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# Band structures for binding and holding of objects made from recycled metallic materials

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**Abstract.** The aim of the present research is the investigation of the possibility and effectiveness of using the band structures made from recycled metallic materials for binding and holding of objects (in particular, tubular objects as pipelines or shells). The using of band elements and structures as such is a perspective way to increase the safety and bearing capacity of the pipelines and vessels. Nowadays during repair works the outer surfaces of the mentioned objects are braided by the steel tapes, i.e. the objects are strengthened by the binding. The mentioned steel bands are specially produced for binding purpose. From the other hand after stamping of small-size details (like the elements of supply chains for different apparatus) the metallic waste in the shape of perforated metallic tapes are received and needs to be reused in compliance with the good practice in effective resource using and recycling. The band structures for binding and holding of tubular objects, produced from the perforated metallic tape by the longitudinal profiling, multilayer and spiral winding are presented. It is proposed to apply in industry the composite band structures made from perforated metallic materials and epoxy matrix for binding and holding of tubular objects as pipelines or shells, which allows simplifying and speeding up the repair works especially in the cases of the local damages.

**Key words:** perforated metallic waste, pipe repair bandages, environment.

## INTRODUCTION

Perforated metallic materials (PMM) have a wide application in mechanical engineering and building including different solutions for ecological tasks (Lisicins et al., 2016). For these purposes the PPM of different shapes, for example, sheet, band, pipe and shell is used (Perforated metal, 2016).

During last years the structures, produced from the PPM, have been used in the modern buildings and constructions as well as in the systems for environmental control and technological facilities for aeration, ventilation, heating and filtration of the different gas and liquid substances as well as for absorption of the acoustic waves. Many of these and other applications are proposed by Mironovs & Lisicins (2015). From all the nomenclature of such structures the tubular perforated elements (Figs 1, 2) are of great importance not only due to functional characteristics, but due to decorative nature as well.

**Figure 1.** Composite sound dumper in perforated steel shell.

**Figure 2.** Perforated metallic roof ventilation lid.

One of the perspective way for applying the PMM is using the band structures made from recycled metallic materials for binding and holding of objects (in particular, tubular objects as high-pressure pipelines or shells) with the goal to increase the safety and bearing capacity of the pipelines and vessels. Nowadays during repair works the outer surfaces of the mentioned objects are braided by the steel tapes, i.e. the objects are strengthened by the binding. The mentioned steel bands are specially produced for binding purpose (Fig. 3). Using of such bands provides the safe transporting, storage, mounting of tubular objects and increases its strength.

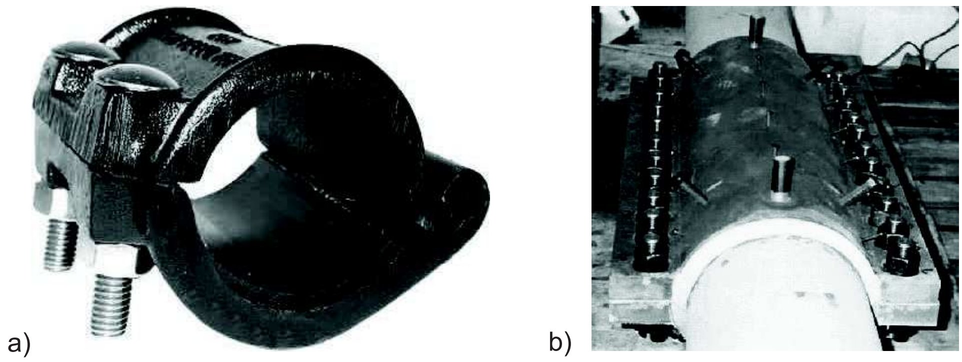


**Figure 3.** View of the band clamp (a) and epoxy shell repair system (b) (Pipeline repair, 2017).

The aim of the present research is the investigation of the possibility and effectiveness of using the band structures made from recycled metallic materials for binding and holding of tubular objects. After stamping of small-size details (like the elements of supply chains for different apparatus) the metallic waste in the shape of perforated metallic tapes are constantly received and needs to be reused in compliance with the good practice in effective resource using and recycling.

