

Metody Elementów Skończonych

Sprawozdanie wykonał Mikita Shmialiou

Temat: Symulacja ustalonych & nieustalonych procesów cieplnych

Symulacja ustalonych procesów cieplnych

Wstęp

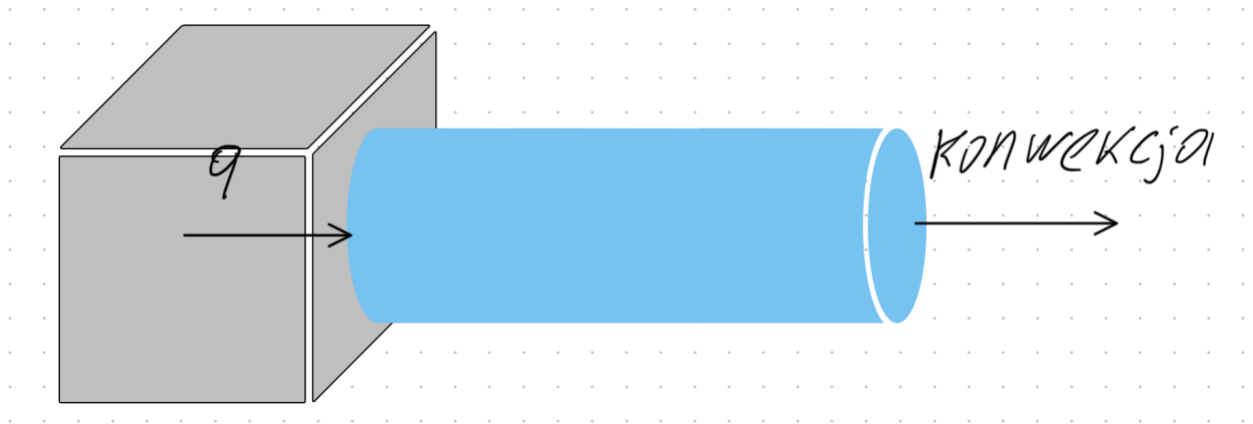
Celem jest obliczenia rozkładu temperatury w jednowymiarowym pręcie. Zadanie będzie rozwiązane na kilka sposobów:

1. Analityczne rozwiązanie układu równań oraz napisanie kodu w Pythonie na podstawie tego rozwiązania
2. przez bezpośrednią minimalizację funkcjonału w programie Excel

Przedstawienie modelu z warunkami brzegowymi

Analiza odbywa się na pręcie o długości L przy procesie ustalonego przewodnictwa ciepła. Zakładamy, że wymiana ciepła odbywa się tylko na końcach pręta:

1. na początku pręta mamy strumień ciepła q
2. na końcu mamy konwekcję



Podstawy rozwiązywania MES dla problemu optymalizacji bezpośredniej

Rozwiązanie polega na poszukiwaniu minimum funkcjonału energetycznego J . Przy jednowymiarowym, ustalonym przepływie ciepła oraz z warunkami brzegowymi J wygląda:

$$J = \int_V \left[\frac{1}{2} \left(k_x(t) \left(\frac{\partial t}{\partial x} \right)^2 + k_y(t) \left(\frac{\partial t}{\partial y} \right)^2 + k_z(t) \left(\frac{\partial t}{\partial z} \right)^2 \right) - 2Qt \right] dV$$

Dane wejściowe:

$$k = 50 \frac{W}{mK}; \alpha = 10 \frac{W}{m^2K}; S = 2 m^2; L = 5 m; L^{(1)} = L^{(2)} = 2.5 m; q = -150 \frac{W}{m^2}; t_{\infty} = 400 K$$

Wyniki MES dla problemu rozwiązywanego Excelem

3-węzłowy element:

$$C^{(1)} = \frac{Sk}{L^{(1)}} = \frac{2m^2 \cdot 50 \frac{W}{mK}}{2.5m} = 40 \frac{W}{K} = C^{(2)};$$

$$\alpha S = 10 \frac{W}{m^2K} \cdot 2m^2 = 20 \frac{W}{K};$$

$$qS = -150 \frac{W}{m^2} \cdot 2m^2 = -300W;$$

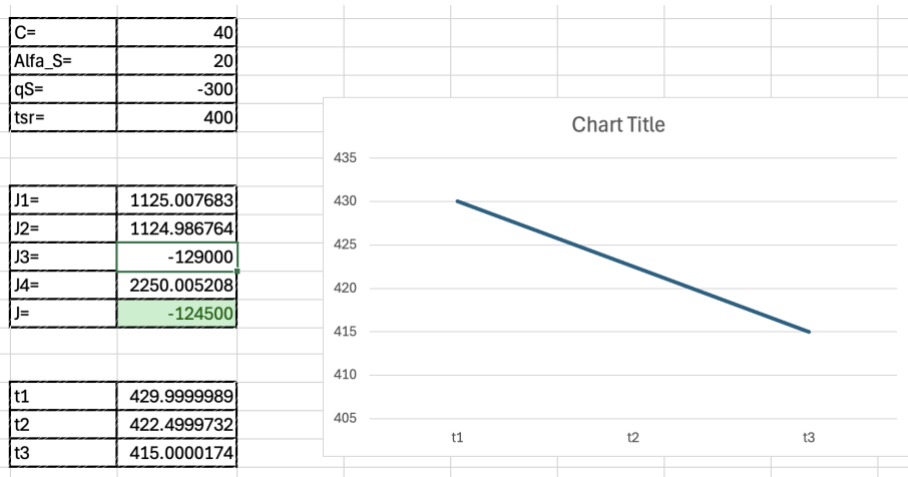
$$\alpha S t_{\infty} = 10 \frac{W}{m^2K} \cdot 2m^2 \cdot 40K = 8000W.$$

Stąd, otrzymuje się następujący układ równań:

$$\begin{bmatrix} 40 & -40 & 0 \\ -40 & 80 & -40 \\ 0 & -40 & 60 \end{bmatrix} \begin{Bmatrix} t_1 \\ t_2 \\ t_3 \end{Bmatrix} + \begin{Bmatrix} -300 \\ 0 \\ -8000 \end{Bmatrix} = 0$$

Po jego rozwiązaniu względem t uzyskano $\{t\} = \{430, 422.5, 415\}$.

$$J = \frac{C^{(1)}}{2} (t_1^2 - 2t_1t_2 + t_2^2) + \frac{C^{(2)}}{2} (t_2^2 - 2t_2t_3 + t_3^2) + qSt_1 + \frac{\alpha S_3}{2} (t_3^2 - 2t_3t_{\infty} + t_{\infty}^2)$$



Wyniki w EXCELU są bardzo bliskie do tych, co były otrzymane analitycznie, co świadczy o tym, że znalezienie temperatur za pomocą SOLVER'a (minimizacja) odbyło się poprawnie.

5-węzłowy element

Dla obliczenia 5 węzłów trzeba delikatnie zmodyfikować plik EXEL'owy. Żeby osiągnąć ten cel trzeba podzielić nasz pręt o długość L na 4 elementy skończony. W rezultacie ilość węzłów będzie wynosiła 5. Trzeba rozszerzyć poprzednie równania do 5 węzłów.

