Министерство образования и науки Российской Федерации

НОВОСИБИРСКИЙ ГОСУДАРСТВЕННЫЙ ТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Кафедра прикладной математики

Лабораторная работа №2

по дисциплине

«Численные методы»

Факультет прикладной математики и информатики

Группа ПМ-01

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Вариант 11

Новосибирск

2012

1. Цель

Разработать программу решения СЛАУ методами Якоби, Гаусса-Зейделя, блочной релаксации с хранением матрицы в 7-ми диагональном формате. Исследовать сходимость методов для различных тестовых матриц и её зависимость от параметра релаксации. Изучить возможность оценки порядка числа обусловленности матрицы путем вычислительного эксперимента.

1. Анализ

Метод Якоби

Каждое следующее приближение в методе Якоби рассчитывается следующим способом:



Метод Гаусса-Зейделя

Каждое последующее приближение рассчитывается по формуле:



Метод блочной релаксации



где A-матрица, X, F – блок-вектора.

1. Код программы

/\*main.cpp\*/

#include "CSlaIt.h"

int main(int argc, char\*\* argv)

{

std::string ar1, ar2, ar3, ar4;

if(argc != 5)

return 1;

ar1 = argv[1];

ar2 = argv[2];

ar3 = argv[3];

ar4 = argv[4];

CSlaIt pr(ar1);

pr.Jakobi(ar2);

pr.Gauss\_Zeidel(ar3);

pr.BlockRelax(ar4);

return 0;

}

/\*CSlaIt.h\*/

#include <stdio.h>

#include <string>

#include <math.h>

typedef double real;

class CSlaIt

{

private:

real \*D, \*F;

real \*L1, \*L2, \*L3, \*U1, \*U2, \*U3;

real \*StartX; //начальное приближение

int n;

int m1,m2; // расстояние между диагоналями

int n1,n2; //количество элементов в побочных диагоналях

real exact; //точность

real w;

int maxiter;

int BlockSize;

public:

CSlaIt(std::string in);

void Jakobi(std::string in);

void Gauss\_Zeidel(std::string in);

void change(real\*, real\*);

void multiply(real \*Xsl, real \*x);

void push( FILE \*fp, int k, real pogr, real \*x);

real otn\_nevjazka(real \*);

real pogresh(real \*);

real num\_obusl(real \*, real);

real otn\_nevjazka\_relax(real \*x);

void makeLU();

void LUsolve(int step, real\* x);

void ResultX(int step, real\* x, real\* oldx);

void Relax(real\* x, real\* oldx);

void BlockRelax(std::string in);

};

/\*CSlaIt.cpp\*/

#include "CSlaIt.h"

CSlaIt::CSlaIt(std::string in)

{

FILE \*fp;

fp = fopen(in.c\_str(),"rt");

fscanf(fp," %i %i %i %lf %i", &n, &m1, &m2, &exact, &maxiter);

n1 = n-3-m1-m2;

n2 = n-2-m1;

register int i;

L3 = new real[n1];

for( i = 0; i < n1; i++)

fscanf(fp, "%lg", &L3[i]);

L2 = new real[n2];

for( i = 0; i < n2; i++)

fscanf(fp, "%lg", &L2[i]);

L1 = new real[n-1];

for( i = 0; i < n-1; i++)

fscanf(fp, "%lg", &L1[i]);

D = new real[n];

for( i = 0; i < n; i++)

fscanf(fp, "%lg", &D[i]);

U1 = new real[n-1];

for( i = 0; i < n-1; i++)

fscanf(fp, "%lg", &U1[i]);

U2 = new real[n2];

for( i = 0; i < n2; i++)

fscanf(fp, "%lg", &U2[i]);

U3 = new real[n1];

for( i = 0; i < n1; i++)

fscanf(fp, "%lg", &U3[i]);

F = new real[n];

for( i = 0; i < n; i++)

fscanf(fp," %lf",&F[i]);

fscanf(fp," %lf", &w);

fscanf(fp," %i", &BlockSize);

fclose(fp);

}

real CSlaIt::otn\_nevjazka(real \*x)

{

register int i, k;

real sum, norma;

real \*f\_;

f\_ = new real[n];

change (f\_,NULL);

sum = 0;

norma = 0;

for( i = 0; i < n; i++)

f\_[i] = D[i]\*x[i];

k = n-n1;

for( i = 0; i < n1; i++, k++) {

f\_[k] += L3[i]\*x[i];

f\_[i] += U3[i]\*x[k];

}

k = n-n2;

for( i = 0; i < n2; i++, k++) {

f\_[k] += L2[i]\*x[i];

f\_[i] += U2[i]\*x[k];

}

k = 1;

for( i = 0; i < n-1; i++, k++) {

f\_[k] += L1[i]\*x[i];

f\_[i] += U1[i]\*x[k];

}

for( i = 0; i < n; i++) {

sum += pow(f\_[i]-F[i],2);

norma += pow(f\_[i],2);

}

norma = sqrt(sum)/sqrt(norma);

return norma;

}

void CSlaIt::change(real\* a, real\* b)

{

register int i;

if(b)

for (i=0; i<n; i++)

a[i] = b[i];

else

for (i=0; i<n; i++)

a[i] = 0.0;

}

real CSlaIt::pogresh(real \*x)

{

real sum = 0, norma = 0;

for(register int i = 0; i < n; i++) {

sum += pow(real(i+1)-x[i],2);

norma +=pow(real(i+1),2);

}

norma = sqrt(sum)/sqrt(norma);

return norma;

}

inline real CSlaIt::num\_obusl(real \*x, real pogr)

{

return pogresh(x)/pogr;

}

void CSlaIt::multiply(real \*Xsl, real \*x)

{

register int i = 0;

register real s = 0.0;

register int u1 = 1;

register int u2 = 2+m1;

register int u3 = 3+m1+m2;

s += D[i]\*x[i]+U1[i]\*x[u1]+U2[i]\*x[u2]+U3[i]\*x[u3];

s = F[i]-s;

Xsl[i] = x[i]+w\*s/D[i];

register int l1 = 0;

i++;

u1++;

u2++;

u3++;

s = 0.0;

for( ; i < n1; l1++, i++, u1++, u2++, u3++) {

s += L1[l1]\*x[l1];

s += D[i]\*x[i];

s += U1[i]\*x[u1];

s += U2[i]\*x[u2];

s += U3[i]\*x[u3];

s = F[i]-s;

Xsl[i] = x[i]+w\*s/D[i];

s = 0.0;

}

s = 0.0;

for( ; i < n2; l1++, i++, u1++, u2++) {

s += L1[l1]\*x[l1];

s += D[i]\*x[i];

s += U1[i]\*x[u1];

s += U2[i]\*x[u2];

s = F[i]-s;

Xsl[i] = x[i]+w\*s/D[i];

s = 0.0;

}

s = 0.0;

for( ; i < n-n2; l1++, i++, u1++) {

s += L1[l1]\*x[l1];

s += D[i]\*x[i];

s += U1[i]\*x[u1];

s = F[i]-s;

Xsl[i] = x[i]+w\*s/D[i];

s = 0.0;

}

int l2 = 0;

s = 0.0;

for( ; i < n-n1; l2++, l1++, i++, u1++) {

s += L2[l2]\*x[l2];

s += L1[l1]\*x[l1];

s += D[i]\*x[i];

s += U1[i]\*x[u1];

s = F[i]-s;

Xsl[i] = x[i]+w\*s/D[i];

s = 0.0;

}

int l3 = 0;

s = 0.0;

for( ; i < n-1; l3++, l2++, l1++, i++, u1++) {

s += L3[l3]\*x[l3];

s += L2[l2]\*x[l2];

s += L1[l1]\*x[l1];

s += D[i]\*x[i];

s += U1[i]\*x[u1];

s = F[i]-s;

Xsl[i] = x[i]+w\*s/D[i];

s = 0.0;

}

s = 0.0;

s += L3[l3]\*x[l3];

s += L2[l2]\*x[l2];

s += L1[l1]\*x[l1];

s += D[i]\*x[i];

s = F[i]-s;

Xsl[i] = x[i]+w\*s/D[i];

}

void CSlaIt::Jakobi(std::string in)

{

FILE \*fp;

fp = fopen(in.c\_str(), "wt");

int k;

real pogr;

real \*x, \*xnew;

xnew = new real[n];

x = new real[n];

change (x,NULL);

change(xnew,x);

pogr = otn\_nevjazka(x);

for( k = 0; k < maxiter && pogr > exact; k++) {

multiply(xnew,x);

change(x,xnew);

pogr = otn\_nevjazka(x);

push(fp,k,pogr,x);

}

fprintf(fp,"x\*-x\n");

for( k = 0; k < n; k++)

fprintf( fp,"%.3le\n",fabs(real(k+1)-x[k]));

fprintf( fp,"\n");

pogr = num\_obusl(x,pogr);

fprintf( fp,"Число обусловленностей:\n");

fprintf( fp,"%.3le\n",pogr);

fclose(fp);

}

void CSlaIt::Gauss\_Zeidel(std::string in)

{

FILE \*fp;

fp = fopen(in.c\_str(), "wt");

int k;

real pogr;

real \*x, \*x\_;

x\_ = new real[n];

x = new real[n];

change (x,NULL);

change(x\_,x);

pogr = otn\_nevjazka(x);

for( k = 0; k < maxiter && pogr > exact; k++) {

multiply(x,x);

pogr = otn\_nevjazka(x);

push(fp,k,pogr,x);

}

fprintf( fp,"x\*-x\n");

for( k = 0; k < n; k++)

fprintf( fp,"%.3le\n",fabs(real(k+1)-x[k]));

fprintf( fp,"\n");

pogr = num\_obusl(x,pogr);

fprintf( fp,"Число обусловленностей:\n");

fprintf( fp,"%.3le\n",pogr);

fclose(fp);

}

inline void CSlaIt::push( FILE \*fp, int k, real pogr, real \*x)

{

fprintf( fp, "%d\n", k);

for (register int i = 0; i < n; i++)

fprintf ( fp, "%.14le\n", x[i]);

fprintf ( fp, "\n%.3le\n\n", pogr);

}

//=================Block\_Relax====================================

real CSlaIt::otn\_nevjazka\_relax(real \*x)

{

int i, k, bcount;

real sum = 0, norma = 0;

real \*f\_;

f\_ = new real[n];

change (f\_,NULL);

bcount = n / BlockSize;

for( i = 0; i < bcount; i++) {

int in = i \* BlockSize;

f\_[in] += D[in]\*x[in];

int in2 = in + BlockSize;

for( k = in + 1; k < in2; k++) {

int in3 = k - 1;

f\_[k] += L1[in3]\*D[in3]\*x[in3];

f\_[k] += (D[k]+L1[in3]\*U1[in3])\*x[k];

}

}

k = n-n1;

for( i = 0; i < n1; i++, k++) {

f\_[k] += L3[i]\*x[i];

f\_[i] += U3[i]\*x[k];

}

k = n-n2;

for( i = 0; i < n2; i++, k++) {

f\_[k] += L2[i]\*x[i];

f\_[i] += U2[i]\*x[k];

}

k = 1;

for( i = 0; i < n-1; i++, k++)

f\_[i] += U1[i]\*x[k];

for( i = 1; i < bcount; i++) {

int in = i \* BlockSize, in2 = in - 1;

f\_[in] += L1[in2]\*x[in2];

}

for( i = 0; i < n; i++) {

sum += pow(f\_[i]-F[i],2);

norma += pow(F[i],2);

}

norma = sqrt(sum)/sqrt(norma);

return norma;

}

void CSlaIt::makeLU()

