Machine Correlation Measurement

ANOVA Method

Global Common

SD-1062

ISSUED February 20, 2024
REVISED

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1. Scope

The intent of this specification is to define a method to obtain machine correlation using the ANOVA calculation method, this method is particularly useful in cases where linear correlation is not suitable due to more than one input factors affecting the machine measure output. This method can be applied to duplicate machines that measure the same product characteristic with the same physical method, where one machine is previously established as a master machine.

It is not within the scope of this method to establish variation from repeatability or reproducibility of the equipment, to avoid this, it is necessary to use only one operator, one fixture, one pallet, and to minimize other known sources of variation for the study, as much as practically possible. Machine qualification process is performed separately from this study and is the approved method for initial machine measurement system validation.

The requirements prior to performing the analysis study are defined in this document, the sequence steps to process the data, and guidelines to determine acceptable study results. To calculate the results Minitab software shall be used.

Although is possible to complete one correlation analysis for a combination of two or more machines, it is important to perform independent studies in pairs of machines. Keeping results separated will result in independent statistically significant values for each duplicate machine.

2. Preparation of Equipment

To obtain good data for the analysis, each machine shall be previously validated using the applicable qualification process according to Nexteer specifications. The following minimum requirements are highly important to be completed successfully prior to performing the correlation study.

- Machine calibration.
- Cycle time confirmed.
- Machine cycle sequence validated.
- Measurement System Analysis study (Gage R&R, Class 1, stability).
- Machine cycle setup (model parameters, machine parameters)

3. Sample Parts

A minimum of 10 parts shall be used for the correlation study, the selection of parts should include parts that cover the range of the product specification. It is highly important that the parts for the study are kept after the completion of the study in case further studies are required to be repeated. Additionally, only parts that have been previously tested to confirm stability shall be used. If available, at least one part slightly out of spec is recommended to be used as one of the selected parts.

4. Machine correlation method (ANOVA)

4.1 Sequence and time requirements

Depending on the physical nature of the machine measurement, the engineer shall define the proper time conditions and sequence conditions for measuring the parts. The list below defines the minimum requirements to be considered in this evaluation before performing the study.

- Part sequence and machine sequence.
- Required elapsed time from cycle to cycle.
- Allowed interruptions (yes or no), such as lunch breaks or shift changes.
- Time of the day for the study, same day for all the machines or same time of the day for each machine.
- Isolate from production, perform study when production is stopped (if applicable).
- Machine warm-up (if applicable).

To help in the explanation of the methodology, one study case is illustrated below. There are factors in a correlation study that shall be defined by the process owner and are shown in the list below. The same corresponding analysis shall be completed by the process owner where the correlation study will be performed.

4.2 Example study case definitions

- Machine type: REPS production EOL Noise Test machine.
- Observed Y response: Max noise value per region in db.
- Required number of cycles: 3 cycles per part and per machine.
- Input degrees of freedom: Machine ID, Part ID, Region (1 to 11), Direction (CW, CCW).

4.3 Calculating ANOVA correlation results (study case)

4.3.1 Collect a minimum of 3 tests of data for 10 parts in each machine. The same parts are tested in each machine.

4.3.2 Extract from test data, the region max values for each direction CCW & CW.

4.3.3 Average each region's max values from all the data points per part and per test machine.
NOTE: The number of test cycles per part should be the same for all the machines.

4.3.4 Arrange the averaged region max values in a flattened structure as shown in Figure 1. A column shall be included for machine ID, part ID, region number, direction and averaged max region value.

Machine	Part	Region	Direction	Max Region Value	Max Region Value, dB
OP250-1	15	1	CCW	0.770745	57.7
...	...	...	...	...	...
OP250-1	79	1	CCW	6.466087	76.2
OP250-1	15	2	CCW	0.137737	42.8
...	...	...	...	...	...
OP250-1	79	2	CCW	0.293109	49.3
OP250-1	15	3	CCW	1.09153	60.8
...	...	...	...	...	...
OP250-1	79	3	CCW	1.177053	61.4

Figure 1: Test Data Max Region Value Data, Flattened Structure for Minitab

4.3.5 Copy this data table into Minitab statistical software for analysis.

4.3.6 Build an ANOVA general linear model by navigating: Stat → ANOVA → General Linear Model → Fit General Linear Model as shown in Figure 2.

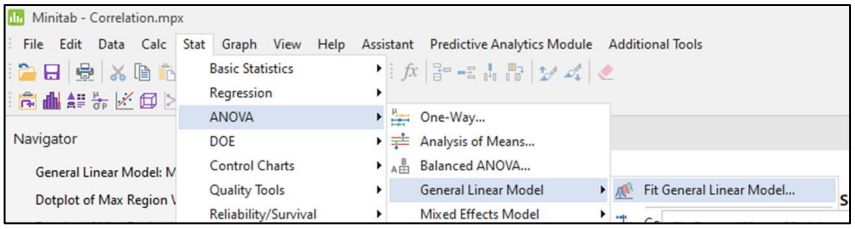


Figure 2: Minitab ANOVA Model Menu Navigation

4.3.7 Select the Max Region Value dB data as the response and the factors to be Machine, Part, Region, and Direction as shown in Figure 3.

