MECHANICAL STRESS ANALYSIS BY EDDY CURRENT METHOD

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A lot of progress is made in the last decade concerning the theoretical and practical aspects of eddy current testing. In addition to the defect characterization, actual studies deal with the metallurgical evaluation of materials. Surface examination allows the prediction of the material strength and consequently its life time.
In order to obtain various microstructures and to modify the mechanical and metallurgical characteristics of materials, samples such as aluminum or steels have been submitted for mechanical stress. We have shown in this work that all microstructure modifications of the samples were detected and can be quantified by eddy current impedance measurement.

The impedance analysis by eddy current will be correlated with the microstructure changes observed in the material because of aging, fatigue.

Introduction

The good mastership of working stresses level in mechanical components and structures is an important factor in engineering industries. Evaluation and monitoring of the stress state of these elements is a time consuming job, beside it involves quite tedious work.
The characterization of microstructures, mechanical properties, deformation, damage initiation and growth by Non-Destructive Evaluation (NDE) techniques is assuming a vital role in various industries because of the growing awareness of the benefits that can be derived by using NDE techniques for assessing the performance of various components. Fracture mechanics based analysis of component integrity requires quantitatively characterization of microstructure defects as well as stresses. Any alteration in the microstructure, which reduces the life or performance, should be predicted sufficiently in advance in order to ensure safe, reliable and economic operation of the components. This prediction is possible with NDE techniques, when it is realised that the interaction of the nondestructive probing medium with the material depends on the substructural / microstructural features such as point defects, dislocations, voids, micro and macro cracks, secondary phases, texture and residual stress. The stress plays a very important role with respect to the different material properties.

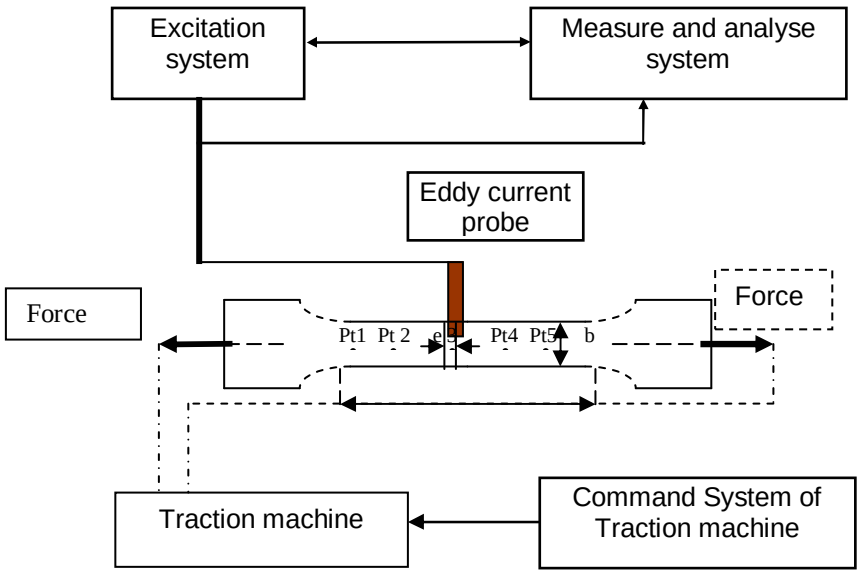
Physical approach

Various non-destructive techniques are available for the measurement of either applied stresses or residual stresses. The non-destructive test method based eddy current is sensible to changes in microstructural characteristics and the stress state of the material and can be used to evaluate these materials characteristics. The eddy current method [1,2] allows to evaluate the state of stress in ferromagnetic material. The given method is used for determining own stress as well as that formed in effect of outside load. The study by Dybiec et al. [1] used the eddy current method to evaluate the state of stress in ferromagnetic material. The given method is used for determining own stress as well as that formed in effect of outside load. It is known that during plastic deformation defects of metal continuity are generated (e.g. micropores, microcracks, vacancies, etc). The defects are observed as early as at early stages of plastic deformation. The formation of discontinuities is accompanied by partial relaxation of elastic energy [1], which leads to changes in the magneto-elastic energy of material in the regions adjacent to the defects. This phenomenon is likely to affect the magnetic and electric parameters of materials. A notable change in the magnetic characteristics occurs as early as at small values of strain degree.

