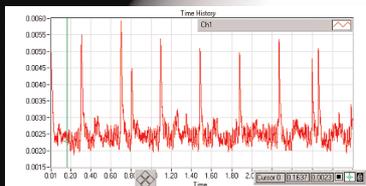
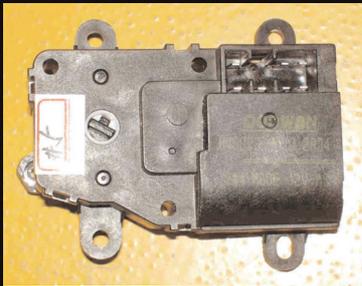
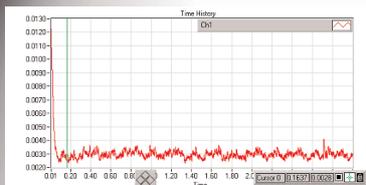


Impulsive noise emitted by automotive climatic dumper actuators: a Quality Assurance application

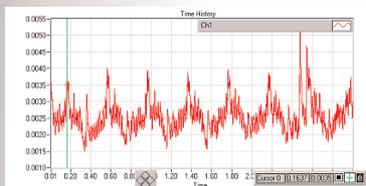
G.Amadasi



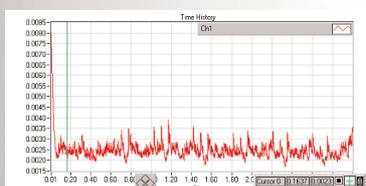
Record B34: SCS9002=Fail - Operator=Fail
Clear presence of "ticks".



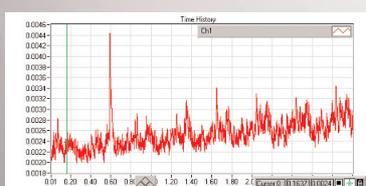
Record B44: SCS9002:OK - Operator:OK
Typical good item



Record B47: SCS9002=Fail - Operator=Fail
Presence of "Modulation".



Record B49: SCS9002=Fail - Operator=?
Presence of ticks with low level



Record G11: SCS9002=Fail - Operator=Fail
Presence of spurious spikes

Problem identification

Our research on Dumper Actuator for climatic system control on vehicles, it has been conducted in 2 different testing sessions in parallel with the operator judgements on good and bad.

We settled up the SCS9002 system and checked on it for measurements precision and repeatability. Than we started to try to understand what the QC engineer was really listening to. It was not clear actually whether operators where listening to some sort of continuous noise or discrete noise (ticks). According to previous info received it was thought that the customer was hearing (and caring) on both type of noise.

We made 2 hypotheses about 2 distinct phenomena: one based on timbres and one based on perceived discrete transient, and we called them "modulation" and "ticks" respectively.

We investigated the continuous type of noise and developed an algorithm for it, which can extract the presence of harmonics components and sidebands of tooth meshing frequencies. We tested the solution with the QC technical engineer and while checking for results, we realized that he was mainly caring to "ticks".

Since the ticks where the major issue, we started to test a preliminary algorithm for ticks detection and the testing where conducted by asking to the engineer to listen and give subjective judgements as "OK" and "Fail", in the mean time he had to describe what he was listening to.

By filling in a table and correlating systems results with operator judgement, we could reach a correlation of about 74% between SCS9002 and operator results.

We started to audio record and analyse each single measurements in order to understand the type of phenomena and how it could influence the "objective" measurements. On some audio recording there where actually a sort of high level "spikes", not related to the "ticks" phenomena; look to the graphic of Record G11 in the figures at side to have an idea about spurious "spikes" present among "ticks" and having strong influence on the measurement.

It was not possible to fully understand the source of those spikes immediately and it was actually possible to make several hypothesis: it could be a poor grounding, it can be a cable movements or possibly a mechanical effects arising when the dumper is forced on the test jig.

