Vpliv različnih parametrov na trdnostni preračun toplotno obremenjenega žarometa

The Effects of Different Analysis Parameters on the Calculated Temperature of a Loaded Headlamp

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Sodobni žarometi so večinoma izdelani iz plastičnih mas, ki so sicer zelo primerne za izdelavo zahtevnih oblik, vendar so navadno temperaturno slabo obstojne. Posledice temperaturnih obremenitev so deformacije, ki imajo lahko vpliv na fotometrične lastnosti ter na odpornost žarometa na zunanje vplive.

V pričujočem prispevku smo z metodo končnih elementov (MKE) za dejanski primer žarometa podjetja Saturnus avtooprema d.d. določili napetostno deformacijsko stanje v okrovu žarometa kot posledico temperaturnih obremenitev. Ugotavljali smo vpliv različnih parametrov in tipa končnih elementov na termo-mehansko analizo. Z metodo končnih elementov smo izračunali deformacije okrova z namenom odprave netesnosti med pokrovom in okrovom žarometa.

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(Ključne besede: žarometi, obremenitve temperaturne, stanja napetostno-deformacijska, metode končnih elementov)

Modern headlamps are made from low-cost plastic materials, which are very convenient for modern headlamp design. On the other hand, plastic materials do not withstand high temperatures. This can cause deformations that result in problems with the photometric properties and with the sealing of headlamp.

In this article the stress-strain state of a fog lamp from Saturnus avtooprema d.d. caused by thermal loads was analyzed with finite-element analyses (FEA). The effects of different analysis parameters and finite-element types on the thermo-mechanical properties were analyzed. With the results of the FEA we determined the deformations to the headlamp housing. This analysis helped us to eliminate the causes of the bad sealing between the housing and the cover of the headlamp.

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(Keywords: automotive headlamp, temperature loads, stress-strain state, finite-element methods)

0 UVOD

V pričujočem prispevku analiziramo avtomobilsko meglenko, za katero poznamo le robne pogoje in obremenitev. Meglenka je temperaturno obremenjena ([3] in [4]), kar povzroči deformacijo meglenke. Temperaturne deformacije imajo določene specifične lastnosti, ki v obravnavanem primeru povzročijo nepopolno tesnjenje meglenke.

Analiza žarometa je bila izvedena s programskim paketom Ansys. V določenih obremenitvenih razmerah napetostno-deformacijska analiza pokaže kritična mesta na okrovu žarometa, ki so vzrok za napake na žarometu. Večje število analiz z uporabo MKE je pokazalo vpliv posameznega

0 INTRODUCTION

This article discusses an automotive fog lamp with a known temperature load and boundary conditions. The deformation of the fog-lamp housing is the result of the temperature load ([3] and [4]). Temperature deformations have specific properties, which results in the fog-lamp housing being badly sealed.

The finite-element analyses were made with Ansys computer-aided analysis (CAE) software. The critical points on the fog-lamp housing which causes the defects of the fog lamp were found as a result of the specific thermal loads. The analyses showed the influences of various parameters on the defects of

parametra na napako na okrovu. Analize z uporabo MKE omogočajo izboljševanje modela brez izdelave orodij in prototipov. S tem načinom dela lahko odpravimo veliko začetniških napak.

Napetostno-deformacijsko analizo izdelamo na temelju s preizkusi izmerjenih temperatur [1], ki definirajo temperaturno polje meglenke. Z interpolacijo določimo najprej funkcijsko odvisnost temperature od lege točke na obravnavanem žarometu. S preliminarnimi izračuni nato analiziramo uporabnost prostorskih in ploskovnih končnih elementov pri temperaturni obremenitvi. S temi izračuni lahko preverimo tudi ujemanje eksperimentalno določenih temperatur z izračunanimi in analiziramo vpliv geometrijske oblike (okrov s pokrovom, okrov brez pokrova) na dobljeno napetostno-deformacijsko stanje.

Iz rezultatov preliminarne analize izhaja izdelava geometrijskega in računskega modela meglenke ter izračun napetostno-deformacijskega stanja zaradi temperaturnih obremenitev.

1 DOLOČITEV TEMPERATURNEGA POLJA

1.1 Izmerjene temperature

Za analizo napetostno deformacijskega stanja temperaturno obremenjene konstrukcije je treba natančno poznati temperaturno polje po celotni konstrukciji. V našem primeru so bile temperature eksperimentalno izmerjene le na določenih mestih [1]. Na podlagi izmerjenih temperatur definiramo interpolacijsko temperaturno odvisnost za notranjo in zunanjo

the fog-lamp housing. The analyses enabled us to make improvements to the model without building prototype or tools. The FEA enabled us to eliminate a lot of the defects in an early stage of the development.
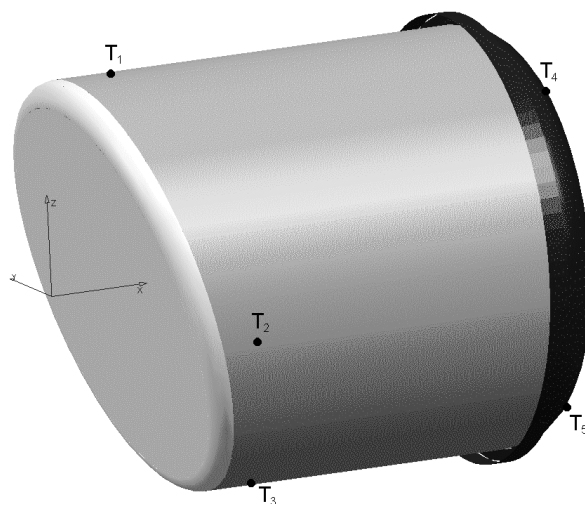
Stress-strain analysis is based on experimental temperature measurements [1], which define the temperature field of the fog-lamp housing. An interpolation function was used to determine the position-dependent temperature field. Preliminary analyses helped us to determinate the applicability of the volume and shell elements for temperature-analysis calculations. These analyses were verified with experimental data. It also helped us to analyze the effect of geometry (the housing with and without the cover) on the stress-strain state of the model.

