Experimental Study of Spatial Piping Mock-Up Behaviour During Dynamic Loads: Earthquake and Aircraft Impact

S. Valicenti, G. Bonacina, A. Castoldi, M. Casirati
ISMES SpA, Bergamo, Italy
M. Mirone, A. Furno
ENEL-DCO, Rome, Italy

ABSTRACT

This paper deals with the dynamic tests performed on a spatial full scale piping mock-up (10inch sch 80), by the Dynamic Test Department of ISMES S.p.A., Bergamo (ITALY), in cooperation with ENEL-DCO Rome. The main purpose of the reserch was to evaluate the global mock-up behaviour (pipe and restraints) consequent to the application of impulsive and transient earthquake loads in order to validate the numerical techniques used for the multisupport pipe design. For more details see reference |1|.

1. INTRODUCTION

The experimental program performed in the framework of an agreement with ENEL, refers to problems related to the design of piping and relevant restraint systems when subjected to two kinds of dynamic loads: aircraft impact and earthquake. A spatial full scale mock-up of the LPCI-C pipeline of ALTO LAZIO power station was reproduced together with the actual restraint conditions. All the tests were repeated in a second restraint condition simulating the failure of dampers.
Due to the very recent conclusion of test, only the preliminary results analysis is presented in the paper. The general conclusions will be the subject of a subsequent paper. Next activity will be related to the numerical evaluation of the experimental results.

2. MOCK-UP DESCRIPTION

The pipe (10 inches Sch 80) was approximately 13 m long. It included 5 elbows, and two simulated valves. The valves simulation was limited to reproduction of the masse and inertial moments. Piping mock-up was supported by means of 6 snubbers and 2 springs and was filled with water not in pressure. The two penetrations were reproduced by means of especially designed frames. A schematic view of the pipe is reported in fig. 1. Photos no. 1, 2, and 3 shows the mock-up under test.

3. EXPERIMENTAL PROGRAM

The following dynamic tests were carried out in the three perpendicular directions X,Y,Z non simultaneously:
. Vibration Response Investigation (monofrequential sinusoidal tests).
. Seismic tests.
. Impact tests with two different time histories.

Fig. 2 summarizes the whole research experimental program performed.

3.1 Vibration Response Investigation (monofrequential sinusoidal tests)

The goals of these tests were the following:

- study of the mock-up frequency response functions and, in case of absence of marked non-linearities, evaluation of the natural frequencies, damping and modal shapes;
- to investigate the restraints influence on the dynamic behaviour of the mock-up;
- validation of the numerical model used for the verification of the pipe design (restraints and stiffnesses reproduction etc.).

The sinusoidal excitation was applied non simultaneously in four points for each direction: at the two penetrations and at the base of the two snubbers mounted along the excitation direction (see Fig. 1). Characteristics of motion were: frequency range 1-50 Hz, peak acceleration: 0,05 and 0,1 g.

3.2 Seismic and impact Aircraft Impact tests

Aims of the tests were:

- the evaluation of the structural behaviour of the mock-up as a whole, when subjected to the design seismic excitation;
- the measurement of the forces transmitted through the restraints when subjected to the design seismic excitation in the comparison with those produced by the impact;
- to supply the necessary data to validate the assumptions made for the piping multi-support design, during a seismic event.

Four seismic excitations were applied simultaneously (P1, P2, P3, P4 - see Fig. 1)
The time history was applied stepwise by gradually increasing its amplitude up to full level (6 steps), in each of the three orthogonal directions (X-Y-Z axes), non simultaneously. In addition as concerns impact tests the influence of different excitation time histories shapes was studied. The total duration of the imposed displacement time-histories was about 300 ms (time history no. 1) and 200 ms (time history no. 2). Both time histories was artificially generated starting from the Required Response Spectrum (RRS) (see fig. 5).

4. TESTS RESULTS

A. The sinusoidal tests, performed with two excitation levels, didn't show significant variation of natural frequencies (see table 1).
An example of first mode shapes, relevant the two restraint conditions examined (with and without snubbers) are shown in fig. 3.
B. Fig. 4 shows an example of comparison between the Required Response Spectrum and the Test Response Spectrum obtained in X direction during seismic tests for two points of excitation. The corresponding excitation time histories are also reported.
C. Fig. 5 shows the required excitation displacement time histories in the case of the impact excitation (simulating the aircraft impact). The response spectra are also illustrated. Furthermore the obtained displacement excitations are illustrated for two different time histories
D. Figs. 6 and 7 show a valve responses measured during the seismic and impact tests in Z directions both with and without snubbers. It is worth noting that

in the case of impulsive excitation: it is evident (fig 7) the influence of the presence or absence ofsnubbers on the damped responses;

As concerns the seismic tests (fig. 6) although the measured time history responses, in terms of peak and RMS values, are practically the same in the two restraint conditions because of the peculiar valve location (near to an excitation point), there is however a large difference for what concerns the response spectra. This result has to be taken into account, for example in the case of qualification of motoroperators or of the valves themselves.