Dane wejściowe, które uległy zmianie:

$$L^{(1)} = L^{(2)} = L^{(3)} = L^{(4)} = 1.25 \text{ m};$$

$$C^{(1)} = \frac{Sk}{L^{(1)}} = \frac{2m^2 \cdot 50 \frac{W}{mK}}{1.25m} = 80 \frac{W}{K} = C^{(2)};$$

Globalna macierz sztywności dla 5 węzłów (5x5):

$$[H] = \begin{bmatrix} C & -C & 0 & 0 & 0 \\ -C & C+C & -C & 0 & 0 \\ 0 & -C & C+C & -C & 0 \\ 0 & 0 & -C & C+C & -C \\ 0 & 0 & 0 & -C & C \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \alpha S \end{bmatrix}$$

[alfaS w ostatnim węźle to konwekcja]

$$[H] = \begin{bmatrix} 80 & -80 & 0 & 0 & 0 \\ -80 & 160 & -80 & 0 & 0 \\ 0 & -80 & 160 & -80 & 0 \\ 0 & 0 & -80 & 160 & -80 \\ 0 & 0 & 0 & -80 & 100 \end{bmatrix}$$

Wektor obciążeń:

$$\{P\} = \begin{pmatrix} -300 \\ 0 \\ 0 \\ 0 \\ -8000 \end{pmatrix}$$

Ostateczny układ równań dla 5 węzłów:

$$\begin{bmatrix} 80 & -80 & 0 & 0 & 0 \\ -80 & 160 & -80 & 0 & 0 \\ 0 & -80 & 160 & -80 & 0 \\ 0 & 0 & -80 & 160 & -80 \\ 0 & 0 & 0 & -80 & 100 \end{bmatrix} \begin{Bmatrix} t_1 \\ t_2 \\ t_3 \\ t_4 \\ t_5 \end{Bmatrix} + \begin{Bmatrix} -300 \\ 0 \\ 0 \\ 0 \\ -8000 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix}$$

Z tego równania wynika, że temperatury są równe:

$$t_1 = 430$$

$$t_2 = 426.25$$

$$t_3 = 422.5$$

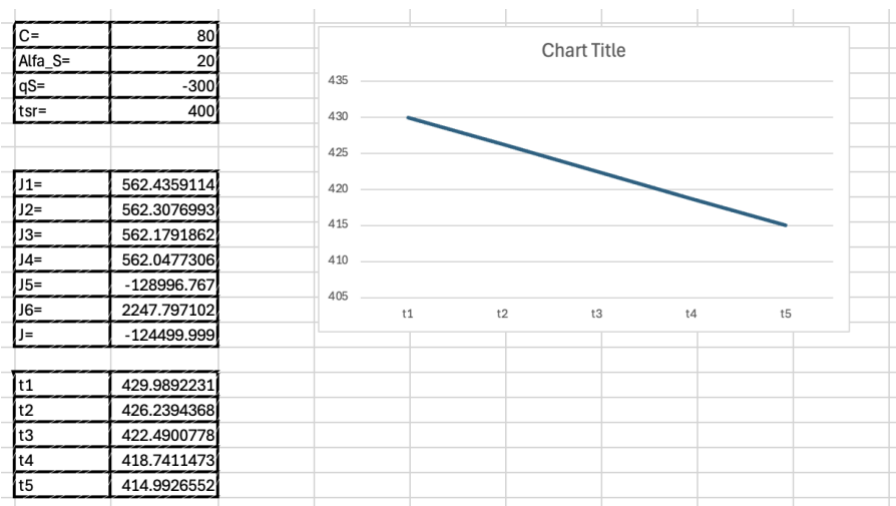
$$t_4 = 418.75$$

$$t_5 = 415$$

Obliczenie w EXCELu

Wzór J dla 5-węzłowego układu:

$$J = \frac{C^{(1)}}{2} (t_1^2 - 2t_1t_2 + t_2^2) + \frac{C^{(2)}}{2} (t_2^2 - 2t_2t_3 + t_3^2) + \frac{C^{(3)}}{2} (t_3^2 - 2t_3t_4 + t_4^2) + \frac{C^{(4)}}{2} (t_4^2 - 2t_4t_5 + t_5^2) + qSt_1 + \frac{\alpha S_5}{2} (t_5^2 - 2t_5t_\infty + t_\infty^2)$$



Wyniki w EXCELu są bardzo bliskie do tych, co były otrzymane analitycznie, co świadczy o tym, że znalezienie temperatur za pomocą SOLVER'a (minizacja) odbyło się poprawnie.

Porównanie z kodem

Kod:

```
main.py 2 x
main.py > ...
You, 1 second ago | 1 author (You)
1 import numpy as np
2 from element import Element
3
4 # dane
5 k = 50 # W/mk
6 alpha = 10 # W/m2K
7 S = 2 # m^2
8 LG = 5 # m - długość
9 q = -150 # W/m^2
10 t_sr = 400 # K
11 ME = 4 # liczba elementów
12 MW = ME + 1 # liczba węzłów
13 delta_L = LG / ME
14 dir = 1 # 1 from left to right; -1 from right to left
15
16 # start
17 final_H = np.zeros(
18     (MW, MW))
19 # macierz o rozmiarze ilość węzłów x ilość węzłów
20 final_P = np.zeros(
21     (MW, 1))
22
23
24 elemnts = []
25
26 for i in range(ME):
27     element: Element = Element(
28         length=delta_L,
29         S=S,
30         k=k,
31         alpha=alpha,
32         q=q,
33         t_sr=t_sr,
34         is_start = (i == 0),
35         is_end = (i == ME-1))
36     elemnts.append(
37         element)
38
39
40
41 for i in range(ME):
42     element: Element = elemnts[i]
43     matrix_h = element.H
44     matrix_P = element.P
45     for row_ind, row in enumerate(matrix_h):
46         for col_ind, val in enumerate(row):
47             final_H[i + row_ind][i + col_ind] += val
48
49     for col_ind, val in enumerate(matrix_P):
50         final_P[i + col_ind][0] += val[0] # val should has only 1 element
51
52 Element.print_equation(
53     final_H,
54     final_P)
55
56
57 res = Element.solve_equation(
58     final_H,
59     final_P)
60
61
62 print(res)
63

element.py 6 x
element.py > ...
You, last month | 1 author (You)
1 import numpy as np
2 from typing import Optional
3
4
5 class Element:
6     def __init__(
7         self, length: float, S: float, k: float,
8         alpha: float,
9         q: float,
10        t_sr: float,
11        dir: int = 1,
12        is_start: bool = False,
13        is_end: bool = False,
14    ) -> None:
15        self.is_start: bool = is_start
16        self.is_end: bool = is_end
17        self.length: float = length
18        self.q: float = q
19        self.t_sr: float = t_sr
20        self.S: float = S
21        self.k: float = k
22        self.alpha: float = alpha
23        self.dir: int = dir # 1 from left to right; -1 from right to left
24
25        if not self.is_start:
26            # we use it only in case of the first element
27            self.q = 0
28        if not self.is_end:
29            # we use it only in case of the last element
30            self.alpha = 0
31
32        self.addon: Optional[any] = None
33        self.C: float = self._calculate_C()
34        self.H: np.ndarray = self._calculate_H()
35        self.P: np.ndarray = self._calculate_P()
36
37    def _calculate_C(self) -> float:
38        return self.S * self.k / self.length
39
40    def _calculate_P(self) -> np.ndarray:
41        return np.array(
42            [
43                self.q + self.S
44                # != 0 only when element is FIRST
45            ],
46            [
47                -self.t_sr + self.alpha * self.S
48                # != 0 only when element is LAST
49            ]
50        )
51
52    def _calculate_H(self) -> np.ndarray:
53        # take a look later
54        conv: float = self.alpha + self.S
55        el_00: float = self.C + (conv if self.dir == -1 else 0)
56        el_11: float = self.C + (conv if self.dir == 1 else 0)
57        return np.array(
58            [
59                [el_00, -self.C],
60                [-self.C, el_11]
61            ]
62        )
63
64    @staticmethod
65    def print_equation(H_lines: np.ndarray, P_lines: np.ndarray) -> None:
66        H_lines = np.array2string(H_lines, separator=' ').splitlines()
67        P_lines = np.array2string(P_lines, separator=' ').splitlines()
68
69        # Zip and print
70        t_ind: int = 1
71        for H_line, P_line in zip(H_lines, P_lines):
72            print(f"({H_line}) | t_{t_ind} |  + ({P_line})")
73            t_ind += 1
74
75    def print(self) -> None:
76        H_lines: List[str] = np.array2string(self.H, separator=' ').splitlines()
77        P_lines: List[str] = np.array2string(self.P, separator=' ').splitlines()
78
79        # Zip and print
80        for H_line, P_line in zip(H_lines, P_lines):
81            print(f"({H_line})  ({P_line})")
82
83    @staticmethod
84    def solve_equation(H: np.ndarray, P: np.ndarray) -> np.ndarray:
85        # Ensure that H is invertible (non-singular)
86        if np.linalg.det(H) == 0:
87            raise ValueError("Matrix H is singular and cannot be inverted.")
88
89        # Solve for t
90        t = -np.linalg.inv(H) @ P
91        return t
92
```

