EAN 2017
55th conference on experimental stress analysis

Thermal FEM analysis of hybrid structure

Luboš LIMBERG[1, a], Milan TANČIN[1, b]

[1] The Faculty of Mechanical Engineering, The University of West Bohemia,
Univerzitni 8, 306 14 Pilsen, CZ

[a] limbi@rti.zcu.cz, [b] milax@rti.zcu.cz

Keywords: Polymer concrete; thermal FEM analysis; stress; deformation; comparative of material, hybrid structure.

Abstract. This article is focuses on mechanical properties of hybrid structure, which is loaded, by a heat. The type of hybrid structure is the hybrid structure of polymer concrete in combination with steel and cast iron. There will be presented a basic information about polymer concrete, steel and iron cast and their properties. In the article is also described the thermal FEM analysis of hybrid structure.

Introduction

Polymer concrete is increasingly used material that is an alternative to cast-iron and steel in the design of beds of machine tools. It is a composite material composed of minerals, which serve as a filler. The matrix consists of resin and a hardener. This material provides interesting and design-advantageous properties, e.g. damping, dimensional and thermal stability, high stiffness, corrosion resistance, etc.

Thanks to high thermal capacity in combination with low thermal conductivity, the polymer concrete responds slower to temperature changes in its surroundings in comparison with cast-iron.

Meaning of analyzes

Polymer concrete has different properties than steel and other metals. Two of them are thermal expansion coefficient and thermal conductivity. Differences of these material properties can cause a tension in the transition layer of hybrid structure. If used high temperatures it can produce a critical stress and then permanent deformations. Polymer concrete is very susceptible to a tensile stress. Therefore, relatively small thermal loads can cause a damage of hybrid structures.

The purpose of the analyses is finding the critical temperature loads. These analyses show the stress in the transition layer of the materials if used different thermal loads.

Mesh

There was used 3D swept mesh (CHEXA (8)) with element size 5mm. 2D mapped mash (CQUAD4) was used for creating the 3D mesh (Fig. 1). Material properties were used according to the table (Table 1).

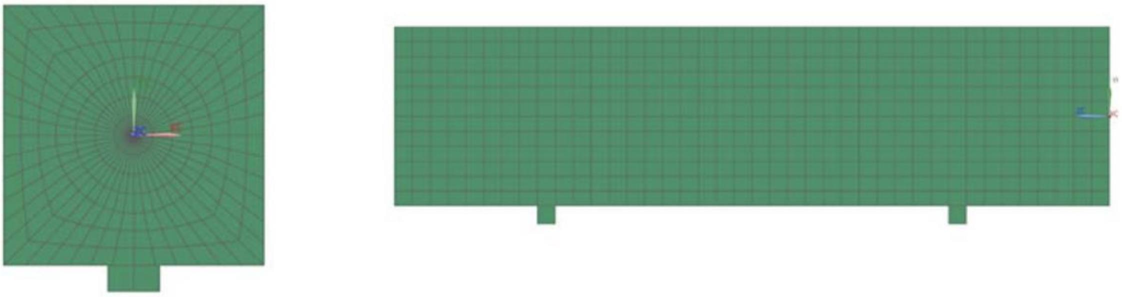


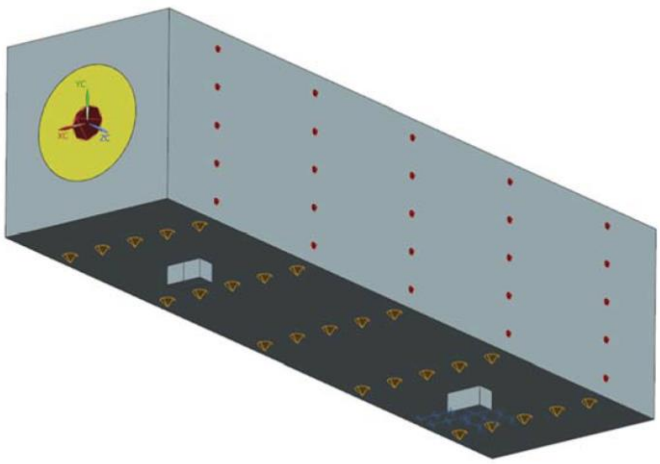
Fig. 1: Meshing model

Table 1: Material properties

	POLYMERCONCRETE	STEEL	IRON CAST G25
Mass density [kg/mm^3]	$2.3*10^{-6}$	$7.85*10^{-6}$	$7.15*10^{-6}$
Young´s modulus E [N/mm^2]	35 000	210 000	90 000
Thermal Expansion Coefficient α [1/K]	$16*10^{-6}$	$12*10^{-6}$	$10.5*10^{-6}$
Thermal Cond. [W/mK]	2	50	58
Specific Heat [μJ/kgK]	943 000 000	500 000 000	434 000 000

Boundary conditions

The connection between materials (steel, iron cast + polymer concrete) is formed using gluing function. The function makes perfectly rigid connection. Perfectly rigid connection can skew the results, but that is the most affordable way to usable results. There are two different thermal loads (with cooling and without cooling).