{

int i, j;

int bcount=n/BlockSize;

for ( i = 0; i < bcount; i++) {

int in = BlockSize+i\*BlockSize-1;

for ( j = i\*BlockSize; j < in; j++) {

L1[j] /= D[j];

D[j+1] -= L1[j]\*U1[j];

}

}

}

void CSlaIt::LUsolve(int step, real\* x)

{

int i;

int j = step \* BlockSize;

int in = BlockSize + j;

for (i = j; i < in; i++)

x[i] \*= w;

for (i = j + 1; i < in; i++) {

int in2 = i - 1;

x[i] -= L1[in2]\*x[in2];

}

x[(step+1)\*BlockSize-1] /= D[(step+1)\*BlockSize-1];

for (i = BlockSize - 2 + j; i >= j; i--) {

x[i] -= U1[i]\*x[i+1];

x[i] /=D[i];

}

}

void CSlaIt::ResultX(int step, real\* x, real\* oldx)

{

int in = BlockSize + step \* BlockSize;

for (int i = step \* BlockSize; i < in; i++)

x[i] += (1-w)\*oldx[i];

}

void CSlaIt::Relax(real\* x,real\* oldx)

{

int i, j, nblock, here, set;

int bcount;

bcount = n / BlockSize;

change(x, F);

for ( i = 0, j = m1+2; i < n1; i++, j++)

x[i] -= U2[i]\*oldx[j] + U3[i]\*oldx[j+m2+1];

for ( j = n-n2+i ; j<n; i++, j++)

x[i] -= U2[i]\*oldx[j];

for (i=0; i<bcount-1; i++) {

j = (i+1)\*BlockSize -1;

x[j] -= U1[j]\*oldx[j+1];

}

LUsolve(0, x);

ResultX(0, x, oldx);

nblock = (m1+2) / BlockSize;

here = (m1+2) % BlockSize;

for (i = 1; i < nblock; i++) {

int in = i\*BlockSize, in2 = in - 1;

x[in] -= L1[in2]\*x[in2];

LUsolve(i, x);

ResultX(i, x, oldx);

}

set = BlockSize - here;

j = nblock\*BlockSize + here;

int in = j;

for(i = 0; i < set; i++, in++)

x[in] -= L2[i] \* x[i];

in = j + m2+1;

for (i = 0; i < set-m2-1; i++, in++)

x[in] -= L3[i]\*x[i];

i = nblock \* BlockSize;

x[i] -= L1[i-1]\*x[i-1];

LUsolve(nblock, x);

ResultX(nblock, x, oldx);

int tek = n - n1;

int ibl = i\*BlockSize;

for( i = nblock + 1; i < bcount; i++ ) {

int in = (i+1)\*BlockSize;

for ( ; tek < in; tek++) {

int in2 = tek-(n-n1);

x[tek] -= L3[in2]\*x[in2];

}

int in2 = BlockSize + i\*BlockSize;

for (j = i\*BlockSize; j < in2; j++) {

int in3 = j-(m1+2);

x[j] -= L2[in3]\*x[in3];

}

x[ibl] -= L1[ibl-1]\*x[ibl-1];

LUsolve(i, x);

ResultX(i, x, oldx);

}

}

void CSlaIt::BlockRelax(std::string in)

{

FILE \*fp;

fp = fopen(in.c\_str(), "wt");

int k;

real pogr;

real \*oldx, \*x;

oldx = new real[n];

x = new real[n];

change(x, NULL);

makeLU();

pogr = otn\_nevjazka\_relax(x);

for ( k = 0; k < maxiter && pogr > exact; k++) {

change(oldx, x);

Relax(x,oldx);

pogr = otn\_nevjazka\_relax(x);

push(fp,k,pogr,x);

}

fprintf( fp,"x\*-x\n");

for( k = 0; k < n; k++)

fprintf( fp,"%.3le\n",fabs(real(k+1)-x[k]));

fprintf( fp,"\n");

pogr = num\_obusl(x,pogr);

fprintf( fp,"Число обусловленностей:\n");

fprintf( fp,"%.3le\n",pogr);

fclose(fp);

}

1. Исследования

Матрица:



Якоби

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | Количество итераций |
| **0.1** | 9.99999999961036e-001  1.99999999995649e+000  2.99999999995400e+000  3.99999999995406e+000  4.99999999995438e+000  5.99999999995563e+000  6.99999999995973e+000  7.99999999995634e+000  8.99999999995562e+000  9.99999999995509e+000  1.09999999999542e+001  1.19999999999540e+001 | 3.896e-011  4.351e-011  4.600e-011  4.594e-011  4.562e-011  4.437e-011  4.027e-011  4.366e-011  4.438e-011  4.491e-011  4.582e-011  4.598e-011 | 6.005e+001 | 27912 |
| **0.2** | 9.99999999961111e-001  1.99999999995657e+000  2.99999999995409e+000  3.99999999995415e+000  4.99999999995447e+000  5.99999999995572e+000  6.99999999995980e+000  7.99999999995642e+000  8.99999999995571e+000  9.99999999995518e+000  1.09999999999543e+001  1.19999999999541e+001 | 3.889e-011  4.343e-011  4.591e-011  4.585e-011  4.553e-011  4.428e-011  4.020e-011  4.358e-011  4.429e-011  4.482e-011  4.573e-011  4.588e-011 | 6.000e+001 | 13949 |
| **0.3** | 9.99999999961049e-001  1.99999999995650e+000  2.99999999995402e+000  3.99999999995407e+000  4.99999999995439e+000  5.99999999995565e+000  6.99999999995974e+000  7.99999999995635e+000  8.99999999995564e+000  9.99999999995511e+000  1.09999999999542e+001  1.19999999999540e+001 | 3.895e-011  4.350e-011  4.598e-011  4.593e-011  4.561e-011  4.435e-011  4.026e-011  4.365e-011  4.436e-011  4.489e-011  4.580e-011  4.596e-011 | 6.002e+001 | 9294 |
| **0.4** | 9.99999999961049e-001  1.99999999995650e+000  2.99999999995402e+000  3.99999999995408e+000  4.99999999995440e+000  5.99999999995565e+000  6.99999999995974e+000  7.99999999995635e+000  8.99999999995564e+000  9.99999999995511e+000  1.09999999999542e+001  1.19999999999540e+001 | 3.895e-011  4.350e-011  4.598e-011  4.592e-011  4.560e-011  4.435e-011  4.026e-011  4.365e-011  4.436e-011  4.489e-011  4.580e-011  4.596e-011 | 6.001e+001 | 6967 |
| **0.5** | 9.99999999961080e-001  1.99999999995654e+000  2.99999999995405e+000  3.99999999995411e+000  4.99999999995443e+000  5.99999999995569e+000  6.99999999995977e+000  7.99999999995639e+000  8.99999999995567e+000  9.99999999995515e+000  1.09999999999542e+001  1.19999999999541e+001 | 3.892e-011  4.346e-011  4.595e-011  4.589e-011  4.557e-011  4.431e-011  4.023e-011  4.361e-011  4.433e-011  4.485e-011  4.577e-011  4.592e-011 | 6.001e+001 | 5571 |
| **0.6** | 9.99999999961255e-001  1.99999999995673e+000  2.99999999995426e+000  3.99999999995432e+000  4.99999999995464e+000  5.99999999995588e+000  6.99999999995995e+000  7.99999999995658e+000  8.99999999995587e+000  9.99999999995535e+000  1.09999999999544e+001  1.19999999999543e+001 | 3.875e-011  4.327e-011  4.574e-011  4.568e-011  4.536e-011  4.412e-011  4.005e-011  4.342e-011  4.413e-011  4.465e-011  4.556e-011  4.571e-011 | 6.002e+001 | 4641 |
| **0.7** | 9.99999999961252e-001  1.99999999995673e+000  2.99999999995426e+000  3.99999999995431e+000  4.99999999995463e+000  5.99999999995588e+000  6.99999999995995e+000  7.99999999995658e+000  8.99999999995587e+000  9.99999999995534e+000  1.09999999999544e+001  1.19999999999543e+001 | 3.875e-011  4.327e-011  4.574e-011  4.569e-011  4.537e-011  4.412e-011  4.005e-011  4.342e-011  4.413e-011  4.466e-011  4.557e-011  4.572e-011 | 6.001e+001 | 3976 |
| **0.8** | 9.99999999961176e-001  1.99999999995665e+000  2.99999999995417e+000  3.99999999995423e+000  4.99999999995454e+000  5.99999999995580e+000  6.99999999995987e+000  7.99999999995650e+000  8.99999999995578e+000  9.99999999995526e+000  1.09999999999543e+001  1.19999999999542e+001 | 3.882e-011  4.335e-011  4.583e-011  4.577e-011  4.546e-011  4.420e-011  4.013e-011  4.350e-011  4.422e-011  4.474e-011  4.565e-011  4.581e-011 | 5.992e+001 | 3477 |
| **0.9** | 9.99999999961136e-001  1.99999999995660e+000  2.99999999995412e+000  3.99999999995418e+000  4.99999999995450e+000  5.99999999995575e+000  6.99999999995983e+000  7.99999999995645e+000  8.99999999995574e+000  9.99999999995521e+000  1.09999999999543e+001  1.19999999999541e+001 | 3.886e-011  4.340e-011  4.588e-011  4.582e-011  4.550e-011  4.425e-011  4.017e-011  4.355e-011  4.426e-011  4.479e-011  4.570e-011  4.585e-011 | 6.001e+001 | 3089 |
| **1.0** | 9.99999999961240e-001  1.99999999995672e+000  2.99999999995424e+000  3.99999999995430e+000  4.99999999995462e+000  5.99999999995587e+000  6.99999999995994e+000  7.99999999995657e+000  8.99999999995586e+000  9.99999999995533e+000  1.09999999999544e+001  1.19999999999543e+001 | 3.876e-011  4.328e-011  4.576e-011  4.570e-011  4.538e-011  4.413e-011  4.006e-011  4.343e-011  4.414e-011  4.467e-011  4.558e-011  4.573e-011 | 6.000e+001 | 2779 |
| **1.01** | 9.99999999961113e-001  1.99999999995658e+000  2.99999999995409e+000  3.99999999995415e+000  4.99999999995447e+000  5.99999999995572e+000  6.99999999995981e+000  7.99999999995642e+000  8.99999999995571e+000  9.99999999995518e+000  1.09999999999543e+001  1.19999999999541e+001 | 3.889e-011  4.342e-011  4.591e-011  4.585e-011  4.553e-011  4.428e-011  4.019e-011  4.358e-011  4.429e-011  4.482e-011  4.573e-011  4.588e-011 | 6.001e+001 | 2751 |
| **1.02** | 9.99999999961152e-001  1.99999999995662e+000  2.99999999995414e+000  3.99999999995420e+000  4.99999999995452e+000  5.99999999995577e+000  6.99999999995985e+000  7.99999999995647e+000  8.99999999995576e+000  9.99999999995523e+000  1.09999999999543e+001  1.19999999999542e+001 | 3.885e-011  4.338e-011  4.586e-011  4.580e-011  4.548e-011  4.423e-011  4.015e-011  4.353e-011  4.424e-011  4.477e-011  4.568e-011  4.584e-011 | 5.991e+001 | 2724 |
| **1.03** | 9.99999999961368e-001  1.99999999995686e+000  2.99999999995439e+000  3.99999999995445e+000  4.99999999995477e+000  5.99999999995601e+000  6.99999999996006e+000  7.99999999995671e+000  8.99999999995600e+000  9.99999999995548e+000  1.09999999999546e+001  1.19999999999544e+001 | 3.863e-011  4.314e-011  4.561e-011  4.555e-011  4.523e-011  4.399e-011  3.994e-011  4.329e-011  4.400e-011  4.452e-011  4.543e-011  4.558e-011 | 6.004e+001 | 2698 |
| **1.04** | 3.33825589749613e+152  -3.69050910850507e+152  2.47793096356326e+152  -2.03231323255623e+152  1.09731554174125e+152  3.36990383770929e+151  -3.69950226247949e+152  3.78147105361777e+152  -3.12296838823344e+152  3.27727342182276e+152  -2.14381965887900e+152  1.66571048431634e+152 | 3.338e+152  3.691e+152  2.478e+152  2.032e+152  1.097e+152  3.370e+151  3.700e+152  3.781e+152  3.123e+152  3.277e+152  2.144e+152  1.666e+152 |  |  |

