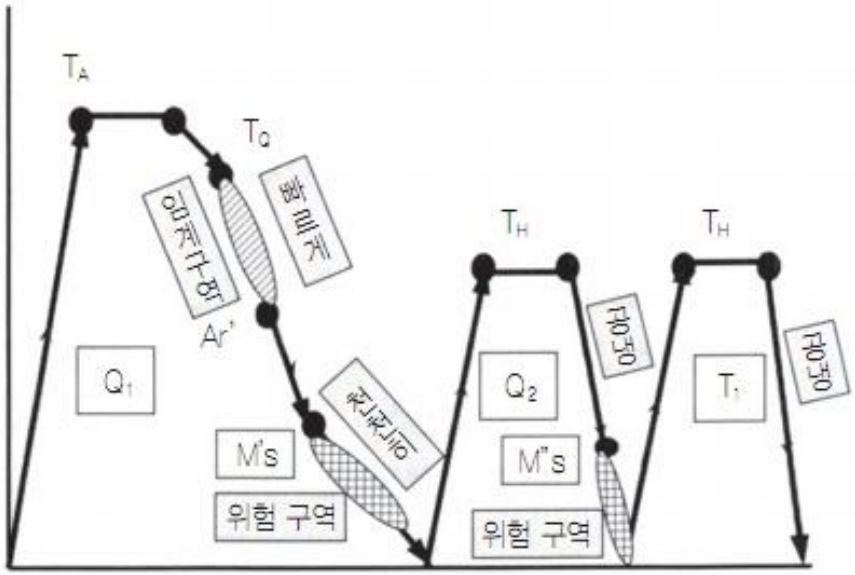
Contracer

Metal Microscope

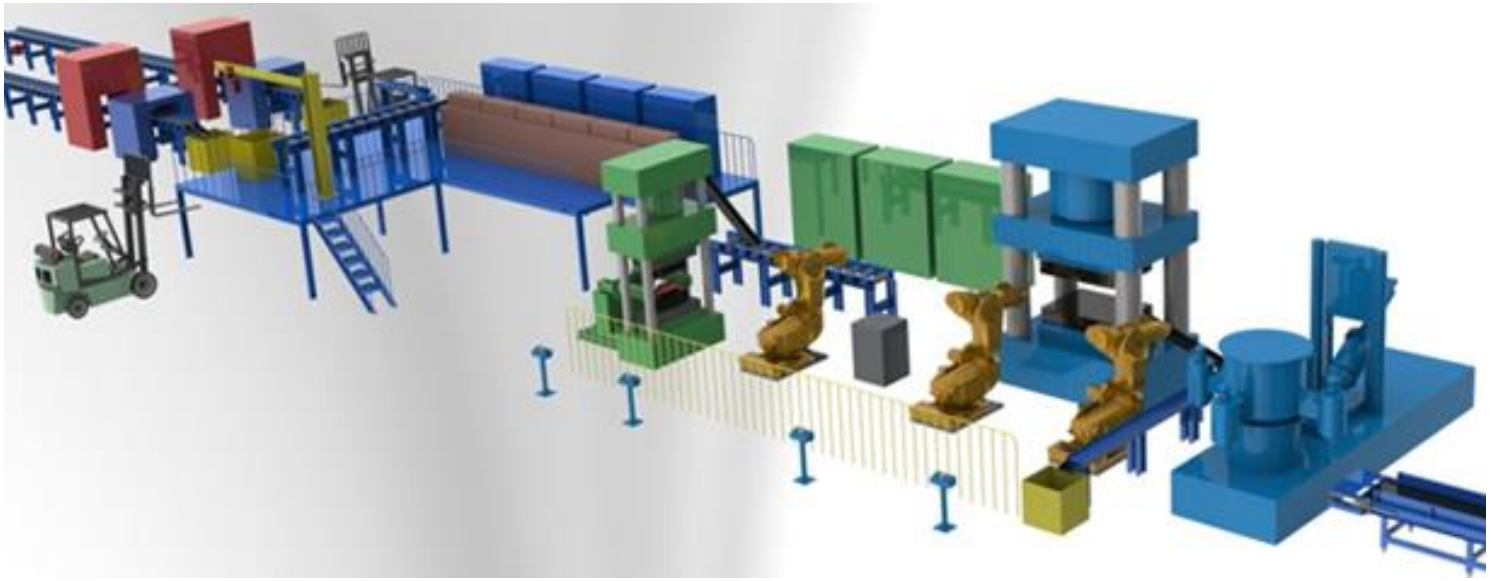
Heat treatment

Heat treatment equipment for dies

Annealing equipment for materials

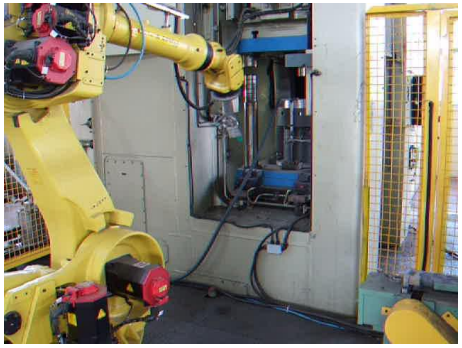


Forging line and automation



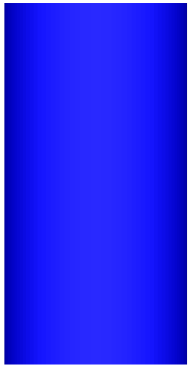
Manufacturing line

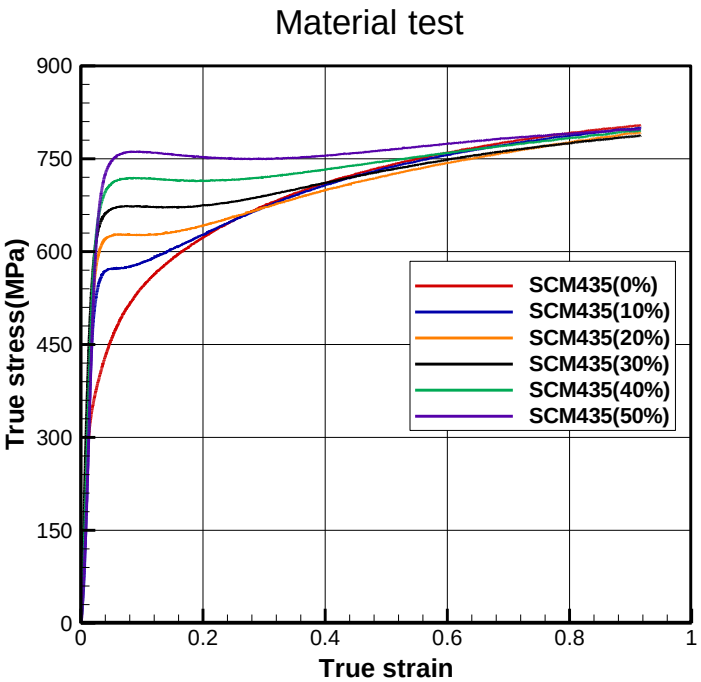
Robot



AC servo transfer feeder

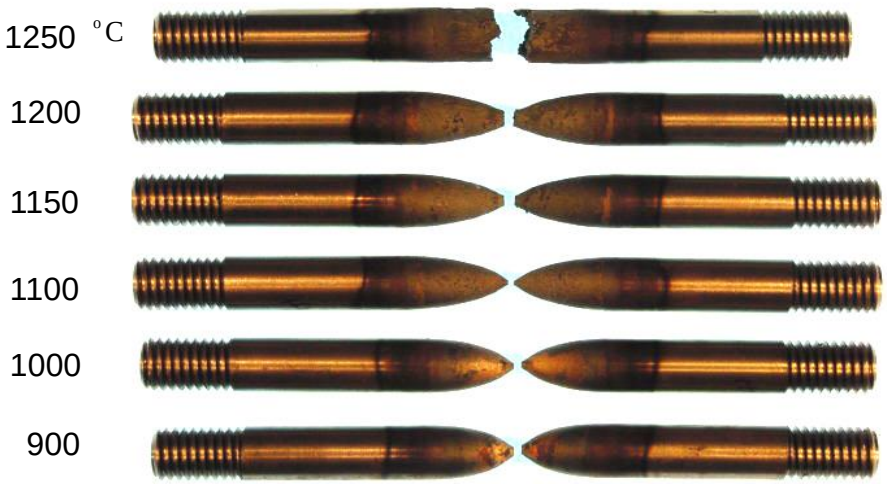
Material for cold forging



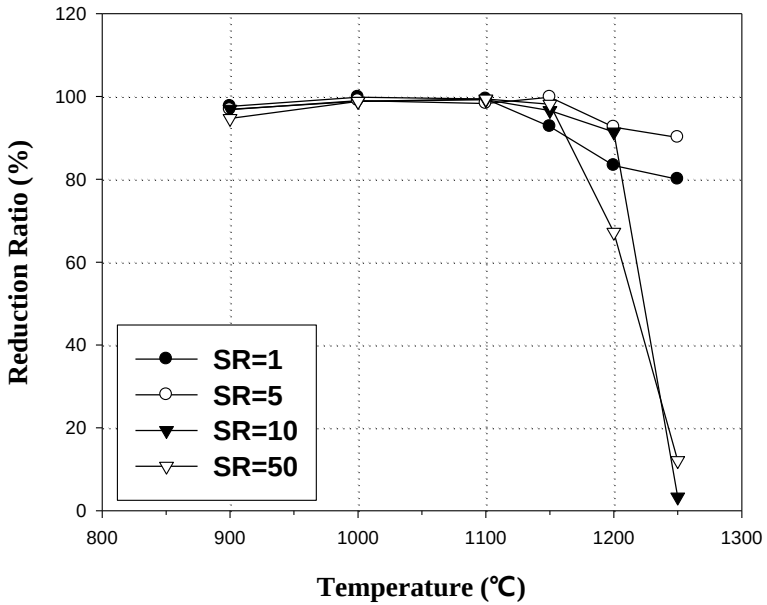


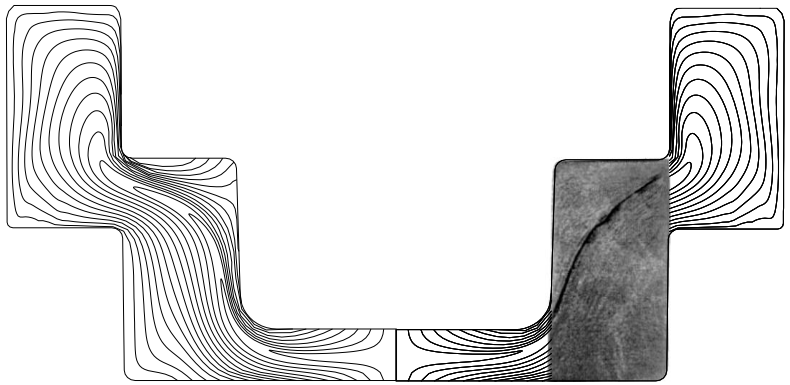
Material for hot forging

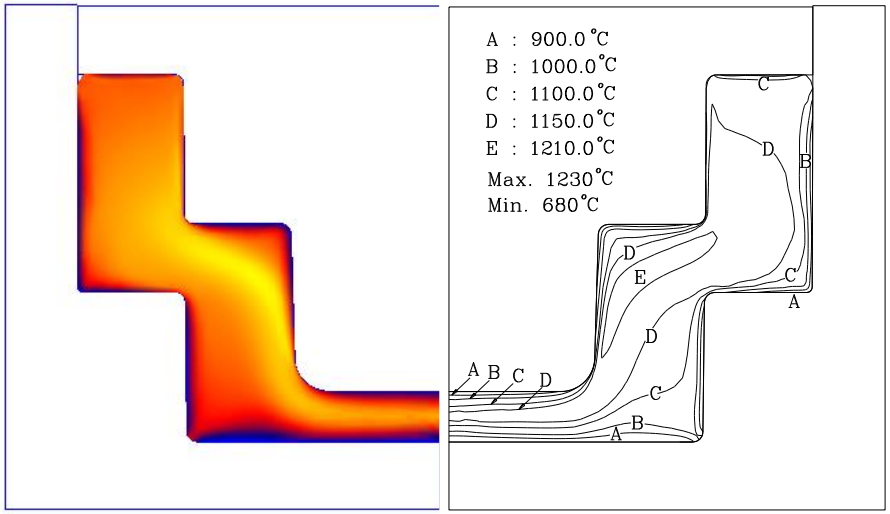
