Identifying Mass Important Requirements

Using the modified M5 Method

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Overview

- Motivation
- Existing Work
  - M5 Method
- Proposed Work
  - Modified M5 Method
- Validation
  - BMW Cooling System Case Study
- Future Work

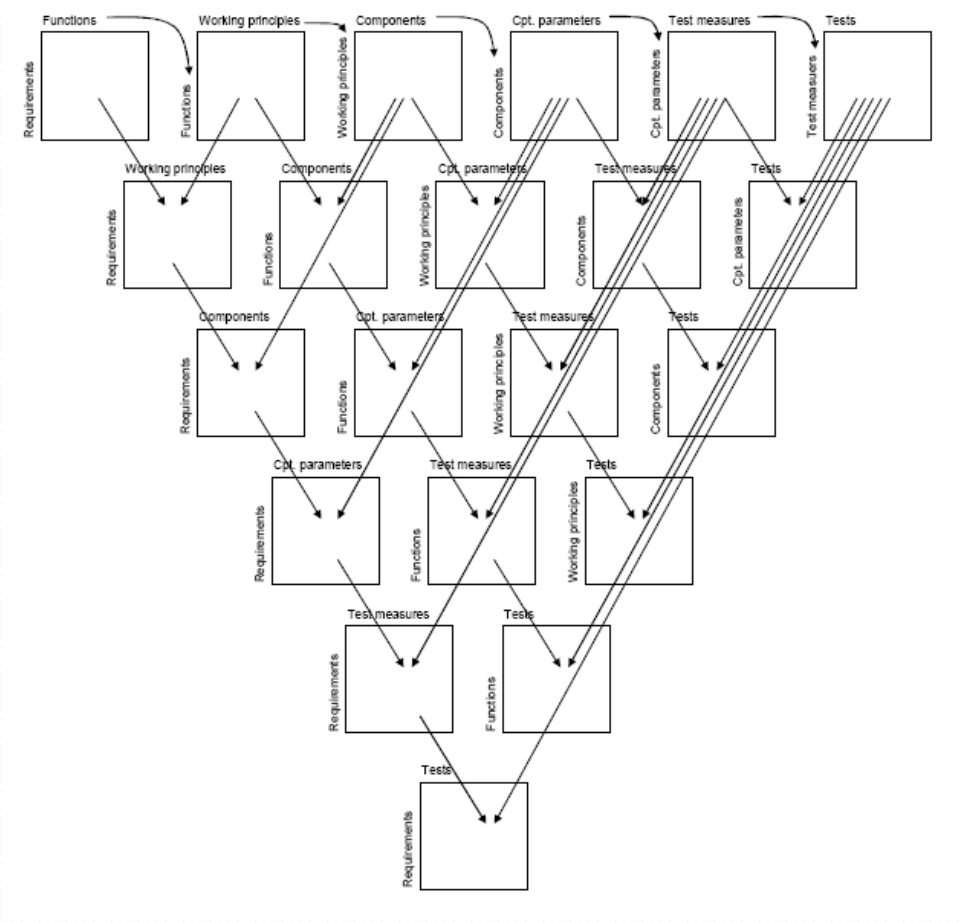
Motivation

- Currently, mass is minimized starting with the final product. Ex: FEA, optimization methods
- At this point, the design space is extremely limited.
- What if we knew which requirements affected mass the most?
- If mass is minimized from the initial design space, there is much more freedom to minimize mass.

Existing Work

- The M5 method is used to generate mass reducing alterations to components by modeling 7 design domains (requirements, functions, working principles, components, component parameters, test measures, tests) using matrices.

M5 Method


Functions
Working principles
Components
Cpt. parameters
Test measures
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Working principles
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Requirements

M5 Method (cont)

- Mass is minimized by using the Requirements to Functions matrix and considering the impact of removing each nonfunctional requirement.
- Possible component alterations that affect mass are then considered

Why Modify the M5 Method?

- Instead of examining each requirement, even the ones that are known will not affect the mass noticeably, it could be more efficient to identify the mass-important requirements first.
- This way, time is spent on the important requirements and not on the unimportant requirements.

Modified M5 Method

- The goal is to find requirements that affect
  1. significant amount of mass
  2. few components
  3. few requirements
- Score each component with a grade (1,3,9) of how much it affects the overall system mass
- Use the Requirements vs. Components Matrix to ascertain how many components are needed to satisfy each requirement
- Calculate a total score for the requirement

Modified M5 Method (cont)

- Each requirement total is divided by the number of components that satisfy the requirement
  - This is done to find the requirements that affect the fewest components. Fewer components mean a higher score
- A requirement vs. requirement matrix is constructed to find requirements that affect few other requirements

Validation

- The requirements identified using the M5 Method were compared with the mass-important requirements identified using the Modified M5 Method.

Figure of Requirements vs. Components Matrix with component scoring, total scoring and total scoring/#components