Гаусс-Зейдель

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | Количество итераций |
| **0.1** | 9.99999999961165e-001  1.99999999995665e+000  2.99999999995416e+000  3.99999999995422e+000  4.99999999995454e+000  5.99999999995580e+000  6.99999999995988e+000  7.99999999995651e+000  8.99999999995579e+000  9.99999999995528e+000  1.09999999999544e+001  1.19999999999542e+001 | 3.883e-011  4.335e-011  4.584e-011  4.578e-011  4.546e-011  4.420e-011  4.012e-011  4.349e-011  4.421e-011  4.472e-011  4.563e-011  4.578e-011 | 5.982e+001 | 26531 |
| **0.2** | 9.99999999961318e-001  1.99999999995684e+000  2.99999999995436e+000  3.99999999995441e+000  4.99999999995474e+000  5.99999999995600e+000  6.99999999996005e+000  7.99999999995671e+000  8.99999999995600e+000  9.99999999995551e+000  1.09999999999546e+001  1.19999999999545e+001 | 3.868e-011  4.316e-011  4.564e-011  4.559e-011  4.526e-011  4.400e-011  3.995e-011  4.329e-011  4.400e-011  4.449e-011  4.539e-011  4.554e-011 | 5.953e+001 | 12567 |
| **0.3** | 9.99999999961657e-001  1.99999999995724e+000  2.99999999995477e+000  3.99999999995482e+000  4.99999999995515e+000  5.99999999995640e+000  6.99999999996042e+000  7.99999999995712e+000  8.99999999995642e+000  9.99999999995596e+000  1.09999999999551e+001  1.19999999999549e+001 | 3.834e-011  4.276e-011  4.523e-011  4.518e-011  4.485e-011  4.360e-011  3.958e-011  4.288e-011  4.358e-011  4.404e-011  4.494e-011  4.509e-011 | 5.898e+001 | 7914 |
| **0.4** | 9.99999999962144e-001  1.99999999995781e+000  2.99999999995536e+000  3.99999999995541e+000  4.99999999995574e+000  5.99999999995698e+000  6.99999999996095e+000  7.99999999995771e+000  8.99999999995701e+000  9.99999999995658e+000  1.09999999999557e+001  1.19999999999555e+001 | 3.786e-011  4.219e-011  4.464e-011  4.459e-011  4.426e-011  4.302e-011  3.905e-011  4.229e-011  4.299e-011  4.342e-011  4.430e-011  4.445e-011 | 5.832e+001 | 5588 |
| **0.5** | 9.99999999962880e-001  1.99999999995866e+000  2.99999999995625e+000  3.99999999995629e+000  4.99999999995662e+000  5.99999999995785e+000  6.99999999996173e+000  7.99999999995857e+000  8.99999999995789e+000  9.99999999995749e+000  1.09999999999566e+001  1.19999999999565e+001 | 3.712e-011  4.134e-011  4.375e-011  4.371e-011  4.338e-011  4.215e-011  3.827e-011  4.143e-011  4.211e-011  4.251e-011  4.337e-011  4.352e-011 | 5.730e+001 | 4193 |
| **0.6** | 9.99999999963477e-001  1.99999999995935e+000  2.99999999995697e+000  3.99999999995701e+000  4.99999999995734e+000  5.99999999995856e+000  6.99999999996237e+000  7.99999999995928e+000  8.99999999995861e+000  9.99999999995825e+000  1.09999999999574e+001  1.19999999999573e+001 | 3.652e-011  4.065e-011  4.303e-011  4.299e-011  4.266e-011  4.144e-011  3.763e-011  4.072e-011  4.139e-011  4.175e-011  4.260e-011  4.274e-011 | 5.603e+001 | 3262 |
| **0.7** | 9.99999999964945e-001  1.99999999996102e+000  2.99999999995872e+000  3.99999999995876e+000  4.99999999995908e+000  5.99999999996026e+000  6.99999999996392e+000  7.99999999996097e+000  8.99999999996033e+000  9.99999999996001e+000  1.09999999999592e+001  1.19999999999591e+001 | 3.505e-011  3.898e-011  4.128e-011  4.124e-011  4.092e-011  3.974e-011  3.608e-011  3.903e-011  3.967e-011  3.999e-011  4.080e-011  4.094e-011 | 5.425e+001 | 2599 |
| **0.8** | 9.99999999965964e-001  1.99999999996219e+000  2.99999999995995e+000  3.99999999995998e+000  4.99999999996030e+000  5.99999999996145e+000  6.99999999996500e+000  7.99999999996217e+000  8.99999999996154e+000  9.99999999996127e+000  1.09999999999605e+001  1.19999999999604e+001 | 3.404e-011  3.781e-011  4.005e-011  4.002e-011  3.970e-011  3.855e-011  3.500e-011  3.783e-011  3.846e-011  3.873e-011  3.951e-011  3.965e-011 | 5.209e+001 | 2100 |
| **0.9** | 9.99999999967818e-001  1.99999999996429e+000  2.99999999996216e+000  3.99999999996218e+000  4.99999999996250e+000  5.99999999996360e+000  6.99999999996695e+000  7.99999999996429e+000  8.99999999996370e+000  9.99999999996349e+000  1.09999999999627e+001  1.19999999999626e+001 | 3.218e-011  3.571e-011  3.784e-011  3.782e-011  3.750e-011  3.640e-011  3.305e-011  3.571e-011  3.630e-011  3.651e-011  3.725e-011  3.738e-011 | 4.936e+001 | 1713 |
| **1.0** | 9.99999999969876e-001  1.99999999996662e+000  2.99999999996461e+000  3.99999999996462e+000  4.99999999996493e+000  5.99999999996598e+000  6.99999999996911e+000  7.99999999996665e+000  8.99999999996610e+000  9.99999999996594e+000  1.09999999999653e+001  1.19999999999651e+001 | 3.012e-011  3.338e-011  3.539e-011  3.538e-011  3.507e-011  3.402e-011  3.089e-011  3.335e-011  3.390e-011  3.406e-011  3.475e-011  3.486e-011 | 4.606e+001 | 1403 |
| **1.1** | 9.99999999972882e-001  1.99999999997001e+000  2.99999999996818e+000  3.99999999996818e+000  4.99999999996847e+000  5.99999999996943e+000  6.99999999997224e+000  7.99999999997006e+000  8.99999999996956e+000  9.99999999996947e+000  1.09999999999689e+001  1.19999999999687e+001 | 2.712e-011  2.999e-011  3.182e-011  3.182e-011  3.153e-011  3.057e-011  2.776e-011  2.994e-011  3.044e-011  3.053e-011  3.114e-011  3.125e-011 | 4.214e+001 | 1150 |
| **1.2** | 9.99999999975790e-001  1.99999999997328e+000  2.99999999997163e+000  3.99999999997163e+000  4.99999999997190e+000  5.99999999997277e+000  6.99999999997527e+000  7.99999999997336e+000  8.99999999997292e+000  9.99999999997290e+000  1.09999999999724e+001  1.19999999999723e+001 | 2.421e-011  2.672e-011  2.837e-011  2.837e-011  2.810e-011  2.723e-011  2.473e-011  2.664e-011  2.708e-011  2.710e-011  2.765e-011  2.775e-011 | 3.771e+001 | 938 |
| **1.3** | 9.99999999978407e-001  1.99999999997624e+000  2.99999999997474e+000  3.99999999997473e+000  4.99999999997499e+000  5.99999999997579e+000  6.99999999997801e+000  7.99999999997635e+000  8.99999999997596e+000  9.99999999997600e+000  1.09999999999755e+001  1.19999999999754e+001 | 2.159e-011  2.376e-011  2.526e-011  2.527e-011  2.501e-011  2.421e-011  2.199e-011  2.365e-011  2.404e-011  2.400e-011  2.449e-011  2.457e-011 | 3.281e+001 | 757 |
| **1.4** | 9.99999999982390e-001  1.99999999998070e+000  2.99999999997945e+000  3.99999999997943e+000  4.99999999997966e+000  5.99999999998033e+000  6.99999999998214e+000  7.99999999998083e+000  8.99999999998051e+000  9.99999999998062e+000  1.09999999999802e+001  1.19999999999802e+001 | 1.761e-011  1.930e-011  2.055e-011  2.057e-011  2.034e-011  1.967e-011  1.786e-011  1.917e-011  1.949e-011  1.938e-011  1.977e-011  1.984e-011 | 2.757e+001 | 602 |
| **1.5** | 9.99999999985924e-001  1.99999999998466e+000  2.99999999998363e+000  3.99999999998361e+000  4.99999999998381e+000  5.99999999998437e+000  6.99999999998581e+000  7.99999999998481e+000  8.99999999998456e+000  9.99999999998472e+000  1.09999999999844e+001  1.19999999999844e+001 | 1.408e-011  1.534e-011  1.637e-011  1.639e-011  1.619e-011  1.563e-011  1.419e-011  1.519e-011  1.544e-011  1.528e-011  1.558e-011  1.564e-011 | 2.223e+001 | 465 |
| **1.57** | 9.99999999987936e-001  1.99999999998693e+000  2.99999999998602e+000  3.99999999998599e+000  4.99999999998618e+000  5.99999999998668e+000  6.99999999998791e+000  7.99999999998711e+000  8.99999999998688e+000  9.99999999998710e+000  1.09999999999868e+001  1.19999999999868e+001 | 1.206e-011  1.307e-011  1.398e-011  1.401e-011  1.382e-011  1.332e-011  1.209e-011  1.289e-011  1.312e-011  1.290e-011  1.316e-011  1.321e-011 | 1.838e+001 | 377 |
| **1.58** | 9.99999999988328e-001  1.99999999998737e+000  2.99999999998648e+000  3.99999999998645e+000  4.99999999998664e+000  5.99999999998713e+000  6.99999999998831e+000  7.99999999998754e+000  8.99999999998733e+000  9.99999999998755e+000  1.09999999999873e+001  1.19999999999873e+001 | 1.167e-011  1.263e-011  1.352e-011  1.355e-011  1.336e-011  1.287e-011  1.169e-011  1.246e-011  1.267e-011  1.245e-011  1.270e-011  1.275e-011 | 1.784e+001 | 365 |
| **1.59** | 9.99999999988636e-001  1.99999999998773e+000  2.99999999998685e+000  3.99999999998682e+000  4.99999999998700e+000  5.99999999998750e+000  6.99999999998862e+000  7.99999999998790e+000  8.99999999998769e+000  9.99999999998792e+000  1.09999999999877e+001  1.19999999999876e+001 | 1.136e-011  1.227e-011  1.315e-011  1.318e-011  1.300e-011  1.250e-011  1.138e-011  1.210e-011  1.231e-011  1.208e-011  1.233e-011  1.237e-011 | 1.724e+001 | 353 |
| **1.60** | 9.99999999998287e-001  1.99999999999869e+000  2.99999999999788e+000  3.99999999999825e+000  4.99999999999839e+000  5.99999999999863e+000  6.99999999999762e+000  7.99999999999932e+000  8.99999999999809e+000  9.99999999999776e+000  1.09999999999982e+001  1.19999999999984e+001 | 1.713e-012  1.311e-012  2.122e-012  1.750e-012  1.608e-012  1.375e-012  2.378e-012  6.777e-013  1.915e-012  2.238e-012  1.831e-012  1.593e-012 | 2.611e+000 | 365 |
| **1.61** | 1.00000000000014e+000  1.99999999999963e+000  3.00000000000019e+000  3.99999999999987e+000  4.99999999999993e+000  5.99999999999939e+000  7.00000000000109e+000  7.99999999999902e+000  9.00000000000009e+000  1.00000000000005e+001  1.10000000000003e+001  1.19999999999998e+001 | 1.412e-013  3.750e-013  1.887e-013  1.252e-013  7.105e-014  6.093e-013  1.094e-012  9.788e-013  9.415e-014  4.530e-013  2.665e-013  2.203e-013 | 6.963e-001 | 444 |
| **1.62** | 1.00000000000011e+000  1.99999999999983e+000  2.99999999999995e+000  3.99999999999987e+000  5.00000000000019e+000  5.99999999999925e+000  7.00000000000115e+000  7.99999999999948e+000  8.99999999999988e+000  1.00000000000001e+001  1.10000000000004e+001  1.19999999999997e+001 | 1.104e-013  1.745e-013  4.841e-014  1.350e-013  1.865e-013  7.505e-013  1.154e-012  5.151e-013  1.226e-013  8.349e-014  4.068e-013  2.807e-013 | 6.911e-001 | 569 |
| **1.7** | -4.28658878651060e+150  3.85564813363196e+152  -6.00718852668632e+152  -6.40552048333697e+151  7.76945566660673e+152  -8.21608020255298e+152  9.10018459192965e+152  9.24446427067818e+152  -6.32684615953812e+152  -9.41690135451623e+152  5.39429398039307e+152  -3.12434562190114e+152 | 4.287e+150  3.856e+152  6.007e+152  6.406e+151  7.769e+152  8.216e+152  9.100e+152  9.244e+152  6.327e+152  9.417e+152  5.394e+152  3.124e+152 |  |  |
| **1.8** | -6.29820015335442e+151  4.84108865692328e+152  -5.29619571397575e+152  3.12517064797844e+151  7.40327511785511e+152  -4.18596190125800e+152  3.44121379181617e+152  1.30222173473003e+153  -5.68361046410752e+152  -1.05959836546752e+153  2.94716558996975e+152  -1.48767517155749e+152 | 6.298e+151  4.841e+152  5.296e+152  3.125e+151  7.403e+152  4.186e+152  3.441e+152  1.302e+153  5.684e+152  1.060e+153  2.947e+152  1.488e+152 |  |  |
| **1.9** | -1.12149398295113e+152  -1.89440687766105e+152  4.90008726652339e+152  -2.77962630040291e+151  -6.98093429890294e+152  1.11796219069692e+153  -1.69262783176021e+153  -5.04677472206531e+152  6.33868551164250e+152  7.84430818019228e+152  -5.51661361895276e+152  3.97776454723780e+152 | 1.121e+152  1.894e+152  4.900e+152  2.780e+151  6.981e+152  1.118e+153  1.693e+153  5.047e+152  6.339e+152  7.844e+152  5.517e+152  3.978e+152 |  |  |
| **2.0** | 9.99595740708648e+151  1.84149390703884e+152  -4.19651917620365e+152  7.83106695574827e+151  6.22067828229773e+152  -9.46844849807674e+152  1.52344818481682e+153  5.36799913130230e+152  -5.76229540501040e+152  -7.50639083840074e+152  4.27916036395756e+152  -3.34267384305149e+152 | 9.996e+151  1.841e+152  4.197e+152  7.831e+151  6.221e+152  9.468e+152  1.523e+153  5.368e+152  5.762e+152  7.506e+152  4.279e+152  3.343e+152 |  |  |