⊙ STB2 tensile test



⊙ Maximum elongation







Friction and lubricants, coating

Lubricated coil

Lubricated billet

Lubricants

TiN coated punches and dies

TD treated WC punches

Graphite powder

Sequence of bolt making process

Coil treatment

Forging

Thread rolling

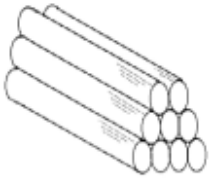
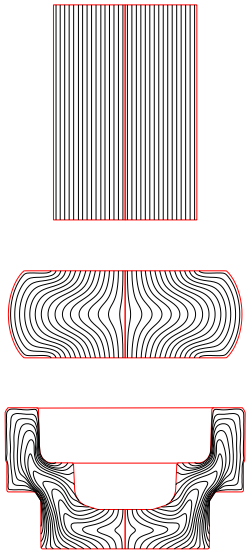
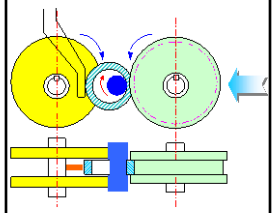
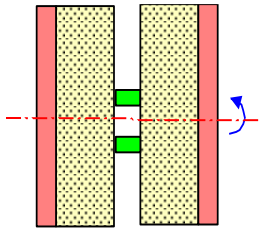
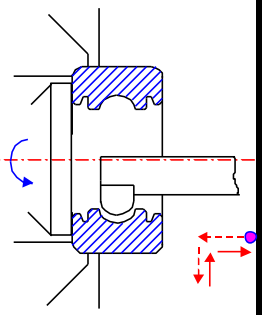
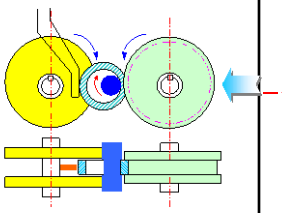
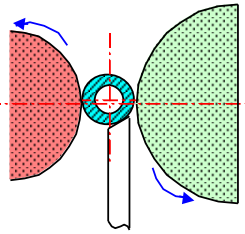
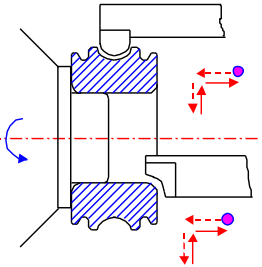
Heat treatment

Coating

