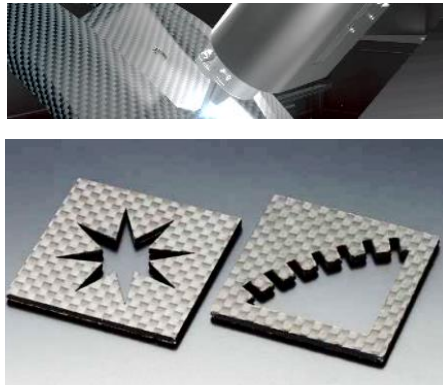
2024.4.18.

EPIC SUMMIT 2024

Mitsubishi Electric

Laser Processing Systems for SDGs



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2. Introduction of CFRP laser processing machine

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4. Introduction of laser wire DED machine

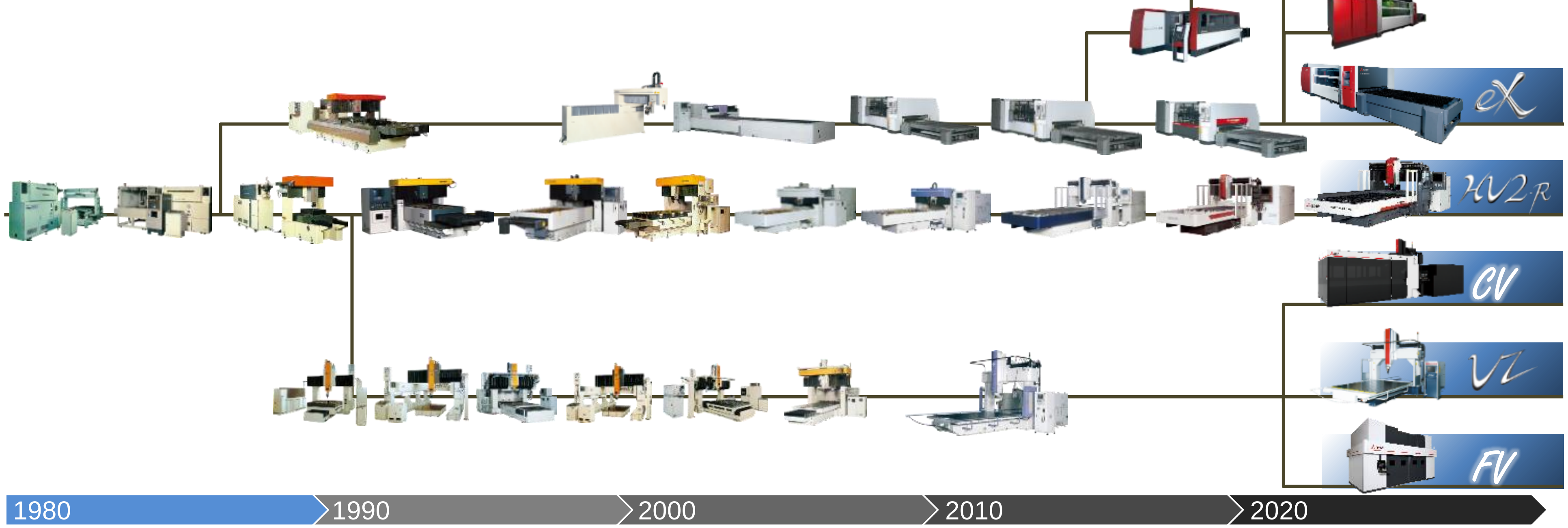
5. Application of laser wire DED machine AZ600

1-1 History of Mitsubishi laser machine

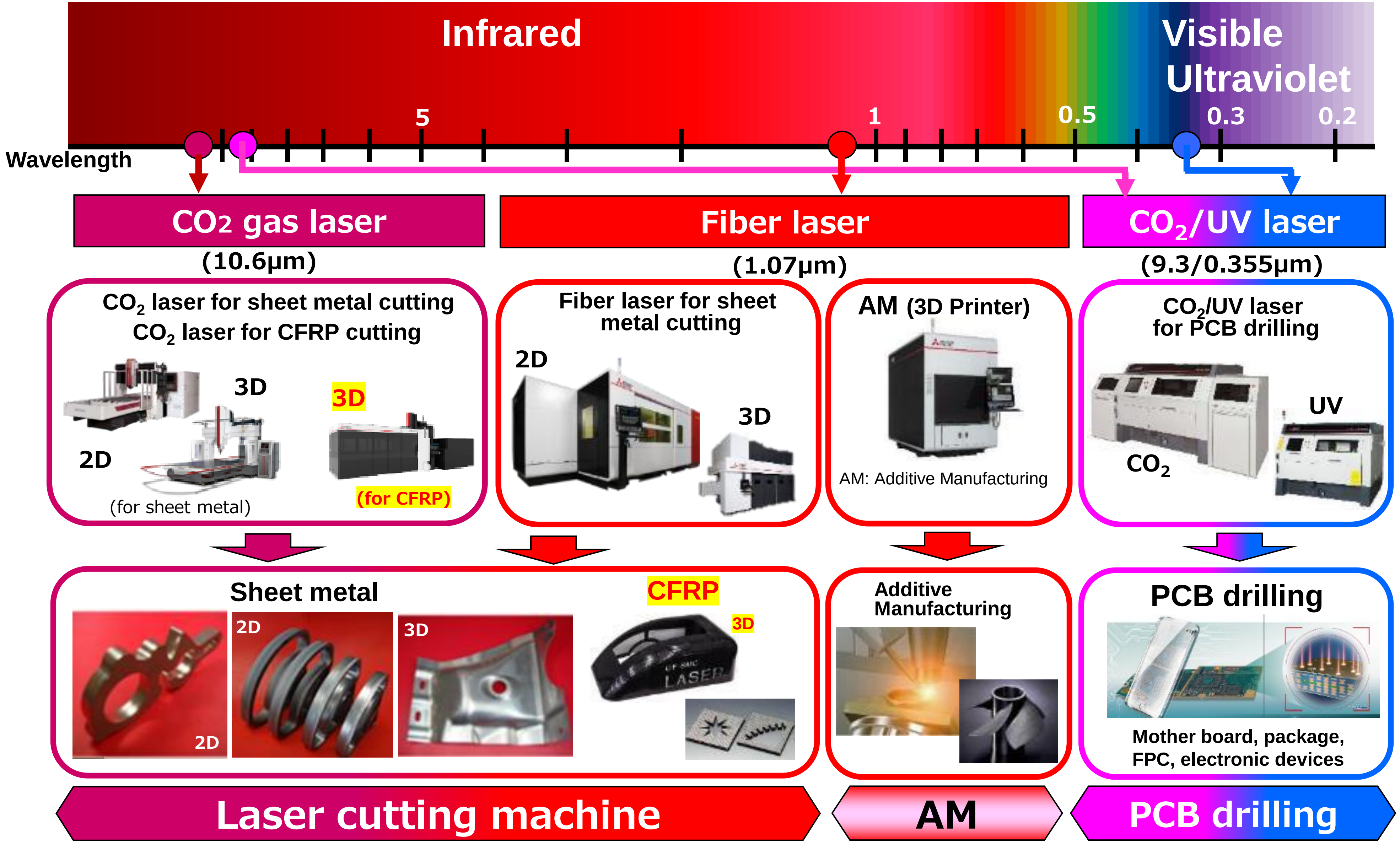
Mitsubishi made 2D CO_2 laser processing machine into a product for the first time in Japan in 1979.