The different methods for producing the band structures from PMM were proposed by Mironovs et al. (2013). Commonly the longitudinal profiling, multilayer and spiral winding are used. Joining of the elements of structures usually was done by soldering, welding or swaging of the band faces. Authors believe that the composite structure could be another one effective solution for binding and holding of tubular objects. It is proposed to use matrix from the epoxy resin reinforced by perforated steel band (Fig. 4). The advantages of proposed solution are the following:

- increased rigidity of the band structure;
- relatively light-weight structure;
- flexibility of the perforated reinforcement and polymer matrix;
- durability of the band;
- simplicity of the binding process;
- recycling of the technological waste.

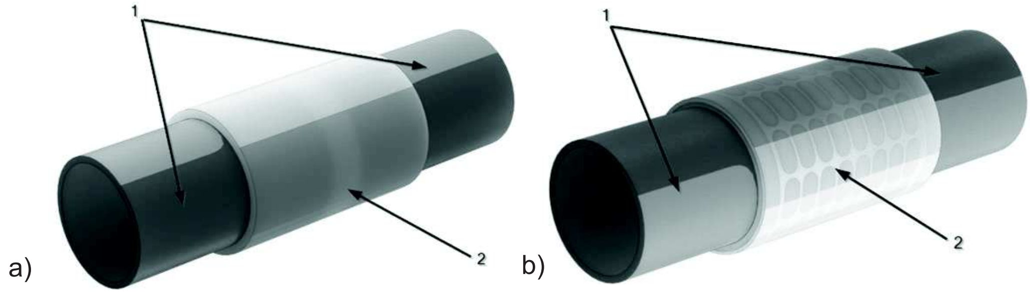



**Figure 4.** Schemes of pipe (1) repair band (2): a) without reinforcing; b) with reinforcing by perforated metallic band.

## MATERIALS AND METHODS

Mechanical and geometrical parameters of PST-1 and PST-2 type perforated steel tape (trade mark of JSC 'DITTON Driving Chain Factory', Latvia), which was used for producing the repair bands for the tubular structures and perforated tubes are shown in Table 1.

For producing composite band with reinforcement from the perforated tape the matrix from the epoxy resin was used. The different composition of the epoxy compounds were used (Table 2) bearing in mind not only the physical and mechanical properties, but the shielding propeprties against electromagnetic fields as well (Mironovs et al., 2014).

It should be mentioned that the colour of compound differs according to material composition from yellow to dark grey. The addition of the basalt fibres allows changing the colour and strengthening the material.

From the mentioned materials the four type of samples with the thickness 8–10 mm and (other dimensions are 90 x 37 mm) were produced: without perforated reinforcement, with reinforcement by one, two and three layers of perforated material (Fig. 5). The thickness of the single perforated material layer is 1.5 mm.

**Table 1.** Mechanical and geometrical parameters of PST-1 type and PST-2 type perforated steel tape, which were used for producing of repair band

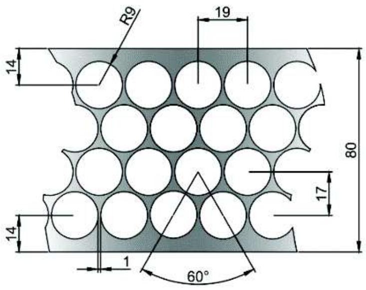
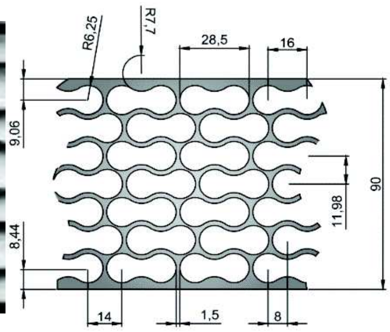
| Parameter | Value | Tape representation | Tape geometry |
|---|---|---|---|
| Designation | PST-1 |  |   |
| Mark of steel | 08пс-OM-T-2-K | | |
| Standard | GOST 503-81 | | |
| Thickness, mm | 1.50 | | |
| Width, mm | 80 | | |
| Permeable area, % | 69.10 | | |
| Effective cross-sectional area, mm$^2$ | 25.13 | | |
| Tensile load bearing capacity, kN | 5.54 | | |
| Tensile strength, MPa | 220.65 | | |
| Displacement, mm | 6.54 | | |
| Strain, % | 3.93 | | |
| Designation | PST-2 |  |   |
| Mark of steel | 50-T-C-H | | |
| Standard | GOST 2284-79 | | |
| Thickness, mm | 1.50 | | |
| Width, mm | 90 | | |
| Permeable area, % | 75.32 | | |
| Effective cross-sectional area, mm$^2$ | 26.43 | | |
| Tensile load bearing capacity, kn | 10.01 | | |
| Tensile strength, MPa | 406.81 | | |
| Displacement, mm | 2.25 | | |
| Strain, % | | | |