Analysis results

Fig. 2: Boundary conditions

Conditions I.

There is thermal load without cooling. Size of thermal loads are 20ºC, 50ºC, 100ºC for the entire model.

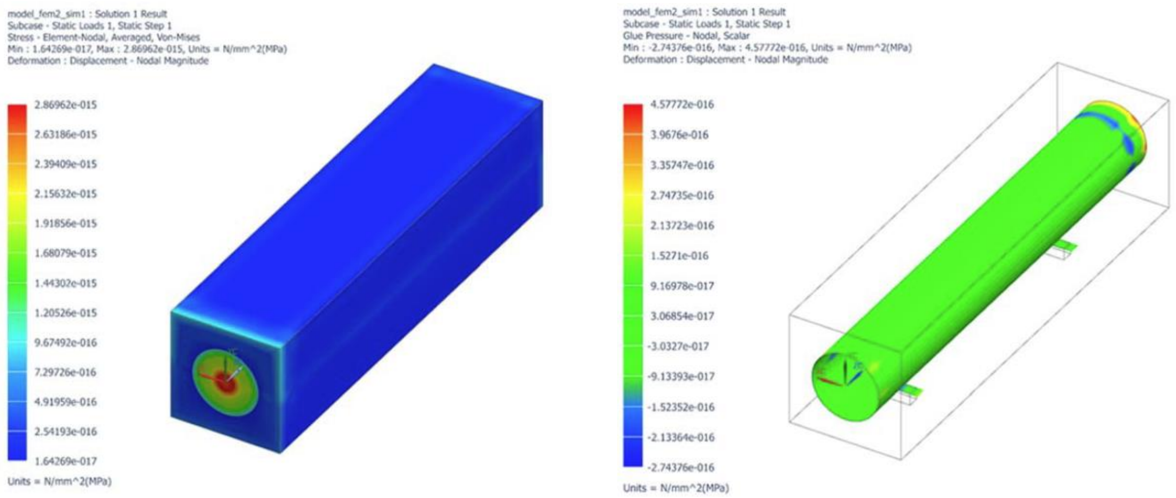


Fig. 3: Overall stress and stress at the transition layer for 20°C / no cooling

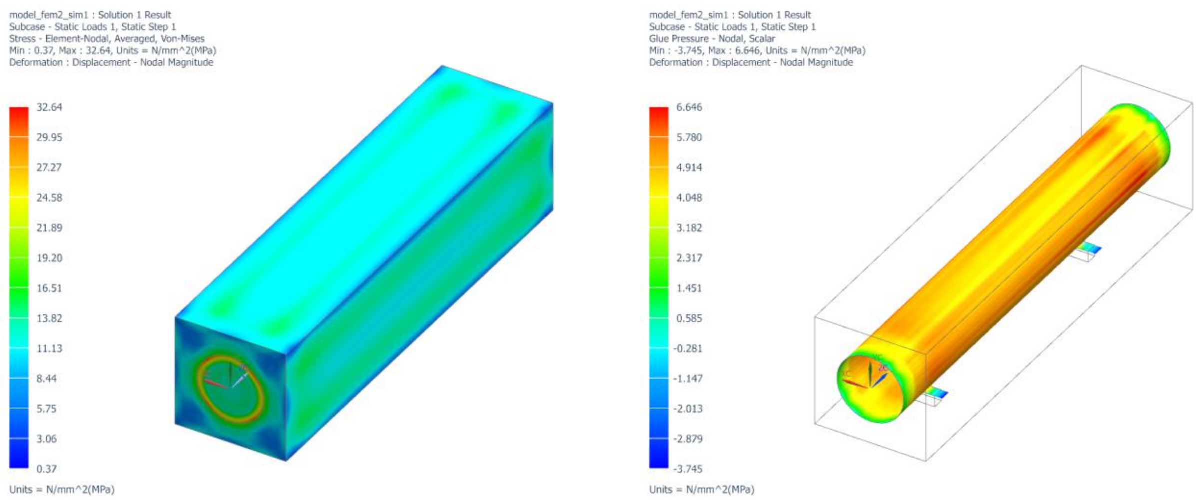


Fig. 4: Overall stress and stress at the transition layer for 50°C / no cooling

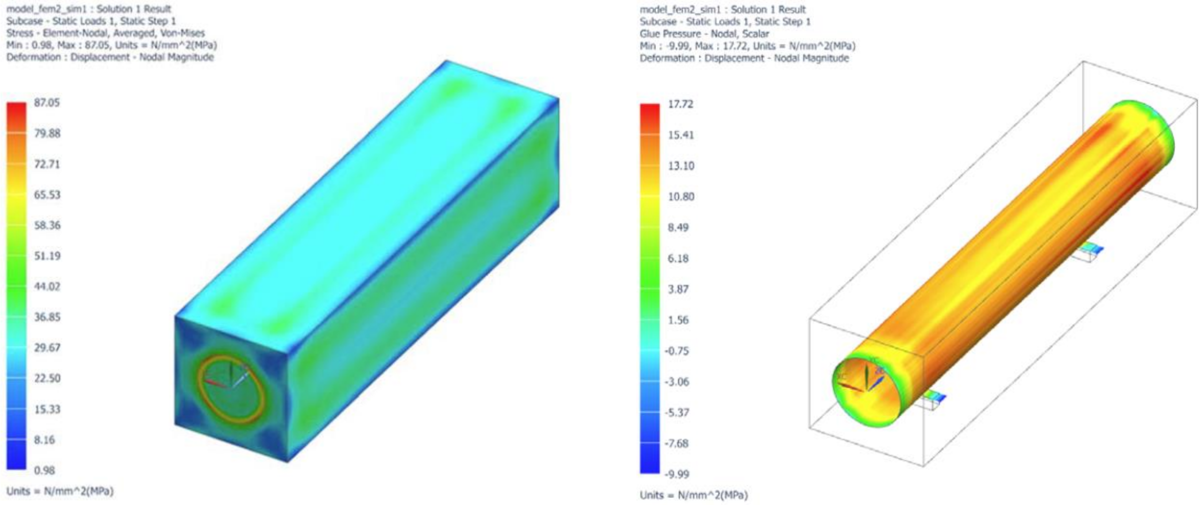


Fig. 5: Overall stress and stress at the transition layer for 100°C / no cooling

Table 2: Conditions I. results