Requirements	Score	Motor Subassembly	Fan	Counterweight	Fan Shroud	Thermostat	Expansion Tank Subassembly	Radiator Cap	Radiator Subassembly	Left Bracket	Right Bracket	Inlet Wate Hose	Outlet Water Hose	Temperature Sensor	Water Pump Subassembly	Engine Coolant	Liquid-Liquid Heat Exchanger Subassembly	Transmission Oil	Drying Container	Condenser Subassembly	Refrigerant	Total Scores	Total Score/# Components
		9	1	1	1	1	1	1	9	1	1	1	1	1	9	9	1	1	1	3	3		
Minimum clearance to engine mounted components in X-direction should be 30 mm					x		x		x						x					x		23	4.6
Minimum clearance to engine mounted components in Y-direction should be 30 mm					x		x		x						x					x		23	4.6
Minimum clearance to engine mounted components in Z-direction should be 20 mm					x		x		x						x					x		23	4.6
Quick fit connectors for all hoses							x		x			x	x		x		x		x	x		26	2.6
Mix-up proof hose connections							x		x			x	x		x		x		x	x		26	2.6
Assembly vertically from underneath should be with a minimum clearance 12mm									x						x		x			x		22	5.5
Vacuum assisted filling process for engine coolant would be 18mbara for 25seconds duration						x	x		x			x	x		x	x	x		x	x		36	3.6
Ambient temperatures outside the vehicle should be -40°C to +120°C		x	x			x	x		x								x			x		25	3.6
Coolant temperatures must be -40°C to +140°C						x	x		x			x	x	x	x	x	x			x	x	39	3.5
Pressures should be 18mbara to 3.5bara						x	x	x	x			x	x	x	x		x		x	x		29	2.60
Should use of common parts internally and externally for reduced development costs tooling investment		x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x		43	2.5
Must be of Uniform periphery		x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x		43	2.5
Should use closed air ducting for cooling system																						0	
Must have mounting brackets for module to include thermostat unit										x	x											2	1
Total frontal area of mesh ca. 26dm2 (580mm x 449mm)									x													9	9
Mesh depth max. 30mm									x													9	9

Requirement vs. Requirement

- Several mass-important requirements were identified

Solt. Req. for M5 Method	Solutions	Solt. Req. for Modified M5 Method	Solutions
Quick Fit Connectors	Sealed Connectors	Total Front Area of Mesh	Minimize Mesh Size, Don't Worry About Specific Dimensions
Mounting Brackets For Thermostat	Mount Thermostat in Expansion Tank	Maximum Mesh Depth	Minimize Mesh Depth
Total Front Area Mesh	Reconfigure Geometry of Non-Functional Components	Quick Connectors for Transmission Fluid	Sealed Connectors

Requirements vs. Requirements Matrix

Requirements	Minimum clearance to engine mounted components in X-direction should be 30 mm	Minimum clearance to engine mounted components in Y-direction should be 30 mm	Minimum clearance to engine mounted components in Z-direction should be 20 mm	Quick fit connectors for all hoses	Mix-up proof hose connections	Assembly vertically from underneath should be with a minimum clearance 12mm	Vacuum assisted filling process for engine coolant would be 18mbara for 25seconds duration	Ambient temperatures outside the vehicle should be -40°C to +120°C	Coolant temperatures must be -40°C to +140°C	Pressures should be 18mbara to 3.5bara	Should use of common parts internally and externally for reduced development costs tooling investment	Must be of Uniform periphery	Should use closed air ducting for cooling system	Must have mounting brackets for module to include thermostat unit	Total frontal area of mesh ca. 26sfn2 (580mm x 449mm)	Mesh depth max. 30mm	Optional low temperature radiator for automatic transmission ca. 4.7dm2	Leak rate 150 l/min at 300mm	In- and outlet should be with a nominal width (NW) 32mm	Bleeding outlet (integrated in inlet connector) should be NW 12mm	Overflow outlet should be NW 12mm	Dimensions of oil cooler's block size X=45mm; Y=165mm; Z=80mm	Quick connectors for transmission fluid and engine coolant	Operating pressures transmission fluid should be in the range of 8bara at –40°C to +160°C	Pressures engine coolant should be in the range of 3bara at –40°C to +143°C	Leak proof tests for transmission fluid is minimum 20barg	Leak proof tests for engine coolant is minimum 2,5barg	Total frontal area of mesh of condenser should be 22.2dm2	Total
Minimum clearance to engine mounted components in X-direction should be 30 mm	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Minimum clearance to engine mounted components in Y-direction should be 30 mm	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Minimum clearance to engine mounted components in Z-direction should be 20 mm	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Quick fit connectors for all hoses	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	9
Mix-up proof hose connections	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	9
Assembly vertically from underneath should be with a minimum clearance 12mm	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	5
Vacuum assisted filling process for engine coolant would be 18mbara for 25seconds duration	0	0	0	0	0	0	1	0	0	1	1	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	8
Ambient temperatures outside the vehicle should be -40°C to +120°C	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Coolant temperatures must be -40°C to +140°C	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3
Pressures should be 18mbara to 3.5bara	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	7
Should use of common parts internally and externally for reduced development costs tooling investment	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	1	22
Must be of Uniform periphery	0	0	0	1	1	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	7
Should use closed air ducting for cooling system	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Must have mounting brackets for module to include thermostat unit	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Total frontal area of mesh ca. 26sfn2 (580mm x 449mm)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Mesh depth max. 30mm	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Optional low temperature radiator for automatic transmission ca. 4.7dm2	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5
Leak rate 150 l/min at 300mm	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	1	0	7
In- and outlet should be with a nominal width (NW) 32mm	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	6
Bleeding outlet (integrated in inlet connector) should be NW 12mm	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5
Overflow outlet should be NW 12mm	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
Dimensions of oil cooler's block size X=45mm; Y=165mm; Z=80mm	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
Quick connectors for transmission fluid and engine coolant	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	7
Operating prossures transmission fluid should be in the range of 8bara at –40°C to +160°C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	3
Pressures engine coolant should be in the range of 3bara at –40°C to +143°C	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	7
Leak proof tests for transmission fluid is minimum 20barg	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	0	5
Leak proof tests for engine coolant is minimum 2,5barg	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	6
Total frontal area of mesh of condenser should be 22.2dm2	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	4
Total	2	2	2	9	9	3	5	4	5	8	19	8	7	3	4	2	5	7	5	6	4	5	9	2	5	4	6	2	

Future Work

- The Modified M5 Method is not a top-down approach.
- However, the Modified M5 Method could be employed on many designs, and studies could be done to identify trends in types of mass-important requirements identified.