MEL-LASER 45th Anniversary 1979-2024

- **2021** 3D laser processing machine for CFRP CV Series was launched
- **2020** 3D fiber laser processing machine was launched
- **2019** Next Generation fiber laser processing machine GX-F was launched
- **2012** Fiber laser processing machine was launched
- **1986** Productization of 3D laser processing machine
- **1979** Productization of 2D CO2 laser processing machine (first in Japan)
- **1967** CO2 laser research started



1-2 Lineup of Mitsubishi laser processing machine



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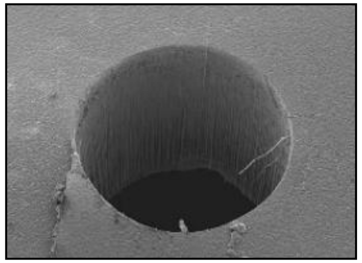
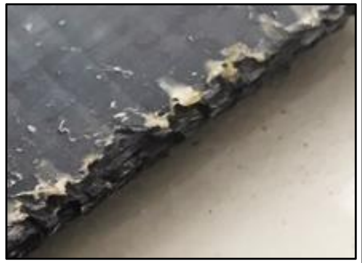
2-1 What type of oscillator is suited for CFRP cutting?

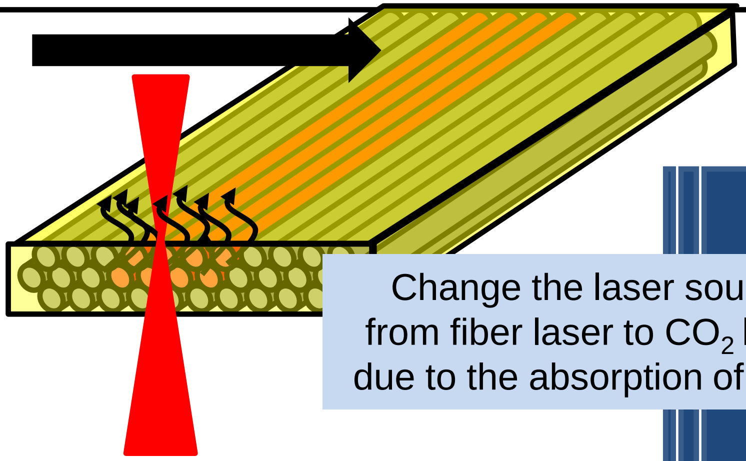
Thermosetting CFRP t2mm

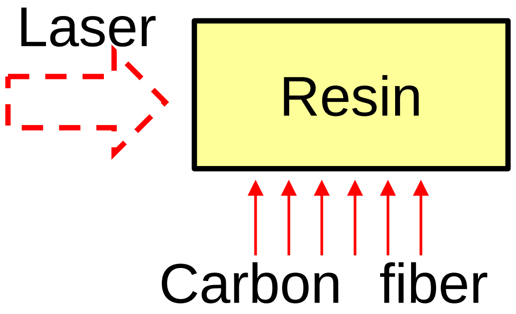
Oscillator	UV laser	CO_2 laser		Fiber laser
		PCB drilling	Sheet metal cutting	Sheet metal cutting
Wavelength	355nm	9.3μm	10.6μm	1.07μm
Pulse/CW	Pulse	Pulse	CW	CW
Average power	4W	200W	2500W	2500W
Pulse width	40ns	4μs	200μs	200μs
Cutting surface				
Cutting quality	◎	○	△	×
Cutting speed	× (0.19mm/min)	△ (2mm/min)	○ (6000mm/min)	○ (600mm/min)
Notes	Multi-pass processing (400Pass)	Multi-pass processing (150Pass)	Single pass processing	Single pass processing

The balance between cutting quality (decrease of heat-affected zone) and cutting speed is an issue for laser processing.
⇒Pulse laser oscillator with high power is necessary.

2-2 Reasons why we chose CO_2 laser

Fiber laser (wavelength: 1.07μm)
absorption rate:
Carbon fiber: 80%
Resin: 0% (Epoxy)

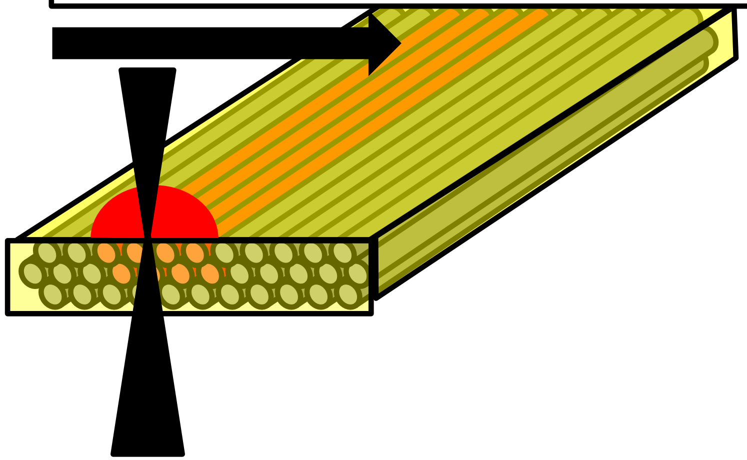


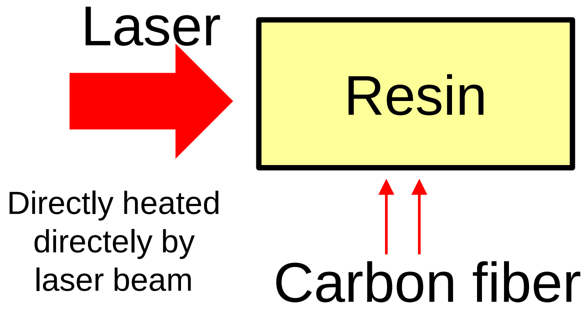


Resin is cut by heat transferred from carbon fiber
→Melts large amount of resin

Change the laser source from fiber laser to CO_2 laser due to the absorption of resin

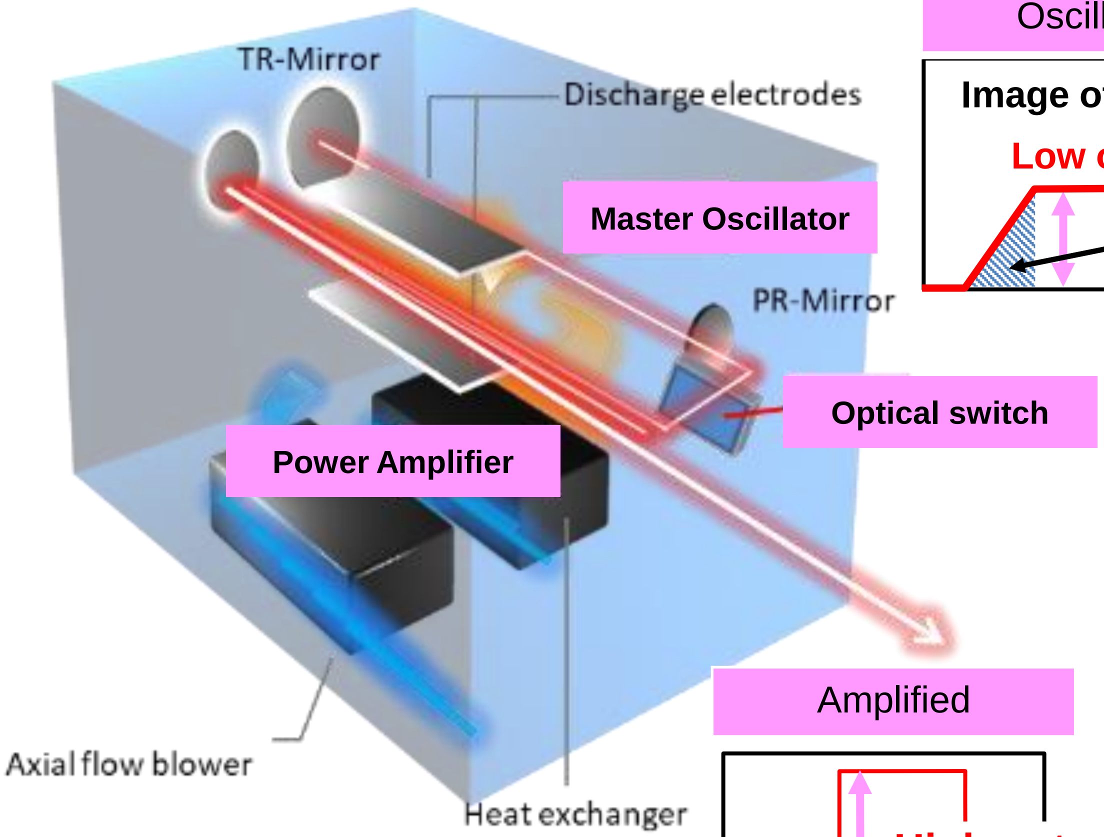
CO_2 laser (wavelength: 10.6μm)
absorption rate:
Carbon fiber: 40%
Resin: 100% (Epoxy)



