



## A comparative analysis of the load capacity of riveted and resistant welded joints

Piotr Lacki<sup>1</sup>, Judyta Niemirowa-Mażniak<sup>2</sup>

### ABSTRACT:

There is a growing development in techniques that use thin-walled elements in construction and other industries, which is dictated primarily by the demand for lightweight, load-bearing structures, that are simple to manufacture and assemble. The paper presents selected methods of joining thin-walled metal structures. Experimental studies of the load capacity of resistance welded joints and riveted joints were carried out for the thickness of 0.8 mm. Graphs detailing the forces and displacements in the tested joints are shown and the method of sample destruction is presented. As a result of the tests, it was concluded that resistance welded joints achieved a load capacity of about 118% greater than the load capacity of riveted joints.

### KEYWORDS:

thin-walled structures; resistance welding; riveting

## 1. Introduction

Since the 1930s, thin-walled elements have become increasingly popular in construction and other industries. The growing demand for this type of structure has been dictated by simple manufacturing, ease of assembly, short construction lead times, and above all, their lightness. Joining methods play an important role in the continuous development and shaping of thin-walled metal structures. Thanks to the possibility of the proper combination of thin materials, elements with a high ratio of load capacity to their mass can be obtained. In paper [1], the load capacity of a beam was tested, whose thin-walled components were joined using resistance welding. In thin-walled constructions, depending on the manufacturing requirements, the type of materials used, and access to the contact point, various connection techniques are used. The paper focuses on two spot joining methods in thin-walled metal elements. A comparative analysis of riveted joints and resistance welded joints was carried out. The experimental tests performed can be used to observe the actual behavior of the structural elements and in subsequent works to create numerical models such as in [2].

## 2. Selected ways of connecting thin-walled metal elements

### 2.1. Riveting

Riveting, which is one of the oldest and most important techniques for joining structural elements, gained special significance at the turn of the 19th and 20th centuries. It became

<sup>1</sup> Czestochowa University of Technology, Faculty of Civil Engineering, ul. Akademicka 3, 42-218 Czestochowa, e-mail: placki@bud.pcz.pl, orcid id: 0000-0002-0787-8890

<sup>2</sup> Czestochowa University of Technology, Faculty of Civil Engineering, ul. Akademicka 3, 42-218 Czestochowa, e-mail: jniemirowa@bud.pcz.pl, orcid id: 0000-0001-6808-7067

the most commonly used method of joining load-bearing iron and steel structures [2]. Between 1835-1925, the technology for producing and assembling using rivets underwent significant changes [3], at the same time, many practical design principles and calculation methods were introduced [4]. Although riveting is increasingly being replaced by welding, this technique is still successfully used in some industrial constructions. The continuation of riveting techniques also favors the desire to design both lighter and rigid structures. Increasingly, therefore, light materials are used, including aluminum and plastics, which are reinforced with fibers (FRP) and magnesium to increase the load capacity. Combinations of materials with different mechanical properties (aluminum, steels, magnesium, plastics) are also used, which means that sometimes, with such different elements, welding cannot be used. Riveting is a process in which we obtain an inseparable, indirect connection of two or more elements. Connection sheets, metal profiles, girders, brackets, or trusses are created by using rivets. Traditional riveting involves making holes in elements and connecting them by piercing or drilling, and then placing rivets in them and hammering them with a hand or pneumatic hammer or pressing with the help of mechanical, hydraulic riveters (press). The shank deforms and a cuff (second head) forms.

The least complicated method is a hand riveter that can work without any power supply, but requires considerable strength and is used to make connections in individual applications and where access is difficult. Pneumatic riveters have greater downforce and aesthetic finish and are most often used on an industrial scale. Numerically controlled (CNC) riveting machines are also increasingly used. They enable the controlled programming of riveting points, which gives the riveted structure high precision. These machines are easy to use and have the ability to store data. Small rivets are inserted while cold, and larger rivets while hot. The length of the shank is selected so that it is equal to the total thickness of the materials to be joined, with an added length for the formation of the head. Rivets usually work for tension or shear, which should be considered when designing the rivet joint.