Temperature for the entire model (no cooling)	20 °C Steel | Cast iron G25		50 °C Steel | Cast iron G25		100 °C Steel | Cast iron G25	
Overall stress [MPa]	2,869e-15	2,297e-15	32,64	18,47	87,05	49,26
Stress at the transition layer [MPa]	4,677e-15 -2,743e-15	3,402e-16 -2,080e-16	6,64 -3,74	5,36 -3,31	17,72 -9,99	14,29 -8,83
Deformation [mm]	1,400e-18	1,189e-18	0,044	0,035	0,117	0,095

Conditions II.

There is thermal load in steel / cast iron with cooling (20 ºC) on sides of polymer concrete. Size of thermal loads are 50ºC, 100ºC.

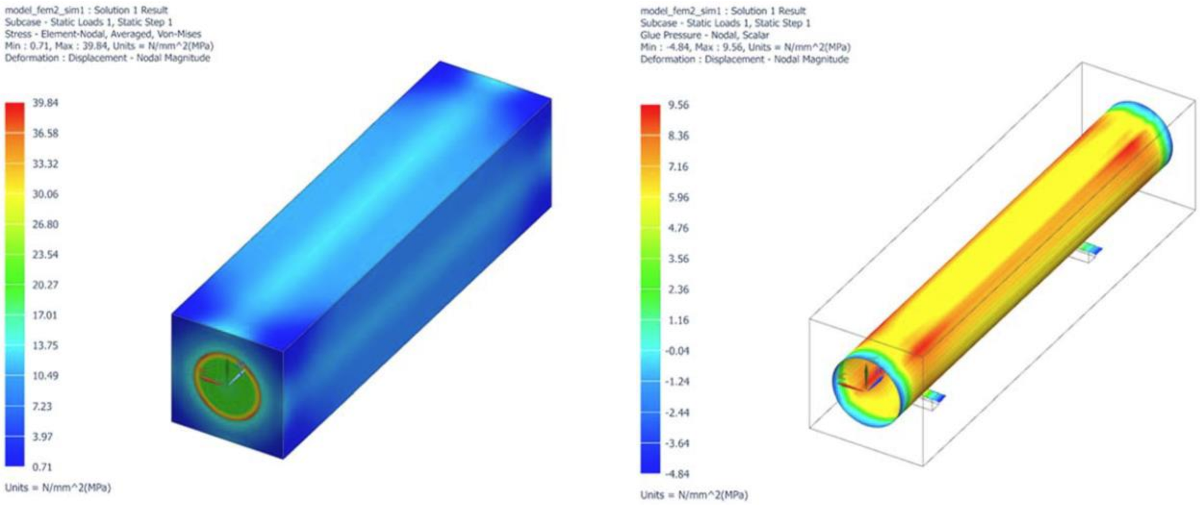


Fig. 7: Overall stress and stress at the transition layer for 50°C / with cooling

