Fatigue behaviour of the screwed/riveted joints and the bonded joints

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Abstract The origin of this work takes place in the framework of an industrial collaboration in order to study the behaviour of a mechanical connection between two sheets, used in the industry of railway structures. The Technology utilised currently to assemble metal sheets is the assembly by fasteners. The economic interest resides in the reduction of the number of these connections in order to limit the operations of assembly and in the installation of an optimized connection as well in an operational way as calculative.
To strongly reduce the number of the fasteners (screw, rivet) we will introduce bonded joint into the structure, to study and to compare the dynamic behaviours of the joints assembled by fasteners and adhesive, we launched an experimental tests of vibratory fatigue on single lap joint under the traction and the shearing.

Keywords: mechanical assemblies, fatigue behaviour, single lap joint, bonded joint, screwed/riveted joint.

1 INTRODUCTION

The cubicles of traction (figure 1) developed by the company ALSTOM Transport are composed of different modules, power, electronic and other modules used in railway traction. This modularity requires a structural assembly with relatively important size. Currently we use mechanical connections for the structural assemblies and in particular riveted and screwed. These technologies of assemblies require a great number of fasteners accompanied by as many installation operations, also the adaptation of tools to reach all the places of the cubicles. Moreover, the assembly must ensure the sealing for protecting the electric components from the environmental constraints. The Structural bonded represents an alternative solution, thanks to the industrial evolution of the structural adhesives.

Fig. 1 – cubicle of traction

The cubicle of traction is a no dismountable structure; it has one lifespan equivalent to that of the train, approximately 25 years. Thus it is necessary to carry out dynamic tests, to know the lifespan on a mechanical connection scale and also to obtain a starting point towards a general study on a cubicle scale of traction.

The realization of the dynamic study necessarily passes by a former realization of static tests which will make it possible to define the elastic limits and with rupture of the connection. We will be able to then define the dynamic loadings of the connection to extract the limit from endurance.

2 SPECIMENS PREPARATION AND MATERIEL

We will study in this article two configurations to represent the principal behaviours in the railway: the traction (figure 2), the load F is perpendicular to the surface of connection and the single-lap-shear (figure 3), the load F is parallel to the surface of connection.

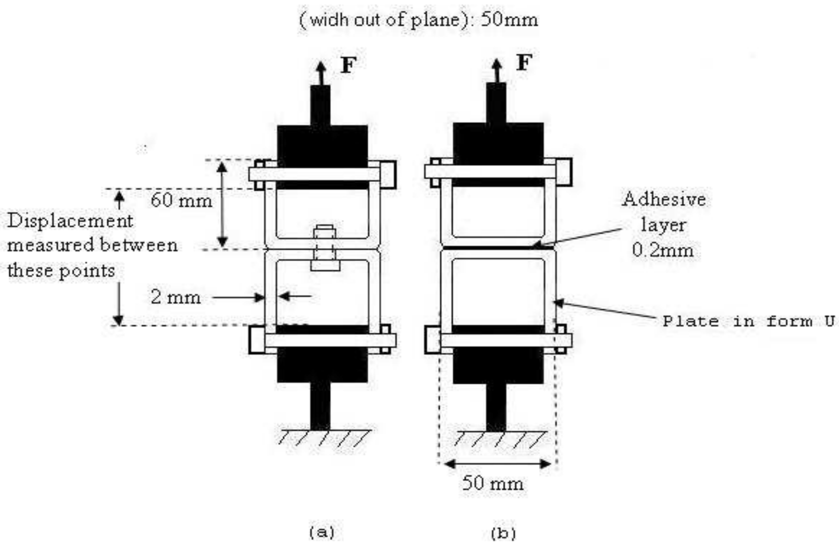


FIG. 2- Experimental arrangement for the joint tests in traction (a): screwed or riveted joint, (b): bonded joint

