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DESIGN OF A TEST BENCH FOR EXPERIMENTAL MEASUREMENT OF STRUCTURAL JOINTS RIGIDITY

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***Abstract*—**This work was born as a result of the need of measuring the mechanical behaviour of a set of structural elements and joints, to correlate the experimental results from previous on road with the bidimensional Finite Element Models ones. To such purpose the Adapted Vehicles and Transport research group has developed a new test bench that will enable more accurate results from Finite Element Models which will allow optimizing the frame structure of heavy vehicles as semitrailers.

***Keywords*—**Bench, chassis, joint, test, vehicle.

I. INTRODUCTION

THE Adapted Vehicles and Transport research group, belonging to the Institute of Design and Manufacturing of the Universitat Politecnica de Valencia, has developed a new test bench for structural joint rigidity measurement. This bench has been developed as result of several on road tests [1] carried out at Applus IDIADA Automotive test track, where the static and dynamic behavior of a semitrailer was measured. The measured stress values where different to the obtained by bidimensional Finite Element Model (FEM) [2], [3]. From this previous work, it was concluded that the stress differences were owed to the influence of the joint rigidity, which in the FEM model was modeled as ideally rigid. So, it was necessary to develop a test bench to measure the join rigidity to feed the FEM.

Once the test bench had been developed, it will be possible to characterize the structural beams (stresses and deformation) and measure the joint rigidity. It will be also possible to reproduce the dynamical loads measured on previous on road tests.

This way, it will be possible to make more accurate bidimensional FEM which will allow developing more complex analysis such as modal and random vibration analysis that finally could lead to vehicle frame optimization.

After a preliminary analysis of the loads magnitude and the beams and joints geometry, it was concluded that it could not be possible to use a conventional test bench. So a new test bench, with simultaneous bending and torsion capabilities on both joint elements, has been developed.

II. TEST BENCH SPECIFICATIONS

The test bench specifications were determined by previous on road test and by the joint geometry as well.

The on road test showed that the best test set up for the structural elements (beams) was the cantilever position. Regarding to the load magnitude (forces and moments), the maximum values for on road tests were initially taken but finally the maximum values that lead to plastic deformation on beams were taken.

Table I shows the magnitude and direction that cause yielding on a standard joint.

TABLE I
MAXIMUM LOADS AND MOMENTS FOR A STANDARD JOINT: I 220 STRONGBACK AND IPN-220 CROSS GIRDER.

Load	Value
Strongback – Fx	12460 (N)
Strongback – Fy	72091 (N)
Strongback – Fz	936000 N
Strongback – Mz	1288 (N·m)
Cross girder – Fy	6130 (N)
Cross girder – Mx	3072 (N·m)

Fig. 1 shows the axes convention [4] used in this work.

In order to set up the geometric specifications, there were considered the different sizes and configurations both for frame elements and joints used by semitrailer frame manufacturers.

From this analysis it was laid down that for steel frames, the biggest strongback and cross girder were I-220 and IPN/UPN/U/Z-80 respectively, while for aluminum frames were I-600 and IPN-220.

The joint diversity goes beyond to this work, but Fig.s 2 to 5 show the most common ones.

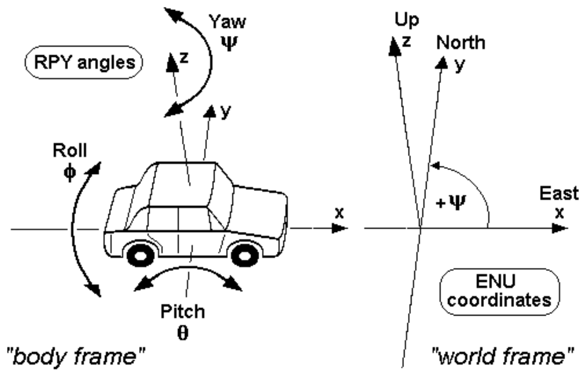

Fig. 1. Axes convention.