(Ważne – zmiana zmiennej dir nie jest poprawnie uwzględniona, czyli wyniki będą złe)

```
→ lab1 git:(master) × echo "3 węzły"; python main.py
3 węzły
[[ 40. -40.  0.] |t_1|  + [[ -300.]
 [-40.  80. -40.] |t_2|  + [  0.]
 [  0. -40.  60.]] |t_3|  + [-8000.]]
[[430. ]
 [422.5]
 [415. ]]
```

Wyniki odpalania programu dla 3 i 5 węzłów

```
→ lab1 git:(master) × echo "5 węzłów"; python main.py
5 węzłów
[[ 80. -80.  0.  0.  0.] |t_1|  + [[ -300.]
 [-80. 160. -80.  0.  0.] |t_2|  + [  0.]
 [  0. -80. 160. -80.  0.] |t_3|  + [  0.]
 [  0.  0. -80. 160. -80.] |t_4|  + [  0.]
 [  0.  0.  0. -80. 100.]] |t_5|  + [-8000.]]
[[430. ]
 [426.25]
 [422.5 ]
 [418.75]
 [415.  ]]
```

Jak widać wyniki są identycznie wynikom otrzymanym analitycznie

Porównanie wyników:

3 węzły

	Kod	Excel	$\Delta t = kod - excel$
t_1	430	429.9999989	1.14895E-06
t_2	422.5	422.4999732	2.67601E-05
t_3	415	415.0000174	-1.7359E-05

5 węzłów

	Kod	Excel	$\Delta t = kod - excel$
t_1	430	429.9892231	1.077688E-02
t_2	426.25	426.2394368	1.056325E-02
t_3	422.5	422.4900778	9.922192E-03
t_4	418.74	418.7411473	-1.147340E-03
t_5	415	414.9926552	7.344792E-03

Różnice między wynikami z kodu i EXCEL'a są niewielkie i wynikają z dokładności narzędzia SOLVER.

Code Addon

Po sprawdzeniu poprawności działania kodu dla obliczenia ustalonego procesu powstał pomysł o zrobieniu wizualizacji do kodu. Wizualizacja polega na korzystaniu z dodatkowych bibliotek, żeby stworzyć graficzny widok do zaprezentowania wyników oraz ułatwienia korzystania z stworzonego narzędzia.