Subjective and Objective Results

Since we could not avoid spikes and they where also impossible to predict, we adjusted the algorithm in order to handle them without disturbing the QC system analysis. At first we called the QC engineer to perform a test on something like 100 dumper (70% good and 30% bad) and we tracked the sub-

jective judgements along to the QC system results. After a further improvement of the tick's detection algorithm we called again the QC engineer to repeat the test on about 70 good and 30 bad. The correlation this time was much better and we kept apart the dumpers in which the operator judgement was different from the system result.

During the test we noticed that operator judgement was sometime different from the previous session, at this point we asked the operator to repeat the judgement on each dumper on which there was discrepancies of subjective judgement in order to understand what could have been the operator level confidence.

Than we measured again and adjust the system parameters, than try again, adjust, and so on. After a cycling of trials we achieved a very good correlation (>90%) between the SCS9002 and the QC operator. Actually, the correlation ended up to 92% without considering "operator repeatability", i.e. we did not take in consideration that on 2 separated test sessions the operator judgements where not 100% correlated. At this point we can be absolutely sure that in a with a few days of data collection and statistics, it would have been possible to achieve a correlation better than 95% on the ticks phenomena.

In the end we than started to take any dumper available and cross check between SCS9002 and operator, and we could match the SCS9002 result with the operator judgements except very few cases.

Based on the experience described above, we may conclude at first that SCS9002 system it has been successfully adapted for QC of dumper actuators.

The QC experience from user side

The SCS9002 system has all the basic tools to do acquisition campaign and either the user or a consultant, or both of them, can actually do the job even without having a deep understanding and experience of noise and vibration measurements principles, transducers conditioner, signal analysis, mechanical vibration, etc. etc.

In other words, it is not normally mandatory that SCS engineers perform personally the investigation, except for "special cases". Alternatively, the user can record data and mail them to SCS for analysis, together with a detailed description of the case and operator description of the phenomena to be spotted out. This type of support it is definitely a "consulting" that SCS can do for free in a moderated way.

It can also be possible to have a rapid and more direct support if the customer can provide an internet connection to the SCS9002 QC system PC.

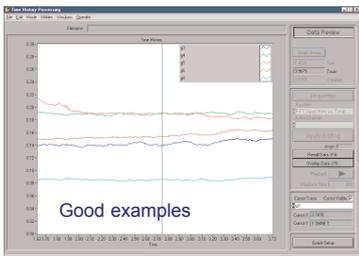
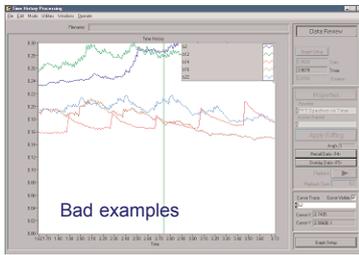


Noise and Vibration
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The QC development prelude - from SCS side

In order to start and understand what to do to check for quality, it is necessary to perform some measurements, typically on good and bad samples provided by the user. In the present case we started by measuring 66 samples pre-judged by the operator as good and bad.

Based on test performed we worked out a preliminary QC strategy based on time domain algorithm using digital filters in the high frequency range since the sample judged as "bad" by the operator shows high time level variances compared to the ones judged as "good" by the operator. Check on the 2 graphs examples.

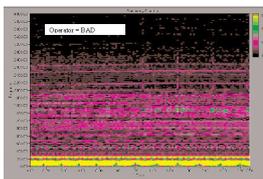
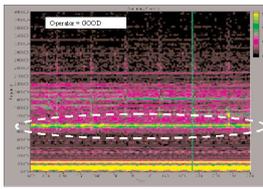


Operator (user) judgement

It is very common, more than one is expecting, that subjective judgements do not correspond to objective measurements in terms of energy level contents.

In other words, a sample having higher vibration energy, or noise level, it is not necessarily a "bad" one in respect to another sample with lower energy, as "judged" by the operator.

So, there is not always a linear dependency between energy and judgement, and this is due to several factors: noisy environment, poor measurements, wrong attitude, influence from one production batch to another, etc. etc.