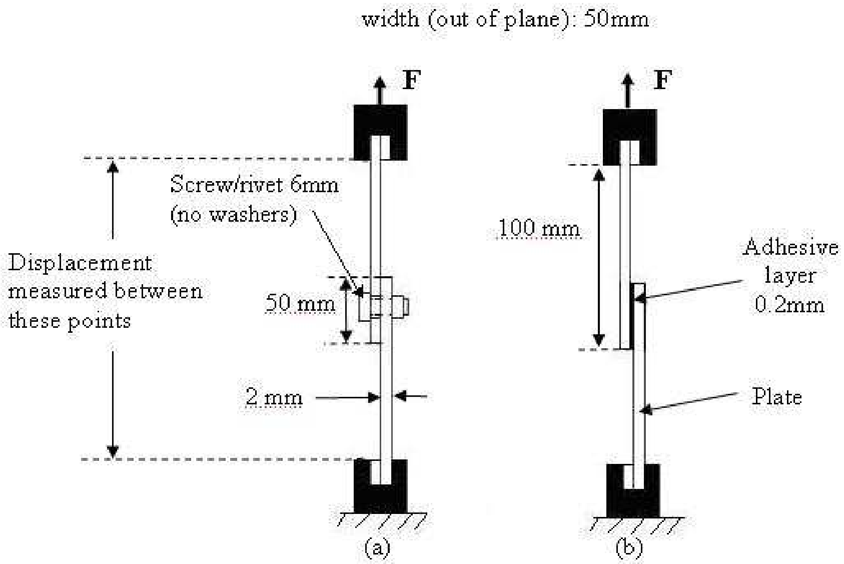


FIG. 3- Experimental arrangement for the joint tests in shearing, (a): screwed or riveted joint, (b): bonded joint

The specimens in our tests must answer industrial reality, while starting with the choice of the material which is steel covered zinc (D X 52D + ZA): Galfan®. The mechanical characteristics data of this material are presented in table 1.

Table 1: mechanical characteristics data of Galfan®

E	ν	Re : yield stress	Rm : rupture limit
200 (GPa)	0. 3	200 (MPa)	270 → 420 (MPa)

The adhesive used in the bonded joints is a structural Epoxy adhesive 3M® Scotch-Weld™ 7240 B/A [1]. Its mechanical characteristics data are obtained by experimental tensile testing on bulk specimen [2] according to standard NF EN ISO 527 (Plastics - determination of the characteristics in traction) table 2. The realization of the bulk specimen by the process of moulding using the silicone moulds.

Table 2: mechanical characteristics data of adhesive 7240 B/A

E	ν	Re : yield stress	Rm : rupture limit
2000 (MPa)	0. 27	25 (MPa)	40 (Mpa)

The adhesive 7240 B/A is charged with the grains of glass of 200 micrometer diameter to gauge the thickness of adhesive layer. The preparation of surfaces is done by a simple degreasing with a product of degreasing like acetone. The adhesive bonded joints are polymerized at ambient temperature to be under the same conditions of assemblies of the cubicle.

In the assembly by fastener we use two technologies of assemblies:

- The first technology of assembly (Figure 4) with a screw forming which forms its tapping in the one of two sheets to be associated, A nut of the Nylstop® type comes to ensure this connection

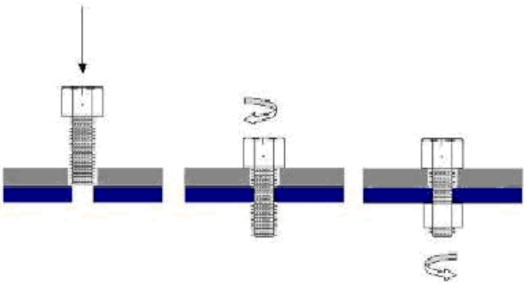


Fig. 4 – screw forming + nut Nylstop®

- The second technology of assembly (Figure 5) is a rivet with ring to be crimped which has the commercial name Magna-grip®.

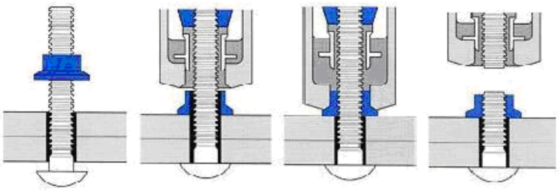
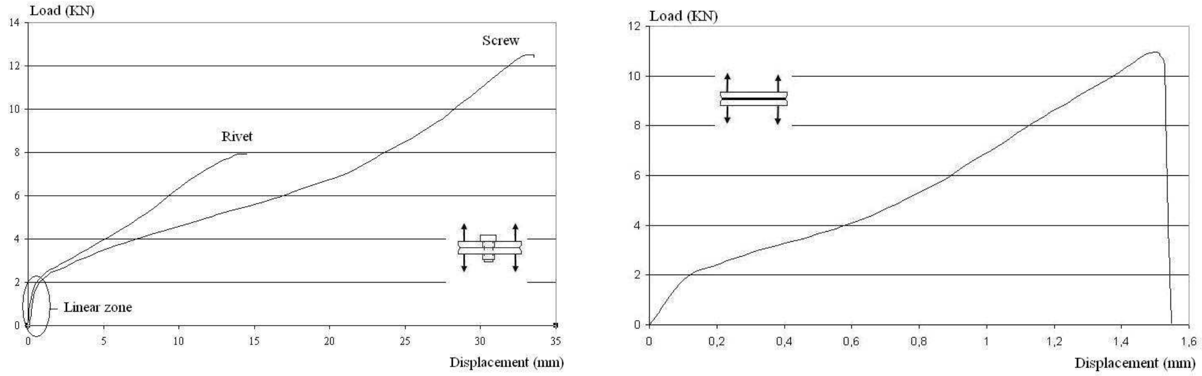


