A parameter less shape optimization process allows to extend fatigue life of structural parts subjected to thermal fatigue

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SVS FEM | Head of R&D

Outline

- Industrial need: **fatigue life control** by simulation and shape optimization
- Technical solution based on **advanced FEA** and **mesh morphing** proposed
- **Industrial case** detailed showing the effectiveness of the proposed approach
- Results

SVS FEM - RBF Morph collaboration

- SVS FEM is an **ANSYS's channel partner** since 1993 and distributes ANSYS software in Czech and Slovakia Country
- RBF Morph has been an **ANSYS's software partner** since 2009 when it became its official software partner entering the ANSYS Partnership Programme.
- **SVS FEM - RBF Morph** collaboration has been started with developing and testing a workflow based on the RBF Morph ANSYS Extension for **Garrett company** which needs optimizing their product parts, where the nonlinear thermo-fatigue solution is necessary to be used.

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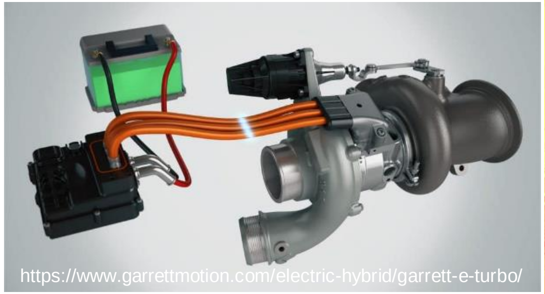

https://www.garrettmotion.com/electric-hybrid/garrett-e-turbo/

Introduction

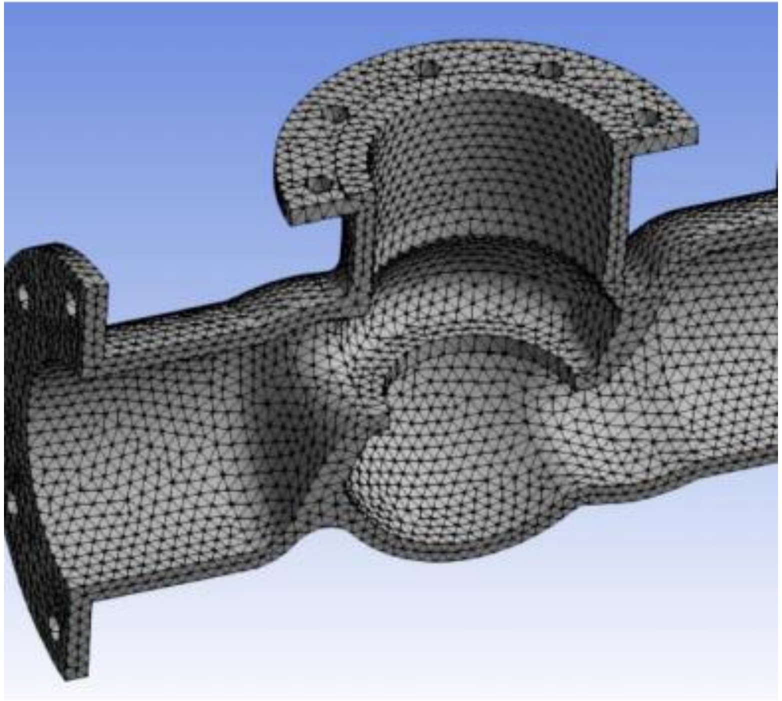
- Many component and systems are subjected to cyclic thermal stresses **and thermal fatigue** is one of the major concerns
- **Hot spot mitigation** is of paramount importance to get a good design.
- The need for tools capable of helping the designer in the definition of the **optimal shape** is still very high because the established approaches usually require the computation of sensitivity and a strong integration with the structural solver

Objective

- In this study we propose an approach based on the **biological growth method** (BGM) and we adopt advanced stress results, as the cumulative plasticity, to drive the shape.
- The method is **local** and based on the **structural solver results** only. The surfaces of the part are reshaped, keeping the same solid mesh attached, by means of RBF mesh morphing.
- The implementation adopted is based on **ANSYS Mechanical** and its companion extension **RBF Morph**.
- The approach is demonstrated on a complex part, a valve, showing how a significant reduction of the hot spot stress level is achieved acting on the complete **thermo-structural workflow** used for baseline fatigue assessment

