ECONOMIC EFFECTS OF FRACTURE

L. Faria [1]

The difficulties of an effective evaluation of the effects of ruin and collapse due to fracture on the economy are put in evidence. The costs of fracture are refered in detail and the measures for potential savings are underlined. A new approach to evaluate the cost of fracture is presented.

1. INTRODUCTION

Corrosion and fracture can be included amongst the main causes that originate the ruin and collapse of systems.

As a rule a complete evaluation of the economic effects due to the ruin and/or collapse of equipments is not made.

The better knowlegde on the behaviour of materials and structures due to research work improved the reliabity of the systems, but there is not yet an effective and permanent transfer of this knowledge from researchers to engineers.

Some of the existing codes are not updated, or do not contemplate important aspects that should be considered at the design and manufacturing phases or during the life of systems.

And many systems, which ruin or collapse influences strongly the corresponding effects on economy, are not designed and manufactured according to codes or standards. For these systems:

- either these codes and standards do not

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- either these codes and standards do not exist,
- or these codes and standards are not entirely followed or are misinterpreted.

The studies [1] [2] to assess the economic effects of fracture on economy revealed its importance and reccomended some actions that could lead to big reductions in the corresponding costs. However a cost--benefit analysis between these reductions and those actions has not yet been made.

2 - EVALUATION OF ECONOMIC EFFECTS

The evaluation of economic effects of ruin or collapse of systems due to fracture is not an easy task. As a matter of fact:

- the ruins and/or collapses are due to complex effects; as a rule it is difficult to disclose the original cause;
- the insurance companies insure the systems against general risks (such as fire, transport, robbing, etc.) and now some started to consider certain specific risks, as for instance, environment; fracture or fatigue are practically unknown in the list of risks;
- in many cases the manufacturers do not wish to reveal the failures, as they consider that their divulgation can give prejudice to their image; and this is also the attitude of many users, as the failures could put in evidence bad use or maintenance;
- even when the failures and corresponding accidents are known and divulged, the corresponding costs are hardly evaluated; as a matter of fact direct and indirect costs (consequential costs, human costs, etc.) are not always known;
- in many cases the end users and the manufacturers accept to replace the damaged parts at their own expenses and in consequence the effect in the prices of equipment or in the maintenance costs is neglected.

3 - COSTS OF FRACTURE

3.1 The factors that influence the cost against fracture, i.e. the provisions in order to avoid fracture, are mainly the following:

- in design, the imposition of large factors of safety due to the uncertainty in the loads, type of loads, loads cycle, localization of loads, calculating methods (deterministic, probabilistic), behaviour of materials, variability of materials properties, use of expensive materials, in resume, the adoption of conservative design;
- in manufacturing and assembly, the uncertainty of preexisting defects in the materials (density of defects, orientation, etc.) and the influence of the processes used (residual stresses, induced stresses, surface defects, etc.) lead also to increase the safety factors;
- in quality control and testing, the capital costs of required equipment and the cost itself;
- in inspection in-service during the product lifetime, the capital costs of required equipment, the cost of parts to be replaced.

3.2 Besides these costs associated with design, manufacturing, quality control and inspection, other associated costs could be added, such as packaging, transport, materials and structure research against fracture, limitation on product lifetime.

3.3 Considering now the failures due to fracture, its costs can include:

- the total or partial loss of equipments and their replacement,
- the consequential costs (loss of use),
- the injuries and deaths,
- environmental damages,
- cleanup,

and the influence in the image of the type of equipment, of the manufacturers and of the users.

3.4 Althogh it is out easy to evaluate the costs of fracture the studies made in Europe and to a certain extent in the United States show the equipments that give a higher contribution to the losses on economy due to fracture are:

- transport equipment (ships, rolling stock, motor cars, trucks and aircraft),
- power stations and systems (boilers, steam and gas turbines, pipes, pinelines, offshore structures, related equipment),
- chemical and petrochemical industries (pressure vessels, pipes, valves, heat exchangers, etc.).

The sectors affected by fracture are heavily dominated by metals, although a significant contribution by equipments where other materials are used, such as concrete, polymers, wood and rubber (tyres), is given.

3.5 To calculate the influence in the economy of a country it is usual to compare the cost of fracture with the G.N.P. (gross national product). The study concerning the United States [1] included all materials and all types of structures and both fracture occurrence and fracture prevention costs; it has been completed for the year 1978 and the evaluation of these costs was of $119 billion per year (1982 dollars), that is about 4% of the American G.N.P., with an uncertainty of ±10%.
Similar studies can be carried out in any country but due to the reasons mentionned on section 2 of this paper we feel that the uncertainty could attaigned a very high percentage and the global results did not give specific reccomendations about the actions to be adopted in each industrial sector or in each type of equipment, contributing significantly to the losses in economy.
So, to obtain good results it will be preferable to study the possible improvements to be introduced in the reliability of each type of equipment and to compare the cost of these improvements with the reduction of the possible corresponding costs due to fracture.