Kod:

```
app.py x README.md Dockerfile cloudbuild.yaml

app.py
1 import streamlit as st
2 import numpy as np
3 from element import Element
4
5 st.set_page_config(page_title="Solve M + P = Q", layout="wide")
6
7 st.title("Visual Finite-Element Solver")
8
9 # 1) Slider inputs
10 st.sidebar.header("Global parameters")
11 M = st.sidebar.number_input("Number of elements (ME)", min_value=1, value=2, step=1)
12 L0 = st.sidebar.number_input("Total length (L0)", min_value=0.1, value=5.0)
13 k = st.sidebar.number_input("Area (S)", min_value=0.1, value=2.0)
14 alpha = st.sidebar.number_input("Conductivity (k)", min_value=0.5, value=10.0)
15 q = st.sidebar.number_input("Conv. coeff. (q)", min_value=0.5, value=10.0)
16 T_dir = st.sidebar.number_input("Ambient temp. (Tdir)", value=100.0)
17 dir_val = st.sidebar.radio("Flow direction (dir)", options=[1, -1], index=0)
18
19 delta_L = L0 / M
20
21 if st.sidebar.button("Solve"):
22     # Sprawdzanie, czy liczba elementów przekracza limit
23     if M > 100:
24         st.warning("Liczba elementów (ME) jest większa niż 100.")
25         "Opcjonalnie nie zostanie wykonane ze względu na potencjalnie wysokie koszty obliczeniowe."
26     else:
27         # 2) build elements & assemble
28         M0 = M0 - 1
29         M_final = np.zeros((M0, M0))
30         P_final = np.zeros((M0, 1))
31         elements = []
32         for i in range(M0):
33             el = Element(length=delta_L, S=S, k=k,
34                           alpha=alpha, q=q, T_dir=T_dir,
35                           dir=dir_val,
36                           ix_start=(i+1), ix_end=(i+M))
37             elements.append(el)
38         # assemble
39         for c in range(2):
40             for i in range(2):
41                 for j in range(2):
42                     M_final[i+j, i+j] = el.M[i, j]
43                     P_final[i+j, 0] = el.P[i, 0]
44
45         # 3) helper to convert numpy -> latex matrix
46         def to_latex(A):
47             return r'\begin{matrix} \end{matrix}'
48
49         # 4) display
50         st.subheader("Assembled Matrices")
51         col1, col2 = st.columns(2)
52         with col1:
53             st.markdown("eq(0) matrix=")
54             st.latex(M = "to_latex(M_final)")
55         with col2:
56             st.markdown("eq(1) vector=")
57             st.latex(P = "to_latex(P_final)")
58
59         st.markdown("eq(2) equation to solve=")
60         st.latex(M0 - 1 - P = Q)
61
62         # 5) solve and show
63         x = Element.solve_element(M_final, P_final)
64         st.subheader("Solution vector (x)")
65         st.latex(x = "to_latex(x.reshape(-1,1))")

Dockerfile
1 # Base image: Ubuntu 20.04
2 FROM python:3.12-slim AS base
3
4 # 1) Instalacja systemowa (dla łatwej instalacji wheel)
5 apt-get update && \
6 apt-get install --no-install-recommends build-essential && \
7 rm -rf /var/lib/apt/lists/*
8
9 # 2) Instalacja python i katalog roboczy
10 RUN python3 --help && \
11 PWD=$(pwd) && \
12 pip install --no-cache-dir -r requirements.txt
13 WORKDIR /app
14
15 # 3) Instalacja polski tłumacz
16 COPY requirements.txt .
17 RUN pip install --no-cache-dir -r requirements.txt
18
19 # 4) Kopia kodu źródłowego
20 COPY . .
21
22 # 5) Komenda startowa - Streamlit w trybie headless na podanej porcie
23 CMD streamlit run app.py --server.port 5001 --server.headless true

cloudbuild.yaml
1 # 1. Build obrazu
2 # 2. Deploy do Cloud Run
3 # 3. Deploy do Cloud Build
4
5 # 1. Build obrazu
6 name: "gcr.io/cloud-builders/docker"
7
8 # 2. Deploy do Cloud Run
9 name: "gcr.io/cloud-builders/gcloud"
10
11 # 3. Deploy do Cloud Build
12 name: "gcr.io/cloud-builders/gcloud"
13
14 # 4. Deploy do Cloud Build
15 name: "gcr.io/cloud-builders/gcloud"
16
17 # 5. Deploy do Cloud Build
18 name: "gcr.io/cloud-builders/gcloud"
19
20 # 6. Deploy do Cloud Build
21 name: "gcr.io/cloud-builders/gcloud"
22
23 # 7. Deploy do Cloud Build
24 name: "gcr.io/cloud-builders/gcloud"
25
26 # 8. Deploy do Cloud Build
27 name: "gcr.io/cloud-builders/gcloud"
28
29 # 9. Deploy do Cloud Build
30 name: "gcr.io/cloud-builders/gcloud"
31
32 # 10. Deploy do Cloud Build
33 name: "gcr.io/cloud-builders/gcloud"
34
35 # 11. Deploy do Cloud Build
36 name: "gcr.io/cloud-builders/gcloud"
37
38 # 12. Deploy do Cloud Build
39 name: "gcr.io/cloud-builders/gcloud"
40
41 # 13. Deploy do Cloud Build
42 name: "gcr.io/cloud-builders/gcloud"
43
44 # 14. Deploy do Cloud Build
45 name: "gcr.io/cloud-builders/gcloud"
46
47 # 15. Deploy do Cloud Build
48 name: "gcr.io/cloud-builders/gcloud"
49
50 # 16. Deploy do Cloud Build
51 name: "gcr.io/cloud-builders/gcloud"
52
53 # 17. Deploy do Cloud Build
54 name: "gcr.io/cloud-builders/gcloud"
55
56 # 18. Deploy do Cloud Build
57 name: "gcr.io/cloud-builders/gcloud"
58
59 # 19. Deploy do Cloud Build
60 name: "gcr.io/cloud-builders/gcloud"
61
62 # 20. Deploy do Cloud Build
63 name: "gcr.io/cloud-builders/gcloud"
64
65 # 21. Deploy do Cloud Build
66 name: "gcr.io/cloud-builders/gcloud"
67
68 # 22. Deploy do Cloud Build
69 name: "gcr.io/cloud-builders/gcloud"
70
71 # 23. Deploy do Cloud Build
72 name: "gcr.io/cloud-builders/gcloud"
73
74 # 24. Deploy do Cloud Build
75 name: "gcr.io/cloud-builders/gcloud"
76
77 # 25. Deploy do Cloud Build
78 name: "gcr.io/cloud-builders/gcloud"
79
80 # 26. Deploy do Cloud Build
81 name: "gcr.io/cloud-builders/gcloud"
82
83 # 27. Deploy do Cloud Build
84 name: "gcr.io/cloud-builders/gcloud"
85
86 # 28. Deploy do Cloud Build
87 name: "gcr.io/cloud-builders/gcloud"
88
89 # 29. Deploy do Cloud Build
90 name: "gcr.io/cloud-builders/gcloud"
91
92 # 30. Deploy do Cloud Build
93 name: "gcr.io/cloud-builders/gcloud"
94
95 # 31. Deploy do Cloud Build
96 name: "gcr.io/cloud-builders/gcloud"
97
98 # 32. Deploy do Cloud Build
99 name: "gcr.io/cloud-builders/gcloud"
100
101 # 33. Deploy do Cloud Build
102 name: "gcr.io/cloud-builders/gcloud"
103
104 # 34. Deploy do Cloud Build
105 name: "gcr.io/cloud-builders/gcloud"
106
107 # 35. Deploy do Cloud Build
108 name: "gcr.io/cloud-builders/gcloud"
109
110 # 36. Deploy do Cloud Build
111 name: "gcr.io/cloud-builders/gcloud"
112
113 # 37. Deploy do Cloud Build
114 name: "gcr.io/cloud-builders/gcloud"
115
116 # 38. Deploy do Cloud Build
117 name: "gcr.io/cloud-builders/gcloud"
118
119 # 39. Deploy do Cloud Build
120 name: "gcr.io/cloud-builders/gcloud"
121
122 # 40. Deploy do Cloud Build
123 name: "gcr.io/cloud-builders/gcloud"
124
125 # 41. Deploy do Cloud Build
126 name: "gcr.io/cloud-builders/gcloud"
127
128 # 42. Deploy do Cloud Build
129 name: "gcr.io/cloud-builders/gcloud"
130
131 # 43. Deploy do Cloud Build
132 name: "gcr.io/cloud-builders/gcloud"
133
134 # 44. Deploy do Cloud Build
135 name: "gcr.io/cloud-builders/gcloud"
136
137 # 45. Deploy do Cloud Build
138 name: "gcr.io/cloud-builders/gcloud"
139
140 # 46. Deploy do Cloud Build
141 name: "gcr.io/cloud-builders/gcloud"
142
143 # 47. Deploy do Cloud Build
144 name: "gcr.io/cloud-builders/gcloud"
145
146 # 48. Deploy do Cloud Build
147 name: "gcr.io/cloud-builders/gcloud"
148
149 # 49. Deploy do Cloud Build
150 name: "gcr.io/cloud-builders/gcloud"
151
152 # 50. Deploy do Cloud Build
153 name: "gcr.io/cloud-builders/gcloud"
154
155 # 51. Deploy do Cloud Build
156 name: "gcr.io/cloud-builders/gcloud"
