# SOLDERING OF STEEL USING SOFT SOLDERS

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**Abstract.** The paper contains strength tests results of joints soldered by use of lead and leadless solders. For tests lead solders of types Sn20Pb80, Sn40Pb60, Sn60Pb40 and type Sn63Pb37 and the leadless solders of types Sn95.5Ag3.8Cu0.7, Sn96Ag4 and type Sn99Cu1 and as jointed material the sheet iron of 1.0 mm thickness were used. Dimensions of test samples were of 20 x 100 x 1 mm. For heating the propane-butane and air flame was used. The tested assemblies were loaded using the universal tensile strength testing machine up to their failure. The force needed for failure and failure type (in the joint, in the basic material) were noted. From carried out tests it follows that practically the same results were obtained at lead solders of types Sn60Pb40 and Sn63Pb37 and at leadless solders of types Sn95.5Ag3.8Cu0.7 and Sn96Ag4. The solders Sn20Pb80, Sn40Pb60 and Sn99Cu1 showed in some degree lower stress values. On the basis of the carried out tests evaluation it is possible to say that the lead solders substitution for the leadless ones in light of the bonded joint strength is possible and in practice no problems should occur.

**Keywords:** soldering, soldered joints, solders, leadless solders, laboratory tests.

## Introduction

Soldering technology belongs to the oldest methods of material jointing using heat. It had been used already 3500 years ago in Old Egypt. In the territory of the Czech Republic soldering is documented by archaeological discovery from the era of the Great Moravia Empire (2. half of the 9. century). It was used in making jewels. But the development of soldering industrial use is dated back to less far past. At the beginning of the twentieth century soldering came into use for jointing of thin metallic materials. Its next development is closely connected with the development of automobile, electrical and light industry. Today it is luxuriantly used not only for single-part production but in serial and mass production, too. Its optimal use is, e.g., at products of general and precision engineering, in electrical, chemical, light and aircraft industry, in cosmonautics, at production of imitation jewelry and in other fields. Properties of soldered joints are specific, e.g., joints can be gas proof, waterproof, electric conductible, corrosion proof etc. Joints are tough both at static and dynamic stress.

In the same way as other methods of jointing the soldering technology is of advantages and disadvantages and therefore of its optimal application fields. Among advantages less energy consumption, higher operating speed, high economy, higher labour productivity, possibility of mechanization and automation, possibility of almost all metallic materials jointing regardless of their size and thickness, only low stress in the joint, lower effect on jointed materials properties and at last a fair visual appearance can be enumerated. Disadvantages are, e.g., lower strength and heat resistance.

At soldering filler materials are used, the so-called solders of various chemical composition and properties. Most often solders are classified according to their working temperature as soft solders (upper melting point < 450 °C) and hard solders (upper melting point > 450 °C).

Compared with hard solders the working temperatures of soft solders are lower and mechanical properties are lower, too. Therefore, they are used for joints which are not so much stressed by strength and heat. From the chemical composition point of view they are tin solders (alloys Sn-Pb with various ratio of both metals) and special solders. Except Sn and Pb these solders contain other metals, most often Cd, Zn, Ag, Cu, Sb, Bi, In. Hard solders are made as alloys on Cu, Al, Mg, Ni, Fe, Ag and noble metals basis.

Relatively new class of soft solders is the so-called leadless solders, in Czech Republic made from the twentieth of the last century. Their importance has increased after the 1$^{st}$ of July, 2006 when the Directive of the European union (EU-WEEE, Waste from Electrical and Electronic Equipment) came into operation. It has restricted the use of lead solders in electrical industry. The elimination of lead from production of light, telecommunication etc. industry will contribute to the human environment betterment. Lead contained in Sn-Pb solders can at unsuitable handling with scrapped electrical and electronic equipments (all equipments which use electric energy, e.g., big and small electrical appliances, computers, monitors, televisions, receivers, toys) contaminate soil and consequently the whole nutritious chain. Leadless soldering influences doubtless commercial effect, when producers of "green products" can expect higher negotiability of their products.

Soft leadless solders are alloys of Sn with addition of Ag, Cu, Bi, In and other chemical elements. From the material point of view they are binary alloys (e.g. Sn-Ag, Sn-Cu, Sn-Sb, Sn-Zn, Sn-Bi), ternary alloys (Sn-Ag-Cu, Sn-Ag-Bi, Sn-Sb-Cu, Sn-Zn-In, Sn-Zn-Bi etc.), quaternary alloys (e.g. Sn-Ag-Cu-Sb, Sn-Ag-Cu-In, Sn-Zn-Bi-X etc.), eventually even more complicated ones.