Problem Description

- The external surfaces of a valve must be **sculpted** in order to optimize **Accumulated Equivalent Plastic Strain** in a thermo-structural analysis
- The goal will be achieved by using the **BGM** (Biological Growth Method) surface sculpting available in **RBF Morph ACT extension** for ANSYS Mechanical



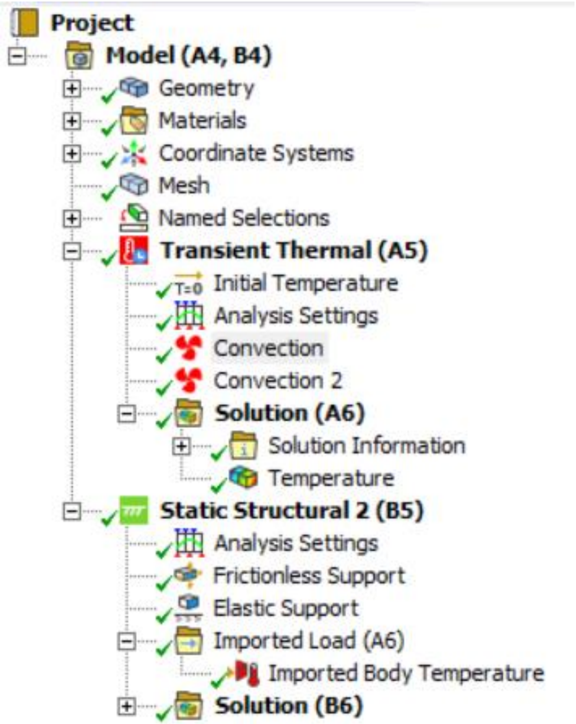
FEM model mesh

Background on RBF and BGM

https://youtu.be/myt2hndckso

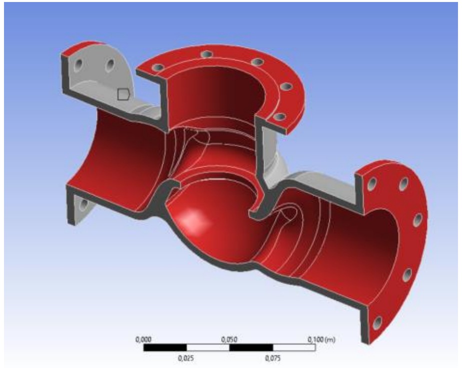
FEM analysis | Set-Up

- The thermo-structural analysis is realized with a system composed by a first **Transient Thermal Analysis** and a subsequent **Static Structural** one
- Temperature results from the Transient Thermal are imported as **thermal loads** in the Static Structural

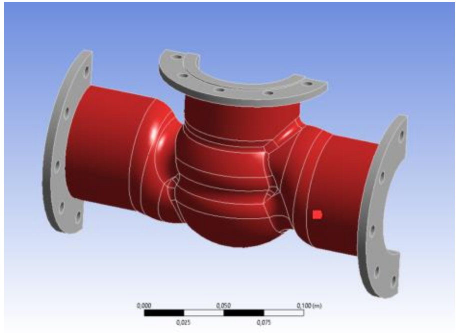


FEM analysis | Thermal loads

- Two **Convection** loads were set in the **Thermal** analysis:
  - The first imposes over the **internal surface** a constant convection coefficient and a profile of temperature with maximum value of **500 °C**
  - The second assigns over the external surface the heat exchange with the external environment at **20°C**
- Both Convection conditions were set using **named selection** suitably defined