157
158 # 52. Deploy do Cloud Build
159 name: "gcr.io/cloud-builders/gcloud"
160
161 # 53. Deploy do Cloud Build
162 name: "gcr.io/cloud-builders/gcloud"
163
164 # 54. Deploy do Cloud Build
165 name: "gcr.io/cloud-builders/gcloud"
166
167 # 55. Deploy do Cloud Build
168 name: "gcr.io/cloud-builders/gcloud"
169
170 # 56. Deploy do Cloud Build
171 name: "gcr.io/cloud-builders/gcloud"
172
173 # 57. Deploy do Cloud Build
174 name: "gcr.io/cloud-builders/gcloud"
175
176 # 58. Deploy do Cloud Build
177 name: "gcr.io/cloud-builders/gcloud"
178
179 # 59. Deploy do Cloud Build
180 name: "gcr.io/cloud-builders/gcloud"
181
182 # 60. Deploy do Cloud Build
183 name: "gcr.io/cloud-builders/gcloud"
184
185 # 61. Deploy do Cloud Build
186 name: "gcr.io/cloud-builders/gcloud"
187
188 # 62. Deploy do Cloud Build
189 name: "gcr.io/cloud-builders/gcloud"
190
191 # 63. Deploy do Cloud Build
192 name: "gcr.io/cloud-builders/gcloud"
193
194 # 64. Deploy do Cloud Build
195 name: "gcr.io/cloud-builders/gcloud"
196
197 # 65. Deploy do Cloud Build
198 name: "gcr.io/cloud-builders/gcloud"
199
200 # 66. Deploy do Cloud Build
201 name: "gcr.io/cloud-builders/gcloud"
202
203 # 67. Deploy do Cloud Build
204 name: "gcr.io/cloud-builders/gcloud"
205
206 # 68. Deploy do Cloud Build
207 name: "gcr.io/cloud-builders/gcloud"
208
209 # 69. Deploy do Cloud Build
210 name: "gcr.io/cloud-builders/gcloud"
211
212 # 70. Deploy do Cloud Build
213 name: "gcr.io/cloud-builders/gcloud"
214
215 # 71. Deploy do Cloud Build
216 name: "gcr.io/cloud-builders/gcloud"
217
218 # 72. Deploy do Cloud Build
219 name: "gcr.io/cloud-builders/gcloud"
220
221 # 73. Deploy do Cloud Build
222 name: "gcr.io/cloud-builders/gcloud"
223
224 # 74. Deploy do Cloud Build
225 name: "gcr.io/cloud-builders/gcloud"
226
227 # 75. Deploy do Cloud Build
228 name: "gcr.io/cloud-builders/gcloud"
229
230 # 76. Deploy do Cloud Build
231 name: "gcr.io/cloud-builders/gcloud"
232
233 # 77. Deploy do Cloud Build
234 name: "gcr.io/cloud-builders/gcloud"
235
236 # 78. Deploy do Cloud Build
237 name: "gcr.io/cloud-builders/gcloud"
238
239 # 79. Deploy do Cloud Build
240 name: "gcr.io/cloud-builders/gcloud"
241
242 # 80. Deploy do Cloud Build
243 name: "gcr.io/cloud-builders/gcloud"
244
245 # 81. Deploy do Cloud Build
246 name: "gcr.io/cloud-builders/gcloud"
247
248 # 82. Deploy do Cloud Build
249 name: "gcr.io/cloud-builders/gcloud"
250
251 # 83. Deploy do Cloud Build
252 name: "gcr.io/cloud-builders/gcloud"
253
254 # 84. Deploy do Cloud Build
255 name: "gcr.io/cloud-builders/gcloud"
256
257 # 85. Deploy do Cloud Build
258 name: "gcr.io/cloud-builders/gcloud"
259
260 # 86. Deploy do Cloud Build
261 name: "gcr.io/cloud-builders/gcloud"
262
263 # 87. Deploy do Cloud Build
264 name: "gcr.io/cloud-builders/gcloud"
265
266 # 88. Deploy do Cloud Build
267 name: "gcr.io/cloud-builders/gcloud"
268
269 # 89. Deploy do Cloud Build
270 name: "gcr.io/cloud-builders/gcloud"
271
272 # 90. Deploy do Cloud Build
273 name: "gcr.io/cloud-builders/gcloud"
274
275 # 91. Deploy do Cloud Build
276 name: "gcr.io/cloud-builders/gcloud"
277
278 # 92. Deploy do Cloud Build
279 name: "gcr.io/cloud-builders/gcloud"
280
281 # 93. Deploy do Cloud Build
282 name: "gcr.io/cloud-builders/gcloud"
283
284 # 94. Deploy do Cloud Build
285 name: "gcr.io/cloud-builders/gcloud"
286
287 # 95. Deploy do Cloud Build
288 name: "gcr.io/cloud-builders/gcloud"
289
290 # 96. Deploy do Cloud Build
291 name: "gcr.io/cloud-builders/gcloud"
292
293 # 97. Deploy do Cloud Build
294 name: "gcr.io/cloud-builders/gcloud"
295
296 # 98. Deploy do Cloud Build
297 name: "gcr.io/cloud-builders/gcloud"
298
299 # 99. Deploy do Cloud Build
300 name: "gcr.io/cloud-builders/gcloud"
301
302 # 100. Deploy do Cloud Build
303 name: "gcr.io/cloud-builders/gcloud"
304
305 # 101. Deploy do Cloud Build
306 name: "gcr.io/cloud-builders/gcloud"
307
308 # 102. Deploy do Cloud Build
309 name: "gcr.io/cloud-builders/gcloud"
310
311 # 103. Deploy do Cloud Build
312 name: "gcr.io/cloud-builders/gcloud"
313
314 # 104. Deploy do Cloud Build
315 name: "gcr.io/cloud-builders/gcloud"
316
317 # 105. Deploy do Cloud Build
318 name: "gcr.io/cloud-builders/gcloud"
319
320 # 106. Deploy do Cloud Build
321 name: "gcr.io/cloud-builders/gcloud"
322
323 # 107. Deploy do Cloud Build
324 name: "gcr.io/cloud-builders/gcloud"
325
326 # 108. Deploy do Cloud Build
327 name: "gcr.io/cloud-builders/gcloud"
328
329 # 109. Deploy do Cloud Build
330 name: "gcr.io/cloud-builders/gcloud"
331
332 # 110. Deploy do Cloud Build
333 name: "gcr.io/cloud-builders/gcloud"
334
335 # 111. Deploy do Cloud Build
336 name: "gcr.io/cloud-builders/gcloud"
337
338 # 112. Deploy do Cloud Build
339 name: "gcr.io/cloud-builders/gcloud"
340
341 # 113. Deploy do Cloud Build
342 name: "gcr.io/cloud-builders/gcloud"
343
344 # 114. Deploy do Cloud Build
345 name: "gcr.io/cloud-builders/gcloud"
346
347 # 115. Deploy do Cloud Build
348 name: "gcr.io/cloud-builders/gcloud"
349
350 # 116. Deploy do Cloud Build
351 name: "gcr.io/cloud-builders/gcloud"
352
353 # 117. Deploy do Cloud Build
354 name: "gcr.io/cloud-builders/gcloud"
355
356 # 118. Deploy do Cloud Build
357 name: "gcr.io/cloud-builders/gcloud"
358
359 # 119. Deploy do Cloud Build
360 name: "gcr.io/cloud-builders/gcloud"
361
362 # 120. Deploy do Cloud Build
363 name: "gcr.io/cloud-builders/gcloud"
364
365 # 121. Deploy do Cloud Build
366 name: "gcr.io/cloud-builders/gcloud"
367
368 # 122. Deploy do Cloud Build
369 name: "gcr.io/cloud-builders/gcloud"
370
371 # 123. Deploy do Cloud Build
372 name: "gcr.io/cloud-builders/gcloud"
373
374 # 124. Deploy do Cloud Build
375 name: "gcr.io/cloud-builders/gcloud"
376
377 # 125. Deploy do Cloud Build
378 name: "gcr.io/cloud-builders/gcloud"
379
380 # 126. Deploy do Cloud Build
381 name: "gcr.io/cloud-builders/gcloud"
382
383 # 127. Deploy do Cloud Build
384 name: "gcr.io/cloud-builders/gcloud"
385
386 # 128. Deploy do Cloud Build
387 name: "gcr.io/cloud-builders/gcloud"
388
389 # 129. Deploy do Cloud Build
390 name: "gcr.io/cloud-builders/gcloud"
391
392 # 130. Deploy do Cloud Build
393 name: "gcr.io/cloud-builders/gcloud"
394
395 # 131. Deploy do Cloud Build
396 name: "gcr.io/cloud-builders/gcloud"
397
398 # 132. Deploy do Cloud Build
399 name: "gcr.io/cloud-builders/gcloud"
400
401 # 133. Deploy do Cloud Build
402 name: "gcr.io/cloud-builders/gcloud"
403
404 # 134. Deploy do Cloud Build
405 name: "gcr.io/cloud-builders/gcloud"
406
407 # 135. Deploy do Cloud Build
408 name: "gcr.io/cloud-builders/gcloud"
409
410 # 136. Deploy do Cloud Build
411 name: "gcr.io/cloud-builders/gcloud"
412
413 # 137. Deploy do Cloud Build
414 name: "gcr.io/cloud-builders/gcloud"
415
416 # 138. Deploy do Cloud Build
417 name: "gcr.io/cloud-builders/gcloud"
418
419 # 139. Deploy do Cloud Build
420 name: "gcr.io/cloud-builders/gcloud"
421
422 # 140. Deploy do Cloud Build
423 name: "gcr.io/cloud-builders/gcloud"
424
425 # 141. Deploy do Cloud Build
426 name: "gcr.io/cloud-builders/gcloud"
427
428 # 142. Deploy do Cloud Build
429 name: "gcr.io/cloud-builders/gcloud"
430
431 # 143. Deploy do Cloud Build
432 name: "gcr.io/cloud-builders/gcloud"
433
434 # 144. Deploy do Cloud Build
435 name: "gcr.io/cloud-builders/gcloud"
436