Packaging

Storing

Ball bearing manufacturing process

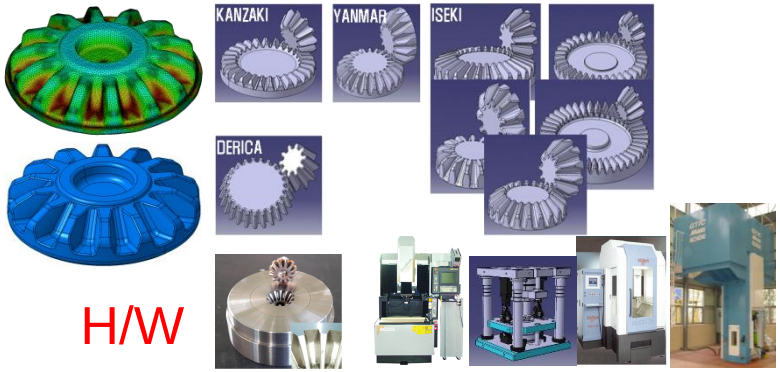
	Raw material	Forging	Annealing	Cold rolling		Soft grinding	Turning
Process flow				Outer ring			
				Inner ring			
Machine							

Coining process

1.4 Process development

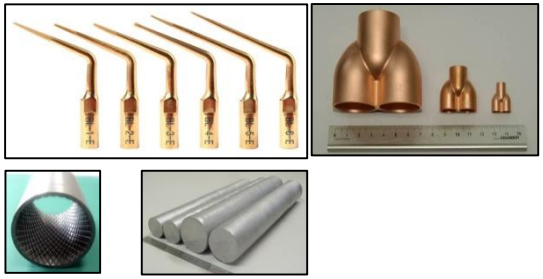
Technology Innovation Center(TIC) of GNU

The only TIC in Korea specialized in metal forming, powder metallurgy



H/W

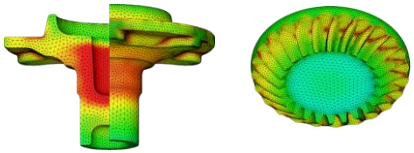
200 bevel gears developed,
150 for Japan, 50 for domestic appl.



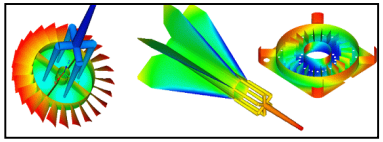
Korea leading research group for powder metallurgy