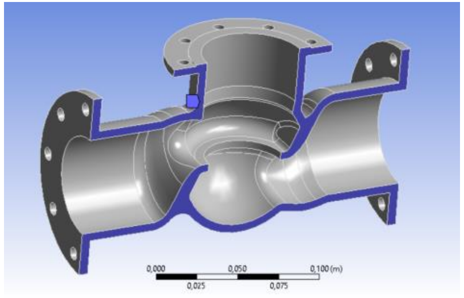
Internal surfaces



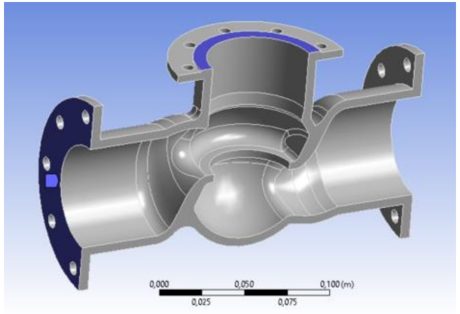
External surfaces

FEM analysis | Structural constraints

- Two **constraints** were set in the **Structural** analysis:
  - The first is a **Frictionless Support** applied to 3 faces laying on the symmetry plane of the model
  - The second is an **Elastic Support** applied to other 3 faces at the extremities of the model
- The **temperature distribution** in the whole component at the end of the thermal analysis is applied as load



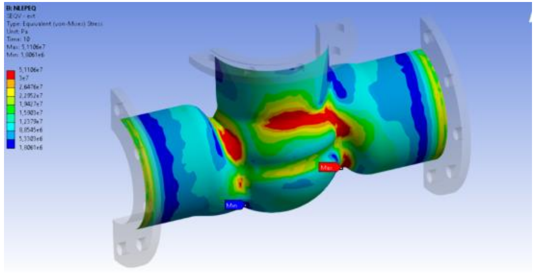
Frictionless Support



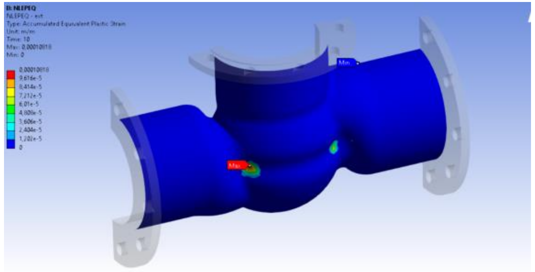
Elastic Support

FEM analysis | Results

- Since only the external surface has to be sculpted, both von Mises Stress (SEQV) and Accumulated Equivalent Plastic Strain (**NLEPEQ**) value were assessed.
- NLEPEQ values are used as **sculpting driver** and, together with SEQV, maximum values are **monitored** during optimization



