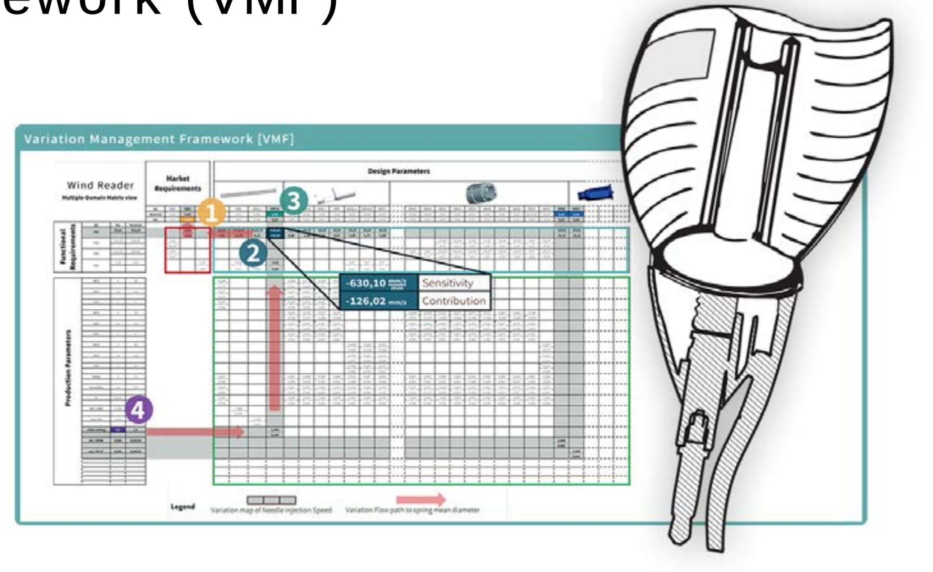
Robust Design Workshop 2016

The Variation Management Framework (VMF)

TASKBOOK



DTU Mechanical Engineering
Department of Mechanical Engineering

Agenda

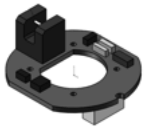
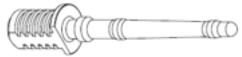
13:15	Introduction to workshop
13:30	TASK 1: Understanding the design of the case product (10min)
13:45	TASK 2: Responding to a production issue without the VMF (10min)
14:00	TASK 3: Experimental verification of sensitivity values (20min) - 5min Break included in this task
14:30	TASK 4: Responding to a production issues with two VMF Quadrants (15min)
14:50	TASK 5: Using the VMF to minimize Quality Loss [competition] (15min)
15:10	Summary (15min)
15:15	END

Task 1 (10mins)

Purpose: To get to know the case product and how its functions are achieved

Task Description: Use the template on the following page and the information in the workbook to identify which Design Parameters (DPs) are linked to which Function Parameters (FPs)

TASK 1

																
Speed FR1					x	x			x							
Direction FR2																
	DP1	DP2	DP16	DP13	DP3	DP4	DP10	DP11	DP5	DP12	DP6	DP7	DP14	DP9	DP8	DP15
	Vane area 1398±4,5 mm^2	Weight of the Rotor 4±0,5g	Vane area difference: 120±0,8m m^2	Mismatch of rotor axis to teeth circle axis 0±0,1mm	Axis alignment-Jack with over mould : 0 to 0,75°	Flange perpendic ularity-Jack: 0 to 1°	Sensor position shift: 0±0,05m m	Sensor size : 4,2±0,05 mm	Parallelis m - resting face in Base: 0 to 0,5°	Base centre plane to mounting line offset 0±0,25m m	Flange perpendic ularity-axel: 0 to 0,5°	Axel Radius: 1,447± 0,01mm	Axel-roundness : 0 to 0,025mm	Axel surface finish : 0,8±0,2 µm	Sleeve Radius: 1,45 ±0,025	Sleeve - roundness : 0 to 0,025mm

List other relevant noise factors and external dimensions that affect the FRs:

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____

____

Task 2 (10mins)

Purpose: To understand the current difficulties in troubleshooting quality issues without the VMF

The Scenario: Our supplier has finished production of 8000 of each of the outsourced components. 30 of each in-house produced component have been produced. Samples of each component have been sent for measurement. The results come back revealing a problem with the Axel which is out of spec. To create and ship a new batch of axels will set the launch back by nearly 2 months at catastrophic costs. A crisis meeting has been called between in-house design and production.