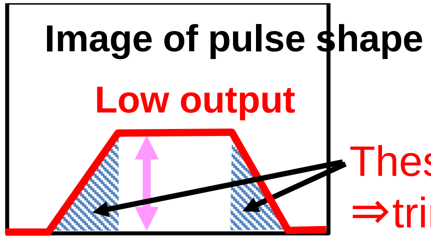


Both carbon fiber and resin are cut by heat input from laser

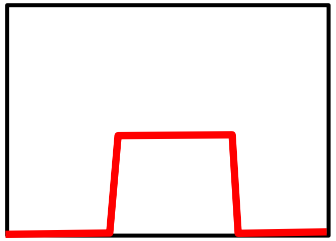
2-3 i-MOPA CO_2 laser for CFRP cutting



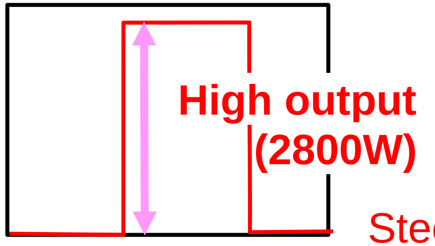
Oscillator



These area can cause thermal effect.
⇒trimmed by using optical switch



Amplified

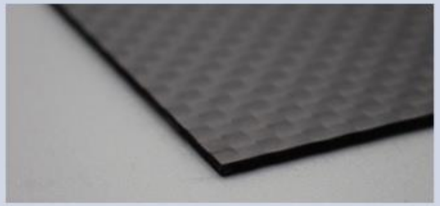
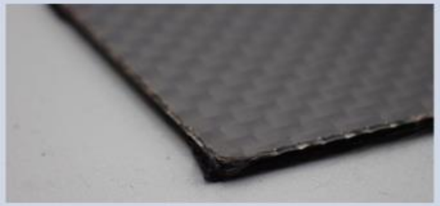
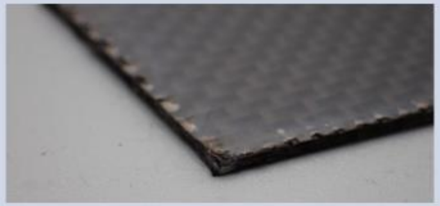
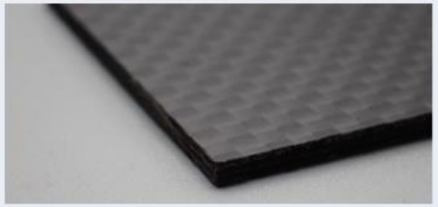
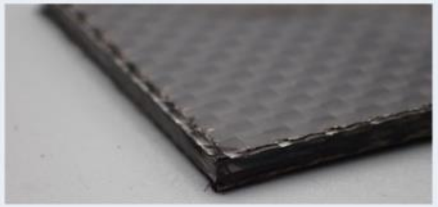
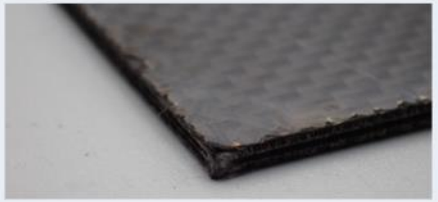
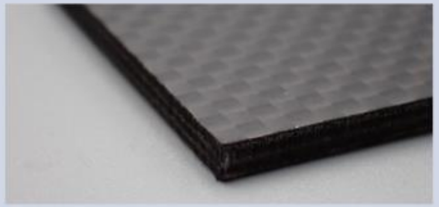
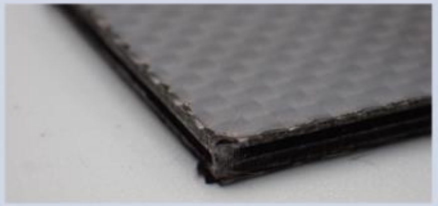
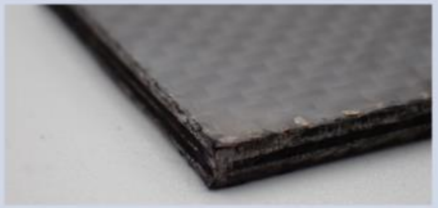


Steep pulse shape and high power

Peak power	2800W
Average power	1200W

2-4 Comparison with conventional laser processing

Cutting material: Thermosetting CFRP (prepreg)

Thickness (mm)	**New CO_2 laser**	Conventional CO_2 laser	Conventional Fiber laser
1.0			
2.0			
3.0			
	Small heat affected zone	Large heat affected zone	Large heat affected zone & crack

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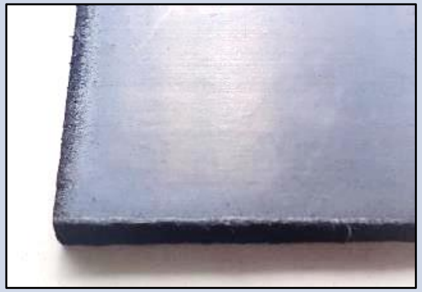
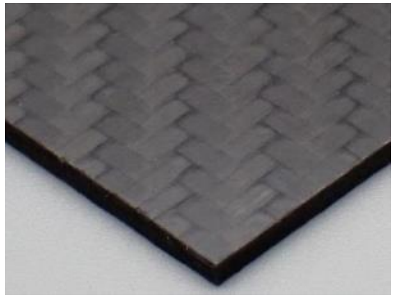
3-1 Examples of CFRTP cutting

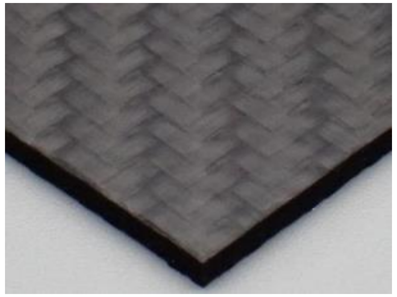
CFRTP (Carbon Fiber Reinforced Thermoplastics) PA6 t3mm

New CO_2 laser for CFRP CV series	Conventional CO_2 laser	Conventional Fiber laser
		

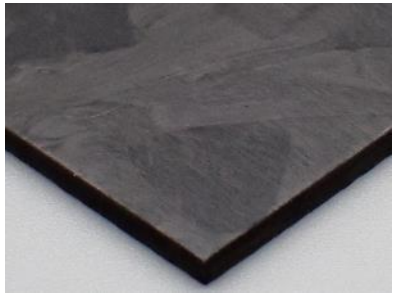
CFRTP t2mm (resin dependence)