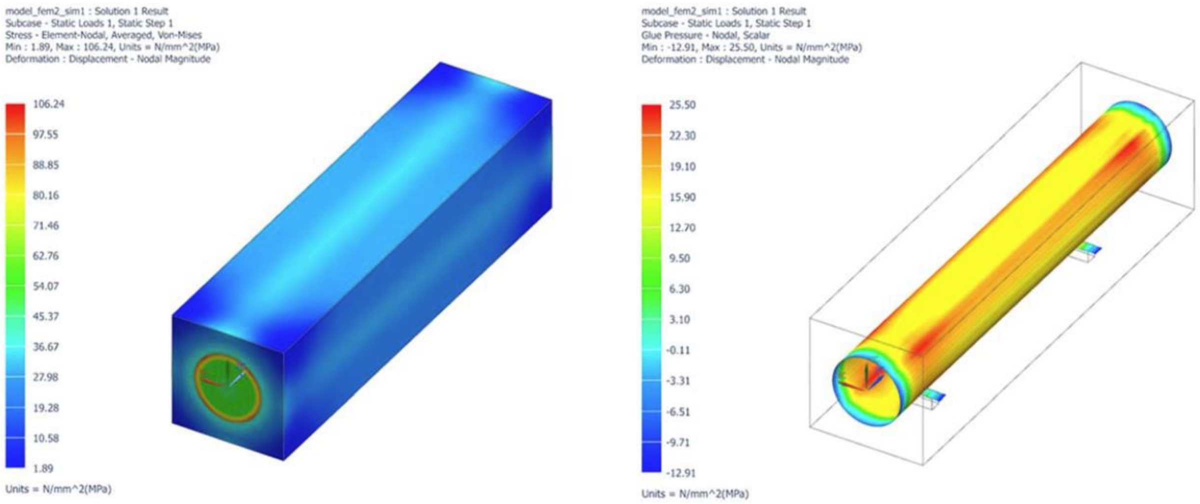


Fig. 6: Overall stress and stress at the transition layer for 100°C / with cooling

Table 3: Conditions II. Results

Temperature in steel/cast iron (cooling)	20 ºC Steel ǀ Cast iron G25		50 ºC Steel ǀ Cast iron G25		100 ºC Steel ǀ Cast iron G25	
Overall stress [MPa]	2,869e-15	2,297e-15	39,84	22,59	106,24	60,25
Stress at the transition layer [MPa]	4,677e-15 -2,743e-15	3,402e-16 -2,080e-16	9,56 -4,84	8 -4,55	25,5 -12,91	21,33 -12,15
Deformation [mm]	1,400e-18	1,189e-18	0,040	0,029	0,107	0,079

Conclusions

There are two types of thermal loads. The first is constant thermal load where both of the parts of the hybrid structure have same temperatures. The second is analysis where one of the parts is cooling to 20 °C. The results of these analyses show the size of deformations and stresses in hybrid structures.

Overall stress of conditions I (no cooling) is lower than overall stress of conditions II (cooling). Maximal tensile stress at the transition layer is around 13 MPa. The critical tensile stress for polymer concrete is around 10-15 MPa so 100 ºC load of condition II can be critical for maintaining the integrity of the polymer concrete.

This paper is based upon work sponsored by TAČR TA project TE01020075

Reference

[1] Jančář, J.: Úvod do materiálového inženýrství polymerních kompozitů. Vyd.1. Brno : Vysoké učení technické v Brně, Fakulta chemická, 2003. 193 s. ISBN 8021424435

[2] Schneeberger.com [online]. 2011 [cit. 2011-05-24]. Mineral casting - Schneeberger. <http://www.schneeberger.com/products/mineralcasting>.

[3] Daďourek, K.: Kompozitní materiály – druhy a jejich využití, Technická univerzita v Liberci, 1. vydání, 113 s., 2007, ISBN 978-80-7372-279-1

[4] Kosnar,M.,Lašová,V. a kol : Závěrečná zpráva projektu 1.2.2, Praha 2005