Fig. 5 –Magna-grip® Rivet

3 STATIC CHARACTERIZATION OF THE JOINTS

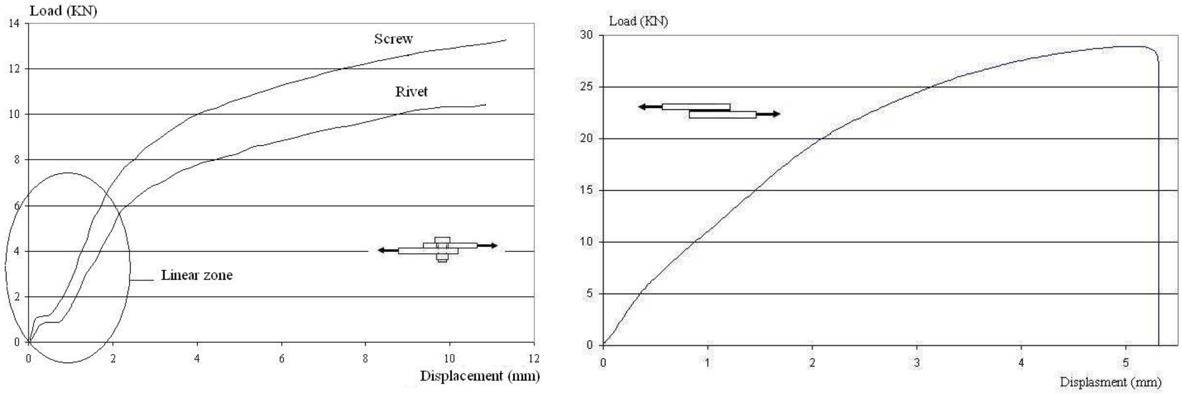
Before beginning the fatigue tests, we carried out tests in static, to identify the behaviours of the joints in traction and shearing. The realization of tests until the rupture gives us also an idea on the modes of failure, especially for the adhesive bonded joints [3].

In the curves of behaviours in traction and shearing of the screwed and riveted joints (figures 6a, 7a), we note that the linear zone is identical, it is the zone where we can quantify the rigidity of the connection (load divided by displacement) [4]. The nonlinear zones are synonymous with a great deformation of sheets of the specimens. During the shear test, we can note a small linear zone that we can explain by a relative slip of sheets before the transfer of load on the fastener [5].



(a) (b)

FIG.6- Static tests in traction of the specimens assembled by screw /rivet (a) & by adhesive (b).



(a) (b)

FIG.7- Static tests in shearing of the specimens assembled by: screw /rivet (a), structural adhesive (b).

In the linear zone of the bonded joints, we have an important rigidity compared to the screwed/riveted joints.The elastic zones observed on the curves load-displacement now enable us to better target the loads to be applied during fatigue tests.

4 DYNAMIC CHARACTERIZATION OF THE JOINTS

The principal objective of the fatigue tests is to obtain the limit of endurance of the screwed/ riveted joint [6] and the bonded joint [7].

The following curves present the results of the dynamic traction (figure 8) and shearing (figure 9) tests.

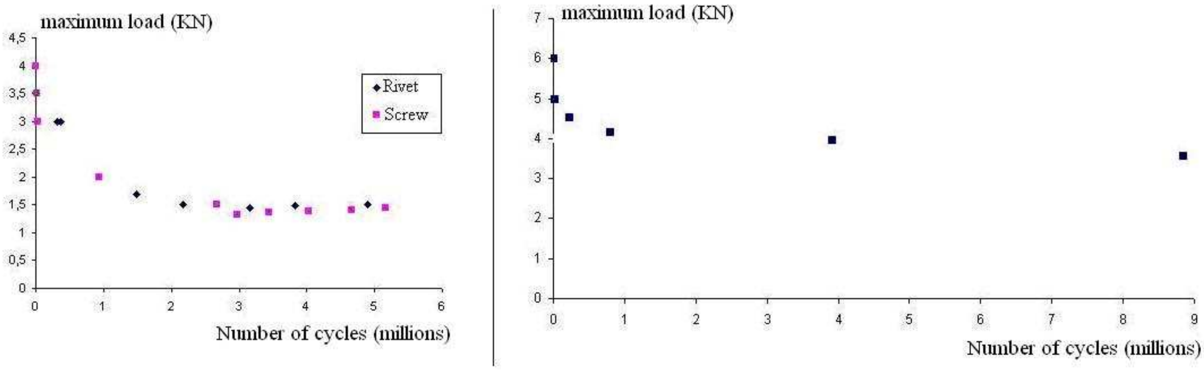


Fig. 8 – Wöhler's curves in traction, screwed and riveted joints (left) & bonded joint (right)

