Decomposition of a tribological system by chaos theory

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1. Introduction

An original mathematical treatment based on the chaos theory is proposed to analyze the number of independent tribological signatures on topographical surfaces.

2. Material and method

Quality of the cutting machining process of martensitic steel is analysed as a function of the cutting speed. This analysis is performed by signal analyses on the topographical measurement of tooled surfaces.

3. Construction of attractor

From the signal of the machined surface, a two-dimensional attractor is constructed after an original method of projection.
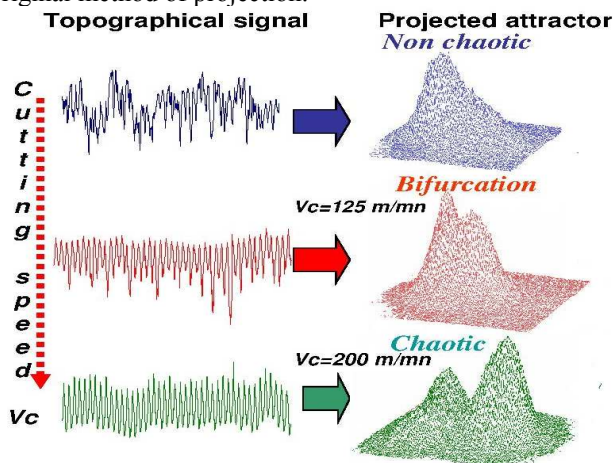

Fig.1   2D projected attractors obtained when cutting speed increases

4. Dimensional analyses and fegeinbaum plot

It is shown that this attractor depends on two mathematical functions (fig.2): The first one characterises the work hardening during the cutting process and the second is related to thermal softening.
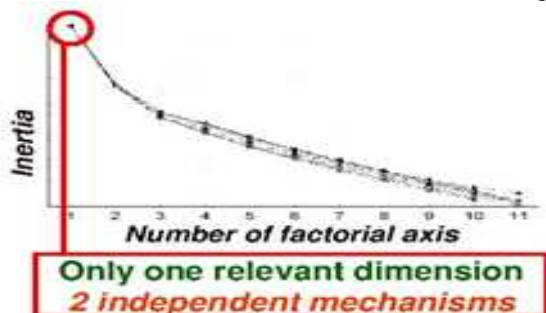

Fig.2   Analyses of the number of independent systems

5. Dimensional analyses and fegeinbaum plot

For a critical cutting speed, these two mechanisms are linked together and lead to a single attracting final state. This stage is governed by generalised work hardening. Above this critical speed, the attractor will present a two branches bifurcation (fig.3), which means that the cutting process is now alternating between the two different states.

Fig.3   Feigenbaum's plot versus the cutting speed.

6. Signal reconstruction for the two mechanisms

The chaotic mode is related to the instability between work hardening and thermal softening. This instability is confirmed by a fractal analysis based on the reconstructed signal from the attractor (fig.4): the higher the cutting speed, the higher the fractal dimension.
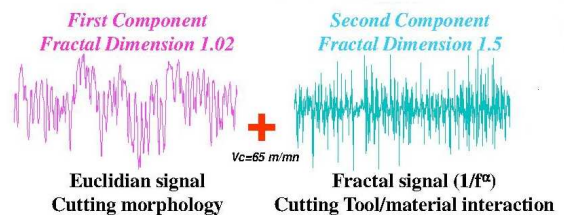

Fig.4   Reconstruction of profiles of the attractor projected on two tribological systems.

7. Summary

An original method of characterization of tribological systems based on chaos theory allows to quantify the cutting speed influence on machinability, via the chaos theory. The apparition of a two states chaotic mode that highlights the confrontation between the strain hardening and the generalized shearing