## 2.2. Resistance welding

Resistance welding is one of the cheapest, most efficient, and commonly used methods for inseparably joining metal elements. It can be achieved using a variety of welders, including linear, multipoint, and spot welders. Spot welding machines are the most widely used, joining various elements in many branches of production. Resistance welding is the method of joining metals by using their electrical resistance. The welding process begins by pressing the to-be-joined elements together by the welding electrodes. Then, as a result of high current, heat is generated on the contact surface, and molten metal (liquid weld core) is formed. The weld core cools down, and a weld nugget is formed. The resistance welding process is illustrated in Figure 1.

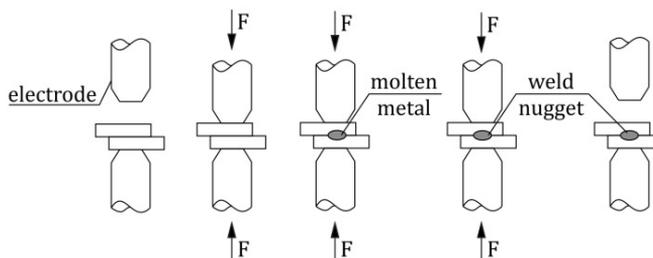


Fig. 1. Resistance welding process

The basic parameters of spot resistance welding (RSW) are:

- welding current flow time
- the intensity of the welding current
- downforce of the electrodes
- dimensions of the contact point electrode material

Energy converted into heat during welding is described by the formula:

$$Q = \int_0^t I^2(t) \cdot R(t) \cdot dt \quad (1)$$

where:  $I$  - the value during the welding process,  $R$  - resistances,  $t$  - welding current flow time.

The size of the weld nugget depends on the value of the energy supplied during welding. A proper weld should have a slight outflow around the point of contact. The process of joining materials is carried out so that the size of the weld nugget ensures the formation of a sufficiently strong joint. The weld core reaches its maximum size when the power is turned off. At that point, the weld remains under the electrodes' pressure, thanks to which, the metal in the weld core undergoes the process of solidification. Resistance welding is gaining more and more popularity. Testing of resistance welding not only of the same metals but also in materials with different mechanical properties, e.g. steel from aluminum, can be observed [5, 6].

### 3. Comparative analysis of the load capacity of the RSW joints and riveting joints

#### 3.1. Experimental research

Comparative tests of two joining methods: riveting and resistance welding were carried out for thin-walled steel elements. Compared were three joints with a single weld RSW and joints with a one-rivet connection, all consisting of the same geometry. The joint geometry is shown in Figure 2. The samples, 25x100 mm, were cut from sheets of 0.8 mm DC01 steel, and then connected by the relevant method. The resistance welding process was carried out on a resistance welding machine. The welding parameters are shown in Table 1. Riveting was done using a pneumatic press. In each of the riveted samples, a hole was made for the rivets with a diameter 5 mm. Rivets MS20615-6M5 with diameter 5 mm and rivet length:  $L = 6$  mm were used. All the joints were subjected to uniaxial shear testing on a testing machine. The test speed was 2 mm/min.

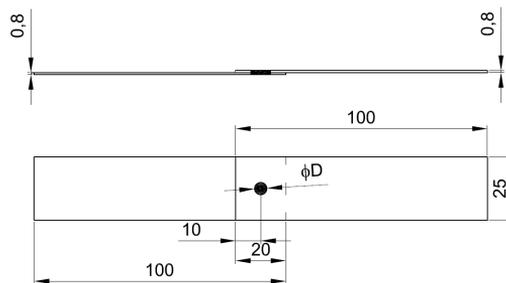


Fig. 2. Geometry of RSW and riveted joints

**Table 1**  
Welding parameters of steel joints

Sample number	Welding parameters		
	Current [kA]	Time [periods]	Downforce [dN]
Sample 1_RSW	6.76	11	700
Sample 2_RSW	6.94	11	700
Sample 3_RSW	6.81	11	700

3.2. Results

As a result of the shear test, the maximum values for the forces transferred by the analyzed RSW joints and riveted joints were obtained. A comparison of the results from the shear test is given in Table 2. The average tensile strength of the resistance welded joint was 4.8 kN, while the riveted joint was 2.2 kN. The average displacement for the RSW 13.51 mm joints, and the riveted joints 0.85 mm was obtained. The Displacement - Force graph is shown in Figure 3. Figure 4 shows the manner of destruction of the joints.