437 # 145. Deploy do Cloud Build
438 name: "gcr.io/cloud-builders/gcloud"
439
440 # 146. Deploy do Cloud Build
441 name: "gcr.io/cloud-builders/gcloud"
442
443 # 147. Deploy do Cloud Build
444 name: "gcr.io/cloud-builders/gcloud"
445
446 # 148. Deploy do Cloud Build
447 name: "gcr.io/cloud-builders/gcloud"
448
449 # 149. Deploy do Cloud Build
450 name: "gcr.io/cloud-builders/gcloud"
451
452 # 150. Deploy do Cloud Build
453 name: "gcr.io/cloud-builders/gcloud"
454
455 # 151. Deploy do Cloud Build
456 name: "gcr.io/cloud-builders/gcloud"
457
458 # 152. Deploy do Cloud Build
459 name: "gcr.io/cloud-builders/gcloud"
460
461 # 153. Deploy do Cloud Build
462 name: "gcr.io/cloud-builders/gcloud"
463
464 # 154. Deploy do Cloud Build
465 name: "gcr.io/cloud-builders/gcloud"
466
467 # 155. Deploy do Cloud Build
468 name: "gcr.io/cloud-builders/gcloud"
469
470 # 156. Deploy do Cloud Build
471 name: "gcr.io/cloud-builders/gcloud"
472
473 # 157. Deploy do Cloud Build
474 name: "gcr.io/cloud-builders/gcloud"
475
476 # 158. Deploy do Cloud Build
477 name: "gcr.io/cloud-builders/gcloud"
478
479 # 159. Deploy do Cloud Build
480 name: "gcr.io/cloud-builders/gcloud"
481
482 # 160. Deploy do Cloud Build
483 name: "gcr.io/cloud-builders/gcloud"
484
485 # 161. Deploy do Cloud Build
486 name: "gcr.io/cloud-builders/gcloud"
487
488 # 162. Deploy do Cloud Build
489 name: "gcr.io/cloud-builders/gcloud"
490
491 # 163. Deploy do Cloud Build
492 name: "gcr.io/cloud-builders/gcloud"
493
494 # 164. Deploy do Cloud Build
495 name: "gcr.io/cloud-builders/gcloud"
496
497 # 165. Deploy do Cloud Build
498 name: "gcr.io/cloud-builders/gcloud"
499
500 # 166. Deploy do Cloud Build
501 name: "gcr.io/cloud-builders/gcloud"
502
503 # 167. Deploy do Cloud Build
504 name: "gcr.io/cloud-builders/gcloud"
505
506 # 168. Deploy do Cloud Build
507 name: "gcr.io/cloud-builders/gcloud"
508
509 # 169. Deploy do Cloud Build
510 name: "gcr.io/cloud-builders/gcloud"
511
512 # 170. Deploy do Cloud Build
513 name: "gcr.io/cloud-builders/gcloud"
514
515 # 171. Deploy do Cloud Build
516 name: "gcr.io/cloud-builders/gcloud"
517
518 # 172. Deploy do Cloud Build
519 name: "gcr.io/cloud-builders/gcloud"
520
521 # 173. Deploy do Cloud Build
522 name: "gcr.io/cloud-builders/gcloud"
523
524 # 174. Deploy do Cloud Build
525 name: "gcr.io/cloud-builders/gcloud"
526
527 # 175. Deploy do Cloud Build
528 name: "gcr.io/cloud-builders/gcloud"
529
530 # 176. Deploy do Cloud Build
531 name: "gcr.io/cloud-builders/gcloud"
532
533 # 177. Deploy do Cloud Build
534 name: "gcr.io/cloud-builders/gcloud"
535
536 # 178. Deploy do Cloud Build
537 name: "gcr.io/cloud-builders/gcloud"
538
539 # 179. Deploy do Cloud Build
540 name: "gcr.io/cloud-builders/gcloud"
541
542 # 180. Deploy do Cloud Build
543 name: "gcr.io/cloud-builders/gcloud"
544
545 # 181. Deploy do Cloud Build
546 name: "gcr.io/cloud-builders/gcloud"
547
548 # 182. Deploy do Cloud Build
549 name: "gcr.io/cloud-builders/gcloud"
550
551 # 183. Deploy do Cloud Build
552 name: "gcr.io/cloud-builders/gcloud"
553
554 # 184. Deploy do Cloud Build
555 name: "gcr.io/cloud-builders/gcloud"
556
557 # 185. Deploy do Cloud Build
558 name: "gcr.io/cloud-builders/gcloud"
559
560 # 186. Deploy do Cloud Build
561 name: "gcr.io/cloud-builders/gcloud"
562
563 # 187. Deploy do Cloud Build
564 name: "gcr.io/cloud-builders/gcloud"
565
566 # 188. Deploy do Cloud Build
567 name: "gcr.io/cloud-builders/gcloud"
568
569 # 189. Deploy do Cloud Build
570 name: "gcr.io/cloud-builders/gcloud"
571
572 # 190. Deploy do Cloud Build
573 name: "gcr.io/cloud-builders/gcloud"
574
575 # 191. Deploy do Cloud Build
576 name: "gcr.io/cloud-builders/gcloud"
577
578 # 192. Deploy do Cloud Build
579 name: "gcr.io/cloud-builders/gcloud"
580
581 # 193. Deploy do Cloud Build
582 name: "gcr.io/cloud-builders/gcloud"
583
584 # 194. Deploy do Cloud Build
585 name: "gcr.io/cloud-builders/gcloud"
586
587 # 195. Deploy do Cloud Build
588 name: "gcr.io/cloud-builders/gcloud"
589
590 # 196. Deploy do Cloud Build
591 name: "gcr.io/cloud-builders/gcloud"
592
593 # 197. Deploy do Cloud Build
594 name: "gcr.io/cloud-builders/gcloud"
595
596 # 198. Deploy do Cloud Build
597 name: "gcr.io/cloud-builders/gcloud"
598
599 # 199. Deploy do Cloud Build
600 name: "gcr.io/cloud-builders/gcloud"
601
602 # 200. Deploy do Cloud Build
603 name: "gcr.io/cloud-builders/gcloud"
604
605 # 201. Deploy do Cloud Build
606 name: "gcr.io/cloud-builders/gcloud"
607
608 # 202. Deploy do Cloud Build
609 name: "gcr.io/cloud-builders/gcloud"
610
611 # 203. Deploy do Cloud Build
612 name: "gcr.io/cloud-builders/gcloud"
613
614 # 204. Deploy do Cloud Build
615 name: "gcr.io/cloud-builders/gcloud"
616
617 # 205. Deploy do Cloud Build
618 name: "gcr.io/cloud-builders/gcloud"
619
620 # 206. Deploy do Cloud Build
621 name: "gcr.io/cloud-builders/gcloud"
622
623 # 207. Deploy do Cloud Build
624 name: "gcr.io/cloud-builders/gcloud"
625
626 # 208. Deploy do Cloud Build
627 name: "gcr.io/cloud-builders/gcloud"
628
629 # 209. Deploy do Cloud Build
630 name: "gcr.io/cloud-builders/gcloud"
631
632 # 210. Deploy do Cloud Build
633 name: "gcr.io/cloud-builders/gcloud"
634
635 # 211. Deploy do Cloud Build
636 name: "gcr.io/cloud-builders/gcloud"
637
638 # 212. Deploy do Cloud Build
639 name: "gcr.io/cloud-builders/gcloud"
640
641 # 213. Deploy do Cloud Build
642 name: "gcr.io/cloud-builders/gcloud"
643
644 # 214. Deploy do Cloud Build
645 name: "gcr.io/cloud-builders/gcloud"
646
647 # 215. Deploy do Cloud Build
648 name: "gcr.io/cloud-builders/gcloud"
649
650 # 216. Deploy do Cloud Build
651 name: "gcr.io/cloud-builders/gcloud"
652
653 # 217. Deploy do Cloud Build
654 name: "gcr.io/cloud-builders/gcloud"
655
656 # 218. Deploy do Cloud Build
657 name: "gcr.io/cloud-builders/gcloud"
658
659 # 219. Deploy do Cloud Build
660 name: "gcr.io/cloud-builders/gcloud"
661
662 # 220. Deploy do Cloud Build
663 name: "gcr.io/cloud-builders/gcloud"
664
665 # 221. Deploy do Cloud Build
666 name: "gcr.io/cloud-builders/gcloud"
667
668 # 222. Deploy do Cloud Build
669 name: "gcr.io/cloud-builders/gcloud"
670
671 # 223. Deploy do Cloud Build
672 name: "gcr.io/cloud-builders/gcloud"
673
674 # 224. Deploy do Cloud Build
675 name: "gcr.io/cloud-builders/gcloud"
676
677 # 225. Deploy do Cloud Build
678 name: "gcr.io/cloud-builders/gcloud"
679
680 # 226. Deploy do Cloud Build
681 name: "gcr.io/cloud-builders/gcloud"
682
683 # 227. Deploy do Cloud Build
684 name: "gcr.io/cloud-builders/gcloud"
685
686 # 228. Deploy do Cloud Build
687 name: "gcr.io/cloud-builders/gcloud"
688
689 # 229. Deploy do Cloud Build
690 name: "gcr.io/cloud-builders/gcloud"
691
692 # 230. Deploy do Cloud Build
693 name: "gcr.io/cloud-builders/gcloud"
694
695 # 231. Deploy do Cloud Build
696 name: "gcr.io/cloud-builders/gcloud"
697
698 # 232. Deploy do Cloud Build
699 name: "gcr.io/cloud-builders/gcloud"
700
701 # 233. Deploy do Cloud Build
702 name: "gcr.io/cloud-builders/gcloud"
703
704 # 234. Deploy do Cloud Build
705 name: "gcr.io/cloud-builders/gcloud"
706
707 # 235. Deploy do Cloud Build
708 name: "gcr.io/cloud-builders/gcloud"
709
710 # 236. Deploy do Cloud Build
711 name: "gcr.io/cloud-builders/gcloud"
712
713 # 237. Deploy do Cloud Build
714 name: "gcr.io/cloud-builders/gcloud"