Preliminary analyses were the basis for the building geometry, the FEM of the fog lamp and the calculations of the temperature-induced stress-strain state.

1 DETERMINING THE TEMPERATURE FIELD

1.1 Measured temperatures

The basis for the stress-strain state of the temperature-loaded model is knowledge of the complete temperature field across the whole model. Experimental measurements were made at only a few measurement spots [1]. The measured temperatures represent input data for determining the interpolation temperature function on the inner and outer sides of the housing. The coefficients of the interpolation function were determined with the least-

Sl. 1. *Lega izmerjenih temperatur na meglenki*
Fig. 1. *Position of the measured temperatures on the fog lamp*

površino z metodo najmanjših kvadratov. Na podlagi teh dveh porazdelitev lahko določimo temperaturno polje po žarometu. Pri določitvi interpolacijske funkcije predpostavimo, da se temperatura spreminja le po dolžini (koordinata x) in višini (koordinata z) meglenke, po širini (koordinata y) pa je nespremenljiva (sl. 1). Tako predpostavko lahko uporabimo le v primeru, ko imamo osnosimetričen žaromet, sicer se zaradi naravne konvekcije vzpostavi zahtevno temperaturno polje [4].

square error method. These temperature functions enabled us to define the temperature field over the entire housing of the fog lamp. The determination of the interpolation temperature function was made with the assumption that the temperature variation is only present over the length (coordinate x) and the height (coordinate z) of the fog-lamp housing. The temperature over the width (coordinate y) of the fog-lamp housing is constant (Fig. 1). Such an assumption could only be made while the housing of the fog lamp was symmetrical. In other cases, a complex temperature field was developed as a result of natural convection [4].

Preglednica 1. *Izmerjene temperature na notranji strani okrova*
Table 1. *Temperatures measured inside the fog-lamp housing*

		$T_{1,not}$	$T_{2,not}$	$T_{3,not}$	$T_{4,not}$	$T_{5,not}$
izmerjena vrednost / measured value [°C]		166,8	101,4	90,7	98,30	77,6
koordinate / coordinates:	X [mm]	24	24	28	100	100
	Y [mm]	0	-40,5	0	0	0
	Z [mm]	40,5	0	-40,5	25,5	-26,5

Preglednica. 2. *Izmerjene temperature na zunanji strani okrova*
Table 2. *Temperatures measured on outer side of the fog-lamp housing*

		$T_{1,zun}$	$T_{2,zun}$	$T_{3,zun}$	$T_{4,zun}$	$T_{5,zun}$
izmerjena vrednost / measured value [°C]		144,6	89,9	80,5	87,5	70,4
koordinate / coordinates:	X [mm]	24	24	28	100	100
	Y [mm]	0	-42,5	0	0	0
	Z [mm]	42,5	0	-42,5	25,5	-26,5

1.2 Interpolacijska temperaturna odvisnost

Če želimo definirati matematični predpis, ki opisuje spreminjanje temperaturnega polja, lahko predpostavimo, da se temperatura v smeri osi x spreminja linearno, v smeri z pa kvadratno. Izbrano funkcijo, ki kaže odvisnost temperature od lege točke (x,z), zapišemo v obliki:

1.2 Interpolation temperature function

The mathematical definition of the temperature field was made with the assumption that the temperature over coordinate x changes linearly and over coordinate z changes quadratically. The mathematical function of the relationship between the temperature and the position (x,z) on the housing that was chosen has the following form:

$$T(x,z) = a + b \cdot x + c \cdot z + d \cdot z^2 \tag{1}$$

Takšno funkcijo smo izbrali zato, ker se je od vseh 2D kvadratnih funkcij izkazala za najbolj primerno, ker se najbolj prilagaja izmerjenemu temperaturnemu polju. Drugim funkcijam ne uspe popisati izrazitega skoka temperature nad žarnico. Konstante a, b, c in d v enačbi (1) določimo z metodo najmanjših kvadratov, pri čemer definiramo funkcijo napake:

The chosen function showed the best correlation with the measured temperature field of all 2D quadratic functions. The other functions had difficulties presenting a huge temperature rise over the electric bulb. The coefficients a, b, c and d of Equation (1) were determined with the least-square error function, which had the following form:

$$Err = \sum_{k=1}^{N} (f(x_k) - y_k)^2 \rightarrow \min \tag{2}$$

kjer so:

where:

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$f(x_k)$ - modelirana vrednost,
y_k - dejanska izmerjena vrednost,
N - število vzorčnih točk.

Z opisano metodo izračunamo neznane konstante a, b, c in d v enačbi (1), in sicer ločeno za izmerjene zunanje in notranje temperature. Iskani funkciji (sl. 2), ki kažeta odvisnost zunanje in notranje temperature od lege točke (*x,z*), zapišemo v naslednjih oblikah:
notranja temperatura

$f(x_k)$ - modeled value,
y_k - actual measured value,
N - number of sampling points.