4 - POTENTIAL SAVINGS

The potential savings in the cost of fracture could be obtained by different ways as follows:

a) Better design, using probabilistic methods, adopting total quality principles and in consequence assuring the fitness for purpose;
b) Selecting materials with adequate properties for the working conditions;
c) Making a correct risk analysis considering the purpose of the equipment;
d) Adopting manufacturing and assembly processes avoiding or limiting the introduction of defects, residual stresses, etc.
e) Modernizing codes, standards and regulations;
f) Best fracture control in quality, inspection, maintenance and repair;
g) Assuring the transfer of recent research results to the designers and manufacturers.

By those means the safety factors adopted can be reduced, the probability of failure can be defined, lowering in consequence the cost of equipments and of their maintenance, assuring a better reliability, increasing the competitivity of industries, eventually reducing the insurance rates.

To obtain the potential savings above refered some actions should be envisaged:

i) Research directed toward fracture related problems concerning materials and structures.
ii) Education and training of engineers concerned with design, manufacture, control and inspection of equipments.
iii) Establishment of mechanical properties data banks.

And last but least persuading industrialists and insurance companies to evaluate the real losses due to fracture. The study made in U.S.A. refered that by technology transfer and fracture-related research about 50% of the American economy losses could be saved [1].

Not considering the global losses in economy, as this evaluation does not give a real picture of what happens in each type of equipment, the effective savings in manufacturing could attaign

very high values of the same order of the profit; and the maintenance costs could also be reduced strongly to one third to one half.
If we consider accidents the economic effects could be very important as it is demonstrated in the annex I.
In our opinion the European Group on Fracture can fulfil a very important role in promoting different activities and suggesting mainly to the European bodies actions leading to reduce the costs of fracture, to reduce manufacturing costs, to avoid accidents (see annex II).

REFERENCES

[1] "The Economic Effects of Fracture in the United States", U.S. Department of Commerce, National Bureau of Standards, Special Publication, 647-1, 647-2.

[2] Faria, Luciano, "Economic Effects of Fracture", Proceedings of SPT-3 International Conference in Vienna, 1989.

A N N E X I

AN EXAMPLE OF COST OF AN ACCIDENT DUE TO FRACTURE

Local: Lavradio (Portugal).

Type of equipments: Reactor (high pressure vessel).

Type of service:

Catalitic reaction (Co shift conversion)

Operating conditions:

58 Bar; 220°C; gas with 47% hidrogen.

Code: AD. Merkblatt; design approved by Lurgi and TUV.

Inspection: Every 5 years.

Failure:

August 1985; 1,5 year operation after the last inspection - severe leack followed by explosion due to a sudden depressurization; the crack occured in a welding.

Main reason of failure:

Existence of thickness reduction between the reactor cylindrical wall and the hemispherical upper head (stress concentration); brittle fracture due to incorrect manufacturing.

Cost of repair and replacement:

456×10^6 Portuguese escudos (1985) corresponding to about 3×10^6 US dollars (1990).

Damage to property:

5×10^6 Portuguese escudos (1988) corresponding 33 000 US dollars (1990).

Consequential costs:

The ammonia plant stopped during 10 months; costs not evaluated but exceeding largely the repair costs.

Suggestions to overcome this type of failure:

Rules concerning materials for hydrogen service. maximum allowable hardness.

A N N E X II

SOME SUGGESTIONS OF ACTIONS LEADING TO REDUCE THE COSTS OF FRACTURE

a- Seminars for industrialists and for insurance companies (economic aspects).

b- Workshops on intensive courses for engineers (update knowledge, transfer of knowledge from research to industry).

c- MSc courses on fracture mechanics (eventually European masters courses under the patronage of EGF, CEC (Petten and/or Ispra JRC) and the University of Europe (Paris).

d- New codes, standards or regulations for equipments and systems for which they do not exist; updating and modernization of existing codes, standards and regulations (patronage of EGF, support of CEN, BCR and JRC).

e- Creation of data banks concerning the mechanical properties of materials (patronage of EGF, support of CEC - Luxembourg).

f- Research required for standardization and for creation of data banks (European research centers, EGF committees, task and working groups).

Note: Actions a) and b) could be organized either by EGF or by the Nacional Groups on Fracture, under the patronage of EGF, and should take place in every European country, member of EGF.