## Materials and methods

The aim of experiments, the results of which are published in this paper, was to state the strength of joints soldered using soft lead and leadless solders. For tests four soft lead solders (Types Sn20Pb80, Sn40Pb60, Sn60Pb40 and Sn63Pb37) and three soft leadless solders (Types Sn95Ag3.8Cu0.7, Sn96Ag4 and Sn99Cu1) and sheet iron of 1.0 mm thickness were used. From this semi-product test samples of dimensions 100 x 20 mm were cut out. Two samples were always put together with different lap (X = about 2.5, 5, 10, 15, 20 and 25 mm), cleaned using soldering flux and soldered. Soldering was carried out using the propane-butane + air flame.

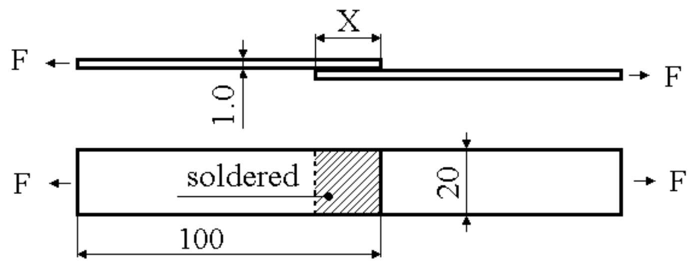


Fig. 1. **Dimensions of the test assembly**

Real dimensions of all tested assemblies soldered surfaces were determined. Next the assemblies were loaded till to the failure. At each test the force needed for the joint failure and the failure type (failure of the soldered joint, failure of the sample basic material) were noted.

## Results and discussion

The relation between the force needed for the failure and the lapping length is presented in Fig. 2. It is evident that the course of all tests is very similar. The force needed for the failure increases at first very rapidly, afterwards its increase is slow. After reaching of soldered surface certain size the failure occurs in the basic material and the increase of soldered surface is purposeless.

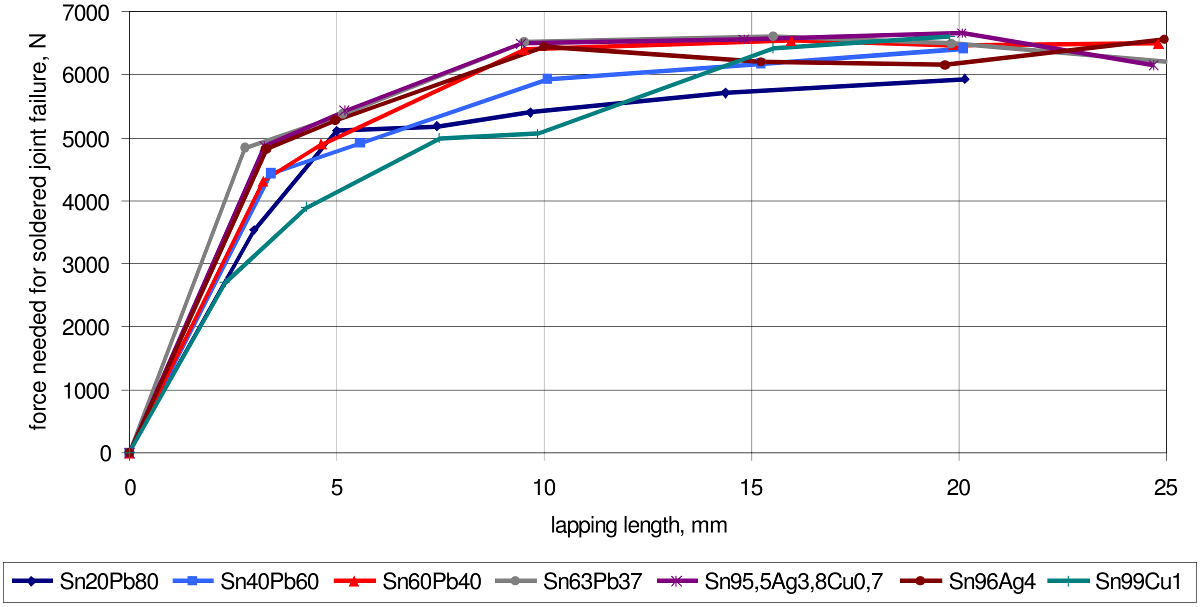


Fig. 2. **Relation between the force needed for the soldered joint failure and lapping length**

From the results of the carried out tests it follows that the highest strength was found at joints soldered using the lead solder of eutectic composition (Type Sn63Pb37). Very good strength properties were also determined ad leadless solders of the types Sn95.5Ag3.8Cu0.7 and Sn96Ag4 and at lead solder of the type Sn60Pb40. Lower strengths were determined at joints soldered using lead solders of lower Sn content of the types Sn20Pb80 and Sn40Pb60 and leadless solder of the type Sn99Cu1. On the basis of the carried out tests it is possible to state that the replacement of lead solders for leadless ones is from the point of view of bonded joints strength possible and in practice no problems should appear.