S/W

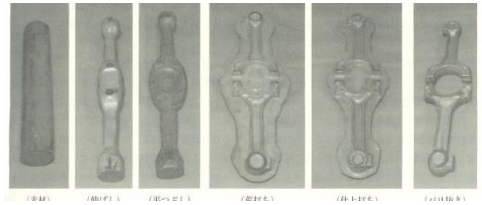
AFDEX

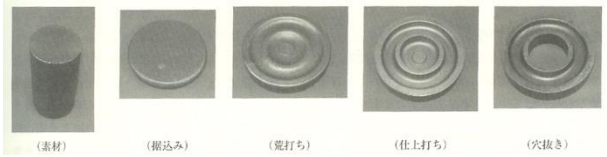


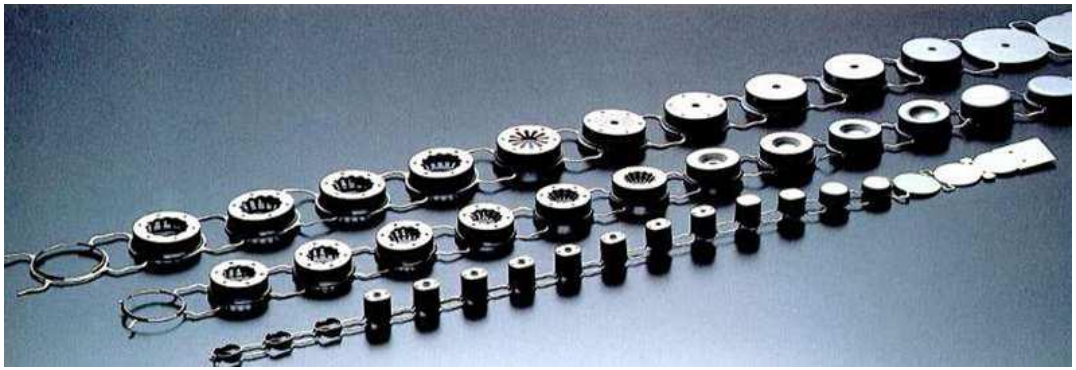
PMsolver
PIMsolver

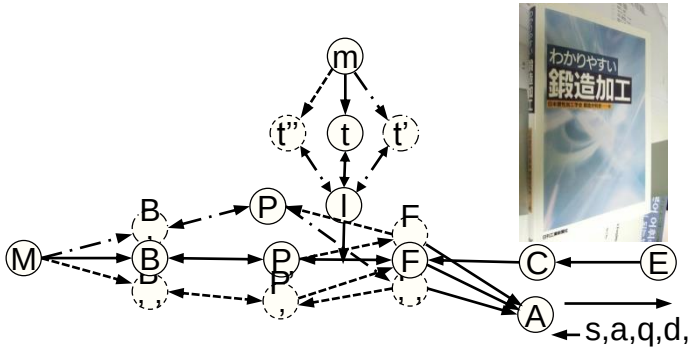


Process design and CAE

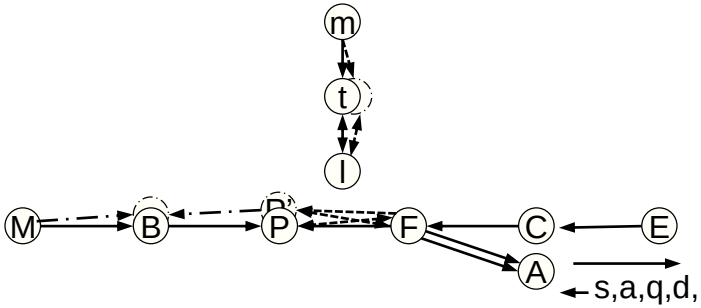




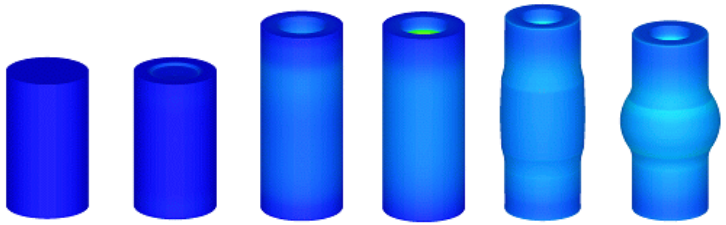


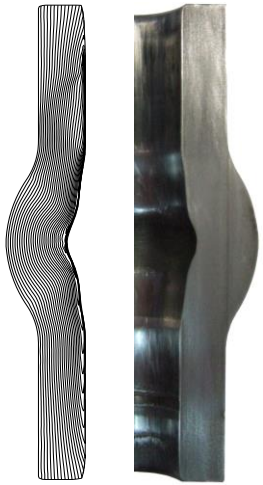


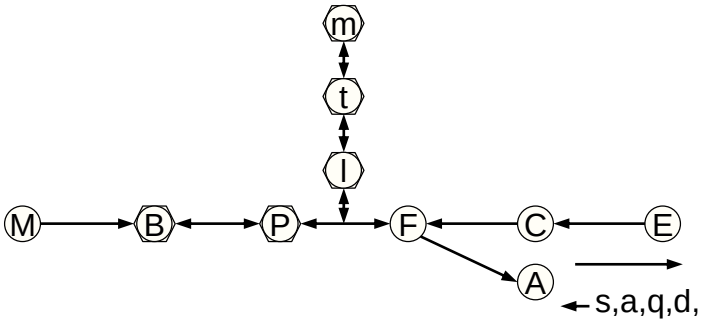
(a) 초보적인 시행착오적 단조작업