Блочная релаксация

Размер блока = 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | Количество итераций |
| **0.1** | 9.99999999963195e-001  1.99999999995882e+000  2.99999999995637e+000  3.99999999995630e+000  4.99999999995679e+000  5.99999999995796e+000  6.99999999996189e+000  7.99999999995858e+000  8.99999999995800e+000  9.99999999995766e+000  1.09999999999566e+001  1.19999999999564e+001 | 3.681e-011  4.118e-011  4.363e-011  4.370e-011  4.321e-011  4.204e-011  3.811e-011  4.142e-011  4.200e-011  4.234e-011  4.342e-011  4.361e-011 | 5.689e+001 | 17982 |
| **0.2** | -9.84674500422602e+306  -6.40610728787800e+306  -2.89229273546554e+306  -3.64282132247521e+306  -2.74303624664315e+306  -1.99444359302583e+306  -4.71037148803191e+306  -3.65985989314068e+306  -5.35013778589926e+307  -1.#IND0000000000e+000  -1.#INF0000000000e+000  -1.#INF0000000000e+000 | 9.847e+306  6.406e+306  2.892e+306  3.643e+306  2.743e+306  1.994e+306  4.710e+306  3.660e+306  5.350e+307  -1.#IOe+000  1.#IOe+000  1.#IOe+000 |  |  |
| **0.3** | 9.99999999963444e-001  1.99999999995909e+000  2.99999999995669e+000  3.99999999995658e+000  4.99999999995711e+000  5.99999999995825e+000  6.99999999996220e+000  7.99999999995891e+000  8.99999999995836e+000  9.99999999995802e+000  1.09999999999570e+001  1.19999999999568e+001 | 3.656e-011  4.091e-011  4.331e-011  4.342e-011  4.289e-011  4.175e-011  3.780e-011  4.109e-011  4.164e-011  4.198e-011  4.301e-011  4.324e-011 | 5.641e+001 | 5360 |
| **0.4** | 9.99999999963845e-001  1.99999999995954e+000  2.99999999995718e+000  3.99999999995705e+000  4.99999999995761e+000  5.99999999995872e+000  6.99999999996265e+000  7.99999999995938e+000  8.99999999995886e+000  9.99999999995853e+000  1.09999999999575e+001  1.19999999999573e+001 | 3.615e-011  4.046e-011  4.282e-011  4.295e-011  4.239e-011  4.128e-011  3.735e-011  4.062e-011  4.114e-011  4.147e-011  4.247e-011  4.272e-011 | 5.586e+001 | 3782 |
| **0.5** | 9.99999999964579e-001  1.99999999996035e+000  2.99999999995806e+000  3.99999999995791e+000  4.99999999995848e+000  5.99999999995956e+000  6.99999999996345e+000  7.99999999996024e+000  8.99999999995975e+000  9.99999999995942e+000  1.09999999999585e+001  1.19999999999582e+001 | 3.542e-011  3.965e-011  4.194e-011  4.209e-011  4.152e-011  4.044e-011  3.655e-011  3.976e-011  4.025e-011  4.058e-011  4.153e-011  4.180e-011 | 5.492e+001 | 2836 |
| **0.6** | 9.99999999965400e-001  1.99999999996127e+000  2.99999999995905e+000  3.99999999995887e+000  4.99999999995947e+000  5.99999999996051e+000  6.99999999996434e+000  7.99999999996119e+000  8.99999999996075e+000  9.99999999996042e+000  1.09999999999595e+001  1.19999999999592e+001 | 3.460e-011  3.873e-011  4.095e-011  4.113e-011  4.053e-011  3.949e-011  3.566e-011  3.881e-011  3.925e-011  3.958e-011  4.048e-011  4.077e-011 | 5.365e+001 | 2205 |
| **0.7** | 9.99999999966358e-001  1.99999999996234e+000  2.99999999996020e+000  3.99999999996000e+000  4.99999999996062e+000  5.99999999996161e+000  6.99999999996537e+000  7.99999999996230e+000  8.99999999996190e+000  9.99999999996157e+000  1.09999999999607e+001  1.19999999999604e+001 | 3.364e-011  3.766e-011  3.980e-011  4.000e-011  3.938e-011  3.839e-011  3.463e-011  3.770e-011  3.810e-011  3.843e-011  3.927e-011  3.957e-011 | 5.185e+001 | 1754 |
| **0.8** | 9.99999999968411e-001  1.99999999996463e+000  2.99999999996265e+000  3.99999999996242e+000  4.99999999996305e+000  5.99999999996396e+000  6.99999999996754e+000  7.99999999996465e+000  8.99999999996430e+000  9.99999999996398e+000  1.09999999999632e+001  1.19999999999629e+001 | 3.159e-011  3.537e-011  3.735e-011  3.758e-011  3.695e-011  3.604e-011  3.246e-011  3.535e-011  3.570e-011  3.602e-011  3.676e-011  3.708e-011 | 4.947e+001 | 1417 |
| **0.9** | 9.99999999970371e-001  1.99999999996682e+000  2.99999999996500e+000  3.99999999996474e+000  4.99999999996538e+000  5.99999999996621e+000  6.99999999996961e+000  7.99999999996688e+000  8.99999999996660e+000  9.99999999996630e+000  1.09999999999656e+001  1.19999999999653e+001 | 2.963e-011  3.318e-011  3.500e-011  3.526e-011  3.462e-011  3.379e-011  3.039e-011  3.312e-011  3.340e-011  3.370e-011  3.436e-011  3.470e-011 | 4.637e+001 | 1154 |
| **1.0** | 9.99999999972491e-001  1.99999999996919e+000  2.99999999996753e+000  3.99999999996724e+000  4.99999999996789e+000  5.99999999996864e+000  6.99999999997185e+000  7.99999999996930e+000  8.99999999996909e+000  9.99999999996880e+000  1.09999999999682e+001  1.19999999999679e+001 | 2.751e-011  3.081e-011  3.247e-011  3.276e-011  3.211e-011  3.136e-011  2.815e-011  3.070e-011  3.091e-011  3.120e-011  3.177e-011  3.212e-011 | 4.265e+001 | 943 |
| **1.1** | 9.99999999975104e-001  1.99999999997210e+000  2.99999999997064e+000  3.99999999997033e+000  4.99999999997098e+000  5.99999999997163e+000  6.99999999997460e+000  7.99999999997228e+000  8.99999999997213e+000  9.99999999997186e+000  1.09999999999714e+001  1.19999999999710e+001 | 2.490e-011  2.790e-011  2.936e-011  2.967e-011  2.902e-011  2.837e-011  2.540e-011  2.772e-011  2.787e-011  2.814e-011  2.860e-011  2.896e-011 | 3.833e+001 | 770 |
| **1.2** | 9.99999999978000e-001  1.99999999997534e+000  2.99999999997409e+000  3.99999999997376e+000  4.99999999997440e+000  5.99999999997495e+000  6.99999999997764e+000  7.99999999997557e+000  8.99999999997549e+000  9.99999999997524e+000  1.09999999999749e+001  1.19999999999745e+001 | 2.200e-011  2.466e-011  2.591e-011  2.624e-011  2.560e-011  2.505e-011  2.236e-011  2.443e-011  2.451e-011  2.476e-011  2.511e-011  2.547e-011 | 3.360e+001 | 625 |
| **1.3** | 9.99999999982008e-001  1.99999999997982e+000  2.99999999997885e+000  3.99999999997851e+000  4.99999999997911e+000  5.99999999997952e+000  6.99999999998181e+000  7.99999999998009e+000  8.99999999998008e+000  9.99999999997987e+000  1.09999999999796e+001  1.19999999999793e+001 | 1.799e-011  2.018e-011  2.115e-011  2.149e-011  2.089e-011  2.048e-011  1.819e-011  1.991e-011  1.992e-011  2.014e-011  2.036e-011  2.071e-011 | 2.857e+001 | 502 |
| **1.4** | 9.99999999985339e-001  1.99999999998355e+000  2.99999999998281e+000  3.99999999998246e+000  4.99999999998304e+000  5.99999999998333e+000  6.99999999998528e+000  7.99999999998386e+000  8.99999999998392e+000  9.99999999998373e+000  1.09999999999836e+001  1.19999999999833e+001 | 1.466e-011  1.645e-011  1.719e-011  1.754e-011  1.696e-011  1.667e-011  1.472e-011  1.614e-011  1.608e-011  1.627e-011  1.638e-011  1.673e-011 | 2.321e+001 | 394 |
| **1.5** | 9.99999999988276e-001  1.99999999998683e+000  2.99999999998630e+000  3.99999999998594e+000  4.99999999998651e+000  5.99999999998670e+000  6.99999999998836e+000  7.99999999998719e+000  8.99999999998732e+000  9.99999999998715e+000  1.09999999999872e+001  1.19999999999868e+001 | 1.172e-011  1.317e-011  1.370e-011  1.406e-011  1.349e-011  1.330e-011  1.164e-011  1.281e-011  1.268e-011  1.285e-011  1.285e-011  1.320e-011 | 1.793e+001 | 297 |
| **1.60** | 9.99999999992252e-001  1.99999999999128e+000  2.99999999999101e+000  3.99999999999066e+000  4.99999999999117e+000  5.99999999999124e+000  6.99999999999245e+000  7.99999999999165e+000  8.99999999999183e+000  9.99999999999170e+000  1.09999999999918e+001  1.19999999999915e+001 | 7.748e-012  8.719e-012  8.993e-012  9.337e-012  8.830e-012  8.757e-012  7.547e-012  8.351e-012  8.171e-012  8.299e-012  8.196e-012  8.505e-012 | 1.245e+001 | 207 |
| **1.63** | 9.99999999992842e-001  1.99999999999195e+000  2.99999999999173e+000  3.99999999999134e+000  4.99999999999189e+000  5.99999999999195e+000  6.99999999999309e+000  7.99999999999234e+000  8.99999999999256e+000  9.99999999999243e+000  1.09999999999926e+001  1.19999999999922e+001 | 7.158e-012  8.054e-012  8.268e-012  8.657e-012  8.114e-012  8.051e-012  6.910e-012  7.660e-012  7.436e-012  7.571e-012  7.432e-012  7.752e-012 | 1.071e+001 | 179 |
| **1.64** | 9.99999999995666e-001  1.99999999999478e+000  2.99999999999471e+000  3.99999999999500e+000  4.99999999999499e+000  5.99999999999403e+000  6.99999999999635e+000  7.99999999999541e+000  8.99999999999510e+000  9.99999999999530e+000  1.09999999999954e+001  1.19999999999950e+001 | 4.334e-012  5.222e-012  5.294e-012  4.999e-012  5.011e-012  5.968e-012  3.650e-012  4.592e-012  4.901e-012  4.700e-012  4.555e-012  5.024e-012 | 7.223e+000 | 172 |
| **1.65** | 1.00000000000010e+000  1.99999999999972e+000  2.99999999999977e+000  4.00000000000041e+000  4.99999999999999e+000  5.99999999999886e+000  7.00000000000070e+000  8.00000000000015e+000  8.99999999999961e+000  9.99999999999995e+000  1.10000000000000e+001  1.19999999999997e+001 | 1.048e-013  2.802e-013  2.256e-013  4.068e-013  5.329e-015  1.141e-012  6.999e-013  1.457e-013  3.908e-013  5.329e-014  1.066e-014  2.984e-013 | 6.843e-001 | 188 |
| **1.7** | 1.00000000000016e+000  1.99999999999974e+000  2.99999999999981e+000  4.00000000000049e+000  5.00000000000004e+000  5.99999999999880e+000  7.00000000000085e+000  8.00000000000022e+000  8.99999999999960e+000  9.99999999999998e+000  1.10000000000000e+001  1.19999999999997e+001 | 1.559e-013  2.580e-013  1.945e-013  4.903e-013  4.352e-014  1.202e-012  8.464e-013  2.203e-013  3.979e-013  1.776e-014  4.796e-014  2.984e-013 | 6.742e-001 | 511 |
| **1.8** | -1.57961349315779e+307  2.32634885992287e+307  2.04453792735866e+307  -4.62293804883175e+307  -5.12041388234764e+306  1.15028794581788e+308  -8.89795723705390e+307  -2.35652071058478e+307  4.25442888098962e+307  2.83899888630306e+306  -1.#INF0000000000e+000  -1.#INF0000000000e+000 | 1.580e+307  2.326e+307  2.045e+307  4.623e+307  5.120e+306  1.150e+308  8.898e+307  2.357e+307  4.254e+307  2.839e+306  1.#IOe+000  1.#IOe+000 |  |  |
| **1.9** | -1.67916800424389e+307  2.23415818799801e+307  2.17459624329080e+307  -4.62740261724124e+307  -6.16910743589026e+306  1.16510531387056e+308  -9.82704501535964e+307  -2.66992085312711e+307  4.71348137181744e+307  3.82947666272069e+306  -1.#INF0000000000e+000  -1.#INF0000000000e+000 | 1.679e+307  2.234e+307  2.175e+307  4.627e+307  6.169e+306  1.165e+308  9.827e+307  2.670e+307  4.713e+307  3.829e+306  1.#IOe+000  1.#IOe+000 |  |  |
| **2.0** | -1.73424099698467e+307  2.10450493139757e+307  2.24721014198725e+307  -4.53412971363264e+307  -7.06584726655599e+306  1.15395042037150e+308  -1.05131055218735e+308  -2.91484660877437e+307  5.05722794512632e+307  4.73182686184430e+306  -1.#INF0000000000e+000  -1.#INF0000000000e+000 | 1.734e+307  2.105e+307  2.247e+307  4.534e+307  7.066e+306  1.154e+308  1.051e+308  2.915e+307  5.057e+307  4.732e+306  1.#IOe+000  1.#IOe+000 |  |  |