715
716 # 238. Deploy do Cloud Build
717 name: "gcr.io/cloud-builders/gcloud"
718
719 # 239. Deploy do Cloud Build
720 name: "gcr.io/cloud-builders/gcloud"
721
722 # 240. Deploy do Cloud Build
723 name: "gcr.io/cloud-builders/gcloud"
724
725 # 241. Deploy do Cloud Build
726 name: "gcr.io/cloud-builders/gcloud"
727
728 # 242. Deploy do Cloud Build
729 name: "gcr.io/cloud-builders/gcloud"
730
731 # 243. Deploy do Cloud Build
732 name: "gcr.io/cloud-builders/gcloud"
733
734 # 244. Deploy do Cloud Build
735 name: "gcr.io/cloud-builders/gcloud"
736
737 # 245. Deploy do Cloud Build
738 name: "gcr.io/cloud-builders/gcloud"
739
740 # 246. Deploy do Cloud Build
741 name: "gcr.io/cloud-builders/gcloud"
742
743 # 247. Deploy do Cloud Build
744 name: "gcr.io/cloud-builders/gcloud"
745
746 # 248. Deploy do Cloud Build
747 name: "gcr.io/cloud-builders/gcloud"
748
749 # 249. Deploy do Cloud Build
750 name: "gcr.io/cloud-builders/gcloud"
751
752 # 250. Deploy do Cloud Build
753 name: "gcr.io/cloud-builders/gcloud"
754
755 # 251. Deploy do Cloud Build
756 name: "gcr.io/cloud-builders/gcloud"
757
758 # 252. Deploy do Cloud Build
759 name: "gcr.io/cloud-builders/gcloud"
760
761 # 253. Deploy do Cloud Build
762 name: "gcr.io/cloud-builders/gcloud"
763
764 # 254. Deploy do Cloud Build
765 name: "gcr.io/cloud-builders/gcloud"
766
767 # 255. Deploy do Cloud Build
768 name: "gcr.io/cloud-builders/gcloud"
769
770 # 256. Deploy do Cloud Build
771 name: "gcr.io/cloud-builders/gcloud"
772
773 # 257. Deploy do Cloud Build
774 name: "gcr.io/cloud-builders/gcloud"
775
776 # 258. Deploy do Cloud Build
777 name: "gcr.io/cloud-builders/gcloud"
778
779 # 259. Deploy do Cloud Build
780 name: "gcr.io/cloud-builders/gcloud"
781
782 # 260. Deploy do Cloud Build
783 name: "gcr.io/cloud-builders/gcloud"
784
785 # 261. Deploy do Cloud Build
786 name: "gcr.io/cloud-builders/gcloud"
787
788 # 262. Deploy do Cloud Build
789 name: "gcr.io/cloud-builders/gcloud"
790
791 # 263. Deploy do Cloud Build
792 name: "gcr.io/cloud-builders/gcloud"
793
794 # 264. Deploy do Cloud Build
795 name: "gcr.io/cloud-builders/gcloud"
796
797 # 265. Deploy do Cloud Build
798 name: "gcr.io/cloud-builders/gcloud"
799
800 # 266. Deploy do Cloud Build
801 name: "gcr.io/cloud-builders/gcloud"
802
803 # 267. Deploy do Cloud Build
804 name: "gcr.io/cloud-builders/gcloud"
805
806 # 268. Deploy do Cloud Build
807 name: "gcr.io/cloud-builders/gcloud"
808
809 # 269. Deploy do Cloud Build
810 name: "gcr.io/cloud-builders/gcloud"
811
812 # 270. Deploy do Cloud Build
813 name: "gcr.io/cloud-builders/gcloud"
814
815 # 271. Deploy do Cloud Build
816 name: "gcr.io/cloud-builders/gcloud"
817
818 # 272. Deploy do Cloud Build
819 name: "gcr.io/cloud-builders/gcloud"
820
821 # 273. Deploy do Cloud Build
822 name: "gcr.io/cloud-builders/gcloud"
823
824 # 274. Deploy do Cloud Build
825 name: "gcr.io/cloud-builders/gcloud"
826
827 # 275. Deploy do Cloud Build
828 name: "gcr.io/cloud-builders/gcloud"
829
830 # 276. Deploy do Cloud Build
831 name: "gcr.io/cloud-builders/gcloud"
832
833 # 277. Deploy do Cloud Build
834 name: "gcr.io/cloud-builders/gcloud"
835
836 # 278. Deploy do Cloud Build
837 name: "gcr.io/cloud-builders/gcloud"
838
839 # 279. Deploy do Cloud Build
840 name: "gcr.io/cloud-builders/gcloud"
841
842 # 280. Deploy do Cloud Build
843 name: "gcr.io/cloud-builders/gcloud"
844
845 # 281. Deploy do Cloud Build
846 name: "gcr.io/cloud-builders/gcloud"
847
848 # 282. Deploy do Cloud Build
849 name: "gcr.io/cloud-builders/gcloud"
850
851 # 283. Deploy do Cloud Build
852 name: "gcr.io/cloud-builders/gcloud"
853
854 # 284. Deploy do Cloud Build
855 name: "gcr.io/cloud-builders/gcloud"
856
857 # 285. Deploy do Cloud Build
858 name: "gcr.io/cloud-builders/gcloud"
859
860 # 286. Deploy do Cloud Build
861 name: "gcr.io/cloud-builders/gcloud"
862
863 # 287. Deploy do Cloud Build
864 name: "gcr.io/cloud-builders/gcloud"
865
866 # 288. Deploy do Cloud Build
867 name: "gcr.io/cloud-builders/gcloud"
868
869 # 289. Deploy do Cloud Build
870 name: "gcr.io/cloud-builders/gcloud"
871
872 # 290. Deploy do Cloud Build
873 name: "gcr.io/cloud-builders/gcloud"
874
875 # 291. Deploy do Cloud Build
876 name: "gcr.io/cloud-builders/gcloud"
877
878 # 292. Deploy do Cloud Build
879 name: "gcr.io/cloud-builders/gcloud"
880
881 # 293. Deploy do Cloud Build
882 name: "gcr.io/cloud-builders/gcloud"
883
884 # 294. Deploy do Cloud Build
885 name: "gcr.io/cloud-builders/gcloud"
886
887 # 295. Deploy do Cloud Build
888 name: "gcr.io/cloud-builders/gcloud"
889
890 # 296. Deploy do Cloud Build
891 name: "gcr.io/cloud-builders/gcloud"
892
893 # 297. Deploy do Cloud Build
894 name: "gcr.io/cloud-builders/gcloud"
895
896 # 298. Deploy do Cloud Build
897 name: "gcr.io/cloud-builders/gcloud"
898
899 # 299. Deploy do Cloud Build
900 name: "gcr.io/cloud-builders/gcloud"
901
902 # 300. Deploy do Cloud Build
903 name: "gcr.io/cloud-builders/gcloud"
904
905 # 301. Deploy do Cloud Build
906 name: "gcr.io/cloud-builders/gcloud"
907
908 # 302. Deploy do Cloud Build
909 name: "gcr.io/cloud-builders/gcloud"
910
911 # 303. Deploy do Cloud Build
912 name: "gcr.io/cloud-builders/gcloud"
913
914 # 304. Deploy do Cloud Build
915 name: "gcr.io/cloud-builders/gcloud"
916
917 # 305. Deploy do Cloud Build
918 name: "gcr.io/cloud-builders/gcloud"
919
920 # 306. Deploy do Cloud Build
921 name: "gcr.io/cloud-builders/gcloud"
922
923 # 307. Deploy do Cloud Build
924 name: "gcr.io/cloud-builders/gcloud"
925
926 # 308. Deploy do Cloud Build
927 name: "gcr.io/cloud-builders/gcloud"
928
929 # 309. Deploy do Cloud Build
930 name: "gcr.io/cloud-builders/gcloud"
931
932 # 310. Deploy do Cloud Build
933 name: "gcr.io/cloud-builders/gcloud"
934
935 # 311. Deploy do Cloud Build
936 name: "gcr.io/cloud-builders/gcloud"
937
938 # 312. Deploy do Cloud Build
939 name: "gcr.io/cloud-builders/gcloud"
940
941 # 313. Deploy do Cloud Build
942 name: "gcr.io/cloud-builders/gcloud"
943
944 # 314. Deploy do Cloud Build
945 name: "gcr.io/cloud-builders/gcloud"
946
947 # 315. Deploy do Cloud Build
948 name: "gcr.io/cloud-builders/gcloud"
949
950 # 316. Deploy do Cloud Build
951 name: "gcr.io/cloud-builders/gcloud"
952
953 # 317. Deploy do Cloud Build
954 name: "gcr.io/cloud-builders/gcloud"
955
956 # 318. Deploy do Cloud Build
957 name: "gcr.io/cloud-builders/gcloud"
958
959 # 319. Deploy do Cloud Build
960 name: "gcr.io/cloud-builders/gcloud"
961
962 # 320. Deploy do Cloud Build
963 name: "gcr.io/cloud-builders/gcloud"
964
965 # 321. Deploy do Cloud Build
966 name: "gcr.io/cloud-builders/gcloud"
967
968 # 322. Deploy do Cloud Build
969 name: "gcr.io/cloud-builders/gcloud"
970
971 # 323. Deploy do Cloud Build
972 name: "gcr.io/cloud-builders/gcloud"
973
974 # 324. Deploy do Cloud Build
975 name: "gcr.io/cloud-builders/gcloud"
976
977 # 325. Deploy do Cloud Build
978 name: "gcr.io/cloud-builders/gcloud"
979
980 # 326. Deploy do Cloud Build
981 name: "gcr.io/cloud-builders/gcloud"
982
983 # 327. Deploy do Cloud Build
984 name: "gcr.io/cloud-builders/gcloud"
985
986 # 328. Deploy do Cloud Build
987 name: "gcr.io/cloud-builders/gcloud"
988
989 # 329. Deploy do Cloud Build
990 name: "gcr.io/cloud-builders/gcloud"
991
992 # 330. Deploy do Cloud
```