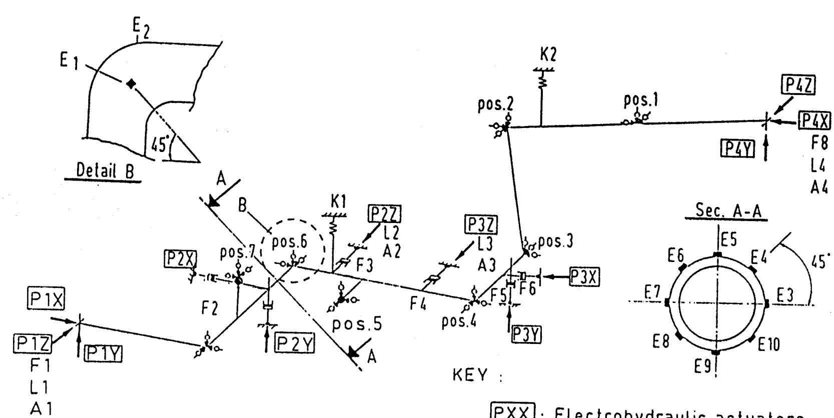
5. CONCLUSION

The following remarks have to be underlined:

1. At the end of tests no damages were found at the restraints. Non distructive controls were also performed on the pipe weldings: no ruptures were detected in spite of the high levels reached.
2. Rather different results were obtained using different time histories. It seems therefore advisable that the choice of a really representative design time history should take into account not only the RRS, but a real description of the impact phenomenon. Nevertheless there is the same ratio about 2 - 3, among the responses measured (peak and RMS values) in the two restraint conditions indipendent on the TH shapes.
3. The reduction of the restraints number in this case did not influence forces measured on the remaining ones.
4. The seismic event is more severe in terms of stresses for the pipe than the restraints, the contrary can be said for the impact.
5. The peak forces are usually higher during impacts, with consequent worst working conditions of the restraints in the case of impulsive excitation. The influence of the two kinds of excitation on the pipe, seems on the rontrary to be negligible. In effect the measured strains are very low (corresponding to the material yielding) in both cases, however higher strains were found during seismic excitation.
6. An extension of the experimental results will be obtained during next phase of the research which concerns numerical evaluation of the experimental data.

6. REFERENCES

|1| 1989 Asme Pressure Vessel and piping conference: Castoldi, A. et al. "Experimental study of spatial mock-up behaviour during dynamic loads: earthquake and aircraft impact".



KEY :

PXX : Electrohydraulic actuators
LX : Displacement transducers
FX : Force transducers
AX : Accelerometers
: Snubbers
EX : Strain gauges

Fig. 1: *Excitation locations; numbering and position of the measurement points*

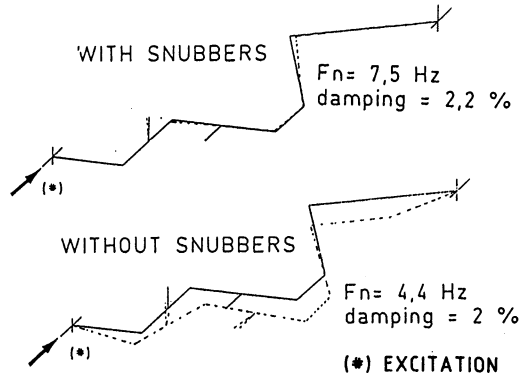


Fig. 3: *First modal shapes*

EXCITATION LEVELS [g]	
0,05	0,1
7,2 (*)	7,5 (*)
4,3 (o)	4,4 (o)