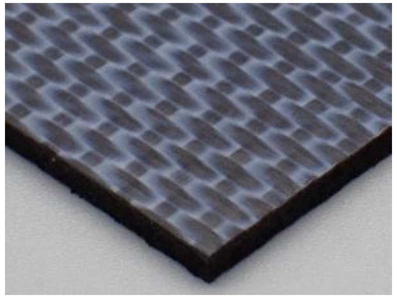
Resin：PC



Resin：PP



Resin：TEP

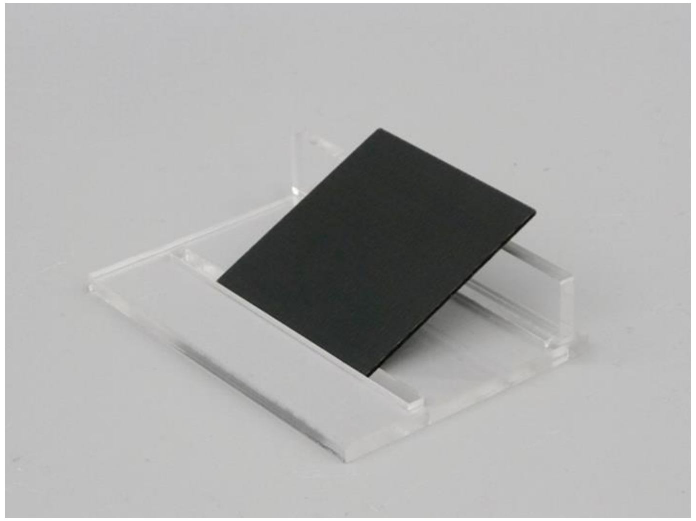


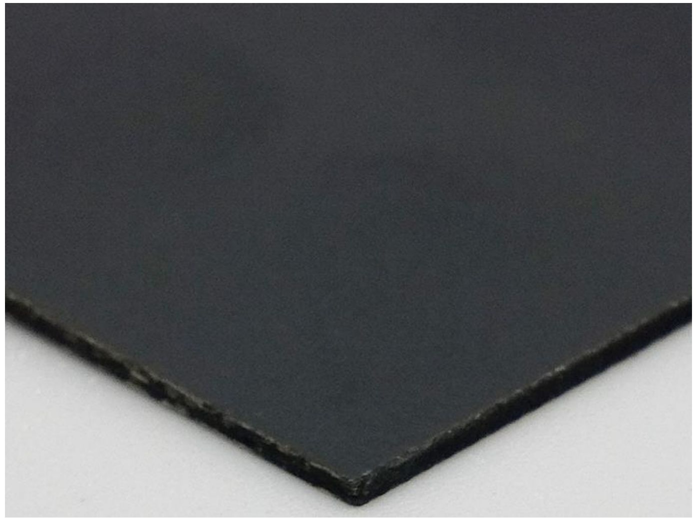
Resin：PEEK

3-2 Examples of GFRP/AFRP cutting

GFRP t1mm

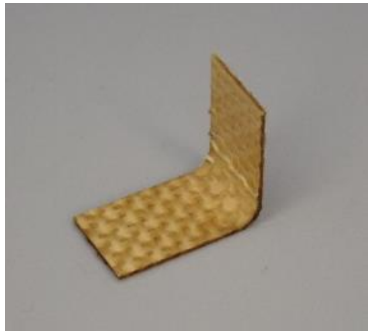
Glass Fiber Reinforced Plastics

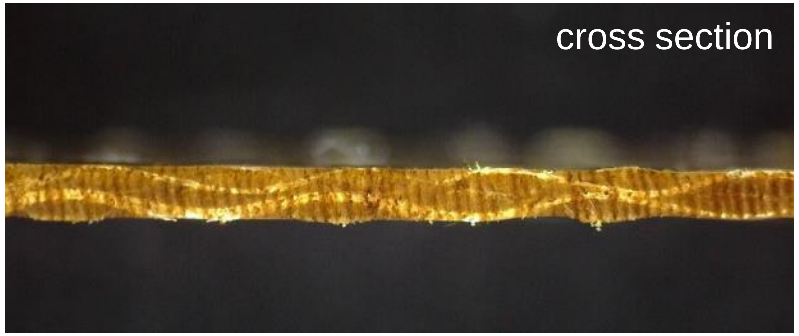




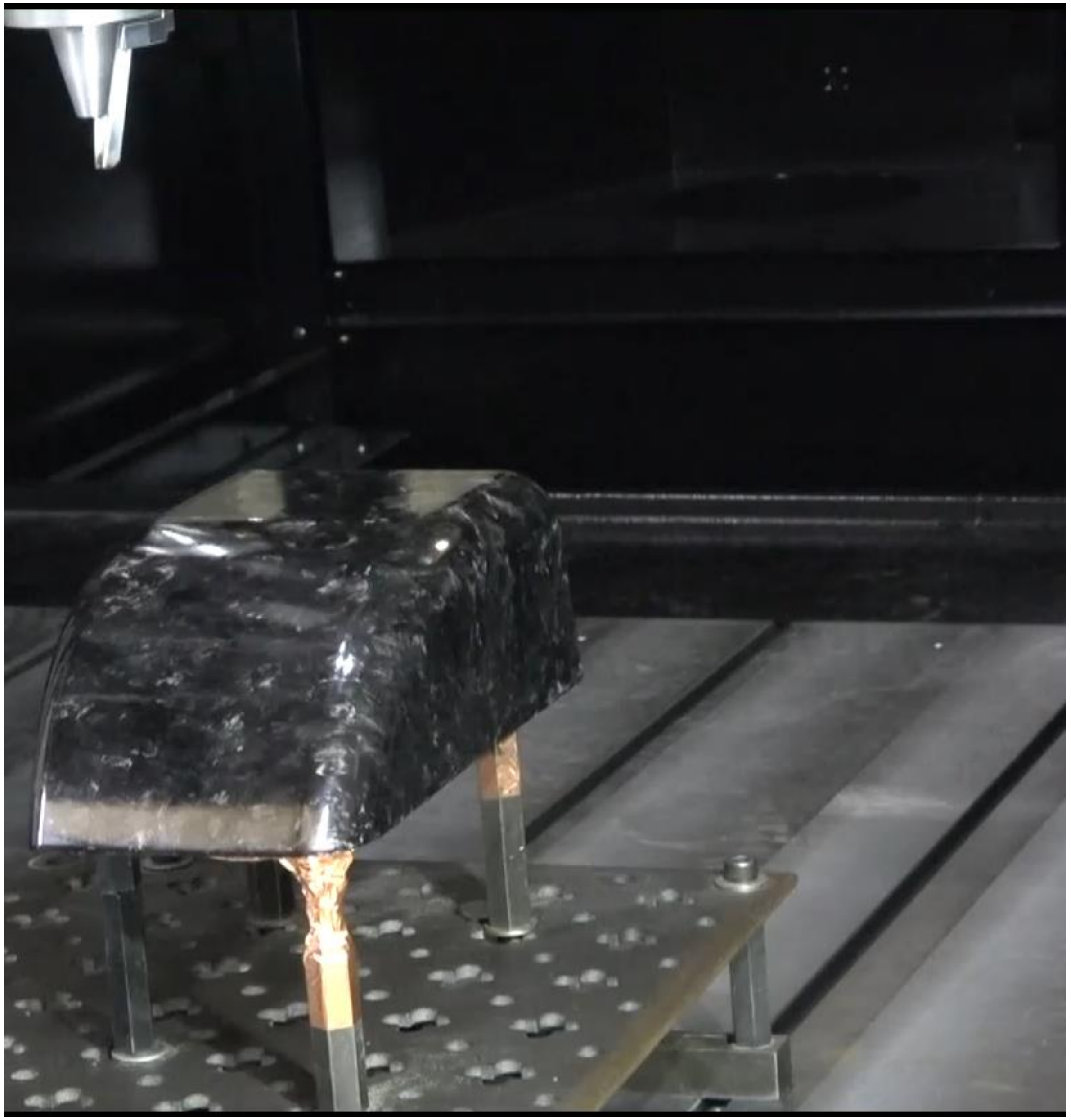
AFRP t1mm

Aramid Fiber Reinforced Plastic





3-3 Examples of 3D CFRP cutting



Material:CF-SMC (Mitsubishi Chemical)
Thickness:t1.4mm
Max Processing Speed:10m/min

