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Selected aspects of the effect of mechanical treatment on surface roughness and adhesive joint strength of steel sheets

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ABSTRACT

The study presents selected problems of the effect of mechanical treatment on surface roughness and adhesive properties as well as adhesive joint strength of steel sheets. In the experiments, the following treatments were applied: grinding, lapping and superfinishing, with variations of some technological machining parameters being taken into account. Based on the conducted experiments, it has been found that the technological parameters of mechanical treatment affect the surface roughness, adhesive properties and adhesive joint strength, depending on the treatment method and parameters applied. It has also been found that the mechanical surface pretreatments have positively affected the adhesive joint strength. The specimens subjected only to degreasing exhibit lower strength.

1. Introduction

Adhesive bonding plays a significant role in contemporary material bonding technology, combining problems that belong to various fields of science, such as chemistry, mechanics, thermodynamics and physics. The process is widely applied for both unit and bulk production in different industrial branches, mainly in aviation, astronautics, construction, automotive and electronics sectors.

Adhesive bonding can become an alternative to other bonding methods, such as heat sealing, soldering or welding. One of the numerous advantages of adhesive bonding is that it offers new possibilities for bonding materials with different physical and geometrical characteristics, without causing any changes in the structure of these materials. Apart from its fundamental bonding function, adhesive bonding enhances the processes of sealing, regeneration and element fastening as well as technical equipment repairs. Also, it is possible to combine adhesive bonding with other bonding methods in order to increase joint strength.

The present study analyzes the effect of surface pretreatments for adhesive bonding and their effect on adhesive joint strength. Numerous studies [1–4] stress the importance of this problem. For example, Critchlow et al. [1] underline that a particular pretreatment for structural bonding will ideally produce a surface which is free from contamination, wettable by the adhesive, highly macro- or micro-rough, mechanically stable, and hydrolytically stable.

The surface pretreatment is one of the first and most important technological stages in the adhesive bonding process. It is preceded by the analysis of properties, type and geometrical structure of a material surface for adhesive bonding, as the choice of an appropriate surface pretreatment method depends on these data. In adhesive bonding, the surface of joined elements is defined as the part of material where interactions with an adhesive occur [2–5]. This is connected both with the area and depth of interaction. In order to produce strong adhesive joints, surface pretreatments for adhesive bonding should ensure the following [1,2,5–7]:

- removal of all contaminants that could significantly decrease adhesive joint strength (such as lubricants, dusts, loose corrosion layers, micro-organisms) from surfaces to be bonded,
- good surface wettability,
- repeatability of properties,
- correct surface development,
- good activation of surfaces of elements being bonded.

Surfaces of materials to be bonded are quite often covered with a thin layer of oxides that cannot be removed by degreasing only [3]. To obtain a correct development of surface, it is recommended that in such situations mechanical treatment be used, which is one of special surface pretreatment operations for adhesive bonding. The method aims at eliminating both organic and inorganic contaminants occurring on adhesively bonded surfaces, such as corrosion products, and at creating geometrical structure. Depending on types of materials being bonded, mechanical treatment can be performed by methods such as shot blasting, grinding, brushing, sand blasting or grit blasting [2,4,8–15].

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Critchlow et al. [1] showed that mechanical treatments include abrasion methods usually combined with degreasing. Degreasing is the minimum pretreatment that is usually carried out prior to bonding. Grit-blasting or other mechanical abrasion methods are recognized as providing a useful increase in initial adhesion level. Mechanical treatment allows the development of actual geometrical structure of adhesively bonded materials, which results in an increased contact area between the molecules of an adhesive and substrate, causing higher intermolecular interactions and, thus, increasing adhesive properties [14,15]. Roughness is a parameter that affects the strength of bonded joint, because it leads to an increased contact area between two substrates and increases the adhesion by mechanical interlocking [2].

In the present study, the following mechanical treatment methods were applied: grinding, lapping and superfinishing.

Grinding is the most widely used mechanical abrasion method characterized by the fact that abrasion is done by tools with unspecified geometry and number, in which grinding grits do not change their position relative to one another owing to the use of a binder [15]. The method is very popular due to its high efficiency as well as high accuracy of shape and dimensions obtained. In addition to that, the method can be applied on a wide scale owing to very good mechanical properties of abrasive materials at increased temperatures. Most commonly used abrasive materials exhibit much higher hardness at increased temperature than constructional materials [15]. Grinding can be applied to materials of different physical and mechanical properties, used in various industry sectors, e.g. sintered carbides, hardened and creep-resisting steels, high-melting metals, sintered aluminum oxides, semiconductors or organic materials [15].