The method described earlier was used to determinate the constants a, b, c, d of Equation (1), separately for each temperature field of the housing. The equations (Fig.2) for the dependency of the inner and outer temperatures of the point position (*x,z*) have the following form:
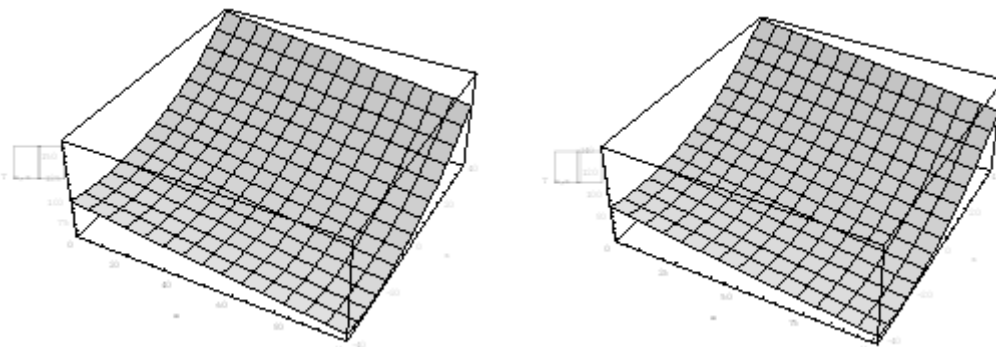the inner temperature:

$$T_{not}(x,z) = 109,22 - 0,3292 \cdot x + 0,7773 \cdot z + 0,0175 \cdot z^2 \tag{3},$$

zunanja temperatura

the outer temperature:

$$T_{zun}(x,z) = 96,14 - 0,2493 \cdot x + 0,6002 \cdot z + 0,0125 \cdot z^2 \tag{4}.$$

2 PRELIMINARNA ANALIZA

S preliminarnimi analizami želimo ugotoviti ustreznost prostorskih in ploskovnih končnih elementov pri temperaturni obremenitvi ter število potrebnih merilnih mest za temperaturo. Napetostno-deformacijska analiza je bila izdelana na zelo poenostavljenem modelu meglenke, pri kateri lahko analiziramo tudi vpliv geometrijske oblike. V dejanskem primeru izdelamo napetostno-deformacijsko analizo za meglenko z zadnjim pokrovom in brez njega.

Izbrani temperaturni funkciji definirata porazdelitev temperature na notranjem in zunanjem obodu meglenke. Pri uporabi ploskovnih končnih elementov lahko neposredno izvedemo napetostno-deformacijsko analizo modela, medtem ko zahteva uporaba prostorskih končnih elementov dodaten toplotni preračun.

2 PRELIMINARY ANALYSIS

The preliminary analysis helped us to determine the appropriateness of the volume and shell elements for the temperature load calculation. It also helped us to determine the number of required temperature-measuring points. The stress-strain analyses were made on a simplified model of the fog lamp, which also enabled us to study the influence of the geometry on the results. This meant that the housing of the fog lamp with and without the cover was analyzed.

Selected temperature functions determine the temperature distribution on the inner and outer side of the fog-lamp housing. When shell elements were used, the stress-strain analysis could be made directly. On the other hand, usage of the volume elements requires an additional thermal analysis.

Sl. 2. *Porazdelitev notranje (levo) in zunanje (desno) temperature*
Fig. 2. *Temperature distribution on inner (left) and outer (right) sides of the housing*

2.1 Prostorski končni elementi

Pri prostorskih končnih elementih vnesemo porazdelitev temperature samo na notranji strani okrova meglenke. Z dodanim toplotnim preračunom določimo temperaturno polje po celotnem okrovu. Pri toplotni analizi predpostavimo prevod toplote skozi okrov in nato prestop toplote na okoliški zrak. Za termično analizo je treba definirati koeficient toplotne prevodnosti λ za okrov, pokrov in lečo meglenke ter koeficient toplotne prestopnosti α_k na okoliški zrak. Natančno vrednost koeficienta toplotne prevodnosti za plastične materiale $\lambda = 0,19$ W/mK in za prestop zraka $\alpha_k = 20$ W/m^{2}K preberemo iz literature [2].

S spreminjanjem oziroma nepravilno izbiro koeficientov λ in α lahko zelo spremenimo temperaturno polje na okrovu. Meritve na zunanjem delu okrova so bile namenjene za primerjavo pravilnosti izračunanega zunanjega temperaturnega polja.

Rezultat toplotnega izračuna je želeno temperaturno polje po vseh končnih elementih oziroma vozliščih modela (sl. 3), ki pomeni temperaturno obremenitev pri napetostno-deformacijski analizi.