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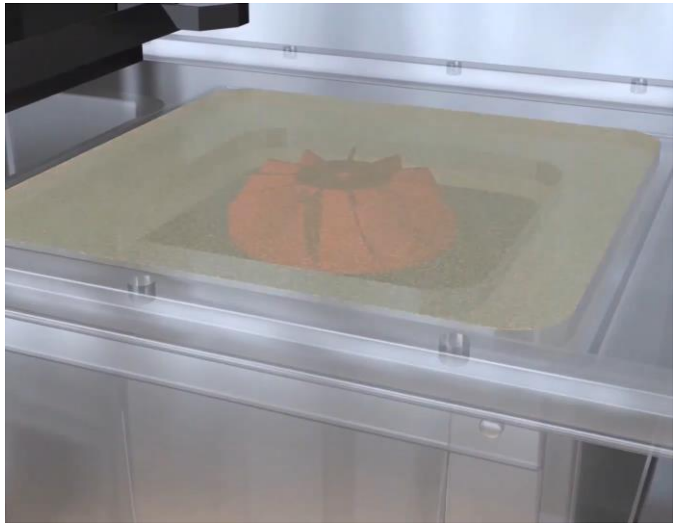
4-1 Background of the development of wire-laser DED

- Main process for metal AM include Directed Energy Deposition and Powder Bed Fusion.
- The two methods are used differently depending on the purpose of processing.

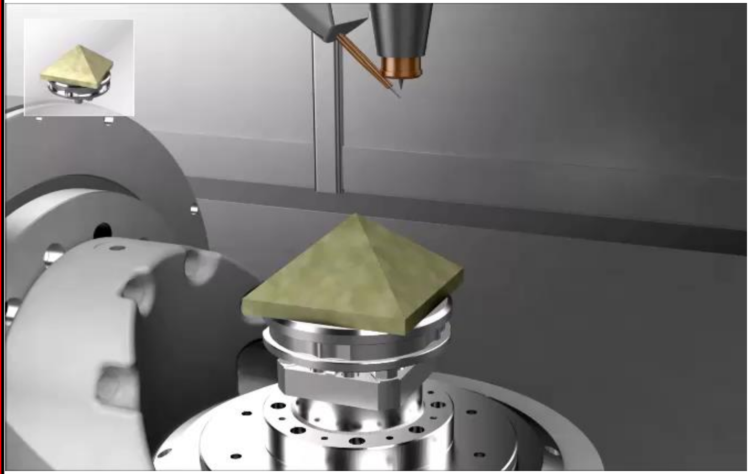
PBF Powder Bed Fusion

additive manufacturing process in which thermal energy selectively fuses regions of a powder bed



DED Directed Energy Deposition

additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being deposited



Features of DED process

- **Increase total productivity** by near-net shape processing
- **Large scale forming** without powder bed
- Deposition for a part of substrate material to **repair applications**
- **High yield** to supply material only to necessary part
- **Additive depositing of materials different** from substrate material

4-2 Background of the development of wire-laser DED

Advantages of wire-feedstock method

- **High-productivity** due to the high yield of feedstock materials
- **High-quality** build without voids inside
- **Clean** machine chamber and safe working environment without scattering metal powder
- **Easy environmental management** of humidity, temperature, etc. for feedstock storage
- **Easy** feedstock material **exchange**
- **Reliable** commercial welding wires available

Advantages of Laser-based method

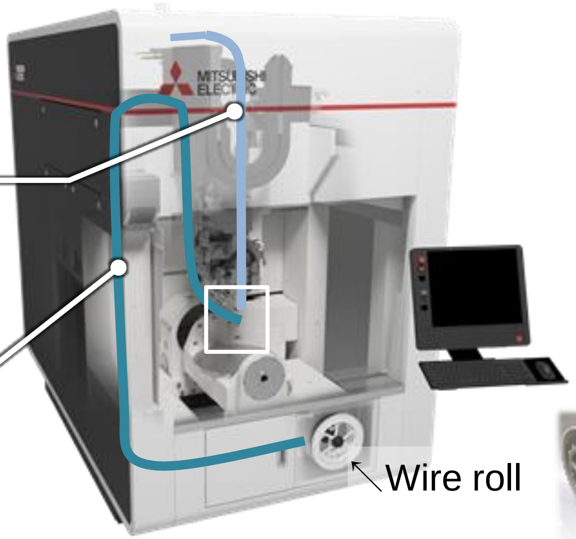
- **No vacuum chamber** that is required for an electron beam system
  - ➢ Reduced setup time
  - ➢ Easy-to-automate system
- **Higher-accuracy build** compared to arc-based DED
  - ➢ Faster post-processing

Each has many advantages, however in order to achieve synergies through combinations, axis movement, wire feed rate, and laser power must be precisely adjusted and controlled.

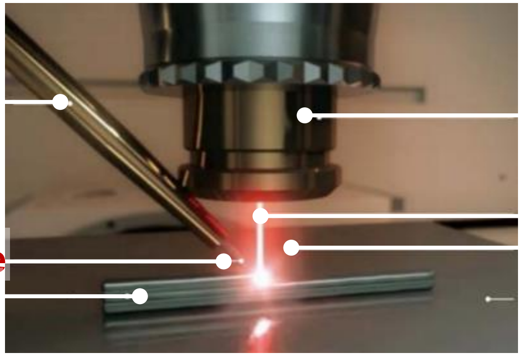
High-precision build control for wire-Laser method can only be developed by CNC manufacturers