Demo

2 elementy

Global parameters

Number of elements (NE)
2

Total length (L0)
5,00

Area (S)
2,00

Conductivity (k)
50,00

Conv. coeff. (a)
10,00

Heat flux (q)
-150,00

Ambient temp. (T_amb)
400,00

Flow direction (dir)
1

Solve

Visual Finite-Element Solver

Assembled Matrices

(H) matrix:
$$H = \begin{bmatrix} 40.00 & -40.00 & 0.00 \\ -40.00 & 80.00 & -40.00 \\ 0.00 & -40.00 & 60.00 \end{bmatrix}$$

(P) vector:
$$P = \begin{bmatrix} -300.00 \\ 0.00 \\ -8000.00 \end{bmatrix}$$

Equation to solve:
$$Ht + P = 0$$

Solution vector (t)
$$t = \begin{bmatrix} 430.00 \\ 422.50 \\ 415.00 \end{bmatrix}$$

4 elementy

Global parameters

Number of elements (NE)
4

Total length (L0)
5,00

Area (S)
2,00

Conductivity (k)
50,00

Conv. coeff. (a)
10,00

Heat flux (q)
-150,00

Ambient temp. (T_amb)
400,00

Flow direction (dir)
1

Solve

Visual Finite-Element Solver

Assembled Matrices

(H) matrix:
$$H = \begin{bmatrix} 80.00 & -80.00 & 0.00 & 0.00 & 0.00 \\ -80.00 & 160.00 & -80.00 & 0.00 & 0.00 \\ 0.00 & -80.00 & 160.00 & -80.00 & 0.00 \\ 0.00 & 0.00 & -80.00 & 160.00 & -80.00 \\ 0.00 & 0.00 & 0.00 & -80.00 & 100.00 \end{bmatrix}$$

(P) vector:
$$P = \begin{bmatrix} -300.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ -8000.00 \end{bmatrix}$$

Equation to solve:
$$Ht + P = 0$$

Solution vector (t)
$$t = \begin{bmatrix} 430.00 \\ 426.25 \\ 422.50 \\ 418.75 \\ 415.00 \end{bmatrix}$$

10 elementów

Global parameters

Number of elements (NE)
10

Total length (L0)
5,00

Area (S)
2,00

Conductivity (k)
50,00

Conv. coeff. (a)
10,00

Heat flux (q)
-150,00

Ambient temp. (T_amb)
400,00

Flow direction (dir)
1

Solve

Visual Finite-Element Solver

Assembled Matrices

(H) matrix:
$$H = \begin{bmatrix} 200.00 & -200.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ -200.00 & 400.00 & -200.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & -200.00 & 400.00 & -200.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & -200.00 & 400.00 & -200.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & -200.00 & 400.00 & -200.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & -200.00 & 400.00 & -200.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -200.00 & 400.00 & -200.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -200.00 & 400.00 & -200.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -200.00 & 400.00 & -200.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -200.00 & 100.00 \end{bmatrix}$$

(P) vector:
$$P = \begin{bmatrix} -300.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ -8000.00 \end{bmatrix}$$

Equation to solve:
$$Ht + P = 0$$

Solution vector (t)
$$t = \begin{bmatrix} 430.00 \\ 428.50 \\ 427.00 \\ 425.50 \\ 424.00 \\ 422.50 \\ 421.00 \\ 419.50 \\ 418.00 \\ 415.00 \end{bmatrix}$$

Podsumowanie i wnioski

W ramach sprawozdania była zrobiona symulacja ustalonego przepływu ciepła w pręcie za pomocą MES. Zastosowane rozwiązania:

1. Rozwiązanie analityczne (układ równań)
2. Minimalizacja funkcjonału za pomocą SOLVER'a
3. Rozwiązanie własnym programem w Pythonie

Wszystkie metody dały zbliżone wyniki, co potwierdza poprawność modeli. Zwiększenie liczby węzłów daje nam bardziej szczegółowy rozkład temperatury, trzymając się przy tym zgodności wartości na brzegach. Stworzenie aplikacji webowej nie było wymagane, ale to stanowi praktyczne rozszerzenie „projektu” oraz ułatwia prezentację oraz analizę wyników.