Experimental Procedure

Merlin machine of traction is used for evaluating the sollicitation degree of material in the specific zone of the specimen. The effect of traction strain and accumulated damage on magnetic properties was studied on standart specimen subjected to elongation. The correlations obtained make it possible to evaluate the traction strain and current damage of metal, as well as to estimate the residual lifetime of an article under traction.
The said equipment is characterized by high sensitivity of indication measurements regarding changes occurring in the material structure. The software allows commanding the load tensile continually or by step. The probe

with eddy currents is placed in the zone of sample rupture that is predetermined as a preliminary test. We have choosed five points impedance measurements by eddy currents in this zone at each load.(figure1) .



Measure conditions

Some recommandations have been required for precisely measure

- determination of the repture load
- the load step is 3KN for the aluninum 2024 with the 3 min of maintain time
- The load step is for the steel 304L with maintain time

At each charge step, we have measured the impedance and the phase of eddy current in the five point chooses

Results and Interpretation

With an aim of finding a relation between the magnetic parameters, electric and mechanics of materials subjected to constraints. We chose an experimental approach which consists in subjecting the sample to traction while taking measurements of the phase and the impedance in several point of the specimen.
The curves (figure 2at 5), presents a stage that corresponds to the zone of trajectory transition.
The same result is obtained for all the points chosen on the level of the sample, which indicates that the structure presents a priori the same electric and magnetic modification.This remark is observed for all courves representing the impedance according the deformation, the contrainte or the elongation. This résult is confirmed for the phase according the deformation, the contrainte or the elongation (figure 6at 9).The comparison between the curves reprenting the charge according the deformation or the elongation give the same conclusion as the phase or the impedance(figure 10-11).Most the phase in (figure9-10) have the same evolution as the mechanical curve.

The remark in the curve (figure 2- 5-6-8), the impedance and the phase have a relation with the young modulus.this remark is very important because we can measure the machanics parametres only by the impedance and phase measure.

