

Laser Cleaning for Surface Preparation for Pre-Weld and Pre-Bonding Applications

Tyler O'Neill
Adapt Laser Systems
1218 Guinotte Avenue
Kansas City, MO
United States of America

ABSTRACT

As laser cleaning continues to gain popularity as a source for surface prep and coating removal, this study will explore the use of laser ablation to remove contaminant oxidation and other contamination from metallic substrates. Laser cleaning systems can target coatings while having a minimal impact to the metallic substrates. This study will demonstrate how using laser cleaning technology can improve the surface free energy of a substrate and promote successful welding and adhesive bonding. The process of ablation is created when the laser wavelength is absorbed into the contaminant or oxidation coating. Material properties drive the absorption abilities for substrates and coatings to absorb different wavelengths of laser energy. This high energy exchange causes the contaminants to rapidly change from a solid to a gas, which is eventually vacuumed away. Readily available laser cleaning systems are currently found in industrial, automotive, and aerospace fields and are being utilized for everyday operations. This study explores and explains the feasibility of using laser cleaning as an adequate preparation technique for cleaning before welding and adhesive bonding.

Key words: Ablation, Laser, Surface Preparation, Adhesion, Pre-weld Cleaning, Oxidation, Surface Contamination

INTRODUCTION

Laser cleaning has been an effective tool in manufacturing and industrial applications for over 20 years. Cleaning, as well as cutting and welding, has shown vast improvements in repeatability and precision with the use of laser technology [4]. Previous bonding techniques such as mechanical fixturing and welding can be inconsistent and cause issues like increased structural weight, decreased structural integrity, galvanic corrosion, and many more potential failures [5]. Laser cleaning may propose a viable option for adhering materials to reduce weight and increase repeatability. Welding practices continue to develop to reduce both weld thickness and porosity. Porosity in welds is typically caused from failure to

prepare the surface adequately [1]. Failures in both welding applications and adhesive bonding applications can be reduced with the use of laser technology.

Laser wavelength, intensity, and energy density need to be taken into consideration to perform satisfactory surface cleaning. Substrate material compositions each have individual properties to absorb or reflect laser light depending on the wavelength of the beam and the beam properties. For instance, polymer materials typically absorb laser wavelengths in the far infrared region more effectively than near infrared or visible. This makes them suitable for cleaning with CO₂ lasers (10600 nm) or lasers that produce wavelengths in the far IR. While Nd: YAG lasers may be better suited for certain metallic substrate applications like aluminum and steels [7]. When using a 1064nm Nd: YAG lasers, coatings such as aluminum oxidation, rust, or paint, absorb the laser beam while the underlying substrates reflect the beam. This is ideal for leaving the substrate completely free from inhibitors and ready for bonding or welding.

Surface conditions for both adhesive bonding and weld prep rely on the quality of the substrate. The most frequent failure mode for adhesive bonding, is an improperly prepared surface. Replacing mechanically fastened joints with adhesives simplifies manufacturing and can create a potential stronger and more reliable joint [3]. Surface treatment for adhesive bonding and welding is similar on many perspectives. A dirty surface that contains particulates (oxidation, oils, debris, etc.) will not be able to perform well in either instance. The two applications differ when considering the compatibility of the adhesive to the substrate, and the need for completely clean surfaces for welding.

Surface free energy is a characterization of the surface of a substrate to determine its effectiveness for interaction with an adhesive. Additionally, a high surface free energy is an indication of a homogenous substrate that is free of contaminants. Increased adhesion is promoted by the compatibility of the surface free energy of the substrate and the surface tension of the glue or adhesive. If the surface free energy of the substrate is greater than that of the adhesive, then the adhesive is known to “wet out” on the surface of the substrate. The surface free energy of a substrate can be improved with laser cleaning.

EXPERIMENTAL PROCEDURE

The quality of a substrate contains an account of the contaminants remaining on the surface after cleaning and the compatibility the surface has with the target application. With previous cleaning methods, the quality of the substrate can be found infrequent and inadequate on many occasions [4]. To ensure a successful cleaned substrate, many tests have been developed for inline process control and examination.

Wettability, contact angle, salt content, dyne ink tests, and many more methods have been used to provide a quantitative analysis of the surface. These methods aim to standardize cleaning techniques and prove consistency for bonding or welding. Intrusive testing methods such as pull tests, hash mark testing, durability testing and chisel tests are used to determine the strength of adhesive bonding. These tests, while effective, are impactful to the coating.

Using Youngs equations, the surface energy of a substrate can be quantified by contact angles from two or more liquids. Typically for industrial applications, a water droplet is used as a quick and easy method to attempt to quantify surface free energy. A water contact angle is the measurement of a single droplet in reference to the normal surface of the substrate. A more accurate method of testing can come from using a device that measures the contact angle of two or more liquids. The two liquid measurement