From the results of all tests presented in Figure 2 only these ones were selected for next evaluation which failed in the soldered surface (not in the basic material). The relation between the solder strength and lapping length is presented in Figure 3. The results of all tested solders are similar – trend of relation is decreasing. It is possible to express the relations by functions presented in Table 1.

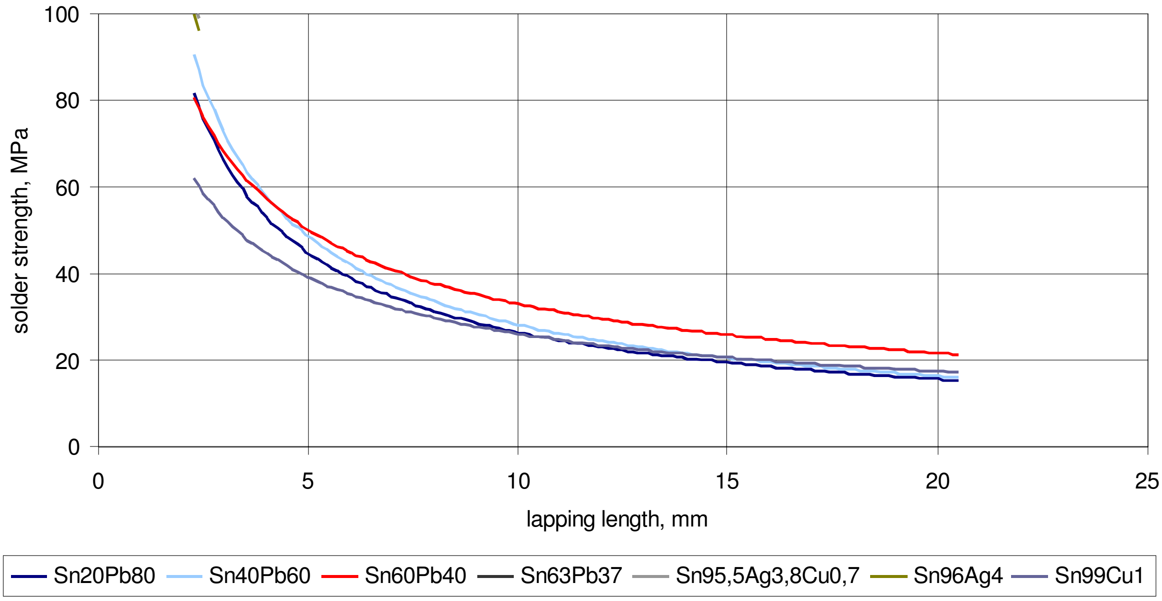


Fig. 3. **Relation between the solder strength and lapping length**

Table 1

**Test results**

| Solder type | Equation of the relationship | Coefficient $R^2$ |
|---|---|---|
| Sn20Pb80 | $y = 152.59\ x^{0.961}$ | 0.969 |
| Sn40Pb60 | $y = 172.04\ x^{0.785}$ | 0.996 |
| Sn60Pb40 | $y = 132.27\ x^{0.603}$ | 0.922 |
| Sn63Pb37 | $y = 199.58\ x^{0.806}$ | 0.996 |
| Sn95.5Ag3.8Cu0.7 | $y = 200.49\ x^{0.812}$ | 0.993 |
| Sn96Ag4 | $y = 193.99\ x^{0.806}$ | 0.993 |
| Sn99Cu1 | $y = 100.43\ x^{0.584}$ | 0.966 |

The lowest strength values were determined by the use of the lead solders of types Sn20Pb80 and Sn40Pb60 and leadless solder of the type Sn99Cu1. The strength values of four remaining solders were practically the same. But the strength differences of the tested solders are not significant.

At the same time the known fact was confirmed that the lapping length of the one-sided lapped joint should be "suitable". No doubt that by the lapping length increase up to a certain value the force needed for joint failure increases but at the same time the solder strength decreases (Fig. 3). In this way the force acts aside the axis and the additional bending moment arises. At the overlapping borders this moment evokes the additional spalling stress.

## Conclusion

1. In the paper the laboratory test results of joints soldered by lead and leadless solders are published. From the results it follows that from the point of view of joint strength and solder strength between solders of types Sn63Pb37, Sn60Pb40, Sn95.5Ag3.8Cu0.7 and Sn96Ag4 only small differences exist. Soldered joints made by using of the next three tested solders, namely of lead solders of the types Sn20Pb80 and Sn40Pb60 and of leadless solders of the type Sn99Cu1 compared with the above mentioned solder types were of slightly lower mechanical properties.
2. On the basis of the results of the carried out tests it is possible to state that the substitution of lead solders by leadless ones is possible without a risk of soldered joints strength decrease.

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