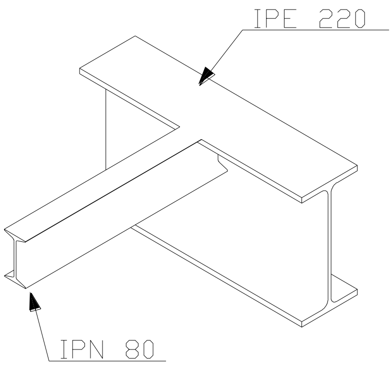

Fig. 2. Joint between IPE-220 strongback and IPN-80 cross girder.

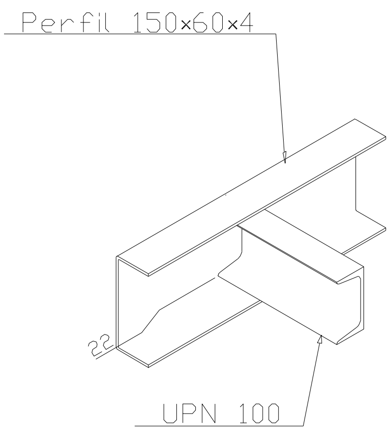

Fig. 3. Joint between U 150x60x4 and UPN100 cross girder.

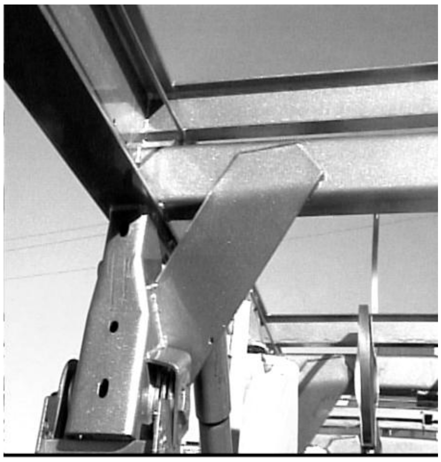

Fig. 4. Joint detail between frame and suspension.

Fig. 5. Joint detail between frame and suspension.

Finally, it is necessary to apply all the specified load states, some of them simultaneously, while assuring an easy test specimen manipulation as their average weight is 150 (kg). Furthermore, as the loads and moments are quite large, a high rigidity is required for the test bench in order to prevent a measurement error induced by the bench deformation.

III. Test Bench Design & Manufacturing

According to previously defined specifications, the decision was to use the bed of a disused shaping machine. Its strength fulfilled the rigidity requirements and the translation mechanism made easy to set up and load the test specimens.

Following a gantry was designed to support the hydraulic cylinders responsible for the joint or member loading. By changing the cylinder position on the gantry, different load states can be obtained. Figures from 8 to 11 show some of test bench set up capabilities.

To ensure a normal load application on the frame elements, cylinders with rod hinges were used.

Following the anchor plate, used to fix the test specimen to the bench test was designed. Its rigidity does not influence on the measured displacements, as the displacement sensors are fixed to the test specimen or the anchor part, as can be seen from Fig. 6 and 7.

Then, a FEM (Finite Element Model) analysis of the anchor part was carried out using Ansys to ensure that it was strong enough to avoid breakage. Fig. 12 shows the stress distribution on the test piece and the bench for a bending test.


Fig. 6. Displacement sensors fixed to the anchor plate.


Fig. 7. Displacement sensors fixed to the test specimen.


Fig. 8. Combined bending and torsion on the strongback.

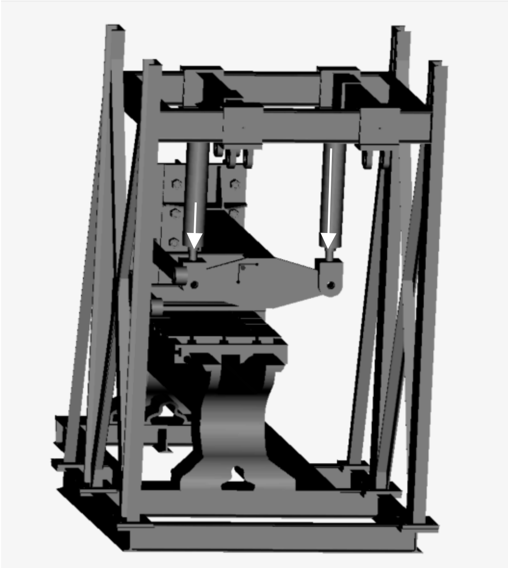
Fig. 9. Combined bending and torsion on the cross girder.