**Table 2.** Material composition of epoxy compounds

| Material | Weight in % |
|---|---|
| Epoxy resin ED-20 | 46.41–47.70 |
| Epoxy resin ED-181 | 32.59–33.50 |
| Hardener | 16.0 |
| Calcium stearate | 0.3 |
| Montmorillonite | 2.0 |
| Basalt fiber | 3.0 |

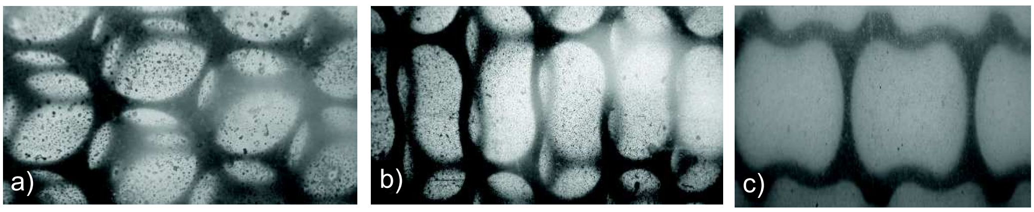



**Figure 5.** The view of the samples with the circular holes (a), oval holes (b) and complex holes (c).

The mechanical properties of the produced samples were tested by the Instron 5567 (USA) mechanical testing machine (Fig. 6): loadings rate was 30 mm min$^{-1}$, air temperature + 24 °C.

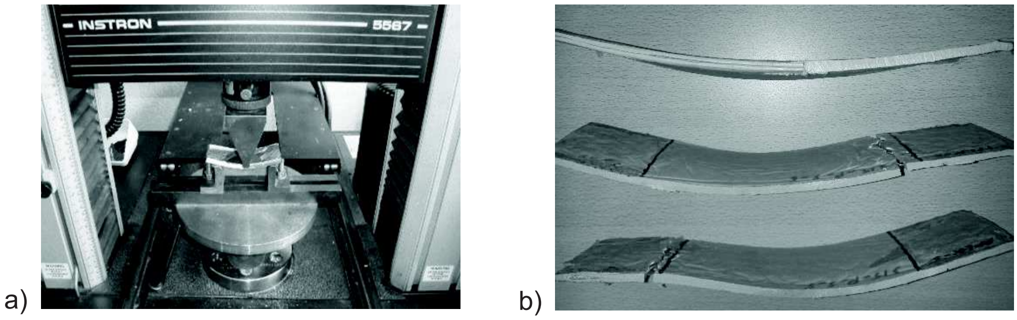



**Figure 6.** The view of the testing process (a) and samples after testing (b).

## RESULTS AND DISCUSSION

First of all, the flexural stress-strain state of the samples was evaluated. Fig. 7 shows the relationship between flexural stress and strain of composite sample with one-layer reinforcement from the perforated tape PST-2. This perforated tape is produced from the steel 50-T-C-H (Table 1) and is characterized by the high strength despite to the larger volume of perforated holes in comparison with the perforated tape PCT-1. As shown the three-point bending testing proves the possibility to use such composite structures for binding the tubular objects as high-pressure pipelines or shells.