Сравнение блочной релаксации

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Размер блока |  |  | Кол-во итераций | Оптимальный параметр релаксации |
| 1 | 9.99999999998290e-001  1.99999999999869e+000  2.99999999999788e+000  3.99999999999825e+000  4.99999999999840e+000  5.99999999999863e+000  6.99999999999763e+000  7.99999999999932e+000  8.99999999999809e+000  9.99999999999777e+000  1.09999999999982e+001  1.19999999999984e+001 | 1.710e-012  1.308e-012  2.119e-012  1.749e-012  1.604e-012  1.368e-012  2.373e-012  6.777e-013  1.910e-012  2.231e-012  1.826e-012  1.588e-012 | 365 | 1.60 |
| 2 | 9.99999999995666e-001  1.99999999999478e+000  2.99999999999471e+000  3.99999999999500e+000  4.99999999999499e+000  5.99999999999403e+000  6.99999999999635e+000  7.99999999999541e+000  8.99999999999510e+000  9.99999999999530e+000  1.09999999999954e+001  1.19999999999950e+001 | 4.334e-012  5.222e-012  5.294e-012  4.999e-012  5.011e-012  5.968e-012  3.650e-012  4.592e-012  4.901e-012  4.700e-012  4.555e-012  5.024e-012 | 172 | 1.64 |
| 3 | 9.99999999998287e-001  1.99999999999869e+000  2.99999999999788e+000  3.99999999999825e+000  4.99999999999839e+000  5.99999999999863e+000  6.99999999999762e+000  7.99999999999932e+000  8.99999999999809e+000  9.99999999999776e+000  1.09999999999982e+001  1.19999999999984e+001 | 1.713e-012  1.311e-012  2.122e-012  1.750e-012  1.608e-012  1.375e-012  2.378e-012  6.777e-013  1.915e-012  2.238e-012  1.831e-012  1.593e-012 | 176 | 1.67 |
| 4 | 9.99999999993125e-001  1.99999999999232e+000  2.99999999999202e+000  3.99999999999178e+000  4.99999999999235e+000  5.99999999999260e+000  6.99999999999326e+000  7.99999999999258e+000  8.99999999999292e+000  9.99999999999281e+000  1.09999999999928e+001  1.19999999999926e+001 | 6.875e-012  7.679e-012  7.983e-012  8.222e-012  7.654e-012  7.400e-012  6.738e-012  7.422e-012  7.082e-012  7.189e-012  7.201e-012  7.372e-012 | 174 | 1.66 |
| 6 | 9.99999999993096e-001  1.99999999999213e+000  2.99999999999130e+000  3.99999999999130e+000  4.99999999999125e+000  5.99999999999135e+000  6.99999999999410e+000  7.99999999999316e+000  8.99999999999211e+000  9.99999999999220e+000  1.09999999999918e+001  1.19999999999917e+001 | 6.904e-012  7.874e-012  8.700e-012  8.705e-012  8.747e-012  8.653e-012  5.898e-012  6.838e-012  7.887e-012  7.798e-012  8.233e-012  8.306e-012 | 190 | 1.59 |

Исследования для матрицы с обратным знаком внедиагональных элементов.

