Aspects and embodiments are directed to a method and system for laser welding metal substrates to one another by applying laser energy to a backside surface of a top plate that forms one of the metal substrates.

According to a first aspect of the present invention~~one embodiment~~, a method for laser welding a first metal substrate to a second metal substrate is provided. The first metal substrate has a first planar surface and a second planar surface disposed opposite the first planar surface, and the method includes selecting first and second metal substrates of a titanium alloy~~having a thickness, surface tension and thermal characteristics suitable for controlled flow thereof when in a molten state~~, placing an end face of the second metal substrate proximate to the first planar surface, generating an input laser beam from a fiber laser having a power of at least 1 kW, providing a beam delivery system ~~configured to~~which receives the input laser beam and~~to~~ generates an output laser beam having a beam spot that moves in a predetermined pattern along a first axis and a second axi~~e~~s, and passing the input laser beam through the beam delivery system to irradiate a target area on the second planar surface of the first metal substrate with the beam spot, the target area positioned over an intersection region of the first planar surface where the end face is positioned proximate to the first planar surface, wherein irradiating in the predetermined pattern along the first axis and the second axis creates a dual fillet weld such that a fillet weld is formed in each corner area between the first and second metal substrates in a single pass of the beam spot.

According to one embodiment, the beam delivery system is configured to generate a defocused output laser beam.

According to another embodiment, ~~irradiating creates a dual fillet weld such that a fillet weld is formed in each corner area between the first and second metal substrates. In another embodiment,~~ each fillet weld has a weld face with a smooth profile.

In another embodiment, irradiating creates a weld region that extends through a thickness of the first metal substrate and a thickness of the second metal substrate. According to another embodiment, a cross section of the weld region has a uniform hardness. In another embodiment, the weld region has a small grain size. In some embodiments the weld region has a low porosity. In some embodiments, a cross section of the weld region has at least one of a uniform hardness, small grain size, and a low porosity.

According to one embodiment, placing the end face of the second metal substrate proximate to the first planar surface includes a gap between the end face and the first planar surface, the gap being a distance of up to about one quarter of the thickness of the first metal substrate.

According to another embodiment, the method further includes positioning the output laser beam to have an incident angle of up to 10 degrees from a reference line perpendicularly incident to the second planar surface.

In certain embodiments, the predetermined pattern is one of a circular pattern, a linear pattern, a figure-eight pattern, and an infinity pattern.

In another embodiment, the method includes directing a flow of inert shielding gas to the target area.

In another embodiment, the method includes aligning the predetermined pattern with the intersection region.

In another embodiment, the method includes directing the beam spot along a length of the first metal substrate.

In accordance with a second~~nother~~ aspect of the present invention~~embodiment~~, a system for laser welding a first metal substrate to a second metal substrate is provided. The first metal substrate has a first planar surface and a second planar surface disposed opposite the first planar surface, and the second metal substrate has an end face positioned proximate to the first planar surface, and the system includes a fiber laser energy source configured to generate an input laser beam having a power of at least 1kW, and a beam delivery system configured to: receive the input laser beam and ~~to~~ generate an output laser beam having a beam spot that moves in a predetermined pattern along a first axis and a second ax~~i~~es, and irradiate a target area on the second planar surface of the first metal substrate with the beam spot, the target area positioned over an intersection region of the first planar surface where the end face is positioned proximate to the first planar surface, the first metal substrate and the second metal substrate are of a titanium alloy, and the fiber laser energy source and the beam delivery system are configured such that the irradiation of the target area forms a fillet weld in each corner area between the first and second metal substrates in a single pass by the beam spot.

According to another embodiment, the system includes a controller configured to control the beam delivery system such that the predetermined pattern is aligned with the intersection region.

According to another embodiment, the beam delivery system is configured to generate a defocused output laser beam.

~~According to another embodiment, the fiber laser energy source and the beam delivery system are configured such that the irradiation of the target area forms a fillet weld in each corner area between the first and second metal substrates.~~

According to some embodiments, each fillet weld has a weld face with a smooth profile.