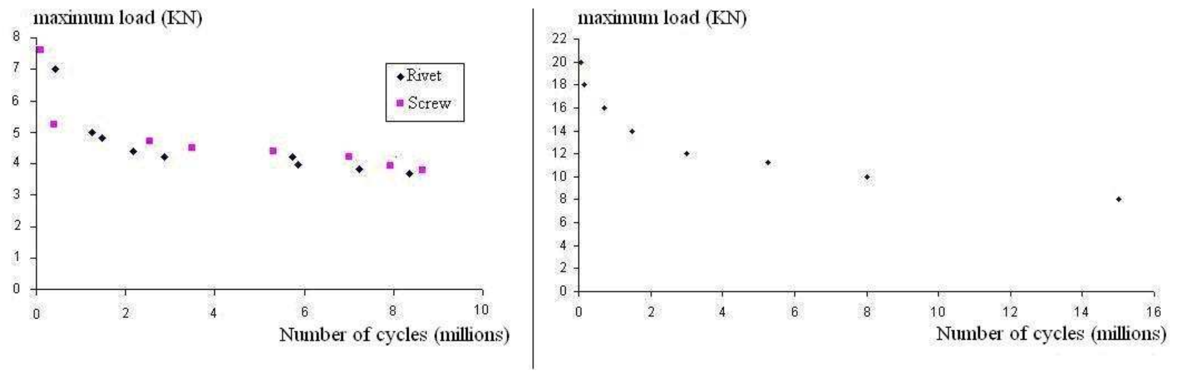


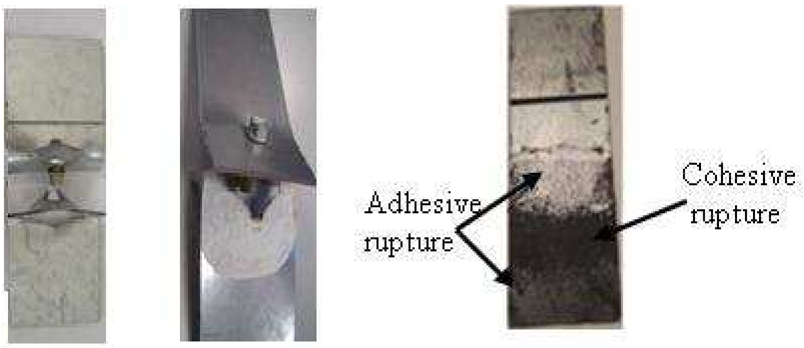
Fig. 9 – Wöhler's curves in shearing, screwed and riveted joints (left) & bonded joint (right)

In the screwed and riveted joints we can notice that the results in fatigue are very similar, and the limit of endurance is around 1.5 KN in traction and 3.8 KN in shearing. The limit of endurance out of bonded joint is approximately the double that riveted and screwed joints with more important numbers of cycles.

During these tests with the screwed and riveted joints, we noted the same phenomena of degradation, with a rotation of the fastener under the effects of the effort, then the appearance of crack in plates until total breaking (Figure 10a, 10b, 11a, and 11b). We noted that the failure of the bonded joints in traction, is always adhesive on the interface between the adhesive layer and the plate (figure 10c) while in shearing is mixed, cohesive failure in the medium and adhesive failure on the edges of the surface of cover (figure 11c),

(a) (b) (c)

Fig. 10 – Rupture of traction: riveted joint (a), screwed joint (b), bonded joint (c)



(a) (b) (c)

Fig. 11 – Rupture of shearing: riveted joint (a), screwed joint (b), bonded joint (c)

5 CONCLUSIONS

In this study we analyzed in static and dynamic, the different types of connections. The static tests permit to obtain the elastic zones and the zones of plastic degradation of plates (screwed, riveted joints) and of adhesive (bonded joint). In the screwed and riveted joints the rupture is always in sheets and not in the fasteners (screw or rivet). It thus proves that its dimensioning is acceptable for the loadings applied.

In the adhesive bonded joints most of the ruptures are adhesives ruptures in the interface between the adhesive layer and one of two plates. This adhesive rupture is caused by the presence of an organic layer Easyfilm® used to protect the galfan® from corrosion [8]. The degreasing we used for the preparation of surfaces does not remove this layer. To improve adhesion it is advised to use galvanized steel in the place of the galfan®.

The limits of endurances and the numbers of the cycles, in traction and shearing are more important in bonded joints than in the two other types of joints, so structural gluing can be an alternative solution in the assemblies of the cubicle. This result is obtained with a cyclic loading at ambient temperature and the next stage is to carry out tests according to the temperature.

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