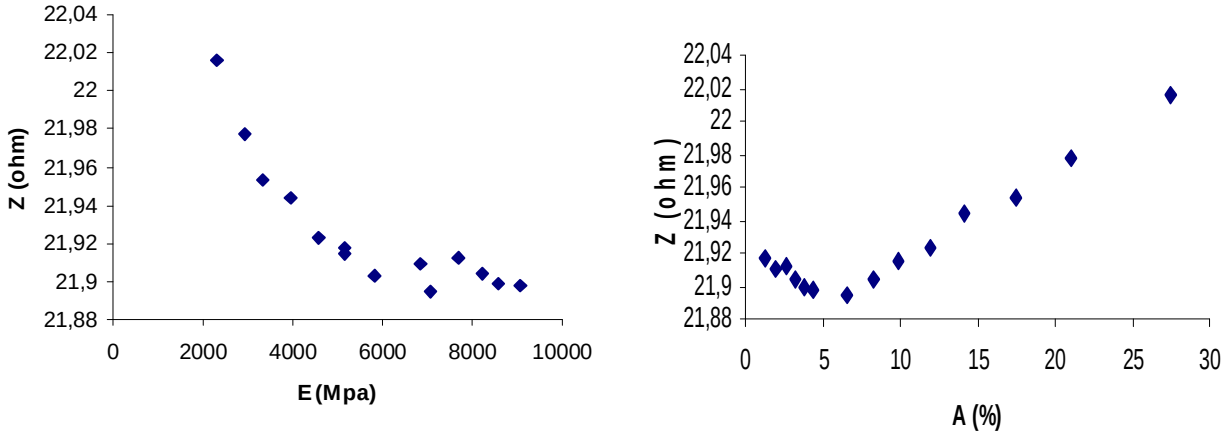


Fig 2 : Impedance according the young modulus and deformation for steel

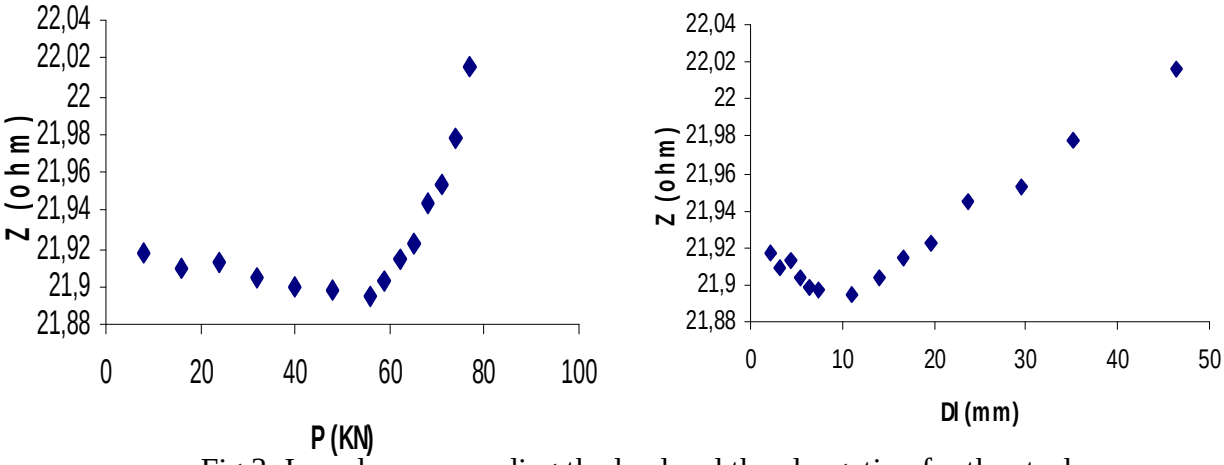


Fig 3: Impedance according the load and the elongation for the steel

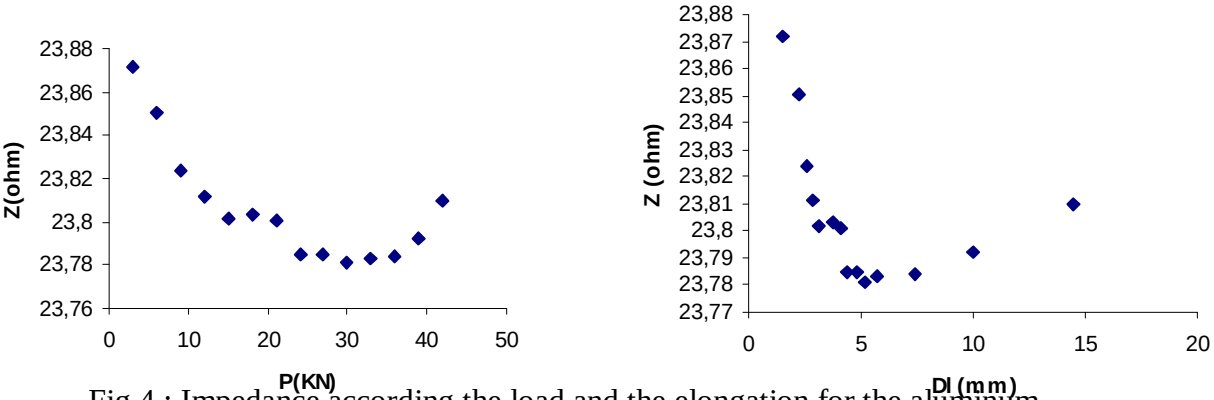


Fig 4 : Impedance according the load and the elongation for the aluminum

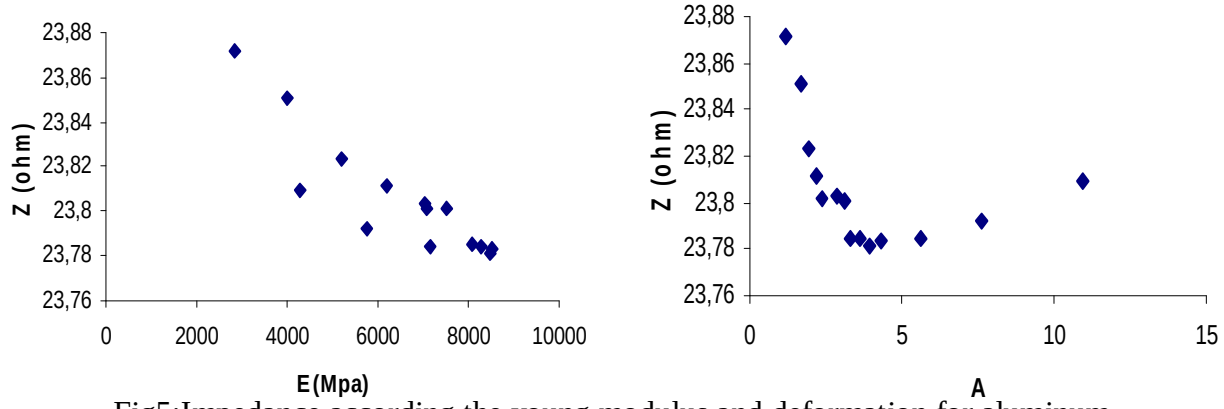


Fig5:Impedance according the young modulus and deformation for aluminum

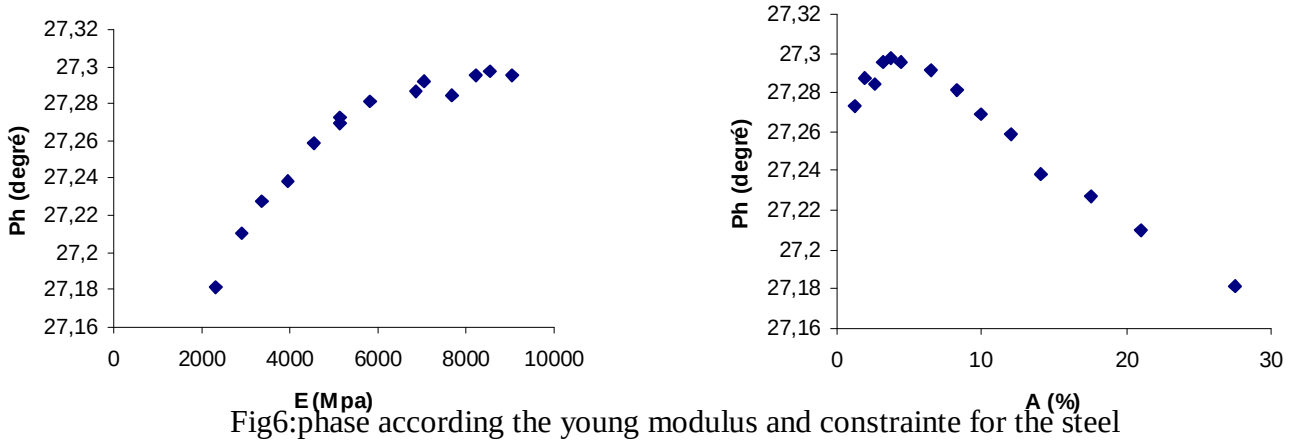