For example: in the 2 spectrograms at side it is possible to see that there is a lot more vibration energy in the sample judged "good" by the operator compared to the one judged as "bad". This might mean that the operator

judgement it cannot be considered at the 100% confidence.

Investigation about subjective judgements

Investigation have been conducted to check for operator judgement by considering the following parameters, being correlated among them:

Subjective evaluation

The evaluation made by the operator

Min

The lowest vibration level in the time domain

Max

The lowest vibration level in the time domain

Vibration Level Difference

The difference between the max and the min

Objective evaluation

The objective evaluation with our algorithm

Logic

FALSE or TRUE; logical operator

Results have been plotted on a graph: where:

TOTAL BAD from operator judgement = 45
 32 out of 45 Operator BAD results BAD also for the QC system
 13 out of 45 Operator BAD results GOOD for the QC system
 TOTAL GOOD from operator judgement = 21
 16 out of 21 Operator GOOD results GOOD also for the QC system
 5 out of 21 Operator GOOD results BAD for the QC system

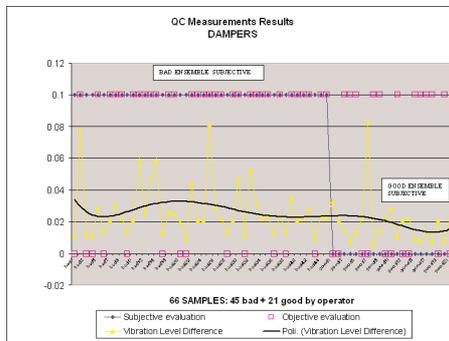
80% but it is evident that the operator judgement do not have 100% confidence!

Considerations

We definitely believe that SCS9002 system can positively recognize good and bad on Dumper actuators with a much higher assurance, close to or greater than 95%, but it is than necessary to do the following steps:

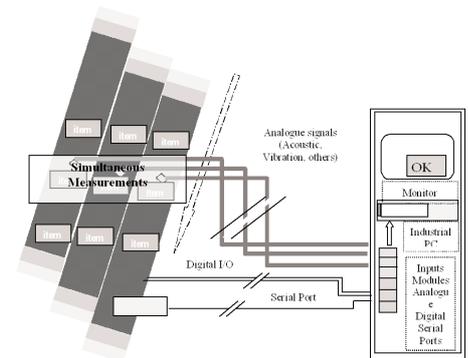
- 1) The production line PLC must supply the information to SCS system about the Damper model "before the test" since SCS system must apply the proper algorithm for each Damper model, the protocol for data transmission should be in ASCII or BCD code and the user should submit it to SCS with all connection specifications
- 2) User must prepare 200-300 sample of "each" type of Damper
- 3) The operator must test 3-4 times all samples (of each type) without knowing the preceding results in order to check on the operator confidence
- 4) A suitable system of transducer connection must be prepared according to SCS specific drawing or at least it is necessary to set-up a testing fixture out of the production line for preliminary tuning of the system
- 5) The measurements should be performed in order to adjust the algorithms

The achievable confidence of the QC system must be interpreted as "better than 95%" of the operator confidence level which, in turns, should be greater than 85% otherwise the statistics results would be inconsistent.



Subjective and Objective results comparison

From the measurements we have taken, and assuming an 100% confidence of the operator judgement, our objective results would have been around 75-



Final SCS9002 configuration for dumper actuators Quality Assurance, serving 3 parallel production lines. System uses accelerometers type transducers automatically connected to the test items.

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The present investigation is a quite common way to develop a QC strategy for complex phenomena in which the operator judgement plays a significant role. The key success it is to correlate operator judgement with some kind of multivariate algorithm to be implemented in the measurement and analysis software.

All preliminary investigation and statistic have been conducted using the SCS 9002 TH (Time History Processing) analysis software, a companion of the SCS 9002 QC system.

SCS 9002 QC on-line information table