(b) 도면으로부터 AI 등과 역추적계산을 이용하여 예비성형품을 정확하게 추정하는 경우

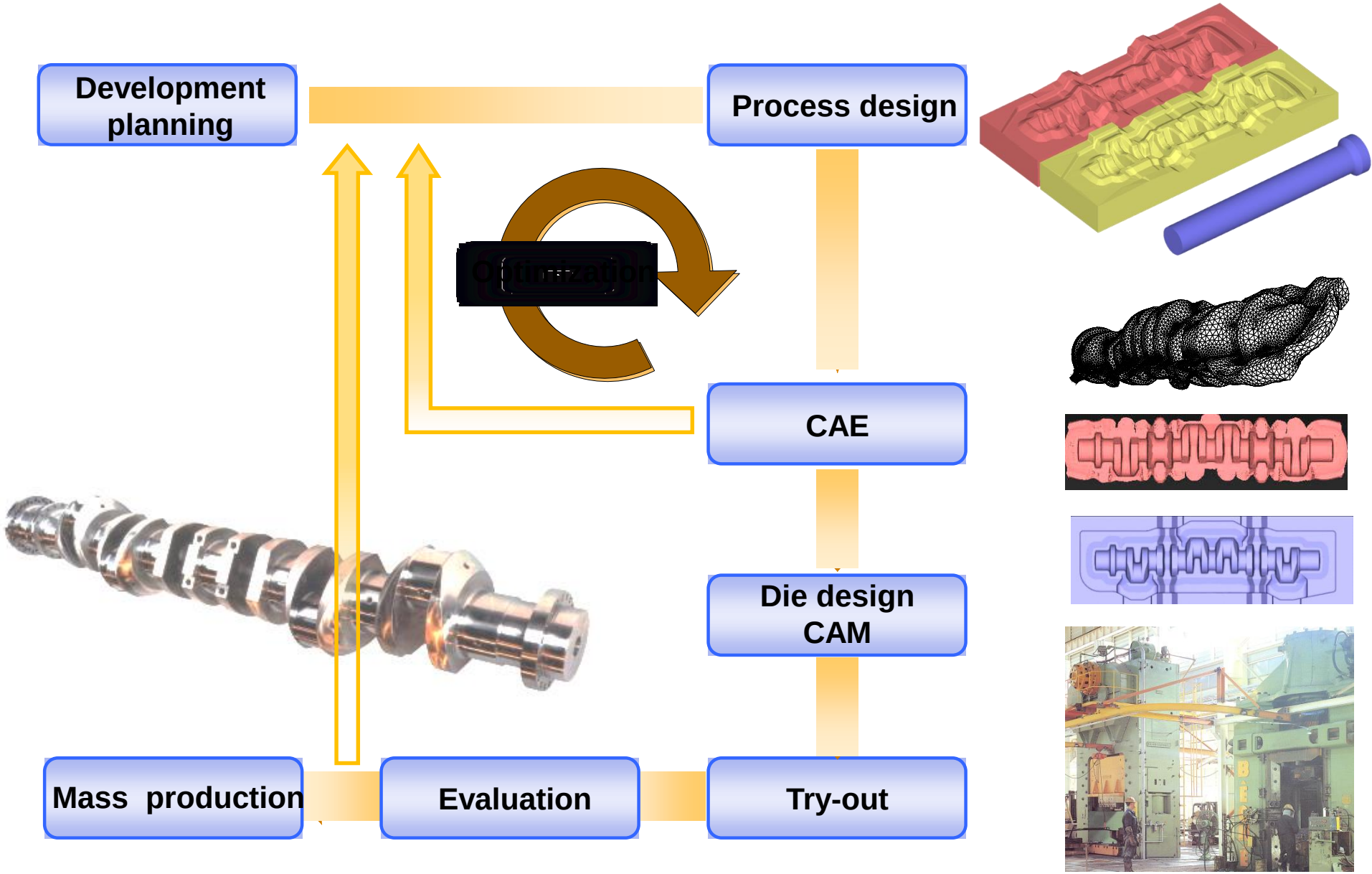




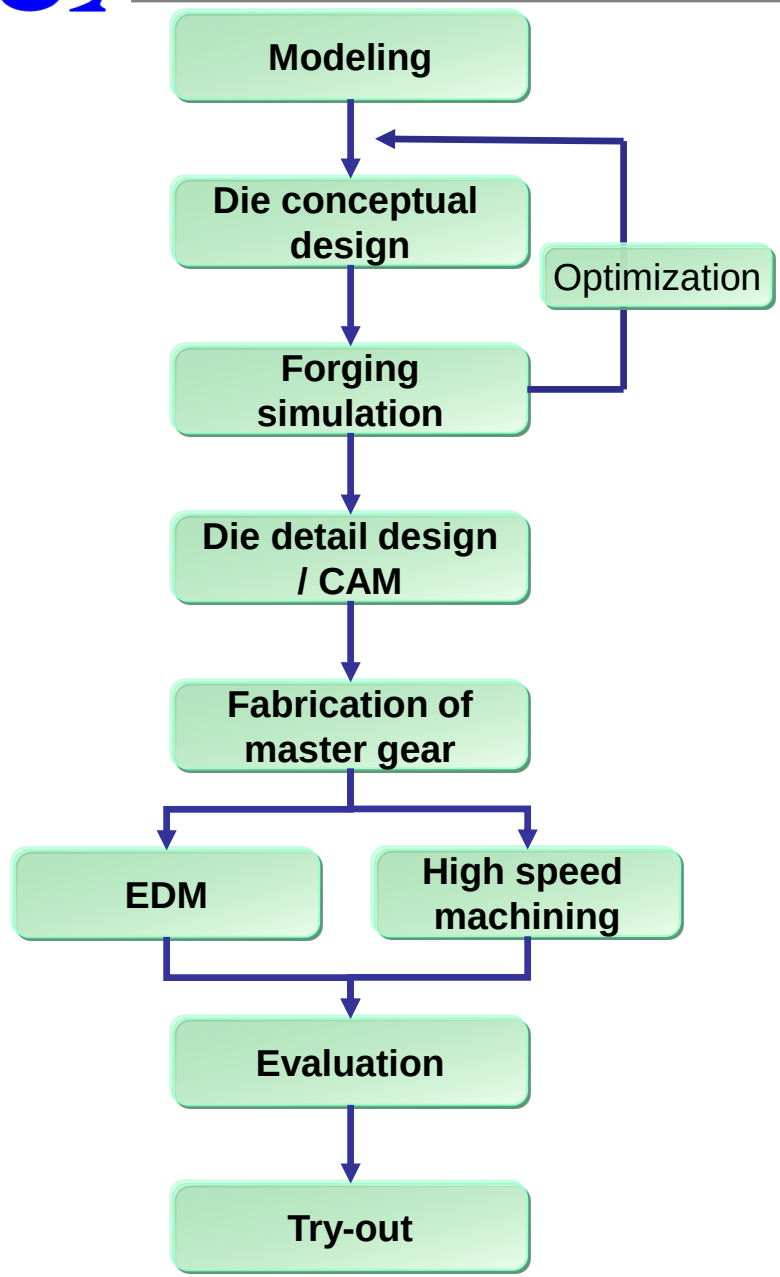


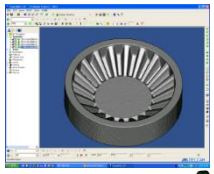
(c) 보다 정확도가 높은 시뮬레이션 기술을 사용하는 경우

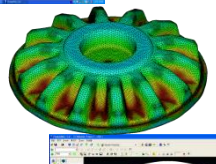
Development procedure of forging process

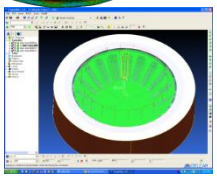


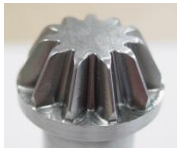
Development procedure of bevel gears in GTIC