Task Description:

1. Determine the impact of the issue on the product performance.
2. What dimensions should production adjust and by how much to recover from performance losses (change as few Process Parameters (PPs) and Design Parameters (DPs) as possible).

Files: Excel file (TASK2.xlsx) - downloadable here: http://pd-symposium.org/ (RDD16)
Hint: Use the production sheet in the workbook an the formulas on the next page
Note: The calculation is based around the average-use wind speed of 5,67m/s

Inspection report

Part	Parameter		Nominal	Tol	Measurement		status
Rotor	Total vane area	A	1398	±4,5mm^2	DP1	1395	OK
	Vane area difference	Ad	120	±0,8mm^2	DP16	120,6	OK
	Teeth circle shift	Tco	0	0 to 0,1	DP13	0,04	OK
	Weight of the rotor	Rw	4	±0,5g	DP2	4,3	OK
Axel	Radius	Ra	1,447	±0,01mm	DP7	1,55	NOK
	Surface finish	Roa	0,8	0,6 to 1μm	DP9	0,9	OK
	Roundness	Aro	0	0 to 0,025mr	DP14	0,02	OK
	Flange parpendicularity	θaf	0	0 to 0,5°	DP6	0,1	OK
Sleeve	Radius	Rs	1,45	±0,025	DP8	1,43	OK
	Roundness	Sro	0	0 to 0,025	DP15	0,025	OK
Base	Mounting point position	Mpp	0	±0,25	DP12	-0,2	OK
	resting parallelism	θrb	0	0 to 0,5°	DP5	0,4	OK
PCB sub-assembly	Sensor position	Sp	0	±0,05	DP10	0,02	OK
	Sensor size	Ss	4,2	±0,05	DP11	4,22	OK
	jack to over mold angle	θjm	0	0 to 0,75°	DP3	0,16	OK
	Flange parpendicularity	θmf	0	0 to 1°	DP4	0,25	OK

Task 3 (20mins)

Purpose: Introduce the VMF Q2 and the sensitivity values by means of an experimental verification procedure.

The Scenario: To better respond to future quality issues, the engineering department have started to collect all sensitivity values from various simulations into the VMF Q2. The sensitivity values have been theoretically calculated and tabulated on the next slide. There is particular concern over the sensitivity of the wind speed accuracy with respect to sleeve radius, due to the uncertainty of the friction coefficient. However, due to the previous production issue, you now have an opportunity to experimentally verify this sensitivity value using the two sleeve dimensions produced.

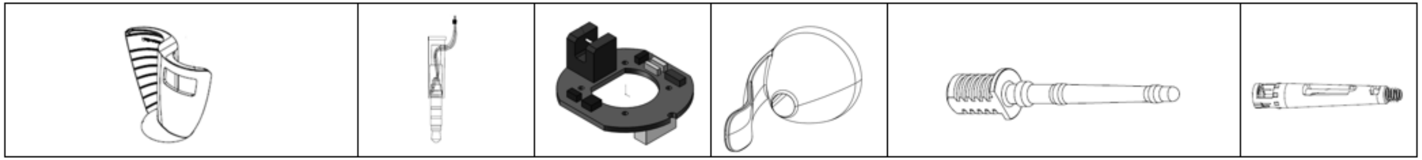
Task Description:

1. Calculate the theoretical sensitivity value (with a linearized approximation) using the ***calculated*** wind speed for the original sleeve (radius 1,43mm) against the wind speed ***calculated*** for your new sample. Using TASK2.xlsx to perform your calculations.
2. Conduct a ***physical experiment*** to verify your calculated sensitivity value by taking an actual wind speed reading for you new sample.