Якоби

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | Количество итераций |
| **0.1** | 9.99999999977830e-001  2.00000000002451e+000  2.99999999998354e+000  4.00000000001350e+000  4.99999999999271e+000  5.99999999999776e+000  7.00000000002457e+000  7.99999999997489e+000  9.00000000002074e+000  9.99999999997824e+000  1.10000000000142e+001  1.19999999999889e+001 | 2.217e-011  2.451e-011  1.646e-011  1.350e-011  7.286e-012  2.239e-012  2.457e-011  2.511e-011  2.074e-011  2.176e-011  1.424e-011  1.106e-011 | 2.513e+001 | 3226 |
| **0.2** | 9.99999999977990e-001  2.00000000002433e+000  2.99999999998366e+000  4.00000000001340e+000  4.99999999999277e+000  5.99999999999778e+000  7.00000000002439e+000  7.99999999997507e+000  9.00000000002059e+000  9.99999999997839e+000  1.10000000000141e+001  1.19999999999890e+001 | 2.201e-011  2.433e-011  1.634e-011  1.340e-011  7.234e-012  2.222e-012  2.439e-011  2.493e-011  2.059e-011  2.161e-011  1.413e-011  1.098e-011 | 2.514e+001 | 1607 |
| **0.3** | 9.99999999977992e-001  2.00000000002433e+000  2.99999999998367e+000  4.00000000001340e+000  4.99999999999277e+000  5.99999999999778e+000  7.00000000002439e+000  7.99999999997507e+000  9.00000000002059e+000  9.99999999997839e+000  1.10000000000141e+001  1.19999999999890e+001 | 2.201e-011  2.433e-011  1.633e-011  1.340e-011  7.233e-012  2.222e-012  2.439e-011  2.493e-011  2.059e-011  2.161e-011  1.413e-011  1.098e-011 | 2.513e+001 | 1067 |
| **0.4** | 9.99999999977999e-001  2.00000000002432e+000  2.99999999998367e+000  4.00000000001339e+000  4.99999999999277e+000  5.99999999999778e+000  7.00000000002438e+000  7.99999999997508e+000  9.00000000002058e+000  9.99999999997840e+000  1.10000000000141e+001  1.19999999999890e+001 | 2.200e-011  2.432e-011  1.633e-011  1.339e-011  7.232e-012  2.220e-012  2.438e-011  2.492e-011  2.058e-011  2.160e-011  1.413e-011  1.098e-011 | 2.513e+001 | 797 |
| **0.5** | 9.99999999978010e-001  2.00000000002431e+000  2.99999999998368e+000  4.00000000001339e+000  4.99999999999277e+000  5.99999999999778e+000  7.00000000002437e+000  7.99999999997509e+000  9.00000000002057e+000  9.99999999997841e+000  1.10000000000141e+001  1.19999999999890e+001 | 2.199e-011  2.431e-011  1.632e-011  1.339e-011  7.230e-012  2.218e-012  2.437e-011  2.491e-011  2.057e-011  2.159e-011  1.412e-011  1.098e-011 | 2.514e+001 | 635 |
| **0.6** | 9.99999999978028e-001  2.00000000002429e+000  2.99999999998369e+000  4.00000000001338e+000  4.99999999999278e+000  5.99999999999778e+000  7.00000000002435e+000  7.99999999997511e+000  9.00000000002055e+000  9.99999999997843e+000  1.10000000000141e+001  1.19999999999890e+001 | 2.197e-011  2.429e-011  1.631e-011  1.338e-011  7.223e-012  2.218e-012  2.435e-011  2.489e-011  2.055e-011  2.157e-011  1.411e-011  1.096e-011 | 2.514e+001 | 527 |
| **0.7** | 9.99999999978217e-001  2.00000000002408e+000  2.99999999998383e+000  4.00000000001326e+000  4.99999999999284e+000  5.99999999999780e+000  7.00000000002414e+000  7.99999999997532e+000  9.00000000002038e+000  9.99999999997862e+000  1.10000000000140e+001  1.19999999999891e+001 | 2.178e-011  2.408e-011  1.617e-011  1.326e-011  7.159e-012  2.202e-012  2.414e-011  2.468e-011  2.038e-011  2.138e-011  1.399e-011  1.087e-011 | 2.513e+001 | 450 |
| **0.8** | 9.99999999978079e-001  2.00000000002424e+000  2.99999999998373e+000  4.00000000001335e+000  4.99999999999280e+000  5.99999999999779e+000  7.00000000002429e+000  7.99999999997517e+000  9.00000000002051e+000  9.99999999997848e+000  1.10000000000141e+001  1.19999999999891e+001 | 2.192e-011  2.424e-011  1.627e-011  1.335e-011  7.205e-012  2.212e-012  2.429e-011  2.483e-011  2.051e-011  2.152e-011  1.408e-011  1.094e-011 | 2.514e+001 | 392 |
| **0.9** | 9.99999999978114e-001  2.00000000002420e+000  2.99999999998375e+000  4.00000000001332e+000  4.99999999999281e+000  5.99999999999779e+000  7.00000000002426e+000  7.99999999997521e+000  9.00000000002048e+000  9.99999999997851e+000  1.10000000000141e+001  1.19999999999891e+001 | 2.189e-011  2.420e-011  1.625e-011  1.332e-011  7.194e-012  2.212e-012  2.426e-011  2.479e-011  2.048e-011  2.149e-011  1.405e-011  1.092e-011 | 2.513e+001 | 347 |
| **0.94** | 9.99999999978622e-001  2.00000000002363e+000  2.99999999998413e+000  4.00000000001302e+000  4.99999999999297e+000  5.99999999999784e+000  7.00000000002369e+000  7.99999999997578e+000  9.00000000002000e+000  9.99999999997901e+000  1.10000000000137e+001  1.19999999999893e+001 | 2.138e-011  2.363e-011  1.587e-011  1.302e-011  7.027e-012  2.156e-012  2.369e-011  2.422e-011  2.000e-011  2.099e-011  1.373e-011  1.067e-011 | 2.514e+001 | 332 |
| **0.95** | 9.99999999978047e-001  2.00000000002427e+000  2.99999999998370e+000  4.00000000001337e+000  4.99999999999278e+000  5.99999999999778e+000  7.00000000002433e+000  7.99999999997513e+000  9.00000000002054e+000  9.99999999997845e+000  1.10000000000141e+001  1.19999999999890e+001 | 2.195e-011  2.427e-011  1.630e-011  1.337e-011  7.217e-012  2.215e-012  2.433e-011  2.487e-011  2.054e-011  2.155e-011  1.410e-011  1.096e-011 | 2.515e+001 | 328 |
| **0.96** | 9.99999999983380e-001  2.00000000001903e+000  2.99999999998779e+000  4.00000000001065e+000  4.99999999999478e+000  5.99999999999863e+000  7.00000000001905e+000  7.99999999998117e+000  9.00000000001616e+000  9.99999999998373e+000  1.10000000000112e+001  1.19999999999919e+001 | 1.662e-011  1.903e-011  1.221e-011  1.065e-011  5.215e-012  1.372e-012  1.905e-011  1.883e-011  1.616e-011  1.627e-011  1.121e-011  8.095e-012 | 2.174e+001 | 328 |
| **0.97** | 1.00000000000057e+000  2.00000000000067e+000  3.00000000000068e+000  4.00000000000070e+000  5.00000000000068e+000  6.00000000000066e+000  7.00000000000062e+000  8.00000000000063e+000  9.00000000000068e+000  1.00000000000007e+001  1.10000000000007e+001  1.20000000000007e+001 | 5.655e-013  6.688e-013  6.768e-013  6.972e-013  6.777e-013  6.617e-013  6.217e-013  6.324e-013  6.786e-013  6.555e-013  6.946e-013  6.821e-013 | 9.117e-001 | 418 |
| **1.0** | 1.00000000000059e+000  2.00000000000066e+000  3.00000000000069e+000  4.00000000000069e+000  5.00000000000069e+000  6.00000000000067e+000  7.00000000000061e+000  8.00000000000066e+000  9.00000000000067e+000  1.00000000000007e+001  1.10000000000007e+001  1.20000000000007e+001 | 5.862e-013  6.564e-013  6.919e-013  6.946e-013  6.866e-013  6.706e-013  6.084e-013  6.573e-013  6.697e-013  6.750e-013  6.946e-013  6.910e-013 | 9.120e-001 | 3232 |

