Efficient TEA CO_2 laser based coating removal system

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ABSTRACT

A high power 1kW pulsed transversely excited atmospheric CO_2 laser that has been developed for the paint stripping of missiles was used to test paint stripping on several metallic and composite aircraft panels to determine the rate at which this laser could remove paint from aircraft.

KEYWORD LIST

CO_2 laser, Laser based paint stripping

INTRODUCTION

The use of lasers for ablative material removal was first proposed in 1987.[1] Although the mechanism of removal is not known with certainty, it may occur as follows as illustrated in figure 1:

- The laser pulse transforms the first microns of the layer into highly compressed plasma.
- The plasma generates a shock wave that ejects the layer as fine particles.
- The substrate is preserved by keeping energy density below the damage threshold.

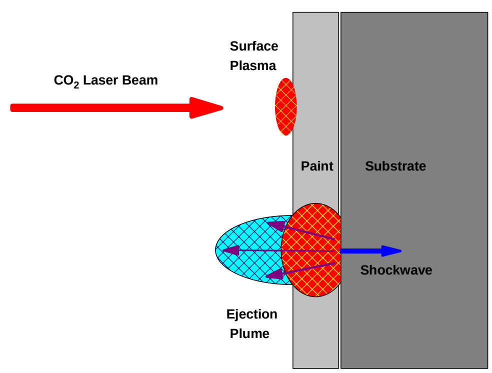

Figure 1: Schematic illustration of laser paint stripping

The advantage of a pulsed TEA CO_2 laser system is that a laser frequency and temporal profile can be chosen to maximize paint removal and concurrently minimize substrate damage. To achieve this the characteristics of the paint and substrate must be well understood to take full advantage of the selectivity of the system.

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LASER BASED PAINT STRIPPING

Important operational issues related to damage of the substrate must be answered before laser based paint stripping will be accepted as an alternative to chemical or mechanical paint stripping. Some of the most important attributes of laser stripping are:

- The process eliminates the use of toxins
- Eliminates large volumes of hazardous wastes
- The small volume of particulate from the coatings and paints, even if hazardous, can be handled easily
- Eliminates potential failures initiated by corrosion caused by chemical residues in surfaces and seams
- Contains and potentially reduces the cost and time of paint stripping operations

The typical intensity required for paint stripping, depending on type of paint, thickness and substrate material, varies between 2 - 5J.cm^{-2}. With regards to the pulse length, a somewhat longer pulse width with a distinct tail is beneficial because it reduces plasma formation and target screening. In addition high repetition rates also helps as the irradiated surface is not allowed to completely cool down between pulses. With 1,500W average power one would be able to strip at a rate of >10m^2/h.[2-6]

EXPERIMENTAL SETUP

A high power pulsed CO_2 laser, WH1000, has been developed and manufactured by SDI.[7,8] A picture of this laser is given below in figure 2.

Figure 2: WH1000 High power transversely excited atmospheric (TEA) CO_2 laser

This laser is being used by Raytheon Missile Systems in a work cell for the decoating of airframes. The typical operating parameters of this laser for extended periods of operation are given below in table 1.

Parameter	Values
Pulse Energy	3.8J
Repetition Rate (Hz)	265Hz
Average Power	1,007W
Pulse Length	10us
Beam Dimensions	30 x 30

Table 1: Typical operating parameters of WH1000 TEA CO2 laser

Following the successful development and implementation of this system, a similar system was used to test several metallic and composite panels of commercial aircraft as well as other painted surfaces as shown in figure 3.

Figure 3: Decoating of a 180 to 230µm thick multi-layer painted surface

A schematic illustration of the experimental laser setup that was used to test these components is shown below in figure 4. To allow the output of this laser to be coupled on to the samples, a beam propagation layout was designed that would create a square beam with an area of 1cm^2 with a long Rayleigh range. The latter is essential, if one wishes to ensure that small distance variation caused by, say a curved surface, does not affect the beam intensity significantly.

Initial tests were done on the samples without nozzle and dust extraction unit. This lead to the production of large amounts of soot that was deposited on the surface of the sample, severe attenuation of the laser beam, and often the frequent creation of a laser sustained plasma in front of the sample as can be seen quite clearly in figure 3. Significant improvements in the stripping rates were achieved once a large volume extraction system and an air knife were installed to remove the dust created by the ablation process.