To perform your wind speed measurement, bring your rotor to the front and mount onto the calibration axel (it is the same axel set up as used for the test with the original sleeve).

Assumption: The effects of the variation in the rotor are negligible.
Note: The wind tunnel is calibrated to speed of 3,20m/s.
Note2: Open the measurement report on your desk for your sample.

TASK 3



		DP1	DP2	DP16	DP13	DP3	DP4	DP10	DP11	DP5	DP12	DP6	DP7	DP14	DP9	DP8	DP15
Speed	FR1	0,008	-0,171			-0,017	-0,017			-0,017		-0,017	-7,624		-0,056	?	
Direction	FR2			-0,276	5,200			28,000	-28,000		9,200			-34,500			-34,500
		Vane area 1398±4,5 mm^2	Weight of the Rotor 4±0,5g	Vane area difference: 120±0,8m^2	Mismatch of rotor axis to teeth circle axis 0±0,1mm	Axis alignment- Jack with over mould : 0 to 0,75⁰	Flange perpendicularity- Jack: 0 to 1⁰	Sensor position shift: 0±0,05mm	Sensor size : 4,2±0,05 mm	Parallelism - resting face in Base: 0 to 0,5⁰	Base centre plane to mounting line offset 0±0,25mm	Flange perpendicularity- axel: 0 to 0,5⁰	Axel Radius: 1,447± 0,01mm	Axel-roundness : 0 to 0,025mm	Axel surface finish : 0,8±0,2 µm	Sleeve Radius: 1,45 ±0,025	Sleeve - roundness : 0 to 0,025mm

EXPERIMENTAL MEASUREMENTS:

Wind speed measured using original 1,43mm radius sleeve ____________

Wind speed measured by your sleeve ____________

radius of your sleeve ____________

Calculated sensitivity of FR1 to sleeve radius change ____________

Experimental sensitivity of FR1 to sleeve radius change ____________

Task 4 (15mins)

Purpose: To introduce how production can utilise engineering design knowledge using the VMF in order to combat production issues and maintain product performance.

The Scenario: The company has overcome the initial design and production issues. Production is now outsourced to Malaysia and ramping up to larger volumes to satisfy growing demand. In order to help maintain product quality during the scaling up phase, two quadrants of the VMF have been implemented. Before today's production run, the uncontrolled (measured) PPs are checked. It is noticed that the relative humidity for the day is notably high at 94%.

Task Description:

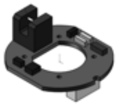
1. What dimensions should production adjust and by how much to recover from performance losses (***change as few PPs as possible***)
2. Compare this process to that in task 2

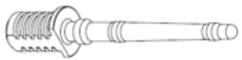
File: Excel file (TASK4.xlsx) - downloadable here: http://pd-symposium.org/ (RDD16)

HINT: Use the contribution values to guide you
(refer back to the workbook for guidance if necessary)
Note: Outsourced components now produced within specification.