4-3 Mitsubishi Electric Metal 3D Printer AZ600

Machine configuration



Processing head



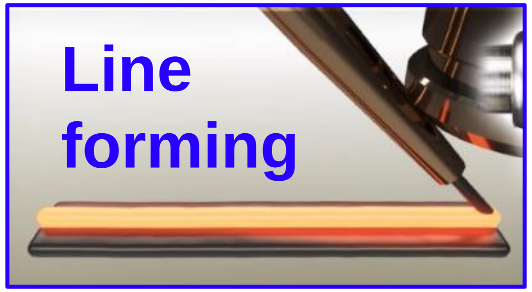
Wire laser DED method

Details

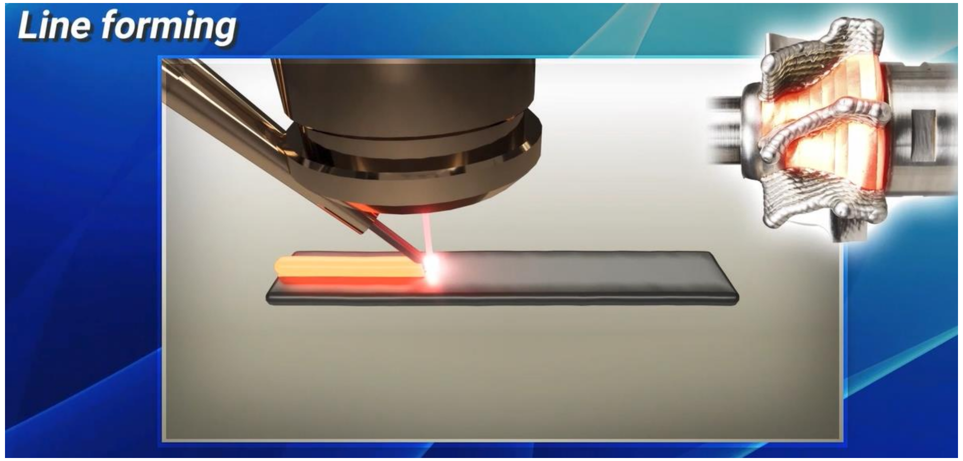
MODEL	AZ600-F20	AZ600-F40
Process category	Directed energy deposition (DED)	
Stroke (X x Y x Z)	600 × 600 × 600 [mm]	
Maximum workpiece size	500 x 500 x 500 [mm]	
Maximum load capacity	500 [kg]	
Laser output power	2 [kW]	4 [kW]
Main standard equipment	✓ 2-axis rotary table BC axis ✓ Height sensor, Shielding gas ✓ NC control ✓ Process monitoring camera ✓ Automatic slide cover (front door)	
Main options	✓ 2-axis rotary table AC axis ✓ Automatic slide cover (side, top)	

*Fume extraction system not included among standard accessories.

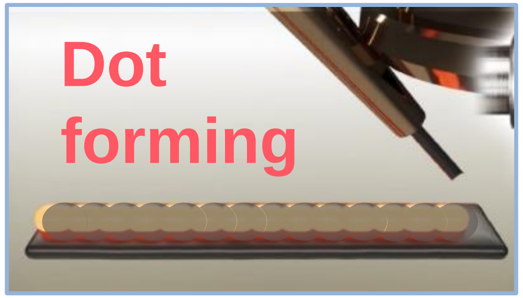
4-4 Forming Method



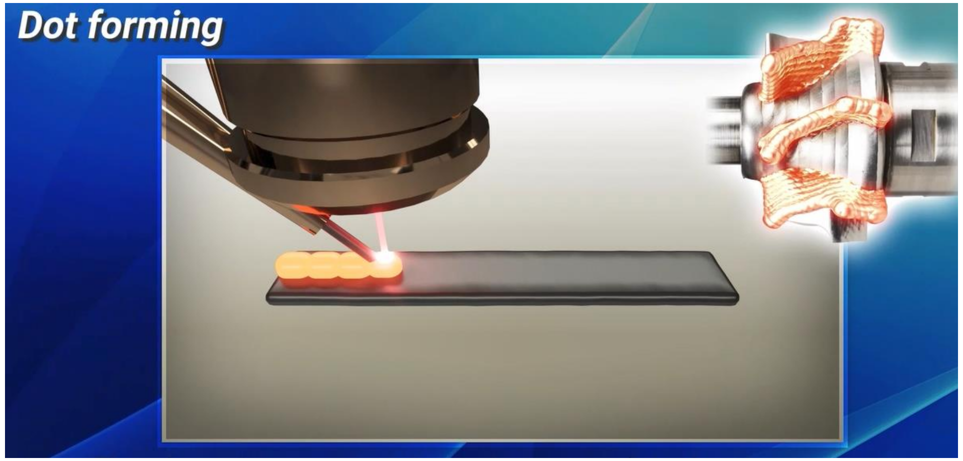
Forming speed: Fast
Temperature: High



- ✓ Normal



Forming speed: Not fast
Temperature : Low

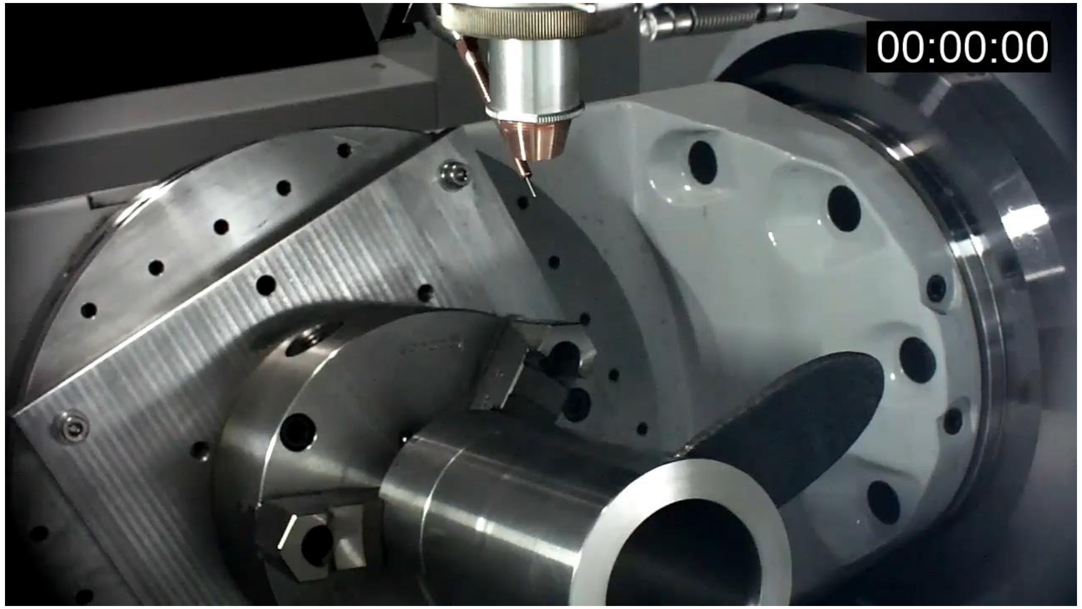


- ✓ Special
  - ・oxidation inhibition
  - ・Improved shape accuracy

4-5 Forming Processes

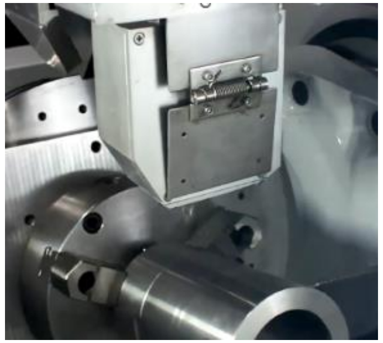
- ✓ AZ600 has a height sensor and a molten pool monitoring system with a coaxial camera.
- ✓ laser power, wire feed rate and Position can be controlled by them.