Гаусс-Зейдель

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | Количество итераций |
| **0.1** | 9.99999999978020e-001  2.00000000002421e+000  2.99999999998388e+000  4.00000000001318e+000  4.99999999999301e+000  5.99999999999758e+000  7.00000000002431e+000  7.99999999997523e+000  9.00000000002038e+000  9.99999999997866e+000  1.10000000000138e+001  1.19999999999893e+001 | 2.198e-011  2.421e-011  1.612e-011  1.318e-011  6.989e-012  2.418e-012  2.431e-011  2.477e-011  2.038e-011  2.134e-011  1.383e-011  1.069e-011 | 2.468e+001 | 3074 |
| **0.2** | 9.99999999978381e-001  2.00000000002372e+000  2.99999999998436e+000  4.00000000001273e+000  4.99999999999340e+000  5.99999999999740e+000  7.00000000002385e+000  7.99999999997579e+000  9.00000000001985e+000  9.99999999997928e+000  1.10000000000133e+001  1.19999999999898e+001 | 2.162e-011  2.372e-011  1.564e-011  1.273e-011  6.604e-012  2.602e-012  2.385e-011  2.421e-011  1.985e-011  2.072e-011  1.327e-011  1.020e-011 | 2.414e+001 | 1449 |
| **0.3** | 9.99999999978733e-001  2.00000000002322e+000  2.99999999998487e+000  4.00000000001225e+000  4.99999999999382e+000  5.99999999999718e+000  7.00000000002339e+000  7.99999999997635e+000  9.00000000001929e+000  9.99999999997992e+000  1.10000000000127e+001  1.19999999999903e+001 | 2.127e-011  2.322e-011  1.513e-011  1.225e-011  6.181e-012  2.823e-012  2.339e-011  2.365e-011  1.929e-011  2.008e-011  1.268e-011  9.676e-012 | 2.348e+001 | 904 |
| **0.4** | 9.99999999979766e-001  2.00000000002196e+000  2.99999999998591e+000  4.00000000001134e+000  4.99999999999449e+000  5.99999999999701e+000  7.00000000002219e+000  7.99999999997768e+000  9.00000000001809e+000  9.99999999998125e+000  1.10000000000116e+001  1.19999999999912e+001 | 2.023e-011  2.196e-011  1.409e-011  1.134e-011  5.514e-012  2.989e-012  2.219e-011  2.232e-011  1.809e-011  1.875e-011  1.164e-011  8.797e-012 | 2.265e+001 | 630 |
| **0.5** | 9.99999999980222e-001  2.00000000002132e+000  2.99999999998659e+000  4.00000000001070e+000  4.99999999999506e+000  5.99999999999671e+000  7.00000000002160e+000  7.99999999997841e+000  9.00000000001736e+000  9.99999999998208e+000  1.10000000000109e+001  1.19999999999919e+001 | 1.978e-011  2.132e-011  1.341e-011  1.070e-011  4.941e-012  3.293e-012  2.160e-011  2.159e-011  1.736e-011  1.792e-011  1.087e-011  8.106e-012 | 2.161e+001 | 463 |
| **0.6** | 9.99999999981229e-001  2.00000000002006e+000  2.99999999998774e+000  4.00000000000966e+000  4.99999999999588e+000  5.99999999999641e+000  7.00000000002042e+000  7.99999999997976e+000  9.00000000001609e+000  9.99999999998348e+000  1.10000000000097e+001  1.19999999999929e+001 | 1.877e-011  2.006e-011  1.226e-011  9.658e-012  4.120e-012  3.593e-012  2.042e-011  2.024e-011  1.609e-011  1.652e-011  9.706e-012  7.093e-012 | 2.031e+001 | 350 |
| **0.7** | 9.99999999983043e-001  2.00000000001791e+000  2.99999999998954e+000  4.00000000000807e+000  4.99999999999702e+000  5.99999999999615e+000  7.00000000001835e+000  7.99999999998202e+000  9.00000000001405e+000  9.99999999998567e+000  1.10000000000080e+001  1.19999999999944e+001 | 1.696e-011  1.791e-011  1.046e-011  8.067e-012  2.978e-012  3.854e-012  1.835e-011  1.798e-011  1.405e-011  1.433e-011  7.997e-012  5.645e-012 | 1.861e+001 | 267 |
| **0.8** | 9.99999999985170e-001  2.00000000001536e+000  2.99999999999194e+000  4.00000000000589e+000  4.99999999999870e+000  5.99999999999556e+000  7.00000000001597e+000  7.99999999998469e+000  9.00000000001151e+000  9.99999999998836e+000  1.10000000000058e+001  1.19999999999963e+001 | 1.483e-011  1.536e-011  8.058e-012  5.886e-012  1.296e-012  4.436e-012  1.597e-011  1.531e-011  1.151e-011  1.164e-011  5.755e-012  3.684e-012 | 1.599e+001 | 199 |
| **0.9** | 1.00000000001167e+000  1.99999999998840e+000  3.00000000000436e+000  3.99999999999751e+000  4.99999999999866e+000  6.00000000000539e+000  6.99999999998749e+000  8.00000000001141e+000  8.99999999999227e+000  1.00000000000077e+001  1.09999999999976e+001  1.20000000000008e+001 | 1.167e-011  1.160e-011  4.364e-012  2.493e-012  1.339e-012  5.392e-012  1.251e-011  1.141e-011  7.725e-012  7.715e-012  2.437e-012  7.585e-013 | 1.195e+001 | 151 |
| **1.0** | 9.99999999991906e-001  2.00000000000758e+000  2.99999999999854e+000  4.00000000000004e+000  5.00000000000278e+000  5.99999999999481e+000  7.00000000000852e+000  7.99999999999272e+000  9.00000000000426e+000  9.99999999999589e+000  1.10000000000000e+001  1.20000000000011e+001 | 8.094e-012  7.584e-012  1.458e-012  4.441e-014  2.782e-012  5.194e-012  8.518e-012  7.283e-012  4.258e-012  4.109e-012  2.132e-014  1.128e-012 | 8.970e+000 | 126 |
| **1.1** | 1.00000000000676e+000  1.99999999999449e+000  2.99999999999851e+000  4.00000000000288e+000  4.99999999999449e+000  6.00000000000679e+000  6.99999999999320e+000  8.00000000000496e+000  8.99999999999834e+000  1.00000000000013e+001  1.10000000000028e+001  1.19999999999963e+001 | 6.757e-012  5.512e-012  1.488e-012  2.876e-012  5.506e-012  6.795e-012  6.803e-012  4.965e-012  1.663e-012  1.318e-012  2.782e-012  3.698e-012 | 6.579e+000 | 106 |
| **1.2** | 1.00000000001350e+000  1.99999999998605e+000  3.00000000001062e+000  3.99999999999101e+000  5.00000000000492e+000  6.00000000000111e+000  6.99999999998631e+000  8.00000000001364e+000  8.99999999998829e+000  1.00000000000112e+001  1.09999999999928e+001  1.20000000000058e+001 | 1.350e-011  1.395e-011  1.062e-011  8.991e-012  4.916e-012  1.108e-012  1.369e-011  1.364e-011  1.171e-011  1.118e-011  7.239e-012  5.771e-012 | 1.549e+001 | 93 |
| **1.28** | 9.99999999996105e-001  2.00000000000237e+000  3.00000000000200e+000  3.99999999999712e+000  5.00000000000457e+000  5.99999999999511e+000  7.00000000000324e+000  7.99999999999829e+000  8.99999999999975e+000  1.00000000000008e+001  1.09999999999969e+001  1.20000000000034e+001 | 3.895e-012  2.373e-012  2.004e-012  2.880e-012  4.566e-012  4.890e-012  3.237e-012  1.712e-012  2.487e-013  8.296e-013  3.148e-012  3.443e-012 | 5.289e+000 | 87 |
| **1.29** | 1.00000000000090e+000  1.99999999999678e+000  3.00000000000775e+000  3.99999999999178e+000  5.00000000000862e+000  5.99999999999380e+000  6.99999999999809e+000  8.00000000000398e+000  8.99999999999424e+000  1.00000000000063e+001  1.09999999999924e+001  1.20000000000073e+001 | 9.031e-013  3.220e-012  7.752e-012  8.219e-012  8.616e-012  6.198e-012  1.910e-012  3.979e-012  5.759e-012  6.262e-012  7.590e-012  7.301e-012 | 9.471e+000 | 85 |
| **1.3** | 1.00000000001161e+000  1.99999999998834e+000  3.00000000000851e+000  3.99999999999293e+000  5.00000000000339e+000  6.00000000000169e+000  6.99999999998844e+000  8.00000000001123e+000  8.99999999999061e+000  1.00000000000087e+001  1.09999999999949e+001  1.20000000000039e+001 | 1.161e-011  1.166e-011  8.506e-012  7.068e-012  3.395e-012  1.693e-012  1.156e-011  1.123e-011  9.390e-012  8.674e-012  5.102e-012  3.885e-012 | 1.234e+001 | 86 |
| **1.4** | 9.99999999995565e-001  2.00000000000257e+000  3.00000000000120e+000  3.99999999999788e+000  5.00000000000409e+000  5.99999999999526e+000  7.00000000000328e+000  7.99999999999831e+000  8.99999999999994e+000  1.00000000000010e+001  1.09999999999968e+001  1.20000000000034e+001 | 4.435e-012  2.570e-012  1.203e-012  2.119e-012  4.091e-012  4.743e-012  3.284e-012  1.692e-012  5.684e-014  1.027e-012  3.183e-012  3.356e-012 | 4.315e+000 | 88 |
| **1.5** | 9.99999999999329e-001  1.99999999999859e+000  2.99999999999935e+000  3.99999999999959e+000  5.00000000000130e+000  6.00000000000033e+000  7.00000000000316e+000  8.00000000000314e+000  9.00000000000027e+000  9.99999999999885e+000  1.09999999999991e+001  1.20000000000000e+001 | 6.707e-013  1.411e-012  6.510e-013  4.143e-013  1.297e-012  3.251e-013  3.161e-012  3.139e-012  2.736e-013  1.153e-012  9.450e-013  3.553e-014 | 2.050e+000 | 117 |
| **1.6** | 1.00000000000004e+000  2.00000000000121e+000  3.00000000000118e+000  3.99999999999982e+000  4.99999999999858e+000  5.99999999999867e+000  6.99999999999753e+000  7.99999999999778e+000  8.99999999999925e+000  1.00000000000016e+001  1.10000000000009e+001  1.20000000000004e+001 | 3.575e-014  1.205e-012  1.175e-012  1.799e-013  1.423e-012  1.330e-012  2.473e-012  2.223e-012  7.532e-013  1.581e-012  8.562e-013  4.299e-013 | 1.859e+000 | 292 |
| **1.7** | -2.86601830547831e+151  -4.96732218618438e+152  -4.14074752460420e+152  5.56222123762125e+151  5.72442478403564e+152  5.22168532074430e+152  1.05599996012644e+153  8.96551813461180e+152  2.93793610090015e+152  -6.53821377022463e+152  -3.28276679149781e+152  -1.67446637765677e+152 | 2.866e+151  4.967e+152  4.141e+152  5.562e+151  5.724e+152  5.222e+152  1.056e+153  8.966e+152  2.938e+152  6.538e+152  3.283e+152  1.674e+152 |  |  |
| **1.8** | -3.77394436746205e+151  -5.01039573126385e+152  -3.61730815039688e+152  4.39107591673701e+151  5.64252868498592e+152  5.06569254785303e+152  1.09918212913669e+153  8.85272227834646e+152  2.79855902505120e+152  -6.57246345299715e+152  -3.15879381841801e+152  -1.59536830381661e+152 | 3.774e+151  5.010e+152  3.617e+152  4.391e+151  5.643e+152  5.066e+152  1.099e+153  8.853e+152  2.799e+152  6.572e+152  3.159e+152  1.595e+152 |  |  |
| **1.9** | 4.45287816283512e+151  5.07635511129325e+152  3.20655017943854e+152  -3.67220929939464e+151  -5.60004970796642e+152  -4.98264576121974e+152  -1.14889003073361e+153  -8.76905128417020e+152  -2.68253941768216e+152  6.61398019749087e+152  3.11065137358670e+152  1.53950004153160e+152 | 4.453e+151  5.076e+152  3.207e+152  3.672e+151  5.600e+152  4.983e+152  1.149e+153  8.769e+152  2.683e+152  6.614e+152  3.111e+152  1.540e+152 |  |  |
| **2.0** | -5.80067534373974e+151  -5.91728241593481e+152  -3.30655306602920e+152  3.81068309547053e+151  6.40548751067020e+152  5.69012310539421e+152  1.38257433861468e+153  9.97766135550588e+152  2.97495476038481e+152  -7.64969425833208e+152  -3.57976432943721e+152  -1.72180460351747e+152 | 5.801e+151  5.917e+152  3.307e+152  3.811e+151  6.405e+152  5.690e+152  1.383e+153  9.978e+152  2.975e+152  7.650e+152  3.580e+152  1.722e+152 |  |  |

