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# ADVANCED METHODS FOR THE DESIGN AGAINST FATIGUE OF ROTATING COMPONENTS IN ELECTRICAL GENERATORS

MarelliMotori
Inspired solutions

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## OBJECTIVE

In this work, advanced design methodologies, recently developed in the scientific literature, have been applied to verify against fatigue a bulk of rotating components in electrical generators produced by Marelli Motori. The long term aim is to potentiate and make more efficient the engineering activities of the R&D department of Marelli Motori, optimizing even better its machines from a performance point of view and increasing their reliability.

## METHOD AND CASE STUDIES

### 1 FATIGUE ASSESSMENT OF THE WELDED JOINTS OF A COOLING FAN

Two recent methods were considered for the advanced design against fatigue of welded joints

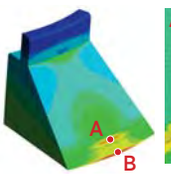
#### 1 ASED (Average Strain Energy Density)

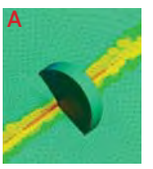
1 Modeling 3D control volumes:
- As a cylinder centred in the highly stressed regions of the model.
- With a specific radius of **Rc = 0.28 mm** (critical radius for steel welded joints [1])

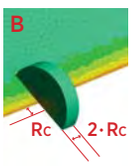
2 Evaluation of the Strain Energy inside the selected volume directly from the FEA model [2-3]

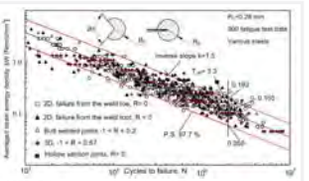
3 Calculation of ASED value according to the expression [2-3]

$$\text{ASED} = \frac{\text{DEFORMATION ENERGY}}{\text{VOLUME}}$$



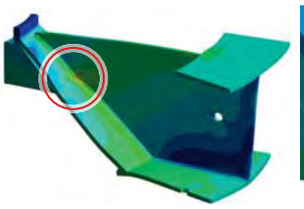



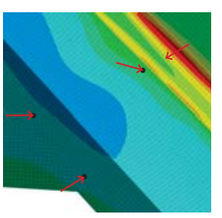



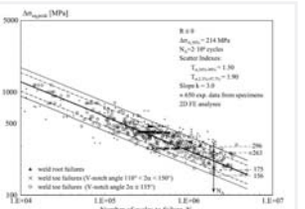
(ASED) Fatigue curve derived from 900 experimental data [1]

#### 2 PSM (Peak Stress Method)

1 FREE regular MESH pattern, according to the suggestions given in ref. [4]
2 Evaluation of the fictitious stress at the weld toe or root from the FE model
3 Stress values correction using specific theory-based formula
4 Fatigue life assessment using a universal scatter band [4]

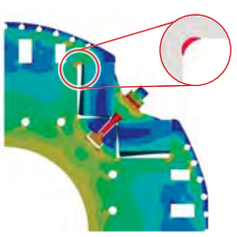




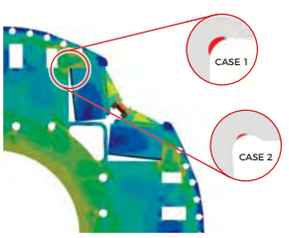


(PSM) Fatigue curve derived from 650 experimental data [4]

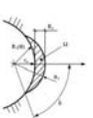
### 2 ANALIZED ACADEMIC CRITERIA: ASED FOR UNWELDED COMPONENTS - ROTOR SHEET ELECTRICAL STEEL ANALYSIS



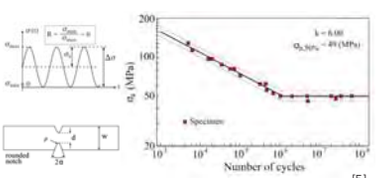
ORIGINAL MODEL




OPTIMIZED MODEL



[6]




[5]

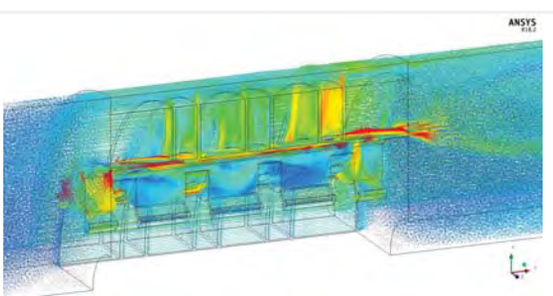
1 Estimation of the characteristic radius value Rc of the control volume for the rotor sheet electrical steel, derived from experimental data found in literature [5] and using notch mechanics based formulations.

2 Implementation of the FEA model of the rotor general assembly and than the application of ASED criterion by modeling the control volume around the tip of the notch (as suggested in [6]). The analysis was carried out both on the original component and on an optimized one, where an air cooling channel was introduced. A mitigation of the stress concentration in the upper rotor sheet notch was obtained, as well, by an ad hoc optimization study.

### 3 CFD ANALYSIS: COOLING EVALUATION BENEFITS OF THE NEW ROTOR GEOMETRY CONFIGURATION

Increasing of the cooling air flow distribution inside the machine

BEFORE

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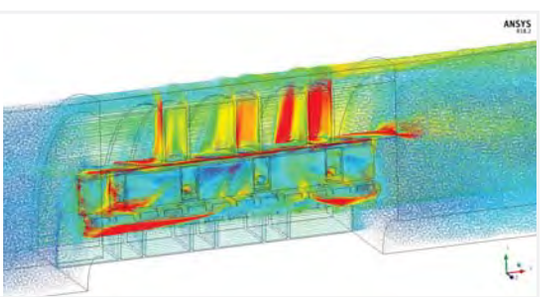


## CONCLUSIONS

**THE ENERGY ASED APPROACH** was found to be a sound design approach, with the advantage to be mesh insensitive method ([2-3], allowing coarse meshes to be used, thus reducing the computational time. On the other hand, the need of creating an «intelligent model», with a well defined, material dependent, control volume may hampering its applicability in the industry.

Differently, **THE PSM METHOD** was found to be capable to reach great results in a reasonable time and with an acceptable approximation. Moreover it allows to estimate ASED energy results in an a more efficient way.

**ROTOR OPTIMIZATION:**

- the change of the geometrical notch's tip radius leaded to a benefit of 45% in the fatigue life;
- the creation of the air cooling channel leads to run more fresh air towards the rotor in the axial direction: this gives an improvement of 30% in the global heat exchange coefficient of the machine.

## REFERENCES

[1] F. Berto, P. Lazzarin, «Recent developments in brittle and quasi-brittle failure assessment of engineering materials by means of local approaches » Materials Science and Engineering R 75, 2014.
[2] Paolo Lazzarin, Filippo Berto, Michele Zappalorto, «Some advantages derived from the use of the strain energy density over a control volume in fatigue strength assessments of welded joints » International Journal of Fatigue 30, 2008.
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[4] G. Meneghetti, C. Guzzella e B. Atzori, «The peak stress method combined with 3D finite element models for fatigue assessment of toe and root cracking in steel welded joints subjected to axial or bending loading,» Fatigue Fract Engng Mater Struct, n. 37, p. 722-739, 2014.
[5] G. Meneghetti, M. Barcaro e N. Bianchi, «Structural analysis of the interior PM rotor considering both static and fatigue loading,» IEEE Transaction on industry application , vol. 50, n. 1, 2014]
[6] Lazzarin P, Berto F. Some expressions for the strain energy in a finite volume surrounding the root of blunt V-notches. Int J Fract 2005; 135:161-185