Fig6:phase according the young modulus and constrainte for the steel

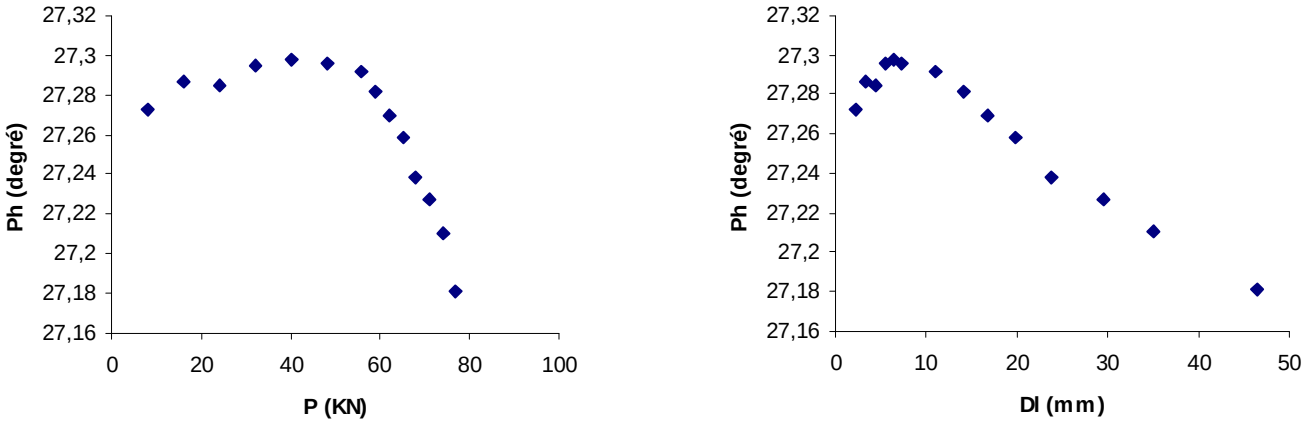


Fig 7 :phase according the elongation and the load for the steel

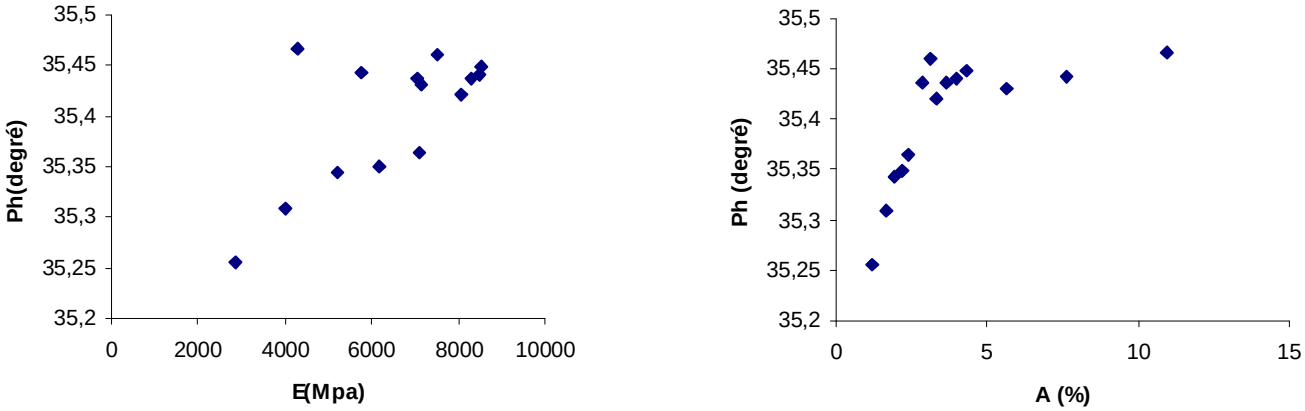


Figure8 : phase according the young modulus and constrainte for aluminum

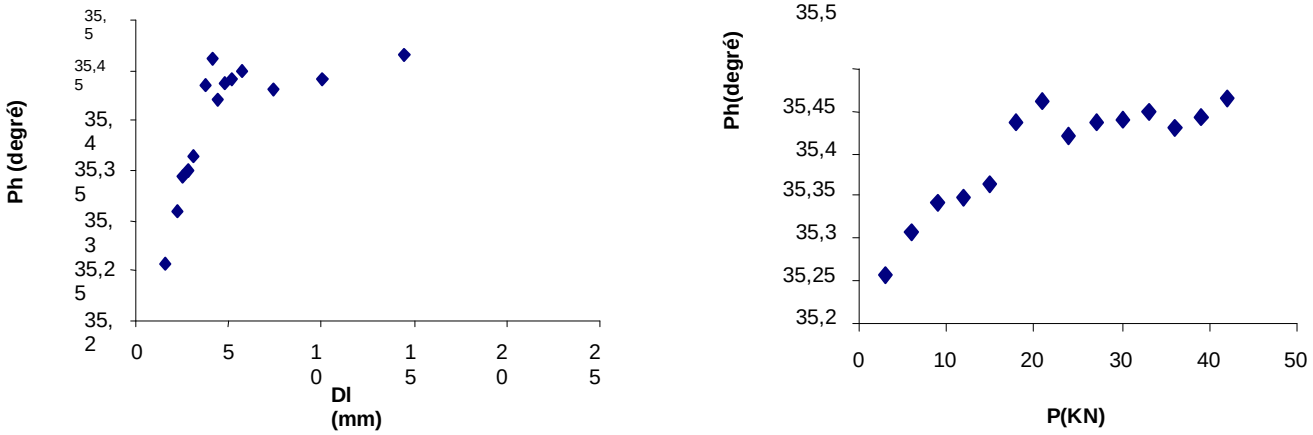


Figure 9 :phase according the elongation and the load for the aluminum

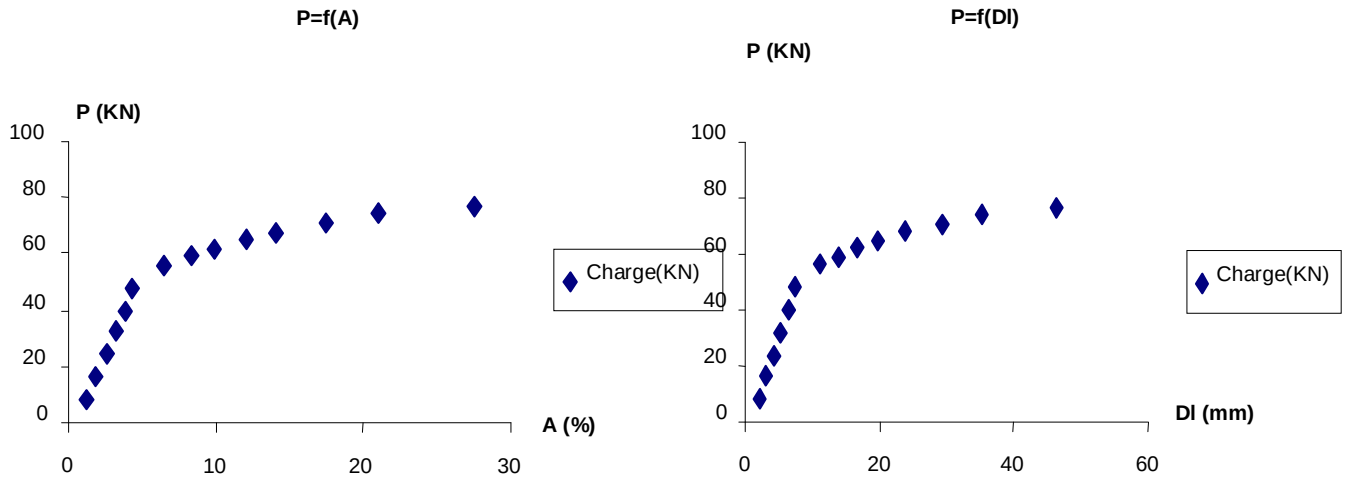


Figure 10: The charge according thedeformation and the elongation for the steel

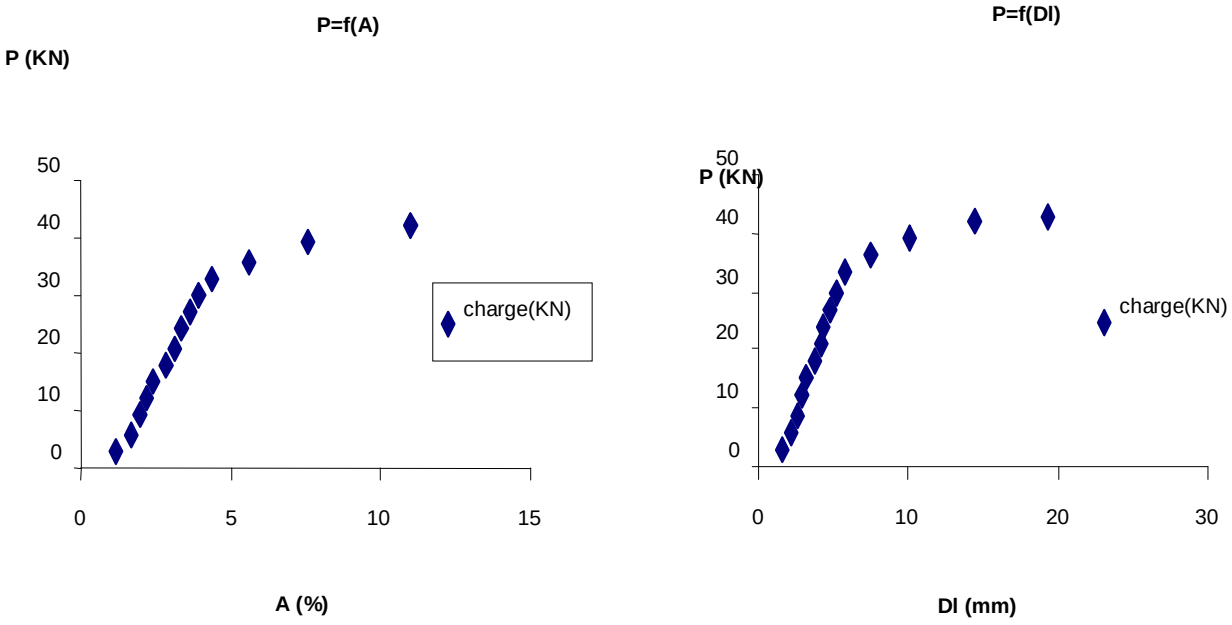