**Table 2**  
Shear test results of steel RSW and riveted joints

Sample number	Maximum force [kN]	The average force [kN]	Displacement [mm]	The average displacement [mm]
Sample 1_RSW	4.78	4,8	12.62	13.51
Sample 2_RSW	4.82		13.71	
Sample 3_RSW	4.81		14.2	
Sample 1_Riveted	2.22	2,2	0.81	0.85
Sample 1_Riveted	2.24		0.96	
Sample 1_Riveted	2.16		0.79	

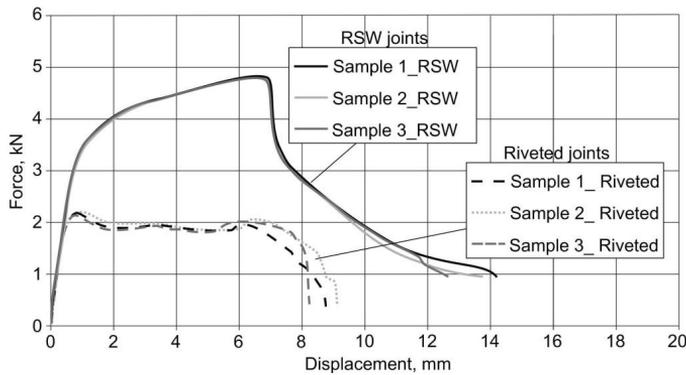


Fig. 3. Shear test results RSW and riveted joints

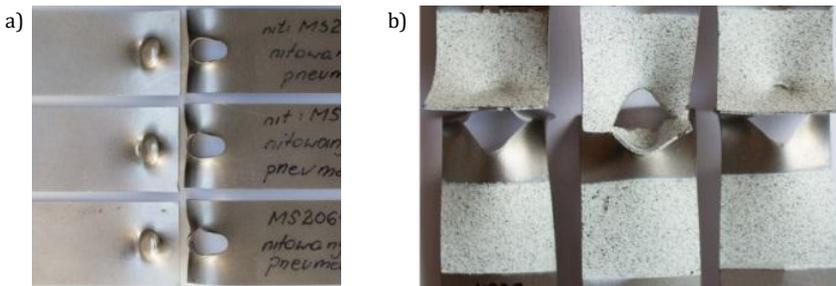


Fig. 4. Method of destruction of steel samples: a) riveted on a pneumatic press, b) resistance-welded

4. Conclusions

In the development of techniques for the use of thin-walled metal elements, it is equally important to develop and expand knowledge about the possibilities of joining individual

elements. The tests carried out in this work gave the opportunity to estimate the differences between the load capacity of riveted joints and resistance welded joints. The obtained displacement-force graph testifies to the repeatability of the results in the series. Resistance welded joints obtained an average load capacity by about 118% higher than the load capacity of the riveted joints. Resistance welding, which is currently the most commonly used method, transfers higher loads than riveted joints. However, this method cannot always be used. When connecting materials with different mechanical properties (aluminum, steel, magnesium, plastics), another method is sometimes required, such as riveting. Riveting is also successfully used in certain industrial constructions. Lap riveting, where the sheets of metal are wrapped around at the edges and secured using a high density of rivets, an extremely tight connection is obtained. It is used for the construction of various types of tanks. Therefore, there is definitely a need for further research into the various possibilities of joining thin-walled metal elements.

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## Analiza porównawcza nośności złączy nitowanych i zgrzewanych oporowo

### STRESZCZENIE:

W budownictwie oraz innych gałęziach przemysłu obserwuje się coraz większy rozwój technik stosowania elementów cienkościennych. Podyktowane jest to przede wszystkim zapotrzebowaniem na lekkie, a jednocześnie przenoszące odpowiednie obciążenia konstrukcje, z prostą technologią wytwarzania i montażem. W pracy przedstawiono wybrane sposoby łączenia cienkościennych konstrukcji metalowych. Przeprowadzono eksperymentalne badania nośności połączeń zgrzewanych oporowo oraz połączeń nitowanych. Statycznej próbie ścinania poddane zostały połączenia zakładkowe z pojedynczą zgrzeiną (nitem). Złącza wykonane zostały z blachy stalowej DCO1 o grubości 0,8 mm. Uzyskano wykresy sił i przemieszczeń dla badanych złączy oraz przedstawiono sposób niszczenia się próbek. W wyniku przeprowadzonych badań wywnioskowano, że złącza zgrzewane oporowo osiągnęły nośność o około 118% większą od nośności złączy nitowanych.

### SŁOWA KLUCZOWE:

konstrukcje cienkościenne; zgrzewanie oporowe; nitowanie