Rezultati preliminarne napetostno-deformacijske analize pri uporabi prostorskih končnih elementov so prikazani v nadaljevanju. Na podlagi prikazanih napetostnih in deformacijskih stanj je mogoče analizirati tudi vpliv dodanega zadnjega pokrova.
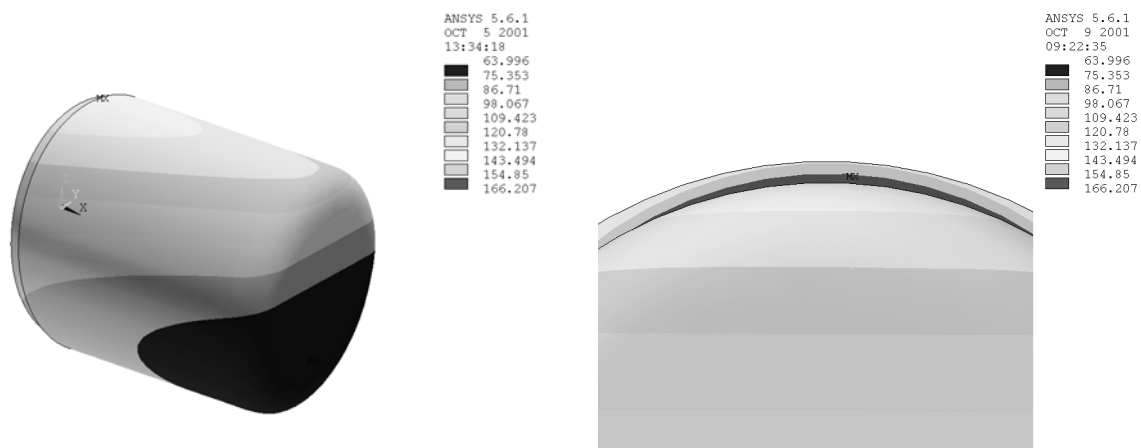
2.1 Volume finite elements

When volume finite elements were used, the inner temperature distribution was needed. An additional thermal calculation is needed to determine temperature distribution over the housing. The assumptions of heat transfer through the housing walls and heat transfer to the environment were made. Thermal analysis needs a determination of the thermal conductivity λ for the lamp housing, the lens and the cover, and the coefficient of the heat transfer a_k to the air environment. The values of the thermal conductivity ($\lambda = 0.9$ W/mK) and the heat transfer of polymer materials ($\alpha_k = 20$ W/m^{2}K) were found in the literature [2].

Irregular choices of the coefficients λ and α have a great effect on the temperature field of the fog-lamp housing. Measurements on the outer surface of the housing were used for a comparison with the results of the calculated outer temperature field.
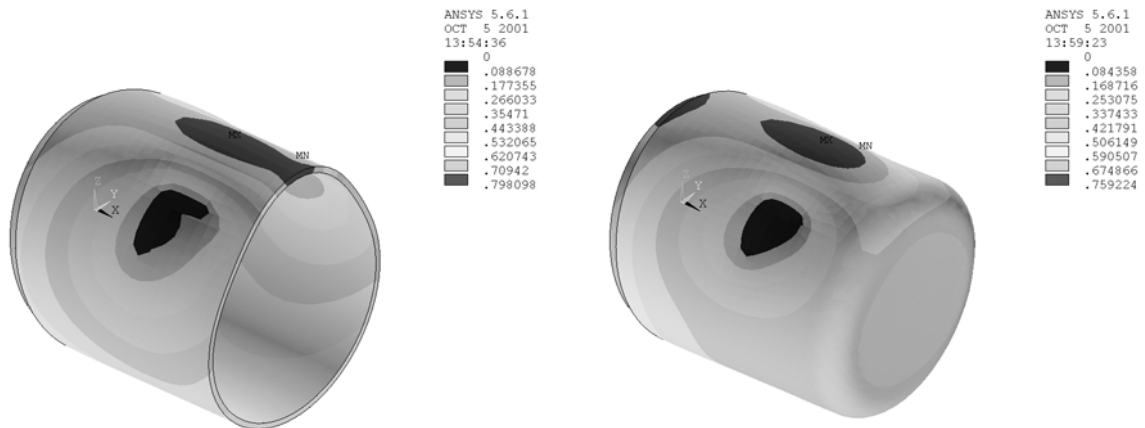
The result of the thermal analysis was a temperature field on all the finite elements and, as result, the nodes (Fig. 3). This temperature field was loaded for a stress-strain analysis.

Results of the preliminary analysis with volume elements are shown in the following pictures. These pictures enable us to analyze the effect of the fog lamp cover on the results.
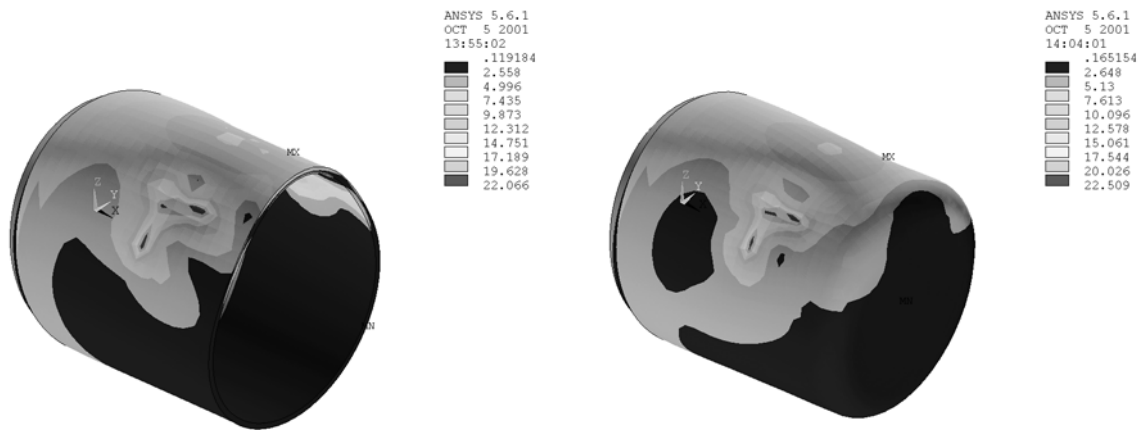