In some embodiments the irradiation of the target area creates a weld region that extends through a thickness of the first metal substrate and a thickness of the second metal

CLAIMS

1. A method for laser welding a first metal substrate to a second metal substrate, the first metal substrate having a first planar surface and a second planar surface disposed opposite the first planar surface, the method comprising:

selecting the first and second metal substrates ~~having a thickness, surface tension and thermal characteristics suitable for controlled flow thereof when in a molten state~~of a titanium alloy;

placing an end face of the second metal substrate proximate to the first planar surface;

generating an input laser beam from a fiber laser having a power of at least 1 kW;

providing a beam delivery system ~~configured to receive~~which receives the input laser beam and ~~to generate~~generates an output laser beam having a beam spot that moves in a predetermined pattern along a first axis and a second ax~~e~~is; and

passing the input laser beam through the beam delivery system to irradiate a target area on the second planar surface of the first metal substrate with the beam spot, the target area positioned over an intersection region of the first planar surface where the end face is positioned proximate to the first planar surface~~.~~.

~~2. The method of claim 1,~~ wherein irradiating in the predetermined pattern along the first axis and the second axis creates a dual fillet weld such that a fillet weld is formed in each corner area between the first and second metal substrates in a single pass of the beam spot.

~~3. The method of claim 2, wherein each fillet weld has a weld face with a smooth profile.~~

2~~4~~. The method of claim 1~~2~~, wherein:

irradiating creates a weld region that extends through a thickness of the first metal substrate and a thickness of the second metal substrate.

~~5. The method of claim 4, wherein a cross section of the weld region has at least one of a uniform hardness, small grain size, and low porosity.~~

~~6~~3. The method of claim 1, wherein placing the end face of the second metal substrate proximate to the first planar surface includes a gap between the end face and the first planar

surface, the gap being a distance of up to about one quarter of the thickness of the first metal substrate.

~~7~~4. The method of claim 1, further comprising positioning the output laser beam to have an incident angle of up to 10 degrees from a reference line perpendicularly incident to the second planar surface.

~~8~~5. A system for laser welding a first metal substrate to a second metal substrate, the first metal substrate having a first planar surface and a second planar surface disposed opposite the first planar surface, and the second metal substrate having an end face positioned proximate to the first planar surface, the system comprising:

a fiber laser energy source configured to generate an input laser beam having a power of at least 1 kW; and

a beam delivery system configured to:

receive the input laser beam and ~~to~~ generate an output laser beam having a beam spot that moves in a predetermined pattern along a first axis and a second axi~~e~~s, and

irradiate a target area on the second planar surface of the first metal substrate with the beam spot, the target area positioned over an intersection region of the first planar surface where the end face is positioned proximate to the first planar surface~~.~~,

~~9. The system of claim 8, further comprising a controller configured to control the beam delivery system such that the predetermined pattern is aligned with the intersection region.~~

~~10. The system of claim 8, wherein the beam delivery system is configured to generate a defocused output laser beam.~~

~~11. The system of claim 8,~~ wherein the first metal substrate and the second metal substrate are of a titanium alloy; and

wherein the fiber laser energy source and the beam delivery system are configured such that the irradiation of the target area forms a fillet weld in each corner area between the first and second metal substrates in a single pass by the beam spot.

~~12~~6. The system of claim ~~11, wherein each fillet weld has~~5, further comprising a ~~weld face~~controller configured to control the beam delivery system such that the predetermined pattern is aligned with the intersection region, and/or wherein the beam delivery system is configured to generate a ~~smooth profile~~defocused output laser beam.

~~13~~7. The system of claim ~~8~~5, wherein the ~~irradiation of~~beam delivery system is configured to irradiate the target area ~~creates~~to create a weld region that extends through a thickness of the first metal substrate and a thickness of the second metal substrate.

~~14. The system of claim 13, wherein the weld region has at least one of uniform hardness, low porosity, and small grain structure.~~

~~8~~15. The system of claim 5~~8~~, wherein~~:~~ the beam delivery system is configured to direct the output laser beam at an incident angle of up to 10 degrees from a reference line perpendicularly incident to the second planar surface~~.~~, and/or

~~16. The system of claim 8, wherein~~ the beam delivery system includes movable mirrors configured to generate the predetermined pattern along the first axis and second ax~~i~~es.

~~17~~9. The system of claim ~~16~~5, wherein~~:~~ the beam delivery system includes movable mirrors configured to generate the predetermined pattern along the first axis and second axis, and the movable mirrors are configured to generate ~~one of a~~ one of a circular pattern, a linear pattern, a figure-eight pattern, and an infinity pattern as the predetermined pattern.

~~18. The system of claim 17, wherein the first and second metal substrates are a titanium alloy.~~

109. The system of claim 85, further comprising a flow of inert shielding gas directed at the target area.

~~20. The system of claim 8, wherein the first and second metal substrates have a thickness, surface tension and thermal characteristics suitable for controlled flow thereof when in a molten state.~~