Блочная релаксация

Размер блока = 6

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | Количество итераций |
| **0.1** | 9.99999999981461e-001  2.00000000002082e+000  2.99999999998800e+000  4.00000000000990e+000  4.99999999999587e+000  5.99999999999583e+000  7.00000000002141e+000  7.99999999997886e+000  9.00000000001656e+000  9.99999999998303e+000  1.10000000000097e+001  1.19999999999928e+001 | 1.854e-011  2.082e-011  1.200e-011  9.903e-012  4.131e-012  4.172e-012  2.141e-011  2.114e-011  1.656e-011  1.697e-011  9.665e-012  7.240e-012 | 2.045e+001 | 1743 |
| **0.2** | 9.99999999981867e-001  2.00000000002037e+000  2.99999999998827e+000  4.00000000000969e+000  4.99999999999596e+000  5.99999999999592e+000  7.00000000002076e+000  7.99999999997949e+000  9.00000000001606e+000  9.99999999998354e+000  1.10000000000094e+001  1.19999999999930e+001 | 1.813e-011  2.037e-011  1.173e-011  9.688e-012  4.042e-012  4.079e-012  2.076e-011  2.051e-011  1.606e-011  1.646e-011  9.376e-012  7.025e-012 | 2.026e+001 | 827 |
| **0.3** | 9.99999999982009e-001  2.00000000002021e+000  2.99999999998836e+000  4.00000000000961e+000  4.99999999999599e+000  5.99999999999595e+000  7.00000000002040e+000  7.99999999997984e+000  9.00000000001578e+000  9.99999999998382e+000  1.10000000000092e+001  1.19999999999931e+001 | 1.799e-011  2.021e-011  1.164e-011  9.614e-012  4.014e-012  4.047e-012  2.040e-011  2.016e-011  1.578e-011  1.618e-011  9.210e-012  6.908e-012 | 1.998e+001 | 521 |
| **0.4** | 9.99999999982545e-001  2.00000000001961e+000  2.99999999998870e+000  4.00000000000933e+000  4.99999999999611e+000  5.99999999999608e+000  7.00000000001959e+000  7.99999999998065e+000  9.00000000001515e+000  9.99999999998447e+000  1.10000000000088e+001  1.19999999999934e+001 | 1.746e-011  1.961e-011  1.130e-011  9.328e-012  3.895e-012  3.924e-012  1.959e-011  1.935e-011  1.515e-011  1.553e-011  8.844e-012  6.633e-012 | 1.960e+001 | 368 |
| **0.5** | 9.99999999983272e-001  2.00000000001879e+000  2.99999999998917e+000  4.00000000000894e+000  4.99999999999627e+000  5.99999999999624e+000  7.00000000001855e+000  7.99999999998168e+000  9.00000000001435e+000  9.99999999998530e+000  1.10000000000084e+001  1.19999999999937e+001 | 1.673e-011  1.879e-011  1.083e-011  8.939e-012  3.730e-012  3.762e-012  1.855e-011  1.832e-011  1.435e-011  1.470e-011  8.374e-012  6.279e-012 | 1.909e+001 | 276 |
| **0.6** | 9.99999999983296e-001  2.00000000001876e+000  2.99999999998919e+000  4.00000000000893e+000  4.99999999999627e+000  5.99999999999624e+000  7.00000000001826e+000  7.99999999998196e+000  9.00000000001413e+000  9.99999999998552e+000  1.10000000000082e+001  1.19999999999938e+001 | 1.670e-011  1.876e-011  1.081e-011  8.925e-012  3.726e-012  3.757e-012  1.826e-011  1.804e-011  1.413e-011  1.448e-011  8.246e-012  6.182e-012 | 1.843e+001 | 214 |
| **0.7** | 9.99999999984814e-001  2.00000000001706e+000  2.99999999999017e+000  4.00000000000811e+000  4.99999999999661e+000  5.99999999999659e+000  7.00000000001633e+000  7.99999999998387e+000  9.00000000001263e+000  9.99999999998706e+000  1.10000000000074e+001  1.19999999999945e+001 | 1.519e-011  1.706e-011  9.828e-012  8.114e-012  3.388e-012  3.414e-012  1.633e-011  1.613e-011  1.263e-011  1.294e-011  7.372e-012  5.528e-012 | 1.758e+001 | 170 |
| **0.8** | 9.99999999984587e-001  2.00000000001731e+000  2.99999999999003e+000  4.00000000000824e+000  4.99999999999656e+000  5.99999999999653e+000  7.00000000001625e+000  7.99999999998395e+000  9.00000000001257e+000  9.99999999998712e+000  1.10000000000073e+001  1.19999999999945e+001 | 1.541e-011  1.731e-011  9.975e-012  8.235e-012  3.437e-012  3.467e-012  1.625e-011  1.605e-011  1.257e-011  1.288e-011  7.336e-012  5.500e-012 | 1.655e+001 | 136 |
| **0.9** | 9.99999999987294e-001  2.00000000001427e+000  2.99999999999178e+000  4.00000000000679e+000  4.99999999999717e+000  5.99999999999714e+000  7.00000000001307e+000  7.99999999998709e+000  9.00000000001011e+000  9.99999999998964e+000  1.10000000000059e+001  1.19999999999956e+001 | 1.271e-011  1.427e-011  8.223e-012  6.789e-012  2.834e-012  2.857e-012  1.307e-011  1.291e-011  1.011e-011  1.036e-011  5.901e-012  4.423e-012 | 1.527e+001 | 110 |
| **1.0** | 9.99999999987774e-001  2.00000000001373e+000  2.99999999999209e+000  4.00000000000653e+000  4.99999999999727e+000  5.99999999999725e+000  7.00000000001219e+000  7.99999999998796e+000  9.00000000000943e+000  9.99999999999034e+000  1.10000000000055e+001  1.19999999999959e+001 | 1.223e-011  1.373e-011  7.912e-012  6.532e-012  2.727e-012  2.751e-012  1.219e-011  1.204e-011  9.429e-012  9.663e-012  5.503e-012  4.125e-012 | 1.377e+001 | 88 |
| **1.1** | 9.99999999991430e-001  2.00000000000963e+000  2.99999999999445e+000  4.00000000000458e+000  4.99999999999809e+000  5.99999999999807e+000  7.00000000000818e+000  7.99999999999192e+000  9.00000000000633e+000  9.99999999999351e+000  1.10000000000037e+001  1.19999999999972e+001 | 8.570e-012  9.626e-012  5.546e-012  4.580e-012  1.911e-012  1.927e-012  8.184e-012  8.083e-012  6.329e-012  6.487e-012  3.693e-012  2.769e-012 | 1.198e+001 | 70 |
| **1.2** | 9.99999999992716e-001  2.00000000000818e+000  2.99999999999529e+000  4.00000000000389e+000  4.99999999999838e+000  5.99999999999836e+000  7.00000000000651e+000  7.99999999999357e+000  9.00000000000503e+000  9.99999999999484e+000  1.10000000000029e+001  1.19999999999978e+001 | 7.284e-012  8.180e-012  4.711e-012  3.888e-012  1.620e-012  1.642e-012  6.507e-012  6.425e-012  5.032e-012  5.159e-012  2.935e-012  2.199e-012 | 9.839e+000 | 53 |
| **1.27** | 9.99999999994741e-001  2.00000000000598e+000  2.99999999999625e+000  4.00000000000302e+000  4.99999999999885e+000  5.99999999999828e+000  7.00000000000401e+000  7.99999999999578e+000  9.00000000000368e+000  9.99999999999632e+000  1.10000000000020e+001  1.19999999999987e+001 | 5.259e-012  5.979e-012  3.751e-012  3.017e-012  1.154e-012  1.724e-012  4.012e-012  4.221e-012  3.681e-012  3.679e-012  1.950e-012  1.311e-012 | 7.621e+000 | 41 |
| **1.28** | 9.99999999996074e-001  2.00000000000391e+000  2.99999999999985e+000  4.00000000000069e+000  4.99999999999896e+000  6.00000000000290e+000  7.00000000000537e+000  7.99999999999651e+000  9.00000000000010e+000  9.99999999999923e+000  1.10000000000015e+001  1.19999999999978e+001 | 3.926e-012  3.910e-012  1.457e-013  6.892e-013  1.041e-012  2.903e-012  5.365e-012  3.487e-012  1.013e-013  7.656e-013  1.450e-012  2.196e-012 | 4.234e+000 | 40 |
| **1.29** | 9.99999999998755e-001  2.00000000000095e+000  3.00000000000131e+000  3.99999999999942e+000  4.99999999999958e+000  6.00000000000307e+000  7.00000000000299e+000  7.99999999999867e+000  8.99999999999868e+000  1.00000000000008e+001  1.10000000000005e+001  1.19999999999986e+001 | 1.245e-012  9.535e-013  1.315e-012  5.840e-013  4.237e-013  3.072e-012  2.995e-012  1.327e-012  1.323e-012  7.603e-013  4.814e-013  1.354e-012 | 2.832e+000 | 42 |
| **1.3** | 9.99999999998903e-001  2.00000000000081e+000  3.00000000000132e+000  3.99999999999939e+000  4.99999999999961e+000  6.00000000000297e+000  7.00000000000284e+000  7.99999999999878e+000  8.99999999999865e+000  1.00000000000008e+001  1.10000000000004e+001  1.19999999999987e+001 | 1.097e-012  8.082e-013  1.322e-012  6.093e-013  3.890e-013  2.974e-012  2.838e-012  1.219e-012  1.346e-012  8.011e-013  4.370e-013  1.293e-012 | 2.799e+000 | 44 |
| **1.4** | 1.00000000000127e+000  1.99999999999907e+000  2.99999999999849e+000  4.00000000000070e+000  5.00000000000045e+000  5.99999999999659e+000  6.99999999999630e+000  8.00000000000159e+000  9.00000000000175e+000  9.99999999999896e+000  1.09999999999994e+001  1.20000000000017e+001 | 1.266e-012  9.328e-013  1.514e-012  6.981e-013  4.459e-013  3.409e-012  3.697e-012  1.588e-012  1.746e-012  1.037e-012  5.684e-013  1.688e-012 | 2.780e+000 | 73 |
| **1.5** | 9.99999999998843e-001  2.00000000000085e+000  3.00000000000139e+000  3.99999999999936e+000  4.99999999999959e+000  6.00000000000312e+000  7.00000000000374e+000  7.99999999999840e+000  8.99999999999823e+000  1.00000000000011e+001  1.10000000000006e+001  1.19999999999983e+001 | 1.157e-012  8.527e-013  1.393e-012  6.439e-013  4.077e-013  3.125e-012  3.741e-012  1.604e-012  1.775e-012  1.055e-012  5.702e-013  1.707e-012 | 2.757e+000 | 158 |
| **1.6** | 9.99999999998769e-001  2.00000000000091e+000  3.00000000000148e+000  3.99999999999932e+000  4.99999999999957e+000  6.00000000000332e+000  7.00000000000433e+000  7.99999999999814e+000  8.99999999999794e+000  1.00000000000012e+001  1.10000000000007e+001  1.19999999999980e+001 | 1.231e-012  9.077e-013  1.480e-012  6.812e-013  4.317e-013  3.318e-012  4.330e-012  1.857e-012  2.057e-012  1.222e-012  6.608e-013  1.966e-012 | 2.738e+000 | 5552 |
| **1.7** | -2.65075512086026e+307  1.94995215138869e+307  3.20010126667670e+307  -1.47553449091130e+307  -9.35328160738311e+306  7.17803538437967e+307  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000 | 2.651e+307  1.950e+307  3.200e+307  1.476e+307  9.353e+306  7.178e+307  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000 |  |  |
| **1.8** | -2.73384514400753e+307  2.01107494923595e+307  3.30041098077638e+307  -1.52178629064927e+307  -9.64646764299401e+306  7.40303660065438e+307  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000 | 2.734e+307  2.011e+307  3.300e+307  1.522e+307  9.646e+306  7.403e+307  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000 |  |  |
| **1.9** | 3.13897700249927e+307  -2.30909860779468e+307  -3.78950292417315e+307  1.74730166393564e+307  1.10759894916082e+307  -8.50010165683710e+307  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000 | 3.139e+307  2.309e+307  3.790e+307  1.747e+307  1.108e+307  8.500e+307  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000 |  |  |
| **2.0** | -2.27710651424598e+307  1.67508824615762e+307  2.74901720768211e+307  -1.26754417064310e+307  -8.03484950765167e+306  6.16622448623415e+307  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000  -1.#IND0000000000e+000 | 2.277e+307  1.675e+307  2.749e+307  1.268e+307  8.035e+306  6.166e+307  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000  -1.#IOe+000 |  |  |

Сравнение блочной релаксации

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Размер блока |  |  | Кол-во итераций | Оптимальный параметр релаксации |
| 1 | 1.00000000000090e+000  1.99999999999679e+000  3.00000000000775e+000  3.99999999999178e+000  5.00000000000861e+000  5.99999999999380e+000  6.99999999999809e+000  8.00000000000397e+000  8.99999999999424e+000  1.00000000000063e+001  1.09999999999924e+001  1.20000000000073e+001 | 9.017e-013  3.215e-012  7.746e-012  8.218e-012  8.614e-012  6.198e-012  1.910e-012  3.974e-012  5.755e-012  6.258e-012  7.589e-012  7.304e-012 | 85 | 1.29 |
| 2 | 9.99999999999519e-001  2.00000000000098e+000  3.00000000000373e+000  3.99999999999623e+000  5.00000000000412e+000  5.99999999999606e+000  6.99999999999830e+000  8.00000000000147e+000  8.99999999999654e+000  1.00000000000033e+001  1.09999999999961e+001  1.20000000000038e+001 | 4.812e-013  9.770e-013  3.730e-012  3.770e-012  4.125e-012  3.943e-012  1.700e-012  1.469e-012  3.464e-012  3.324e-012  3.890e-012  3.810e-012 | 42 | 1.30 |
| 3 | 1.00000000000014e+000  1.99999999999963e+000  3.00000000000019e+000  3.99999999999987e+000  4.99999999999993e+000  5.99999999999939e+000  7.00000000000109e+000  7.99999999999902e+000  9.00000000000009e+000  1.00000000000005e+001  1.10000000000003e+001  1.19999999999998e+001 | 1.412e-013  3.750e-013  1.887e-013  1.252e-013  7.105e-014  6.093e-013  1.094e-012  9.788e-013  9.415e-014  4.530e-013  2.665e-013  2.203e-013 | 46 | 1.35 |
| 4 | 9.99999999996110e-001  2.00000000000539e+000  2.99999999999623e+000  4.00000000000260e+000  4.99999999999825e+000  6.00000000000170e+000  7.00000000000167e+000  7.99999999999723e+000  9.00000000000371e+000  9.99999999999648e+000  1.10000000000020e+001  1.19999999999982e+001 | 3.890e-012  5.391e-012  3.773e-012  2.601e-012  1.755e-012  1.701e-012  1.665e-012  2.769e-012  3.705e-012  3.523e-012  2.018e-012  1.783e-012 | 45 | 1.41 |
| 6 | 9.99999999996074e-001  2.00000000000391e+000  2.99999999999985e+000  4.00000000000069e+000  4.99999999999896e+000  6.00000000000290e+000  7.00000000000537e+000  7.99999999999651e+000  9.00000000000010e+000  9.99999999999923e+000  1.10000000000015e+001  1.19999999999978e+001 | 3.926e-012  3.910e-012  1.457e-013  6.892e-013  1.041e-012  2.903e-012  5.365e-012  3.487e-012  1.013e-013  7.656e-013  1.450e-012  2.196e-012 | 40 | 1.28 |

1. Вывод

При исследовании зависимости скорости сходимости от параметра релаксации было выявлено, что решение плавно сходится к искомому, а затем начинает быстро расходиться. Однако скорости сходимости определяются самими матрицами.

Исследуя матрицы на число обусловленности было выявлено, что чем меньше число обусловленности, тем быстрее сходится решение.

Лучший размер блока, в методе блочной релаксации определяется видом матрицы, в исследованиях, наилучшим оказался размер блока равный 2.