Your starting point for TASK 4








FP / PP	ΔFP / ΔPP	(DP1) Vane area 1398±4,5mm²	(DP2) Weight of the Rotor 4±0,5g	(DP16) Vane area difference: 120±0,8mm²	(DP13) Mismatch of rotor axis to tooth circle axis 0±0,1mm	(DP3) Axis alignment- Jack with overmould: 0 to 0,75°	(DP4) Flange perpendicularity- Jack: 0 to 1°	(DP10) Sensor position shift: 0±0,05mm	(DP11) Sensor size: 4,2±0,05mm	(DP5) Parallelism - resting face in Bore: 0 to 0,5°	(DP12) Bore center plane to mounting line offset: 0±0,25mm	(DP6) Flange perpendicularity- axel: 0 to 0,5°	(DP7) Axel radius: 1,447±0,01mm	(DP14) Axel- roundness: 0 to 0,025mm	(DP9) Axel surface finish: 0,8±0,2μm	(DP8) Sleeve radius: 1,45±0,025	(DP15) Sleeve - roundness: 0 to 0,025mm
ΔDP		-1,858	0,125	0,240	0,040	0,363	0,250	0,020	0,020	0,390	-0,200	0,100	0,005	0,020	0,100	-0,083	0,025
Speed Measurement accuracy test acceptance 0±0,22m/s	-0,221	0,004 -0,008	-0,185 -0,023			-0,007 -0,003	-0,013 -0,003			-0,005 -0,002		-0,005 0,000	-2,000 -0,010		-0,030 -0,003	2,040 -0,169	
Wind direction accuracy test acceptance 0±3,5degree	-3,311			-0,300 -0,072	5,200 0,208			28,000 0,560	-28,000 -0,560		9,200 -1,840			-35,700 -0,714			-35,700 -0,893
Rotor raw material - Melt density 1020 ± 10 kg/m3 (incoming mtl report)	7		0,025 0,175														
Jack Dia difference at rests 0 to 0,05 (from supplier report)	0,03					10 0,3											
Ambient temperature 21°C ± 10 (from weather report)	-5	0,024 -0,12															
Ambient relative humidity 80% ± 20 (from weather report)	14	-0,042 -0,588	-0,025 -0,35													-0,0045 -0,063	
Rotor - Mould variation - axis to tooth circle shift in mould 0 to 0,05mm (mould inspection report)	0,02				2 0,04												
Rotor - Mould Cooling Time 10 ±3sec	-3	0,15 -0,45		-0,04 0,12													
Rotor - injection Pressure 100 ±5 Mpa	5	0,31 1,55	0,06 0,3	-0,056 -0,28													
Rotor - Mould Temperature 85±5°C	5	-0,45 -2,25		0,08 0,4													
Jack overmould cooling time 12±4sec	-1					-0,0625 0,0625	-0,25 0,25										
Bore - Mould Cooling Time 10±4sec	-2									-0,1 0,2	0,05 -0,1						
Bore - Mould injection Pressure 100 ±5Mpa	1									-0,01 -0,01	-0,02 -0,02						
Bore - Mould Temperature 85 ± 5°C	-4									-0,05 0,2	0,02 -0,08						
Sleeve - Mould Cooling Time 8±4sec	0															0,0075 0	0,01 0
Sleeve - Mould injection Pressure 90 ±5 Mpa	-5															0,004 -0,02	0,005 -0,025
Sensor resting position in assembly fixture 0±0,05	0,02							1 0,02									

Task 5 (15mins)

Purpose: To introduce how production can utilise the VMF to optimise product performance and minimise quality loss expected by the customer.

The Scenario: An in-depth study has been conducted with users of the wind reader to find out what's important and how variation in the FPs creates quality loss to the customer. The head of product development has worked to integrate the data (which can be found in the workbook) into the VMF, in a newly created first quadrant.

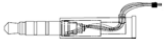
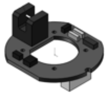
Task Description:

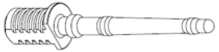
Optimise your in-house PPs in order to minimise the Quality Loss of your product.

File: Excel file (TASK5.xlsx) - downloadable here: http://pd-symposium.org/ (RDD16)

Competition rules: Every time the "Recalculate" button is press it is recorded. Each team is allowed only 10 recalculations, so be systematic! The team that records the lowest quality loss wins (a prize will be awarded to the winners). A running scoreboard will be displayed on the projector to track your progress relative to other teams.