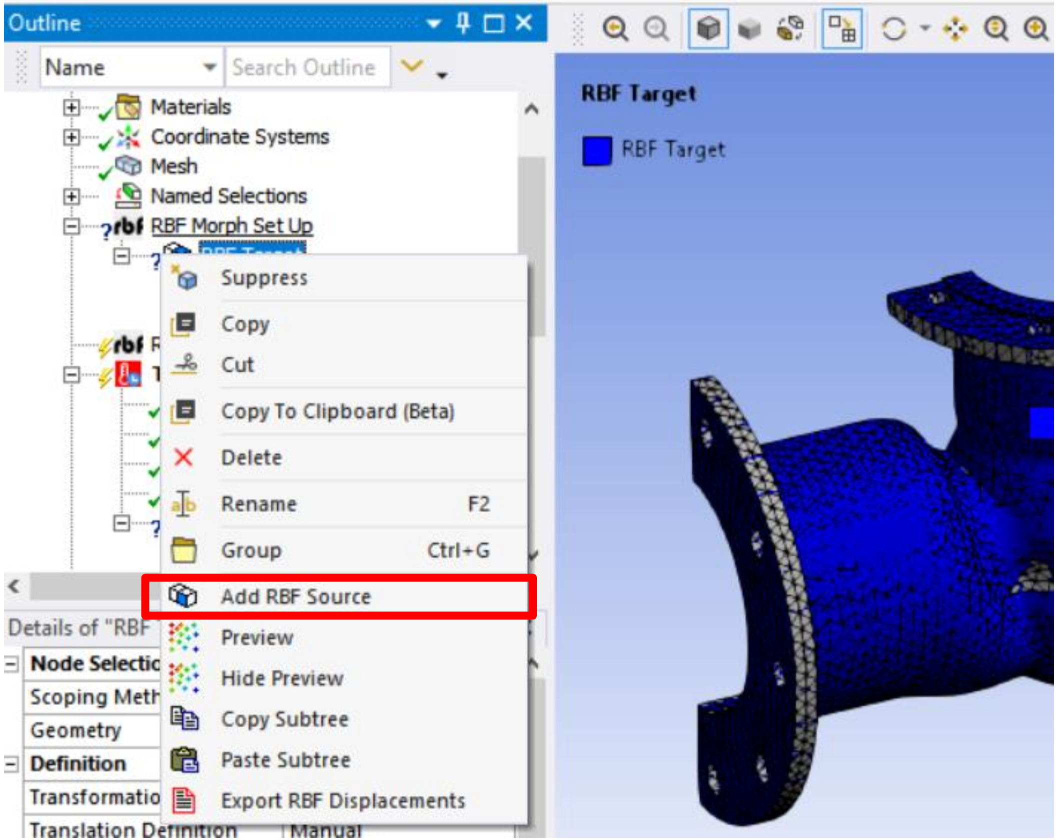
SEQV



NLEPQ

Optimization | RBF Set-up

- **BGM settings** are assigned in the Details panel of RBF Morph Set-Up
- The **whole valve** is set as morphable part
- The internal surface is **kept fixed** during optimization
- **NLEPEQ** over the external surface of the valve drive the morphing action
- 4 output variables concerning SEQV and NLEPEQ are set



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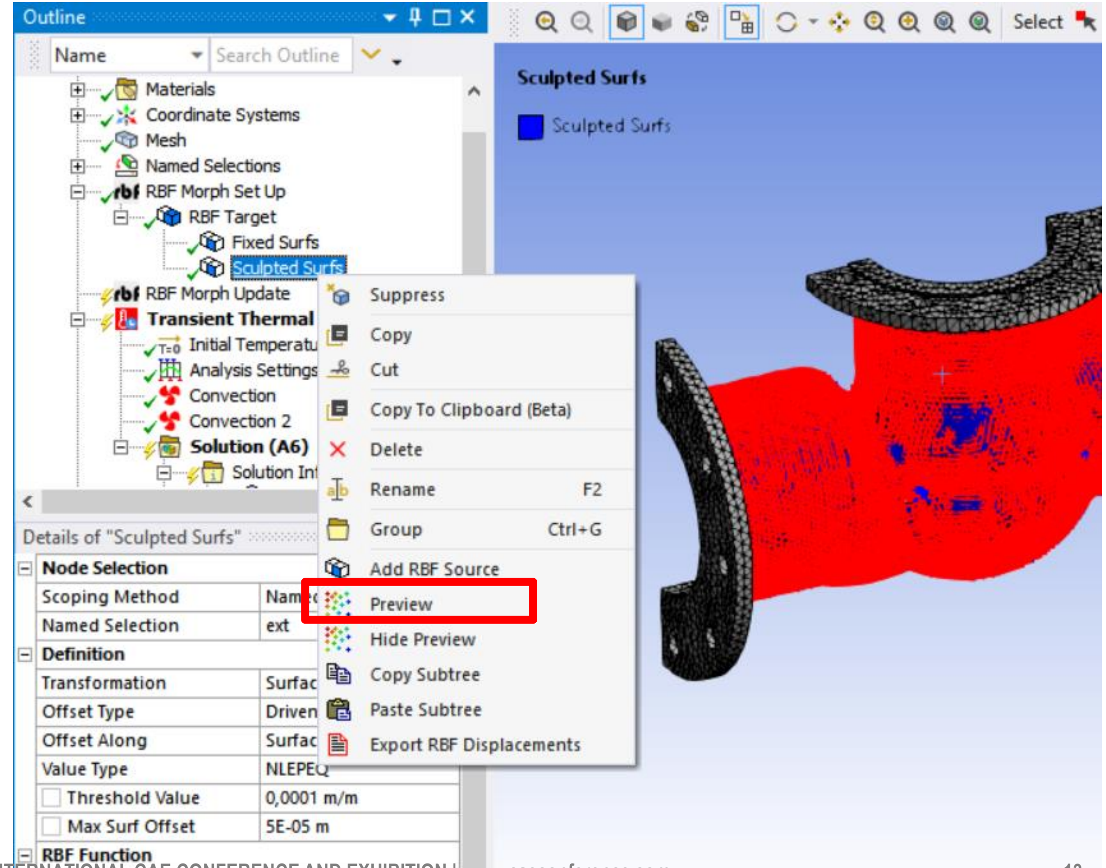