(*) With snubbers
(o) Without snubbers

Table 1: *First natural frequency (Hz)*

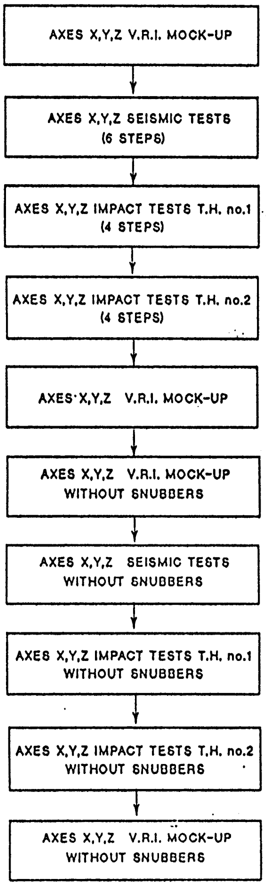


Fig. 2: *Experimental program*

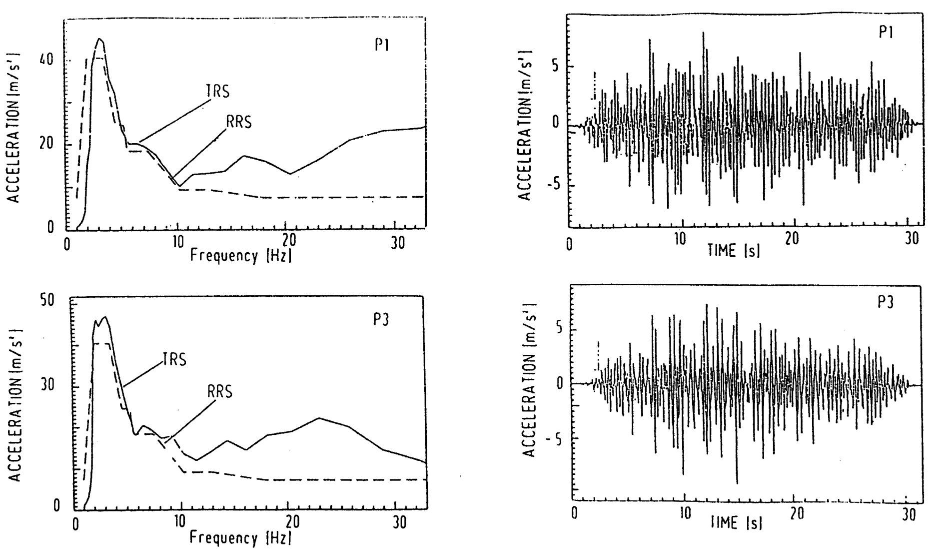


Fig. 4: *Seismic test: X axis*

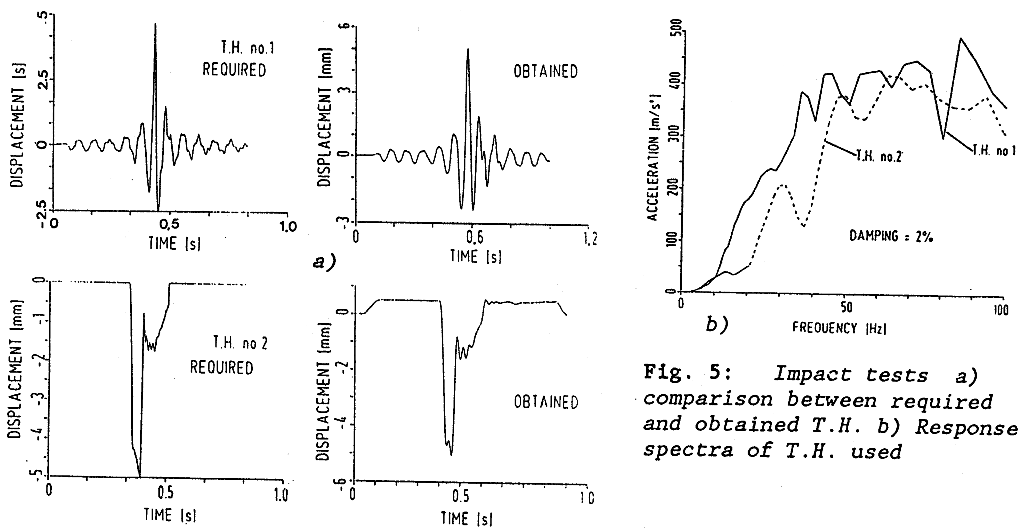


Fig. 5: *Impact tests a) comparison between required and obtained T.H. b) Response spectra of T.H. used*

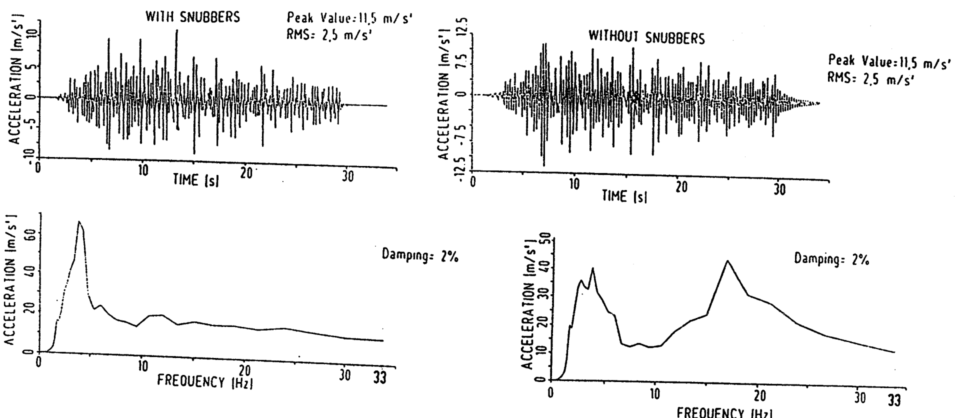


Fig. 6: *Seismic test (Z axis)- valve responses with two different restraint conditions (time histories and relevant response spectra)*