Sl. 3. *Temperaturno polje poenostavljenega modela s pokrovom (levo) in porazdelitev temperature po debelini stene na mestu spoja leče in okrova (desno)*
Fig. 3. *Temperature field on simplified model with cover (left) and temperature distribution over the wall thickness on the connection spot of the fog-lamp housing and cover (right)*

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Sl. 4. *Deformacija poenostavljenega modela brez pokrova (levo) in s pokrovom (desno)*
Fig. 4. *Deformed, simplified model with (right) and without (left) cover*

Sl. 5. *Porazdelitev napetosti v poenostavljenem modelu brez pokrova (levo) in s pokrovom (desno)*
Fig. 5. *Stress distribution on simplified model with (right) and without (left) cover*
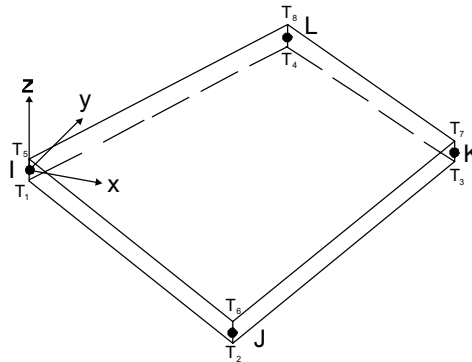
2.2 Ploskovni končni elementi

Uporaba ploskovnih končnih elementov ne terja predhodnega toplotnega preračuna, saj z uporabo izbranih temperaturnih odvisnosti za zunanji in notranji obod žarometa že določimo porazdelitev temperature vseh potrebnih vozliščih končnih elementov. Ploskovni elementi namreč terjajo, da pri temperaturnem robnem pogoju podajamo temperature na notranji in zunanji površini (sl. 6). To pomeni, da lahko v tem primeru neposredno izvedemo napetostno-deformacijsko analizo modela.

Rezultati preliminarne napetostno-deformacijske analize pri uporabi ploskovnih končnih elementov so prikazani v nadaljevanju. Tudi tu lahko na osnovi prikazanih napetostnih in deformacijskih stanj analiziramo vpliv dodanega zadnjega pokrova.
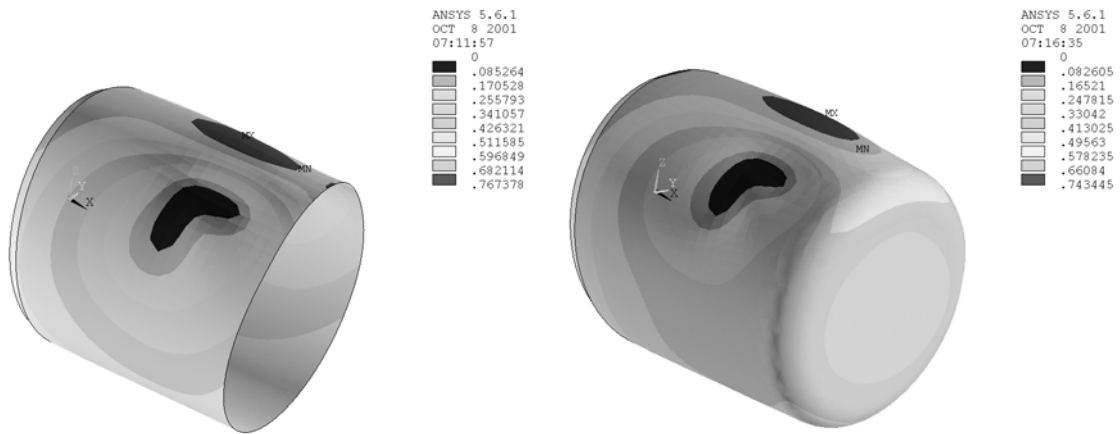
2.2 Shell finite elements

Shell finite elements do not require additional thermal analysis. In this case we used the temperature function calculated for the inner and outer surfaces of the housing. This enables us to determine the temperature field on every node of the housing. Shell elements require the temperature boundary condition on the inner and outer sides of the housing (Fig 6). This means that the stress-strain analysis was calculated directly.
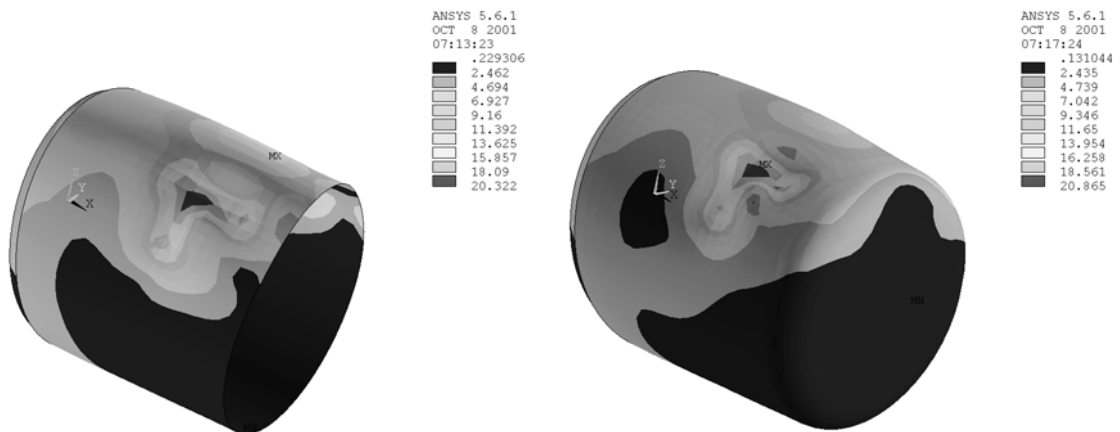
The results of the preliminary analysis with shell elements are shown on the following pictures. Those pictures enable us to analyze the effect of the fog-lamp cover on the results.