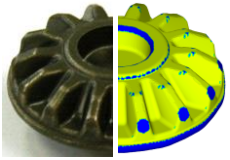


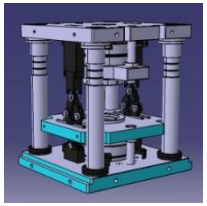




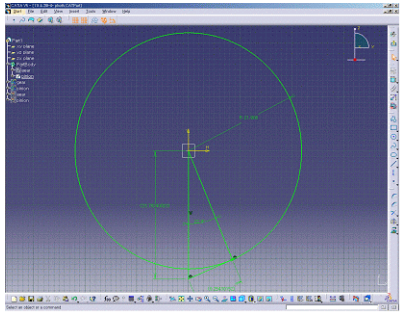


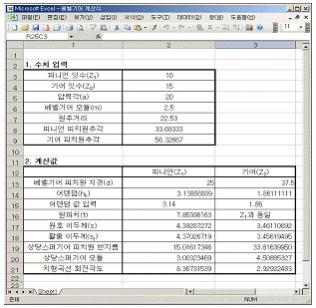


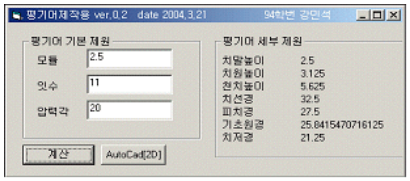


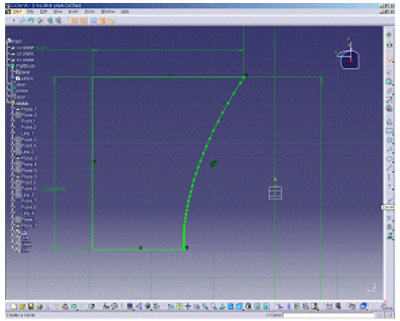


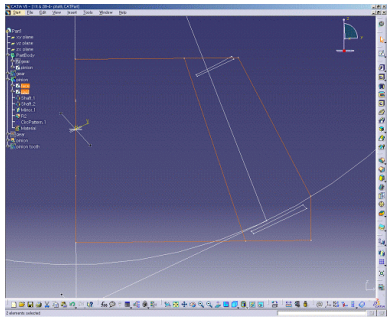
Bevel gear cold forging – Modeling, CAD

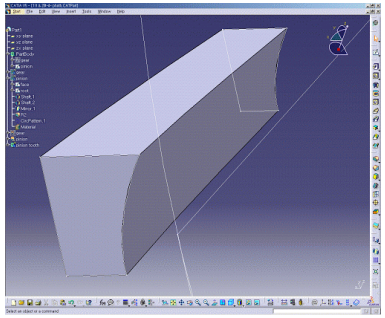


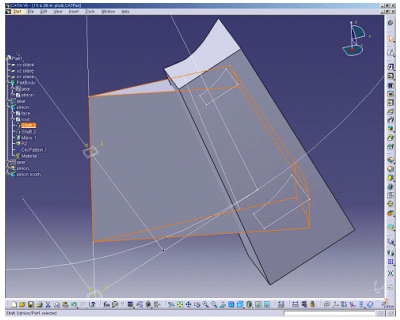


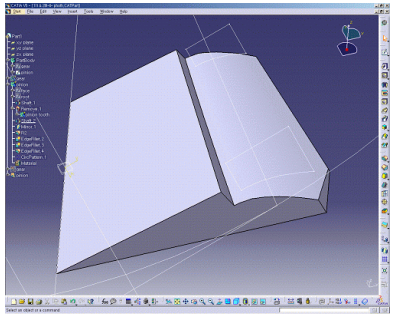


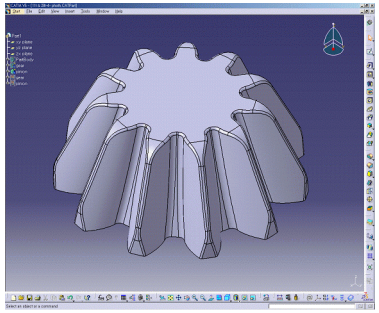










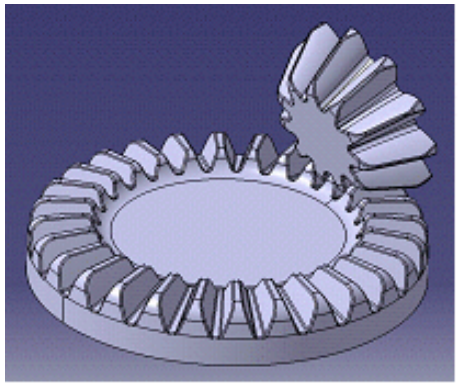