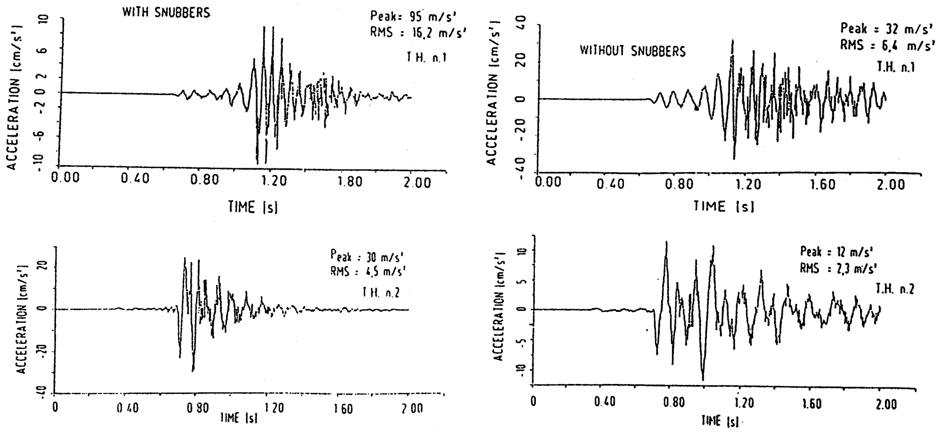
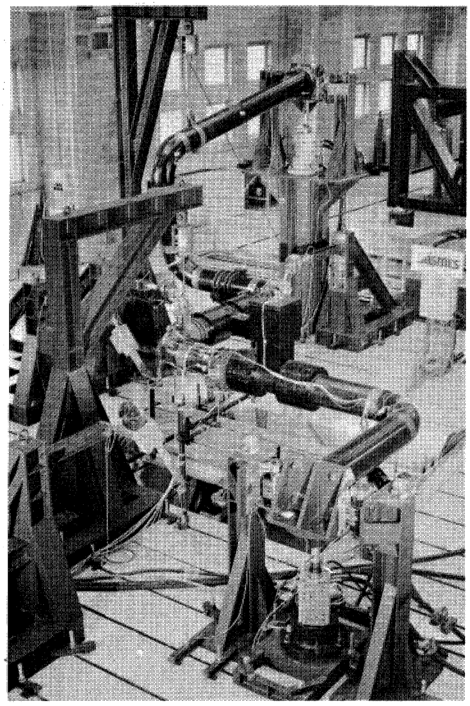


Fig. 7: *Impact test (Z axis) - valve responses with two different excitation (T.H. no. 1 and T.H. no. 2) and restraint conditions*



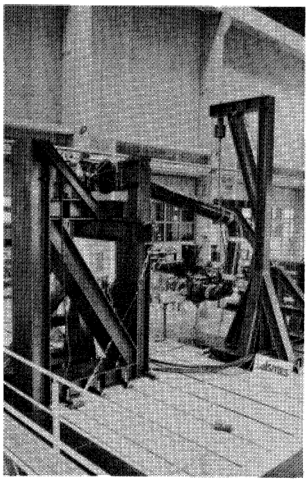


Photo 2: *Detail of the upper penetration (P4)*

Photo 1: *View of the mock-up (without snubbers)*

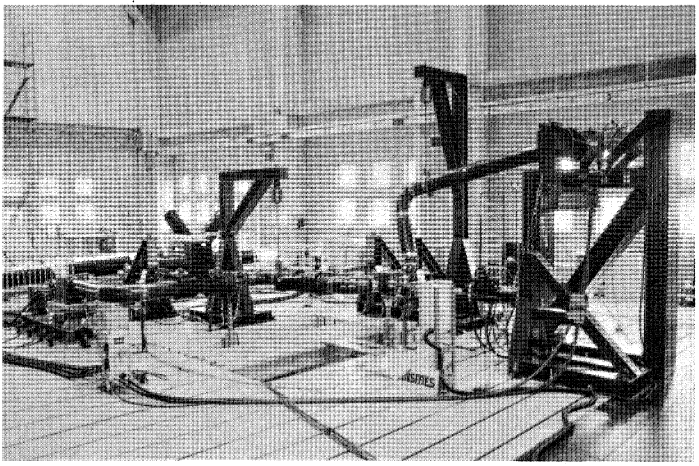


Photo 3: *View of the mock up (2 configuration with snubbers)*