Lapping is an abrasive surface finish process wherein a surface with a very high accuracy can be produced. The process is carried out using tools, called laps, and a paste or abrasive grain slurry. The slurry is brought in between the workpiece and tool. As a result of clamp and motion, the abrasive micrograins penetrate both surfaces – the less hard the lap structure is, the deeper the micrograins penetrate it; the harder the surface being treated is, the shallower the grain penetration is. Grain settling is however undurable, as grains predominantly roll in the lapping process, indenting with their consecutive edges. Superfinishing, also known as short-stroke honing, is a process which improves surface finish, ensuring that the surface being treated is smooth. The process is most often used in the treatment of external roll surfaces; sometimes of hole surfaces; flat or spherical surfaces [15].

Stones (one or more) are elastically pressed with a low force against a rotating roll; the stones perform both a feed motion and reciprocating motion at low pitch and high frequency (the so-called “oscillatory motion”).

The problems of mechanical treatments as surface pretreatment have been discussed in numerous studies [2–4,7,13]. Spadaro et al. [3] tested different surface treatments applied to aluminum alloy 2024 to bonding, including mechanical grinding. Da Silva et al. [4] presented the research of different surface patterns and depths created during the milling process, which shows that the surface patterns influence the joint strength.

Mechanical treatment leads to the forming of a good outer layer geometrical structure, yet it does not ensure good surface activation. For this reason, chemical treatment is often employed as a complementary method [2,3,7,11].

The available studies provide information on the effect of surface roughness parameters on adhesive joint strength. Based on these works, it can be concluded that the most favorable properties are obtained when surface roughness (described by the maximum roughness height $R_{z\ max}$) is in the range of 7–25 μm [15].

2. Experimental tests

2.1. Materials and specimen

For the experiments, a simple geometry specimen was chosen (Fig. 1).

The geometrical dimensions of the real adhesive joint were respectively:

- length of elements to be bonded, $l = 100 \pm 1.2$ mm,
- width, $b = 20 \pm 0.26$ mm,
- thickness of sheets to be bonded, $g_k = 1.5 \pm 0.08$ mm.

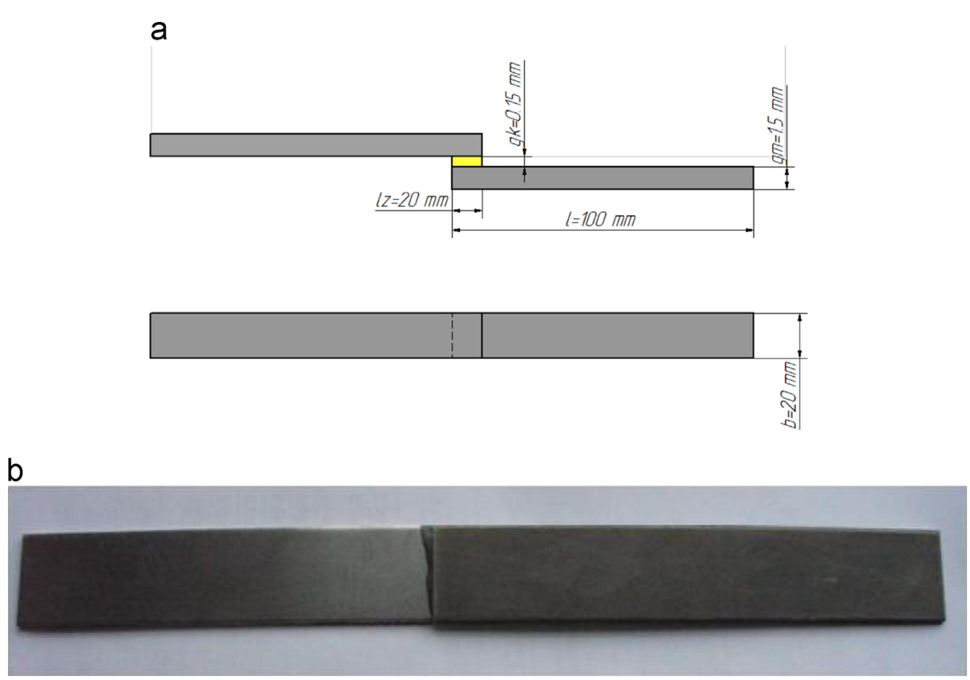

Fig. 1. Single-lap joint geometry.