Modeling of bevel gear

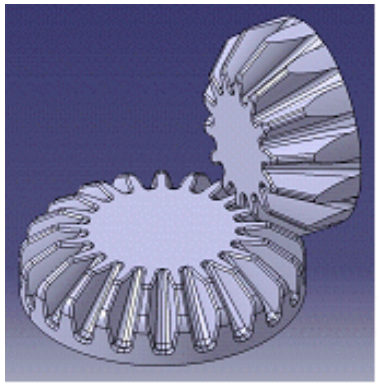
Compare the Master gear and Modeling

Bevel gear cold forging – Examples of CAD model

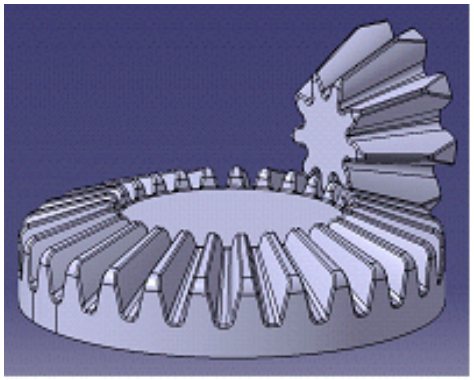
(1) KANZAKI

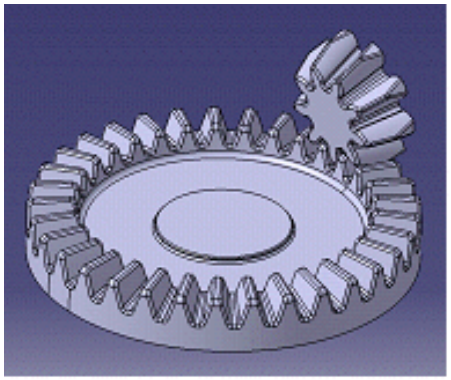


(3) YANMAR

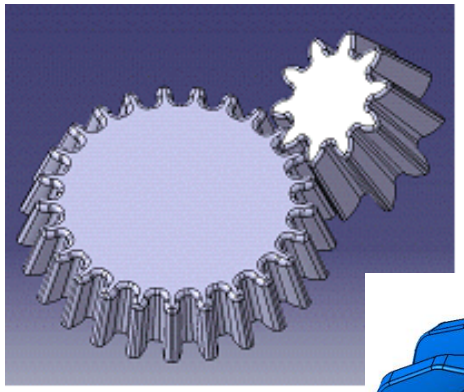


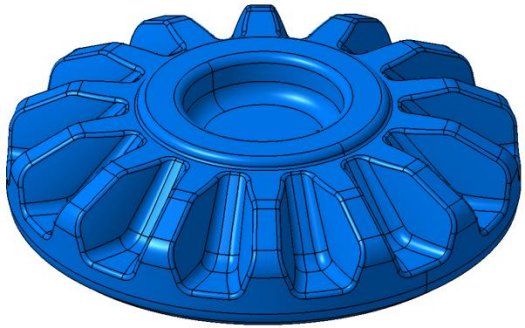
(4) ISEKI

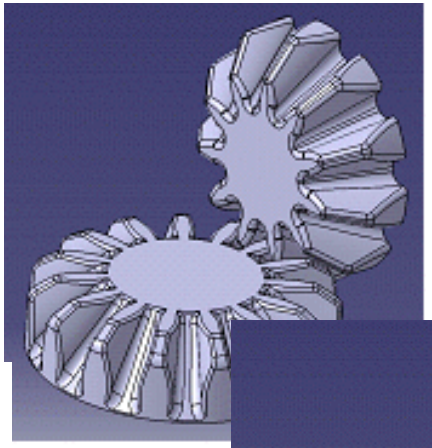


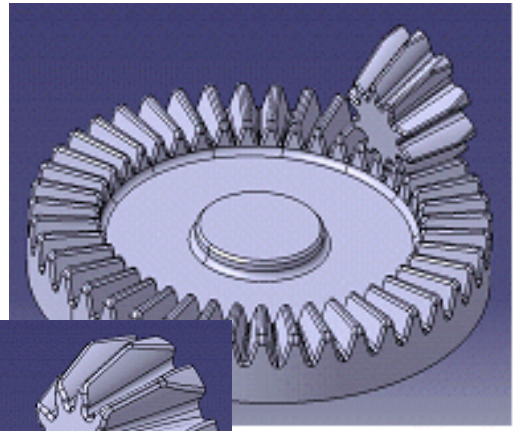


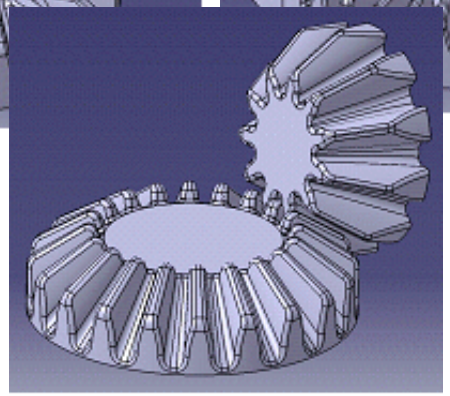
(2) DERICA



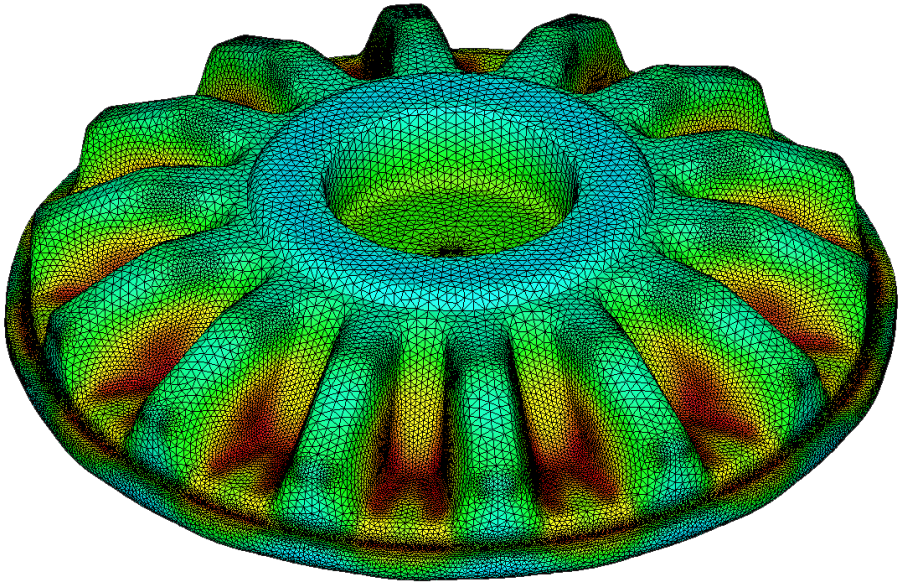


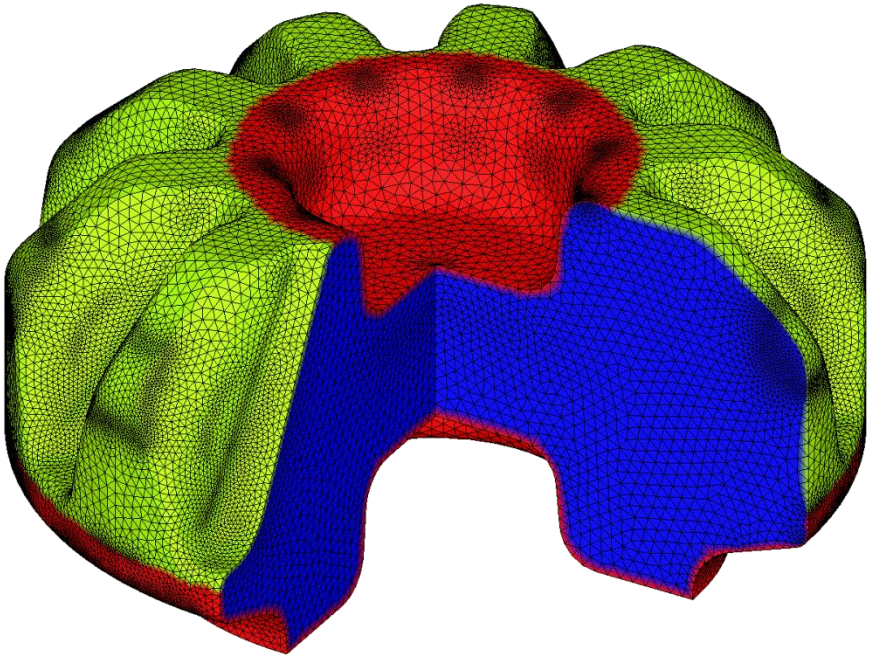