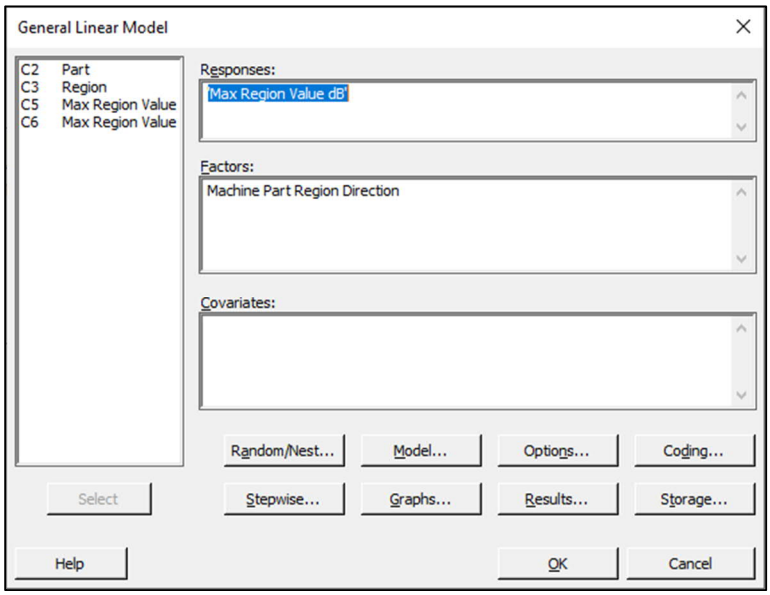
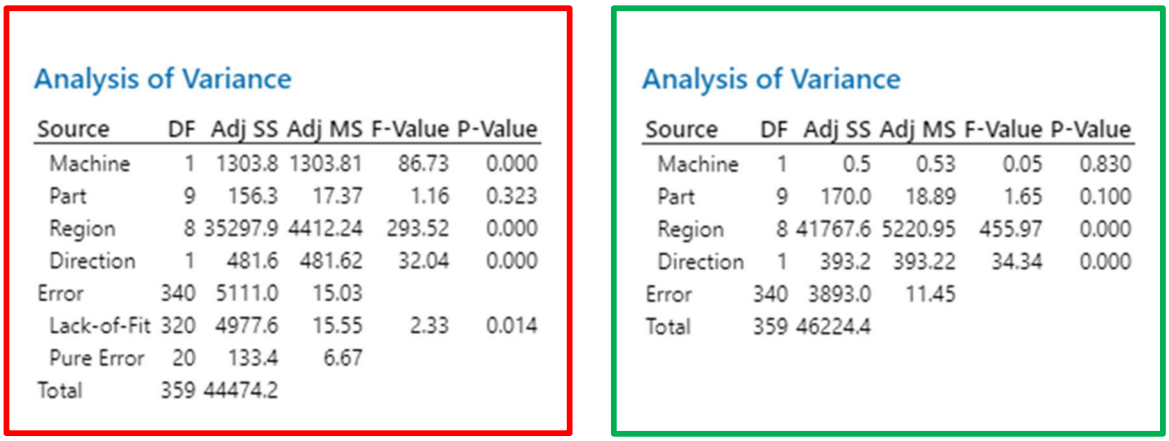


Figure 3: Minitab ANOVA Model Setup

4.3.8 The results of the model indicate statistical significance of the sources of variance using the P-value. An example of the ANOVA model output is shown in Figure 4.



Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Machine	1	1303.8	1303.81	86.73	0.000
Part	9	156.3	17.37	1.16	0.323
Region	8	35297.9	4412.24	293.52	0.000
Direction	1	481.6	481.62	32.04	0.000
Error	340	5111.0	15.03		
Lack-of-Fit	320	4977.6	15.55	2.33	0.014
Pure Error	20	133.4	6.67		
Total	359	44474.2			

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Machine	1	0.5	0.53	0.05	0.830
Part	9	170.0	18.89	1.65	0.100
Region	8	41767.6	5220.95	455.97	0.000
Direction	1	393.2	393.22	34.34	0.000
Error	340	3893.0	11.45		
Total	359	46224.4			

Figure 4: ANOVA Results P-Value Example (REPS production EOL Noise Test machine)

4.4 ANOVA Machine Correlation Acceptability Criteria

A p-value of less than 0.10 for any degree of freedom indicates that a statistically significant impact from that factor at 90% confidence. A p-value greater than 0.10 means there is not sufficient evidence of a difference in that factor at 90% confidence. For acceptable machine correlation, the p-value should be 0.10 or larger.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Machine	1	0.5	0.53	0.05	0.830
Part	9	170.0	18.89	1.65	0.100
Region	8	41767.6	5220.95	455.97	0.000
Direction	1	393.2	393.22	34.34	0.000
Error	340	3893.0	11.45		
Total	359	46224.4			

Figure 5: Statistical significance

If the p-value is found to be statistically significant at less than 0.10, the absolute difference between the averages of each machine should be evaluated by the process owner for practical significance. This is given by the study in the same engineering units than the observed Y response.

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1.8054	0.0835	21.62	0.000	
Machine					
OP250-2	-0.1839	0.0426	-4.31	0.000	1.33

Figure 6: Practical significance

It is highly recommended, in the case that practical significance is used for correlation acceptance, the decision is consulted with the local technical team including; Process Owner, ME manager, QE manager and/or I&CIM Manager, in order to approve the selected acceptable coefficient value.

If the difference observed is both statistically and practically significant, actions shall be taken to address the difference before re-evaluating the equipment.

RECORD OF REVISIONS

Revision No	Date	Section	Description
001	20FE24	ALL	Initial release of SD-1062.
002			
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