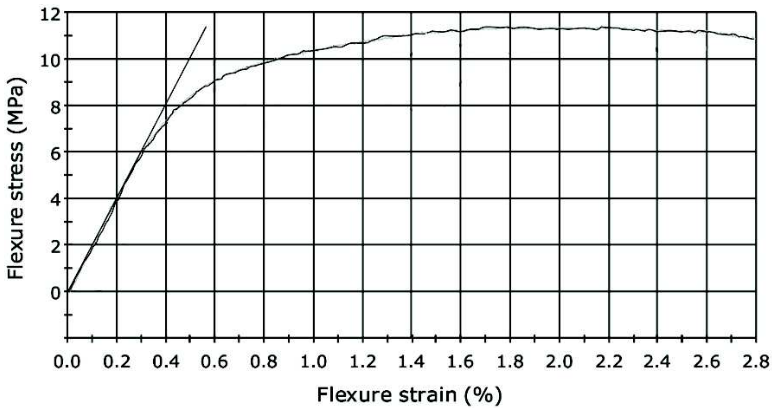



**Figure 7**. The relationship between flexure stress and flexure strain of composite sample, the straight line reflects the modulus of elasticity in shear.

After bending testing till destruction the different mechanism of destruction was revealed: commonly the breakage of the epoxy matrix was observed (Fig. 8, a), but in a number of cases firstly the perforated reinforcement (tape) was damaged or breaked (Fig. 8, b and c). It shold be noticed that the damage of the bands in all cases was starting with the delamination of the epoxy layer.

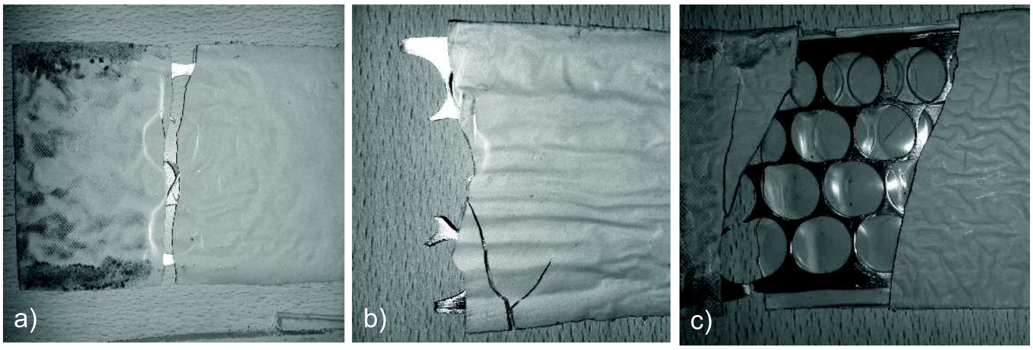



**Figure 8.** Macrostructure of the samples after breakage: a) breakage of the epoxy layer; b) breakage of the perforated reinforcement; c) damage of the perforated reinforcement.

In general the results of testing proves the high cohesive strength between the epoxy matrix and perforated reinforcement due to perforated holes filling by epoxy compound during the producing of the band. Taking into account the technological advantage (winding without complications) the application of perforated tape PST-1, which has lower strength, but higher plasticity than tape PST-2 seems more appropriate.

## CONCLUSIONS

The using of the composite band structures made from perforated metallic materials and epoxy matrix for binding and holding of tubular objects as pipelines or shells allows simplifying and speeding up the repair works especially in the cases of the local damages. Because of perforation holes such binding decreases the weight of the band in comparison with the traditional band, produced specially from the solid metallic tapes. The existence of the perforation holes provides the strong cohesive strength between the epoxy matrix and perforated reinforcement, as well as sufficient mechanical properties of the bands, which were proven experimentally.

It was shown that for the producing the band it is recommended to use the more flexible perforated tape due to the better manufacturability during winding.

Thus, the application of the composite band structures allows eliminating possible ecological threats from the damages and breakdown of the pipelines etc. From the other hand using of such structures allows to recycle valuable perforated metallic waste, which at this time mainly not reused. For example, according to the information of the JSC 'Ditton Driving Chain Factory' (Ditton Driving Chain Factory, 2017) only this enterprise produces the few tons of the perforated steel waste per year. This company specializes in a wide range of roller-, bush-, leaf and other chains and produces not only mentioned products, but also the technological waste after cold stamping of the elements of driving chains of the motors. That's authors believe that the results of given research are useful and needed to be implemented.

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