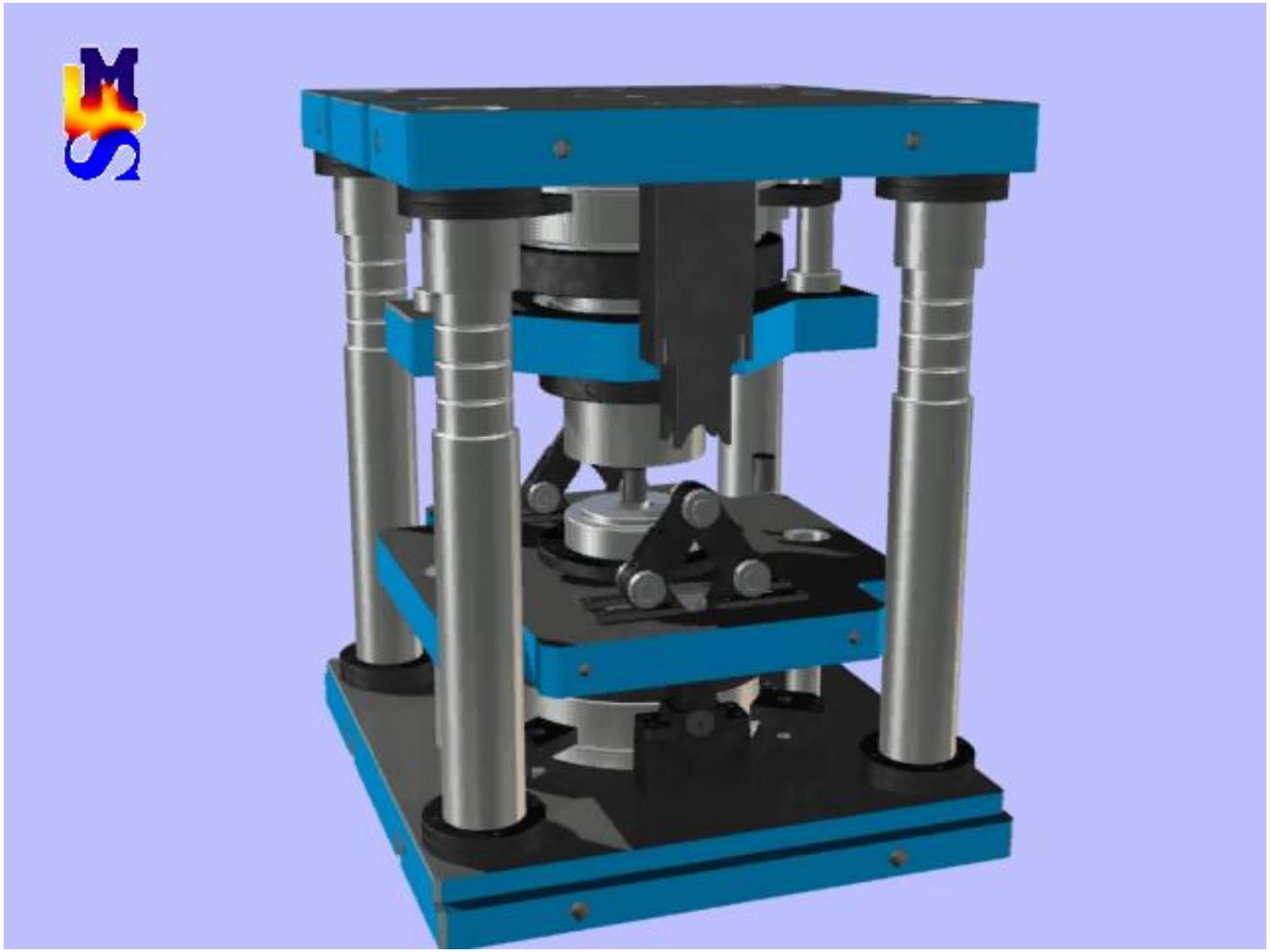


Bevel gear cold forging – FE Simulation

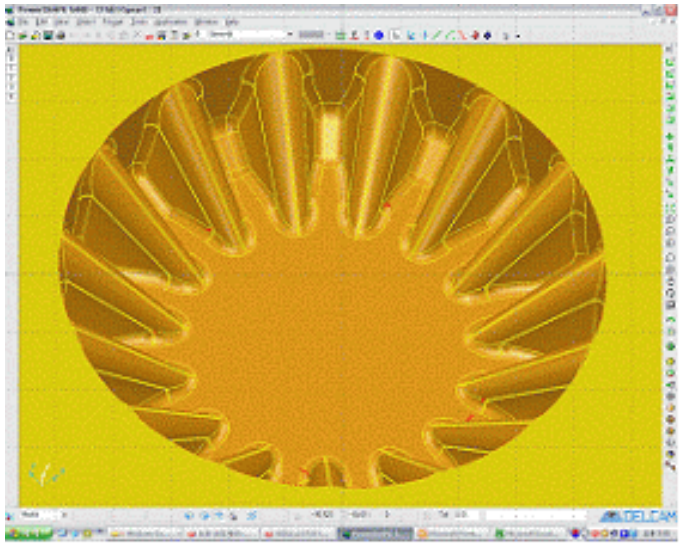


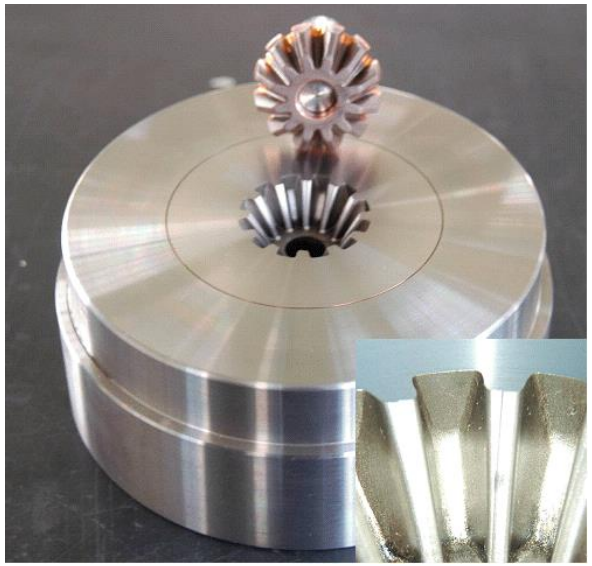


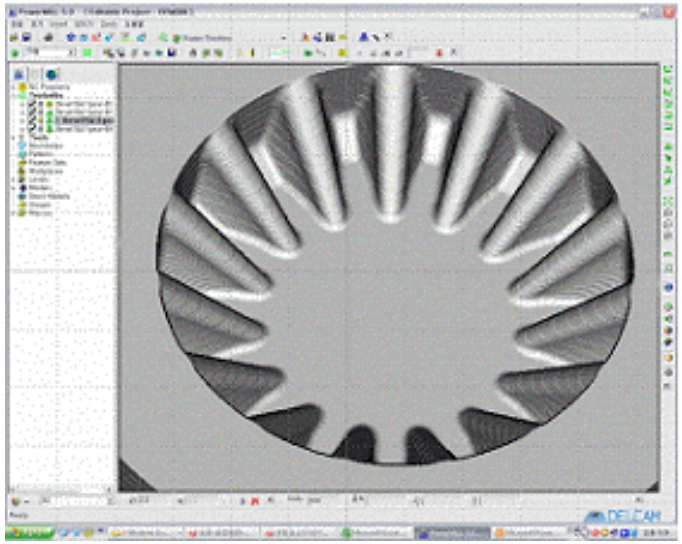
Bevel gear cold forging – Die set design

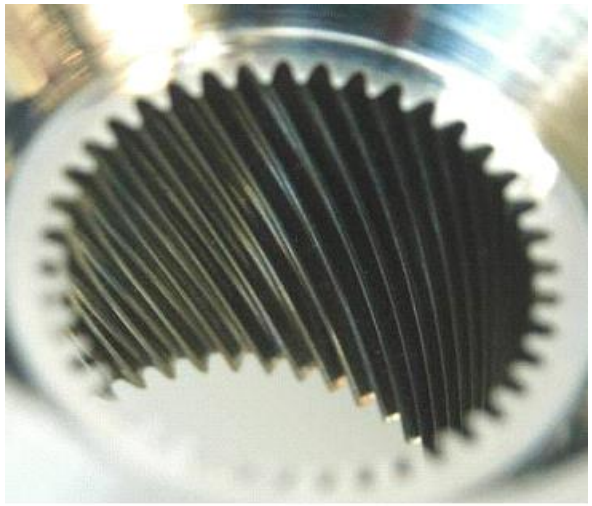


Bevel gear cold forging – CAM, Die making





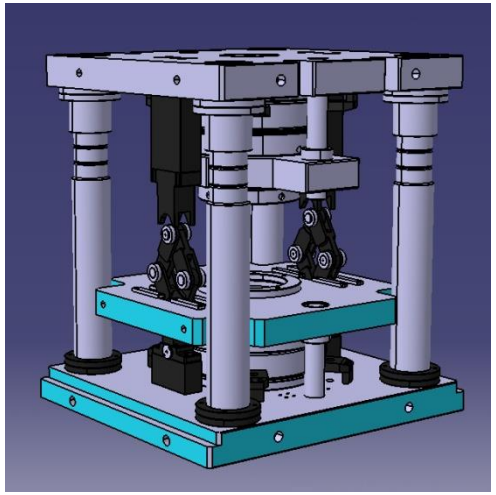


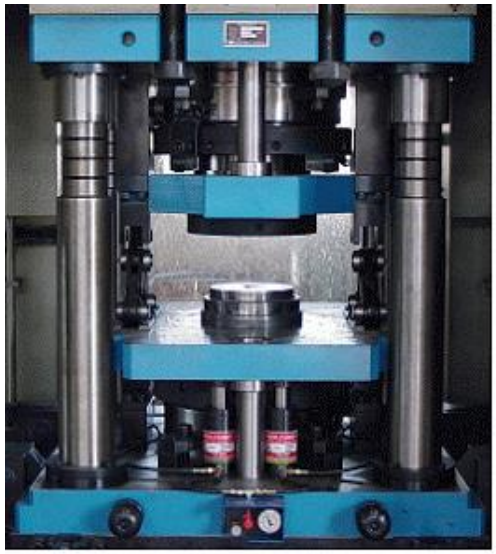


Bevel gear cold forging – Try-out

⊙ Forging equipment

⊙ Enclosed die set





⊙ Dies

Bevel gear cold forging – Evaluation