Sl. 6. *Temperaturni robni pogoji pri ploskovnih elementih*
Fig. 6. *Input temperature on shell elements*

Sl. 7. *Deformacija poenostavljenega modela brez pokrova (levo) in s pokrovom (desno)*
Fig. 7. *Deformed simplified model with (right) an without (left) cover*

Sl. 8. *Porazdelitev napetosti v poenostavljenem modelu brez pokrova (levo) in s pokrovom (desno)*
Fig. 8. *Stress distribution on simplified model with (right) and without (left) cover*

2.3 Ugotovitve preliminarne analize

S preliminarnimi analizami smo pridobili vrsto koristnih podatkov in primerjav, ki omogočajo lažjo razlago rezultatov pri nadaljnjih analizah z zahtevnejšimi problemi. V primeru, da so stene okrova dovolj tanke, so analize pokazale, da ni bistvenih razlik v napetostno-deformacijskem stanju pri uporabi ploskovnih ali prostorskih elementov. Izračunani rezultati kažejo, da so vidne razlike pri uporabi modela s pokrovom ali brez njega. Pri uporabi pokrova je deformacija zadnjega dela okrova zadržana. V tem primeru se okrov enakomernejše deformira (sl. 4 in 7). Pri modelu brez pokrova pride do neenakomernega deformiranja okrova (spremeni se oblika zadnjega robu). Opazimo lahko tudi dobro ujemanje izmerjenih [1] in izračunanih zunanjih temperatur pri toplotni analizi. Meritev temperatur na zunanji strani okrova zaradi dobrega ujemanja rezultatov ni potrebna, to pa pomeni velik prihranek časa pri meritvah in zmanjšanje možnosti pojava napake.

3 PRERAČUN PROBLEMA

Na temelju ugotovitev preliminarne analize se odločimo za izdelavo geometrijskega modela meglenke s pokrovom, pri kateri je zadnji pokrov stalno utrjen na okrov le na treh pritrdilnih mestih, kakor je to dejansko izvedeno (sl. 9). Pri izdelavi računskega modela bomo uporabili ploskovne končne elemente, saj so časi, potrebni za izračun, krajši kakor pri prostorskih končnih elementih, dobljeni rezultati pa praktično enaki. Ustrezen stik med ohišjem in zadnjim pokrovom bomo izvedli z uporabo linijskih stičnih elementov.

Model končnih elementov za analizo napetostno-deformacijskega stanja je izdelan na osnovi izhodiščnega 3D modela meglenke.

Meglenka je narejena iz dveh vrst materialov. Ohišje in pokrov sta narejena iz polipropilena, leča je izdelana iz polikarbonata. Upoštevali smo nelinearnost obeh materialov. Material smo upoštevali kot homogen in izotropen.

Meglenka je togo vpeta na pritrdilnih mestih.

3.1 Obremenitveni primeri

Meglenka je togo podprta na pritrdilnih mestih, kar je prikazano na sliki 9. Napetostno-deformacijska analiza je izdelana za obremenitveni primer, ko je meglenka

2.3 Findings of the preliminary analysis

The preliminary analysis provided us with useful data. With a comparison of this data and the results a better understanding and interpretation of the more complex problems was gained. Preliminary analysis showed that if the thickness of the housing is small there are insignificant differences in the stress-strain state due to the different type of finite elements. Calculations show significant differences between the model with a cover and the model without a cover. When the cover is used, the deformation of the back part of the housing is restrained. This enables the deformation to be more evenly spread (Fig. 4 and 7). When the model without the cover was used the deformation of the rear part of the housing was uneven (the shape of the rear edge was changed). The thermal analysis gave a good correlation between the measured and the calculated outer-surface temperatures. This made it possible to measure the inside temperature only, which reduced the measurements time and introduced the possibility of a measurement error.

3 PROBLEM ANALYSIS

Based on the findings of the preliminary analysis, a decision was made to model the geometrical model of the fog lamp with the cover. The rear cover was fixed on the housing with only three points, like with the real lamp (Fig. 9). The model was meshed with shell elements, as this reduces the required calculation time with the same results as with volume finite elements. The connection between the housing and the cover was modeled with contacts elements.
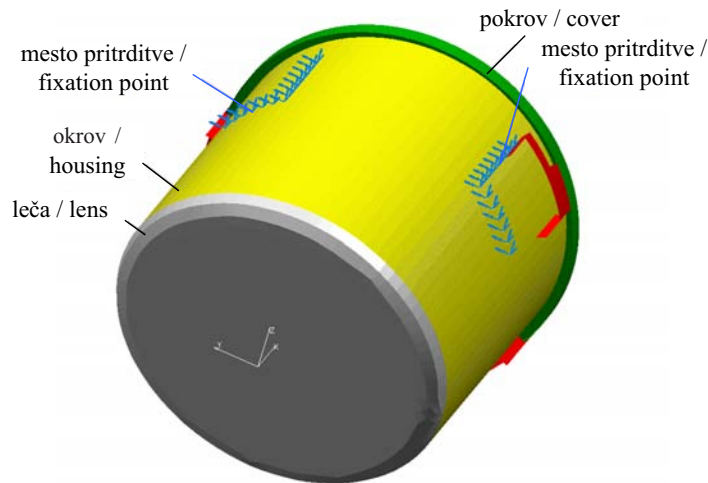
The finite element model of the stress-strain analysis was made on basis of the 3D geometrical model of the fog lamp.