Figure11: The charge according thedeformation and the elongation for aluminum

Conclusion

Lifetime extension of components in technical applications is a general task with economical benefits. This holds for mass products also, so far safety aspects are under consideration, i. e. in the transportation industry. Lifetime management is a continuous demand. NDT/NDE has developed first attempts for materials characterization taking into account damage assessment as part of the in service inspection. We could show in this work the relation between eddy currents measurements and the mechanical parameters. The curve representing the impedance or the phase according to the elongation or the deformation follows a well determined trajectory where the elastic limit is defined for the material. The relation between the impedance and Young modulus are closer to the proportionnality .The curves obtained in the phase and the young modulus fellow the determined trajectory.These results are very significant for the determining the machanical parameters or for the use in the In Service Inspection.

References

1. Dybiec, C., Wlodarczyk, S. and Dybiec, M., " Measurement of Own Stress Using the Eddy Current Method", ECNDT, Vol. 3 December 1998
2. C.Dybiec and all “Determining Residual Austenite Wiith Eddy Current Method”,ECNDT Vol3 Decembre 1998
3. Baldev Raj ,V.Moorthy,T.Jayakumar and K.Bhanu Sankara Rao,”Assessmentof Microstructures and Mechanical behaviour of Metallic Materials Through Non Destructive Characterisation”International Materials Reviews October 2003,Vol 48 ,N°5