Your starting point for TASK 5




50	11
2,50	8

Quality Loss

Quality loss
19,3

CS

Customer Satisfaction
80,7

Recalculate

No. of recalculatio 0 out of 10

No. of PPs change 0

Best out of first 1(80,7

	ΔFP / ΔPP	(DP1) Vane area 1398±4,5mm²	(DP2) Weight of the Rotor 4±0,5g	(DP16) Vane area differance: 120±0,8mm²	(DP13) Mismatch of rotar axis to teeth circle axis 0±0,1mm	(DP3) Axis alignment-Jack with overmould : 0 to 0,75°	(DP4) Flange perpendicularity-Jack: 0 to 1°	(DP10)Sensor position shift: 0±0,05mm	(DP11) Sensor size : 4,2±0,05mm	(DP5) Parallelism - resting face in Base: 0 to 0,5°	(DP12) Base center plane to mounting line offset : 0±0,25mm	(DP6) Flange perpendicularity-axel: 0 to 0,5°	(DP7) Axel radius: 1,447±0,01mm	(DP14) Axel-roundness: 0 to 0,025mm	(DP9) Axel surface finish : 0,8±0,2 μm	(DP8) Sleeve radius: 1,45 ±0,025	(DP15) Sleeve roundness: 0 to 0,025mm
ΔDP		-1,858	0,125	0,240	0,040	0,363	0,250	0,020	0,020	0,390	-0,200	0,100	0,005	0,020	0,100	-0,083	0,025
FP: Speed Measurement accuracy test acceptance 0±0,22m/s	-0,221	0,004 / -0,008	-0,185 / -0,023			-0,007 / -0,003	-0,013 / -0,003			-0,005 / -0,002		-0,005 / 0,000	-2,000 / -0,010		-0,030 / -0,003	2,040 / -0,169	
FP: Wind direction accuracy test acceptance 0±3,5degree	-3,311			-0,300 / -0,072	5,200 / 0,208			28,000 / 0,560	-28,000 / -0,560		9,200 / -1,840			-35,700 / -0,714			-35,700 / -0,893
PP: Rotor raw material - Melt density 1020 ± 10 kg/m3 (incoming mtl report)	7		0,025 / 0,175														
PP: Jack Dia difference at rests 0 to 0,05 (from supplier report)	0,03					10 / 0,3											
PP: Ambient temperature 21°C ± 10 (from weather report)	-5	0,024 / -0,12															
PP: Ambient relative humidity 80% ± 20 (from weather report)	14	-0,042 / -0,588	-0,025 / -0,35													-0,0045 / -0,063	
PP: Rotor - Mould variation - axis to teeth circle shift in mould 0 to 0,05mm (mould inspection report)	0,02				2 / 0,04												
PP: Rotor - Mould Cooling Time 10 ±3sec	-3	0,15 / -0,45		-0,04 / 0,12													
PP: Rotor - injection Pressure 100 ±5 Mpa	5	0,31 / 1,55	0,06 / 0,3	-0,056 / -0,28													
PP: Rotor - Mould Temperature 85±5°C	5	-0,45 / -2,25		0,08 / 0,4													
PP: Jack overmould cooling time 12±4sec	-1					-0,0625 / 0,0625	-0,25 / 0,25										
PP: Base - Mould Cooling Time 10±4sec	-2									-0,1 / 0,2	0,05 / -0,1						
PP: Base - Mould injection Pressure 100 ±5Mpa	1									-0,01 / -0,01	-0,02 / -0,02						
PP: Base - Mould Temperature 85 ± 5°C	-4									-0,05 / 0,2	0,02 / -0,08						
PP: Sleeve - Mould Cooling Time 8±4 sec	0															0,0075 / 0	0,01 / 0
PP: Sleeve - Mould injection Pressure 90 ±5 Mpa	-5															0,004 / -0,02	0,005 / -0,025
PP: Sensor resting position in assembly fixture 0±0,05	0,02							1 / 0,02									

Referencing and using this material

Boorla S.M., Eifler T., Göhler S.M., Pedersen S.N., Bjarklev K., Kronborg N.T., & Howard T.J. (2016) "*The Variation Management Framework (VMF)*" – Robust Design Day 2016 Workshop

The material can be delivered for both university and industry workshops on request. Please contact: info@robustdesign.org