Optimization | Workbench Set-up

- ‘Design Point Initiation’ is set as ‘From Previous Updated’ to enable **sequential** morphing of BGM
- **12 DPs** are created lo leave BGM to sculpt the external surface of the valve

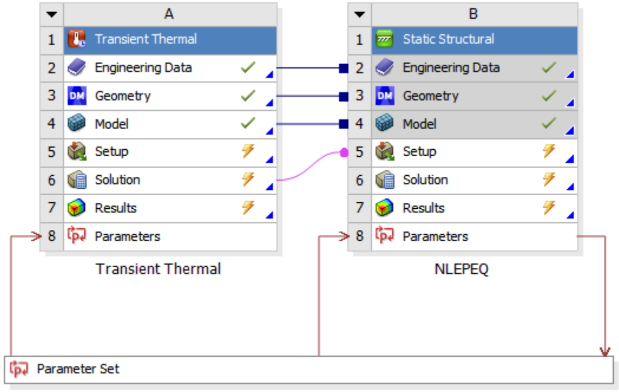


Table of Design Points

	A	B	C	D	E	F	G	H	I
1	Name	Update Order	P1 - RBF Morph Set Up Shape ID	P2 - SEQV Maximum	P3 - SEQV - ext Maximum	P4 - NLEPEQ Maximum	P5 - NLEPEQ - ext Maximum	☑ Ret...	Retained Data
2	Units			Pa	Pa	m m^-1	m m^-1		
3	DP 0 (Current)	1	0					☑	
4	DP 1	2	1					☑	
5	DP 2	3	2					☑	
6	DP 3	4	3					☑	
7	DP 4	5	4					☑	
8	DP 5	6	5					☑	
9	DP 6	7	6					☑	
10	DP 7	8	7					☑	
11	DP 8	9	8					☑	
12	DP 9	10	9					☑	
13	DP 10	11	10					☑	
14	DP 11	12	11					☑	
15	DP 12	13	12					☑	
*								☐	

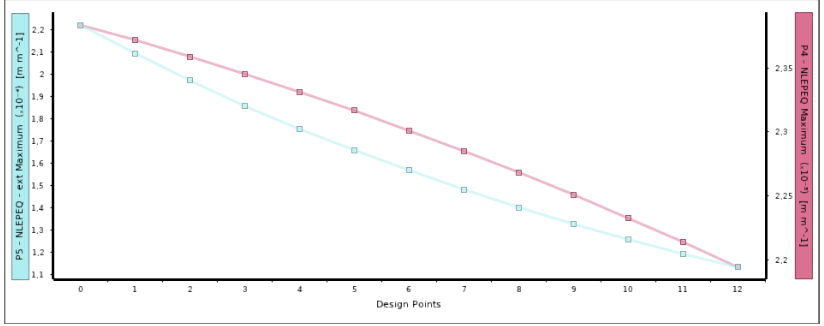
Optimization | Workbench Set-up

- After the run completion, NLEPEQ value on external surfaces (P5) is **substantially decreased (-49%)**
- Other parameters have smaller variation