Propeller sample



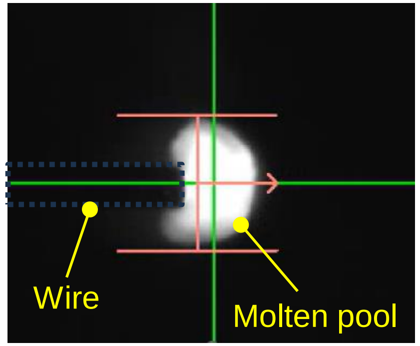
Wire	Stainless steel(17-4H)
Base material(ϕ99)	Stainless steel(304)
Printing time	90 min

Height measure



Printing

Molten pool monitoring



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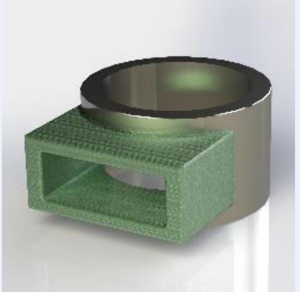
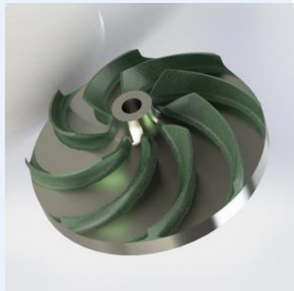
5-1 Application Cases

Types of test samples AZ600 specializes in

Partial formed



Flange
(Semiconductor manufacturing equipment)

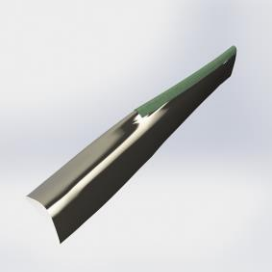


Impellers
(for hydraulic power generation)

■ Machinery Manufacturing

Partial reinforcement

Drill Bits
(for mining drilling)

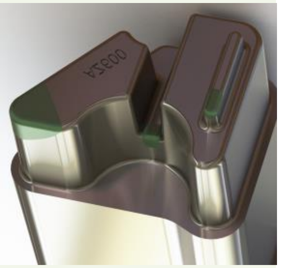


Turbine Blades
(Gas turbine)

■ Energy, Oil & Gas, Heavy & Agricultural Machinery, Tools & Gears, Seals & Valves, etc.

Mold Repair

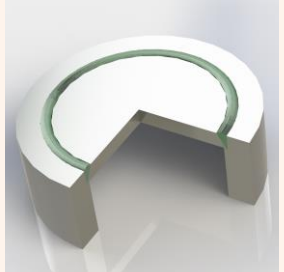
Glass mold manufacturing



Die casting mold repair

■ Automotive & mold industry

Welding



TIG welding alternative
(Gas turbine combustors)

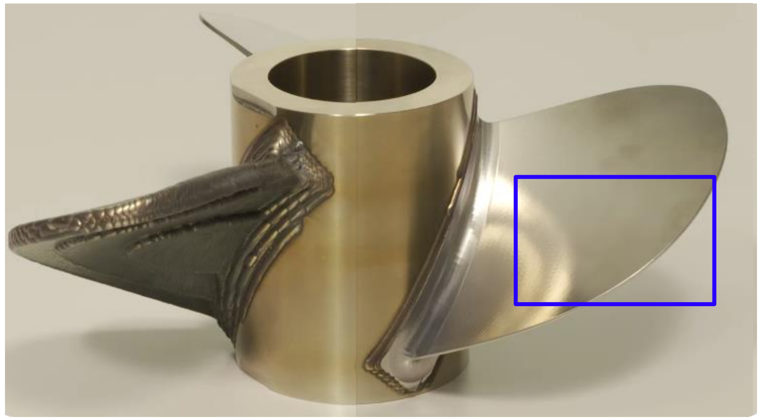
groove welding

■ Energy & Infrastructure, Aerospace, Oil & Gas, Construction & Agricultural Machinery, etc.

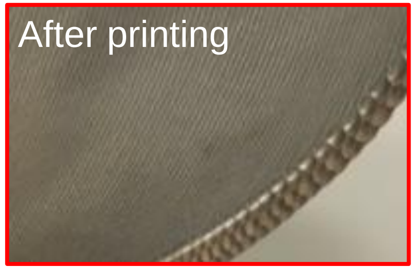
5-2 Application Case -Propeller-

- Taking time to prepare the balk material and wasting resources.
- Estimated 80% reduction in machining time by combining multilayer molding and cutting.

Propeller for marine industry



Wire: Stainless steel(φ300) Substate: SUS304(φ99)

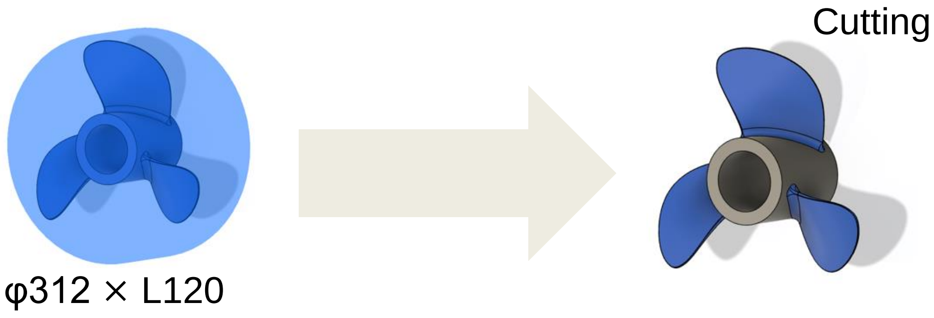


Time: 9 hours

Time: 31 hours

Comparison between cutting and 3D printing

Conventional(cutting processing)



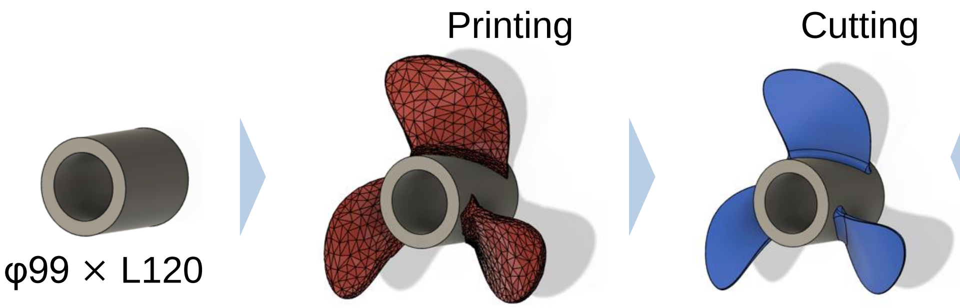
Cutting time

160 hours

(300 kg・CO_2)

DOWN 80% of Processing time

3D printing by AZ600



Total time

40 hours

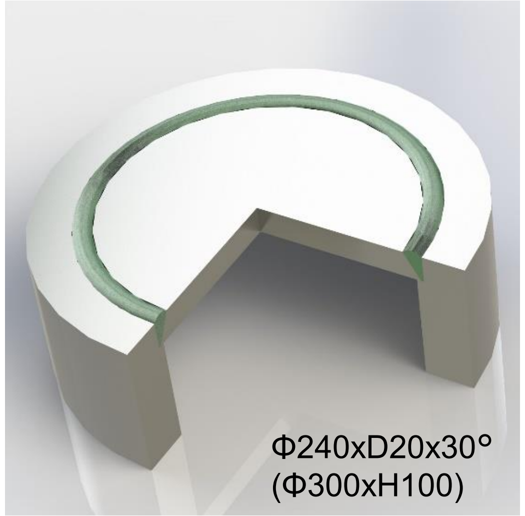
(100 kg・CO_2)

5-3 Application Case -Alternative for TIG welding-

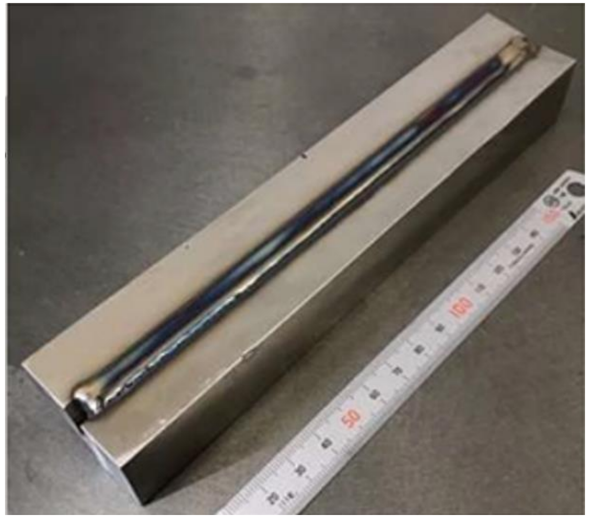
- The wire-Laser metal 3D printer as an alternative to TIG welding
- This process also addresses the automation and labor savings of the welding industry, which requires experience and know-how.