The fog lamp is made of two materials. The housing and the cover are made form polypropylene, the lens is made of polycarbonate. The nonlinearity of the materials was taken into account. The material is regarded as homogenous and isotropic.

The fog lamp had a rigid support at the fastening points.

3.1 Load case

The fog lamp had a rigid support, as shown in Figure 9. A stress-strain analysis was made for the temperature-load case defined in

Sl. 9. *Obremenitveni primer; točke prikazujejo togo podprtje meglenke*
Fig. 9. *Load case; rigid support points of fog lamp*

obremenjena s temperaturno obremenitvijo, ki je določena v poglavju 1. Obremenitev je podana v obliki točkovnih temperatur na vozlišča posameznih elementov. Pri izdelavi računskega modela smo uporabili ploskovne končne elemente, ki smo jim predpisali ustrezno temperaturno obremenitev. Ker je temperatura meglenke na notranji strani različna od temperature na zunanji strani, je treba v vsakem vozlišču določiti dve temperaturi (sl. 6).

3.2 Rezultati napetostno-deformacijske analize

Na naslednji strani so prikazani rezultati izračuna napetostno-deformacijskega stanja za izbrani model končnih elementov. Rezultati kažejo, da ima način vpetja žarometa velik vpliv na napetostno-deformacijsko stanje. Vpetje povzroči, da se ohišje v predelu netesnosti premakne navznoter (sl. 12), pokrov pa se deformira navzven (sl. 13).
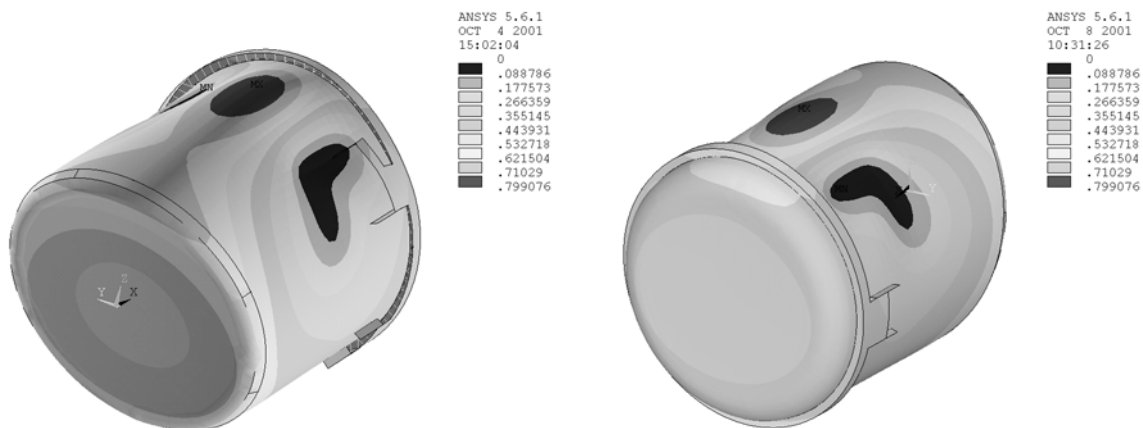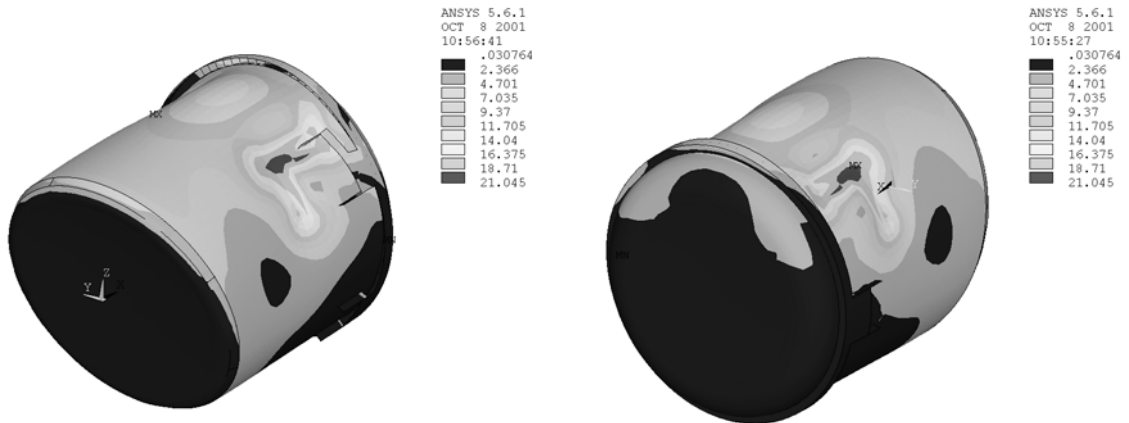
the second section. The loads were applied as nodal loads on every element node. The shell finite elements with an appropriate temperature load were used. As the temperature differs on the inner and outer sides of the housing, two temperatures had to be defined on each node (Fig. 6).

