FRICTION COEFFICIENT CALCULATION IN COMPRESSION COUPLINGS USING EXPERIMENTAL AND NUMERICAL MODELS

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Abstract

Object of this work is to define a mathematical model witch can calculate effectively the skin friction forces produced in shaft-hub compression couplings.
In order to reach this goal we applied the DOE (Design Of Experiment) statistical approach particularly focused on the choosing of the most significant parameters and values (levels) for each parameter.
General results obtained are the possibility to preview and to calculate the friction forces depending on the parameters level and to choose the best parameters level combination depending on the design specifications.
The effectiveness of the model is verified by a finite element (FEM) analysis and by some tests made on fork-tube couplings produced by the Paioli S.p.A for a 250cc motor scooter.
The model is used to optimize the coupling design and to point out quickly the maximum and minimum allowable interference.

Introduction

The shaft-hub compression coupling design is uncertain mainly because the coefficients of skin friction are not exactly known. These coefficients depend on a high number of factors and then the forces produced by the surface pressure cannot be exactly defined. In fact the value of the coefficients of friction used in the formulas for the calculation of the amount of interference depending on the sliding forces, must be well known in all conditions; on the contrary they are often assumed to be constant for a lot of different type of couplings.
Therefore for the correct design of the shaft-hub couplings it's necessary to execute a lot of tests and some cyclical analysis before to reach the optimal solution and then the costs and the time to market of products rise a lot.
For these reasons we set up together with ing. Toselli, chief director of the technical area of Paioli, a specific methodology for the calculation of series of shaft-hub couplings characterized by some significant parameters. We therefore planned a set of experimental tests (DOE) choosing the right values (levels) for the parameters and applying analysis of variance (ANOVA) in order to define the mathematical model capable to define the friction sliding forces.
At the same time we verified the experimental results with some calculations of pressure forces and tensile state made by one specific FEM analysis.
The analysis of the theoretical and experimental results produced some reliable mathematical models which are able to define the values of the sliding friction forces and the values of the metallic adhesion forces due to the coupling surfaces oxidation.

Fig. 1 Fork-Pin coupling

Fig. 2 Fork-pin model

Methodology

First of all we chose the materials and the type of couplings to be investigated; then we pointed out all the parameters which influence the coefficients of friction and we chose the ones which may be easily studied.

In order to obtain good results from the experimental tests we studied eight shaft-hub couplings with the same levels (values) of the parameters and then we verified that the variance of the other parameters and of the experimental errors had the same size.

Then we designed the factorial full plane for three parameters with two levels (2^3=8 tests); each test was replicated four times in order to calculate the variance of effects and the confidence interval. The couplings were also instrumented with some strain gages glued on the external cylindrical surfaces in order to calculate the pressure forces at the interfaces of the couplings. At the same time we performed some FEM analysis with the goal to compare the values of theoretical stresses with the experimental ones.

Finally we made other tests over ten fork-tube couplings taken out of production line in order to compare these experimental results with the theoretical and numerical ones.

Fig. 3 Mmesch of the fork

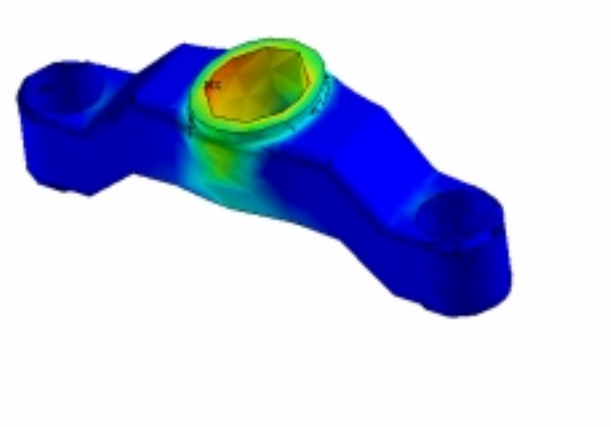

Fig. 4 Numerical results

Results

The fundamental goal of this work is to define a mathematical model which allows to calculate exactly the friction forces due to some shaft-hub compression couplings. With this mathematical model it's quickly possible to define the optimum combinations of the parameters levels in function of the design specifications and then it's possible to reduce the costs and the time to market of products.

Second goal is to verify the good results given by the experimental methodology used for the present couplings and then it may be possible to apply the same methodology to other couplings realized with different materials.

Finally the mathematical model will be successfully used to calculate the allowable interferences for the fork-tube coupling of a 250cc motor scooter; particularly it will be possible to find the minimum interference value required to exceed the releasing tests imposed by the standard specifications.

In the future, on the base of Paioli wishes, we think to study other fork-tube couplings which are made in different material and which have different dimensions.

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