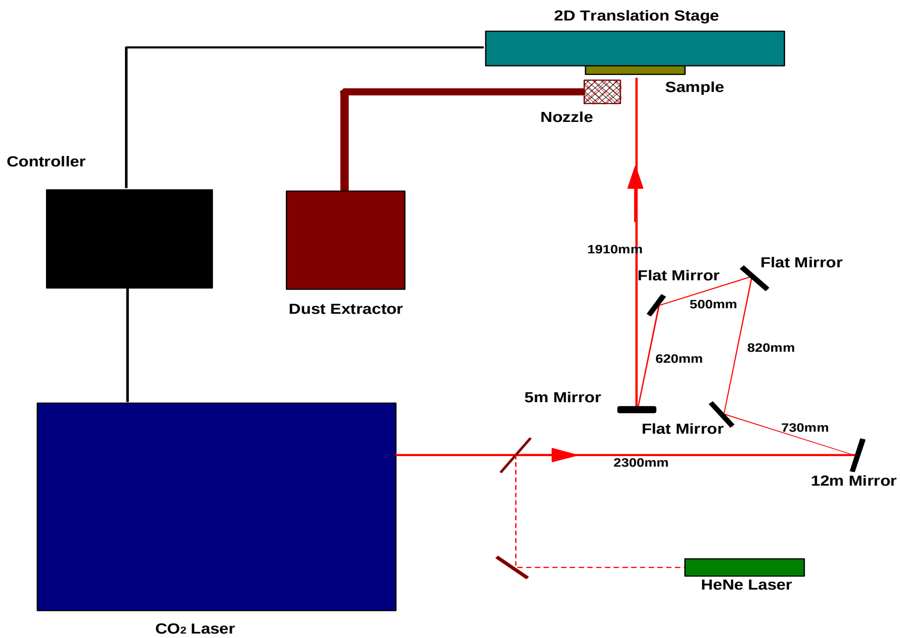

Figure 4: Paint stripping system beam layout

RESULTS

The tests on the aircraft panels immediately showed that the temporal profile, repetition rate and intensity play the greatest roles in determining the optimum stripping rate for both metallic and composite substrates.

Aluminium Panels

The first series of tests were performed on Aluminium aircraft panels. Measurements showed that the paint thickness on the plates varied between 150 to 230µm and consisted of between 3 and 7 layers of paint. The appearance of a typical plate after irradiation is shown below in figure 5.

This plate was raster scanned once the best parameter set had been determined. The results demonstrated that both flat and curved surfaces of aircraft panels could be cleaned without any paint residuals. The ability of the system to clean rivet holes is also shown in the illustration below in the bottom part of the picture. The optimized scanning speed corresponds to an achievable cleaning tempo of 6.3m^2 per hour.

Subsequent surface analysis of the substrate surface showed no changes to the characteristics of the Aluminium. The marks on the panel are the result of previous chemical stripping and hand sanding. Tests also showed that during the decoating process, the temperature of the substrate at no time exceeded 80^{o}C, a very important parameter as far as the aerospace industry is concerned as this is the limit set for any paint stripping process by the accepted aerospace industry standard.[9]

Figure 5: Honeycomb Aluminium plate after irradiation scan

Composite panels

The second series of tests were performed on the composite panels. Measurements showed that the paint thickness on the plates also varied between 150 to 230μm.

These tests were done at a lower repetition rate of 200Hz. The lower repetition rate is a result of the material structure of the panel that necessitates a more careful irradiation of the panel. If over-irradiated the laser penetrates the bottom vapor deposited Aluminium layer and damages the structure of the underlying composite material.

In addition it was found that the composite panels were patched in several places. These patches destroy the bottom metallic layer and make the panel even more susceptible to damage due to the increased absorption of the patching material. The result of an optimized paint removal parameter set is shown below in figure 6. The cleaning rate that can be achieved is 5.2m² per hour.

Subsequent surface analysis of the surface showed no changes to the characteristics of the Aluminium coating. Tests also showed that during the decoating process, the temperature of the substrate at no time exceeded 80^{o}C.[9]

Particle Analysis

During combustion a suspension of particles in a mixture of gaseous combustion products and surround atmosphere, was created. SIMS analysis of the surface of the irradiated targets shows the composition to be almost exclusively $Ti0_2$, suggesting a solidification of on the surface of already present solid particles in the combustion products.