3.2 Results of the stress-strain analysis

The results of the stress-strain analysis are presented on the following page. These results show that the fastening points of the head-lamp housing have a significant effect on the stress-strain analysis results. The effect of the fastening points was a displacement of the housing of the lamp inwards (Fig. 12) in the region of the bad sealing and, as a result, the cover moves outwards (Fig. 13).
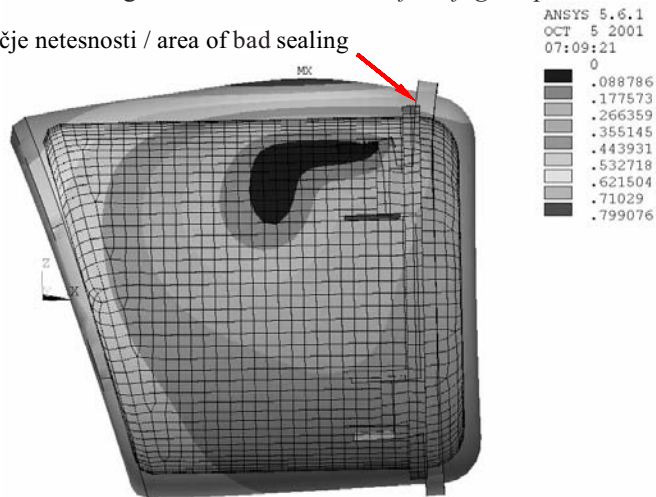

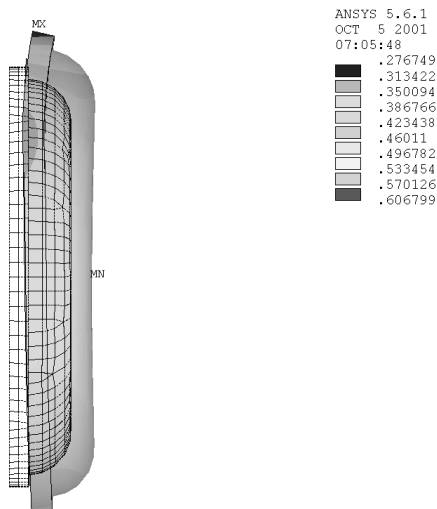Sl. 10. *Deformacije meglenke*
Fig. 10. *Deformations of the fog lamp*

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Sl. 11. *Porazdelitev napetosti v meglenki*
Fig. 11. *Stress distribution of the fog lamp*

područje netesnosti / area of bad sealing

Sl. 12. *Deformirana in nedeformirana oblika meglenk*e
Fig. 12. *Deformed and undeformed shape of the fog-lamp housing*

Sl. 13. *Deformirana in nedeformirana oblika zadnjega pokrova*
Fig. 13. *Deformed and undeformed shape of the fog-lamp rear cover*

4 SKLEP

Napetostno-deformacijska analiza meglenke je bila izdelana na temelju računskega modela, pri katerem so bile upoštevane ugotovitve preliminarne analize. V obravnavanem primeru se izkaže, da nastale deformacije, ki so posledica temperaturne obremenitve, deformirajo meglenko tako, da tesnjenje med pokrovom in okrovom ni več zadostno. Kritično mesto je najvišja točka spoja med pokrovom in okrovom med fiksnima pritrdilnima točkama, kjer se zadnji pokrov močno deformira (sl. 13). Okrov meglenke se na področju spoja pomakne proti sredini, pokrov pa se izboči navzven (sl. 12). Izkaže se, da ima največji vpliv na deformacijo način vpetja žarometa. V okolici togih pritrdilnih mest so namreč deformacije prisilno zadržane, kar vpliva na obliko deformacije okrova in prek spoja posredno na deformacijo pokrova. Uporaba stičnih elementov je omogočila, da se okrov in pokrov v skladu s pravili stika prosto deformirata, kar še poveča deformacijo.

Morebitno mesto nezadostnega tesnjenja se zato lahko pojavi v okolici stalne pritrditve. Problem bi lahko rešili z uporabo le enega stalnega pritrdilnega mesta meglenke na preostalo konstrukcijo ali pa s pomikom sedanjih pritrdilnih mest dovolj stran od spoja med pokrovom in okrovom.

4 CONCLUSION

A stress-strain analysis of the fog lamp was made with help of the results and knowledge gained with a preliminary analysis. The results show that the temperature-induced load causes such a big deformation of the fog lamp housing that it does not seal. The bad sealing point on the housing is at the top, between the fastening points on the contact edge of the housing and the cover (see Fig. 13). For this point the deformations of the cover are also the biggest. At the critical point the housing of the lamp moves inwards and the cover moves outwards (see Fig. 12). The method of fastening the fog lamp has a major effect on the results. Around the fastening points the deformations are constrained, which causes a specific deformation of the housing and, consequently, deformations of the cover. The application of the contact elements enabled free movement in accordance with constraints of the housing and the cover. This causes even larger deformations.

The final point of the bad seal appeared around the fastening points. However, the problem could be solved by using only one fix fastening point to the surrounding elements. The other solution would be to move the fastening points away from contact edge between the housing and the cover of the fog lamp.

5 LITERATURA
5 REFERENCES

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