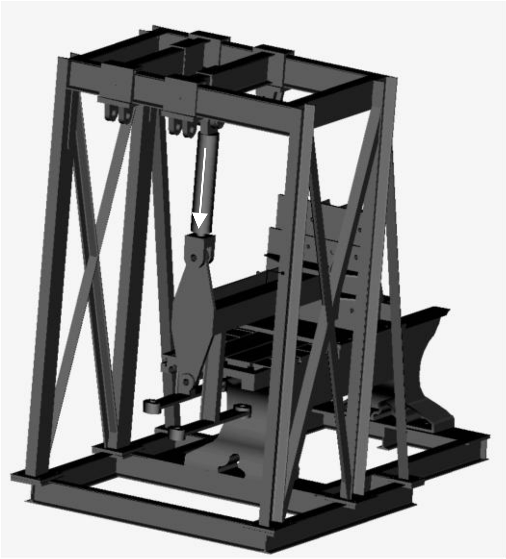
Fig. 10. Lateral bending on the strongback.


Fig. 11. Lateral bending on the cross girder.

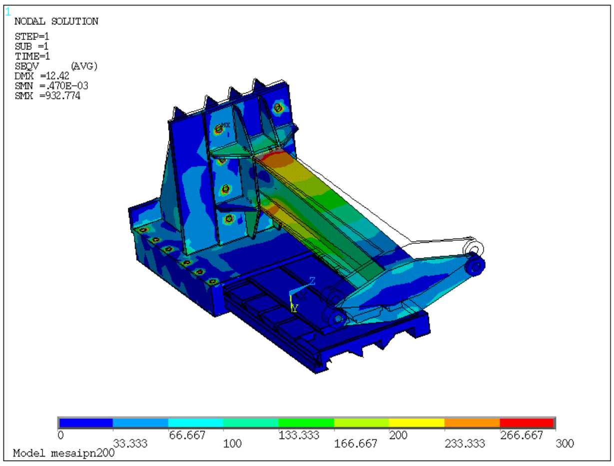

Fig. 12. FEM analysis for a bending test.

Finally, the hydraulic system was designed. It is comprised by a gear pump, a safety pressure relief valve, a proportional pressure valve, two proportional directional valves and four cylinders. This allows conducting experiments with displacements up to 300 mm in dynamic conditions.

Once the test bench was made, it could be checked that its maximum loads and moments are 100 (kN) and 3072 N·m which is high enough to conduct all the desired experiments. Fig. 13 shows the test bench without instrumentation.

Fig. 13. Manufactured test bench.

IV. Test Bench Calibration

Once the bench test was manufactured, the next step was the developing of the measurement chain and its inherent errors in order to calibrate the bench test. To this end the selected data acquisition system was MGCPlus together with the software Catman from the manufacturer Hottinger Baldwin Messtechnik.

The magnitudes measured by de data acquisition system were:

1) *Strain, measured by strain gauges [5].*
2) *Displacements, measured by potentiometric displacement sensors, placed on the test pieces.*
3) *Force, measured by load cells placed in the cylinders rods.*
4) *Pressure, measured by pressure sensors [6].*
5) *For the strain gauges, the main errors are [7]:*
6) *Gauge factor tolerance: 1,5 %.*
7) *Gauge factor variation ought to cable length: negligible, corrected by software.*
8) *Linearity error: lower tan 0,5% for strain lower to 0,5 %.*
9) *Transversal sensivity error: negligible, corrected by software.*
10) *Temperature error: avoided with a thermal compensation gauge. Polynomial correction using software.*

For displacement sensors, the main error is the linearity error which in the worst case scenario (highest displacements) is lower to 1%.

For force sensors, the main error is the linearity error which in the worst case scenario (highest pressure) is lower to 0,2%.

For pressure sensors, the main error is the linearity error which in the worst case scenario (highest pressure) is lower to 0,2%.

The overall error of the test bench is, considering the root mean square error:

1) *0,65% for strain measurements*
2) *0,42% for displacement measurements.*

V. Conclusion

After the bench manufacturing, and the first test results, the design can be considered fully satisfactory. The next stage will be the test bench set up with the on road parameters in order to reproduce these load states.

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