Table of Design Points

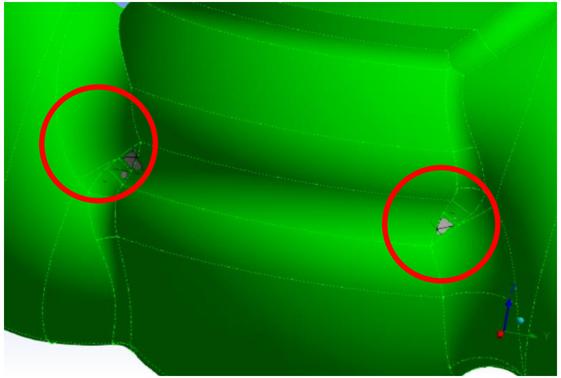
	A	B	C	D	E	F	G	H	I	J
1	Name	Update Order	P1 - RBF Morph Set Up Shape ID	P2 - SEQV Maximum	P3 - SEQV - ext Maximum	P4 - NLEPEQ Maximum	P5 - NLEPEQ - ext Maximum	☑ Ret...	Retained Data	Note
2	Units			Pa	Pa	m m^-1	m m^-1			
3	DP 0 (Current)	1	0	1,5402E+08	5,363E+07	0,0023835	0,00022191	☑	✓	
4	DP 1	2	1	1,5425E+08	5,356E+07	0,0023718	0,00020926	☑	✓	
5	DP 2	3	2	1,5325E+08	5,2605E+07	0,0023588	0,00019708	☑	✓	
6	DP 3	4	3	1,5285E+08	5,25E+07	0,0023452	0,00018557	☑	✓	
7	DP 4	5	4	1,5243E+08	5,2377E+07	0,0023311	0,00017529	☑	✓	
8	DP 5	6	5	1,5266E+08	5,2267E+07	0,0023166	0,00016586	☑	✓	
9	DP 6	7	6	1,5293E+08	5,2144E+07	0,0023008	0,00015691	☑	✓	
10	DP 7	8	7	1,5322E+08	5,2022E+07	0,0022849	0,00014824	☑	✓	
11	DP 8	9	8	1,535E+08	5,1888E+07	0,0022683	0,00014026	☑	✓	
12	DP 9	10	9	1,5378E+08	5,1748E+07	0,0022509	0,00013278	☑	✓	
13	DP 10	11	10	1,5407E+08	5,1598E+07	0,0022324	0,00012589	☑	✓	
14	DP 11	12	11	1,5435E+08	5,1443E+07	0,0022139	0,00011936	☑	✓	
15	DP 12	13	12	1,5463E+08	5,1265E+07	0,0021941	0,00011347	☑	✓	
*								☐		

Parameter Chart 0

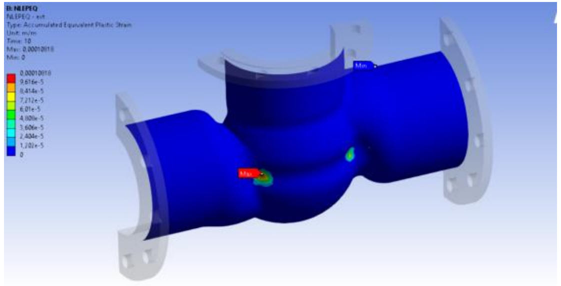


FEM analysis | Optimization results

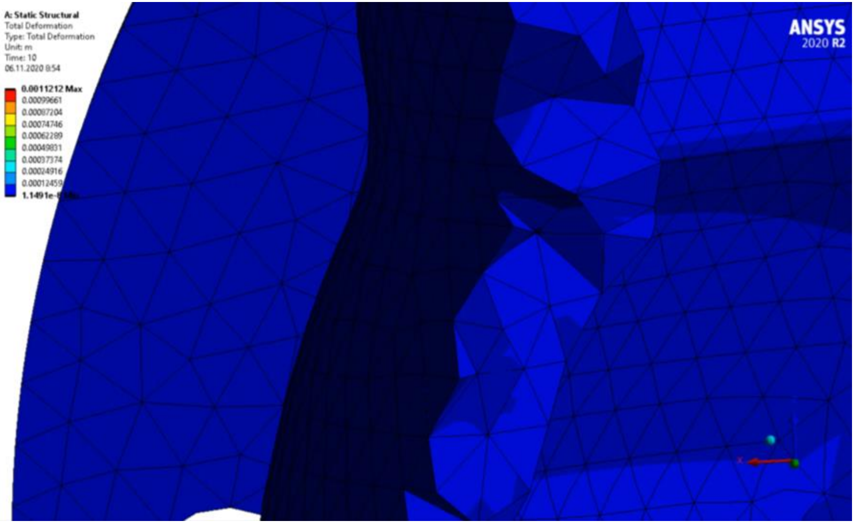
- Mesh modification can be **inspected** visualizing elements passing across surfaces (elements moved outward)
- Results in the last mesh configuration can be also inspected by selecting proper result node in the Mechanical tree.



SEQV



NLEPQ



Conclusions

- A **parameter less shape optimization** process that allows to extend **fatigue life** of structural parts subjected to **thermal fatigue** was described
- Such an approach is based on the use the **biological growth method** which is driven by the cumulative plasticity to modify the mesh through **RBF mesh morphing**
- A **significant reduction (49%)** of the hot spot stress level was achieved acting on the complete thermo-structural workflow used **for baseline fatigue assessment**

Thank you!

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