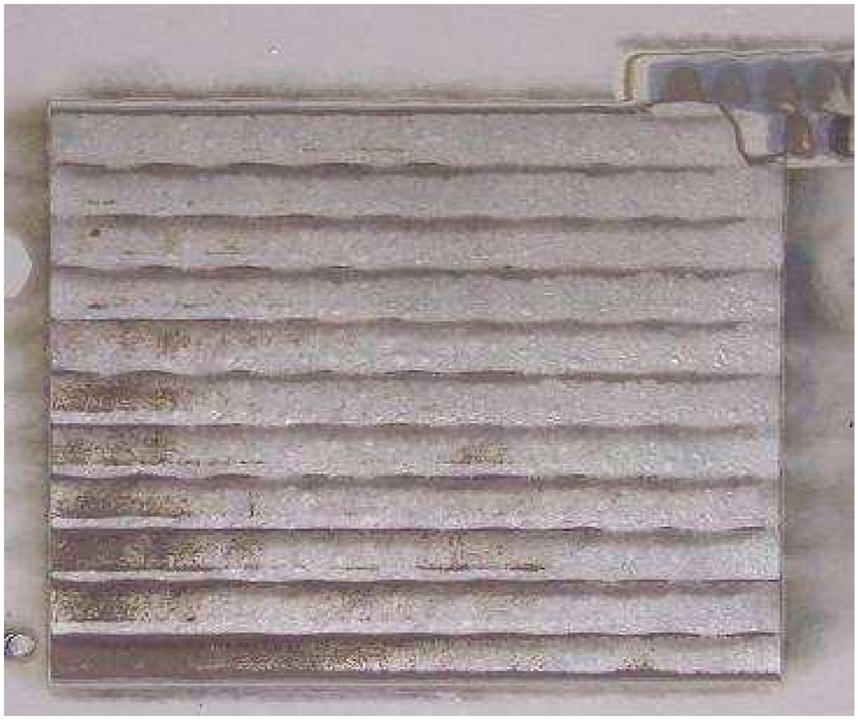

Figure 6: Paint stripping of honeycomb composite aircraft panels

Tests also showed that one of the main influences upon the particle characteristics would be the laser power as the particle size distribution increased once the laser power was increased. The increase of the particle itself, when increasing laser power, I_e, irradiance, probably originates from the increased penetration depth and therefore increased amount of bulk coating material affected.

An analysis of published data on the formation of particles during the combustion of polymer materials shows that the quantity and nature of these particles depend on the chemical structure of the polymer, the composition of the material, the percentage of O_2 in the surrounding atmosphere and the nature of the combustion mechanism.[10]

CONCLUSIONS

The conclusions that can be made from these results are:

- Laser based coating removal will ablate and capture paint from metal surfaces and composite surfaces.
- Laser based coating removal is effective in removing paint from flat and curved surfaces, depressions, and holes.
- Laser based coating removal will generate negligible amounts of waste in comparison to competing technologies.

In addition CO2 lasers exhibit the following advantages over other types of lasers:

- Absorption for Al alloys is ~2% for the CO2 laser, ~6% for the Nd:YAG laser and ~12-13% for the diode laser
- Absorption for aerospace paints is ~92% for CO2 laser, ~11% for the Nd:YAG laser; and ~11% for the diode laser

This means that a CO_2 laser will remove paint much more efficiently and be less likely to damage the substrate than other lasers.

The preliminary tests have therefore proven without a doubt that laser based coating removal is effective. As a result SDI will be proceeding with the development and manufacture of a larger robotized 1,750W TEA CO_2 laser to increase the paint stripping rate to the >10m² per hour level required by commercial aviation industry. A conceptual design of this system is shown above in figure 7.

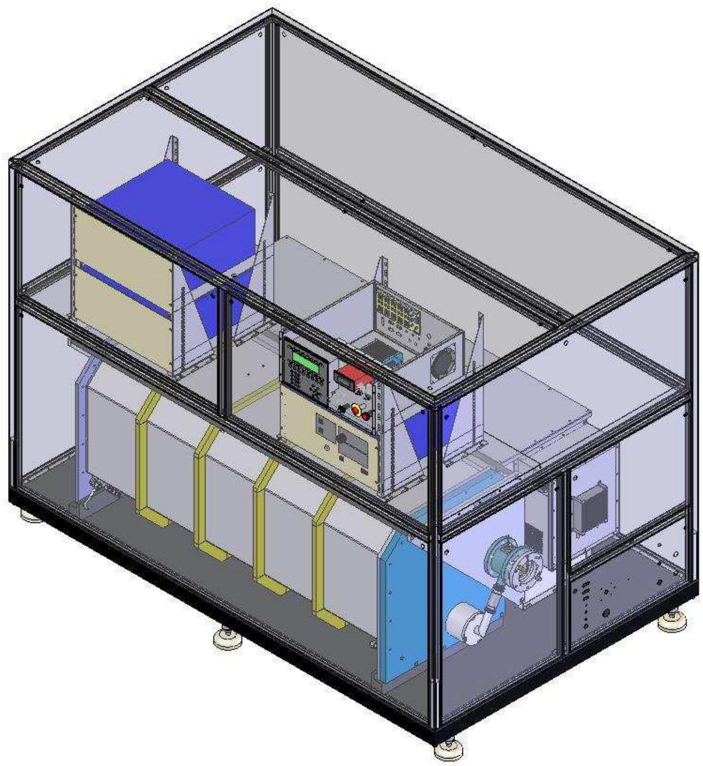

Figure 7: Concept design of 1,750W TEA CO_2 laser

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