Groove welding on stainless steel parts

Customer needs

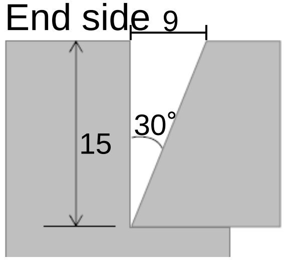


Practice geometry

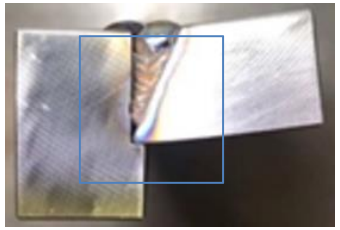


Substate geometry and results

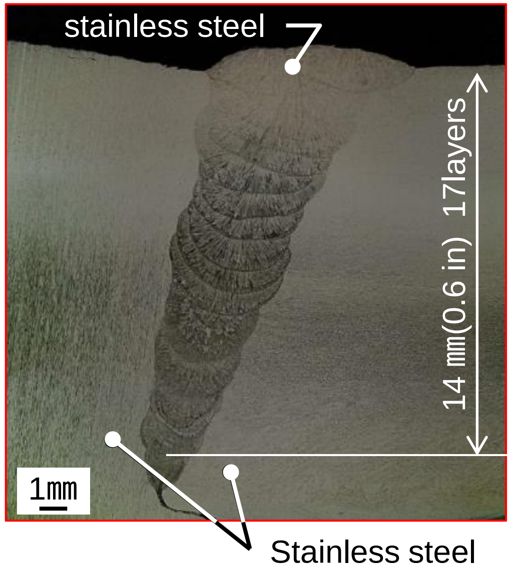
End side



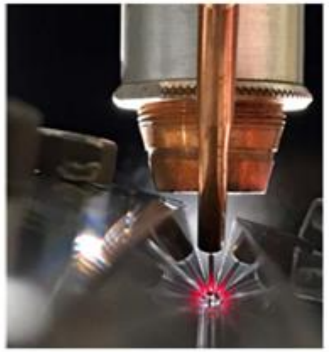
Unit:mm



Optical microscope image



Stainless steel
(Substrate)



Approachable head to the edge

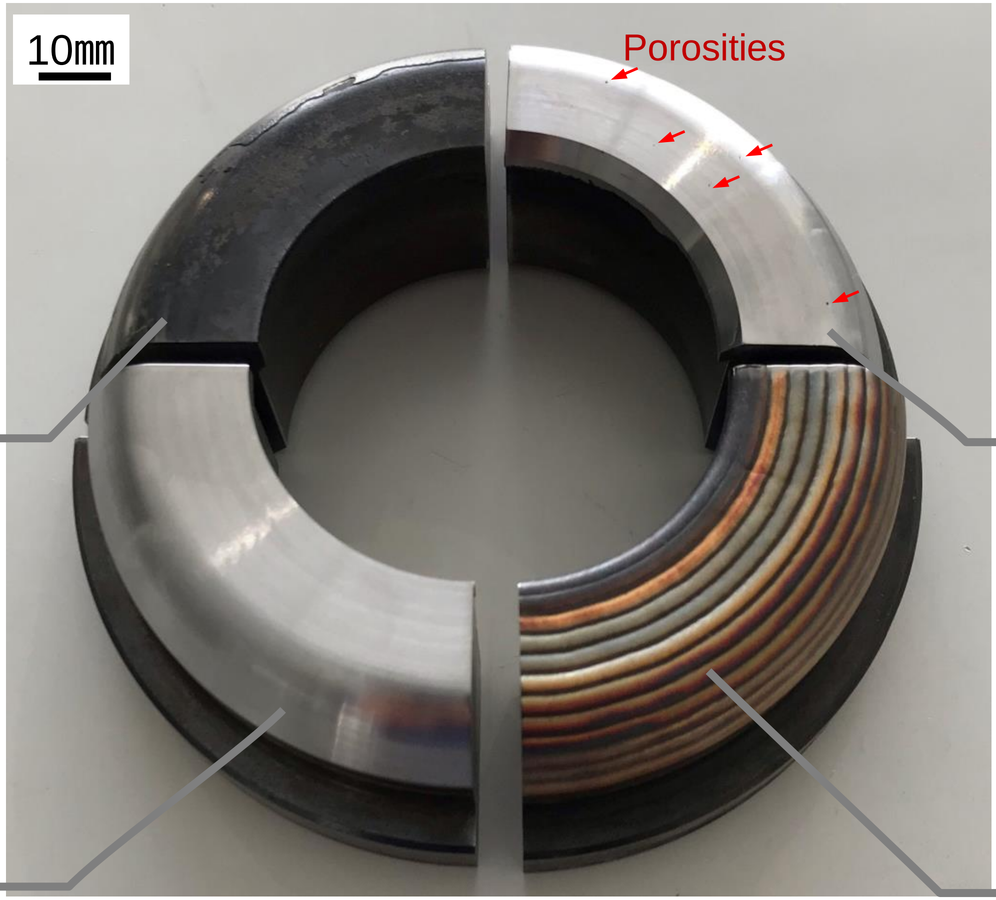
5-4 Application Case -Mold Repair-

- Application case for hot forging die in the automotive industry.
- Conventionally, the dis is repaired by TIG welding which defects have remained.
  TIG welding time: 90 min. vs. 3D printing time; 14 min. Base material and wire are H13

Broken mold

1

- ✓ Problem: Abrasion



Pre-processing

2

- ✓ Turning

3D printing

3

Purposes:

- ✓ C/t reduction
- ✓ Quality improvement

Post-processing

4

- ✓ Turning

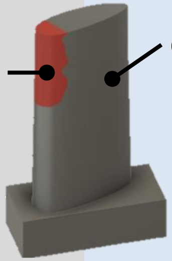
5-5 Application Case -Turbine MRO-

■ There has been a noticeable rise in demand for turbine blades within the maintenance, repair and overhaul (MRO) market

Turbine blade

Corrosion

Conventional	AM built Turbine
Repairing Stellite®6 **by TIG welding**	ex)Stainless Steel **by AZ600* DED**
Issues by hand-welding	**Merits of AZ600**
✓ Handcraft	**5-axis control** **Improving quality**
✓ Time(Efficiency)	**High-speed (High-efficiency)**



AM processes (in-house process validation)

1) Preparing the substrate(□70×t35㎜)
2) AM printing of Stainless Steel 17-4PH
3) Workpiece setup and wire feedstock require manual alteration
4) AM building of Stellite®6

Building time:
17-4PH= 195 mins.
Stellite®6= 3 mins.

*AZ600 can't achieve "Directional Solidification" on AM processes, therefore NSG 9.B.1.c is not applicable.

Conclusion

1. **CFRP laser processing**
   (1) High-Speed
   Cutting speed is more than twice that of conventional
   (2) Low Running Cost
   Few consumable parts and industrial waste

2. **Laser Wire DED**
   (1) Near net shape
   Effective for reducing material costs and total machining time
   (2) Dissimilar material depositing
   Improving functionality by building up different types of materials
   (3) Clean & Eco
   The material scatters less and almost all materials are used to be built.

Thank you for your attention

MITSUBISHI ELECTRIC

Changes for the Better