# DISERTASI

# PENGEMBANGAN STABILITAS NANOFLUIDA MELALUI METODE TERMOAKUSTIK PADA PENUKAR KALOR

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**UNIVERSITAS SRIWIJAYA**

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## HALAMAN PENGESAHAN

# PENGEMBANGAN STABILITAS NANOFLUIDA MELALUI METODE TERMOAKUSTIK PADA PENUKAR KALOR

**DISERTASI**

Diajukan untuk Melengkapi Salah Satu Syarat Memperoleh Gelar Doktor
dalam Bidang Ilmu Teknik Mesin


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Palembang, Agustus 2023

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# HALAMAN PERSETUJUAN

Disertasi berjudul "**Pengembangan Stabilitas Nanofluida Melalui Metode Termoakustik pada Penukar Kalor**" telah dipertahankan di hadapan tim penguji pada ujian Disertasi Program Doktor Fakultas Teknik Universitas Sriwijaya pada hari Jumat tanggal 11 Agustus 2023.

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## KATA PENGANTAR

Alhamdulillah karena limpahan rahmat Allah SWT penulis dapat menyelesaikan disertasi dengan judul "**Pengembangan Stabilitas Nanofluida Melalui Metode Termoakustik pada Penukar Kalor**" yang merupakan salah satu persyaratan untuk menyelesaikan studi Doktor Ilmu Teknik pada Fakultas Teknik Universitas Sriwijaya.

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Semoga disertasi ini dapat menjadi amal jariah bagi penulis dan bermanfaat bagi para pembaca.

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Astuti

## RINGKASAN

PENGEMBANGAN STABILITAS NANOFLUIDA MELALUI METODE TERMOAKUSTIK PADA PENUKAR KALOR

Karya Tulis Ilmiah berupa Disertasi, Agustus 2023

Astuti, Prof. Dr. Ir. Kaprawi, DEA dan Dr. RR. Sri Poernomo Sari, S.T., M.T.

iv+ 188 halaman, 58 Gambar, 25 Tabel.

Nanofluida merupakan dua campuran fase dimana fase yang biasanya cairan dan fase yang terdispersi terdiri dari nanopartikel padat yang sangat halus, berukuran lebih kecil daripada 100 nm. Penelitian dalam bidang nanofluida banyak dilakukan khususnya dalam aplikasinya sebagai pendingin dalam sistem penukar panas (heat exchanger). Nanofluida memiliki sifat–sifat yang berbeda dengan fluida dasarnya sehingga memilki potensi untuk dapat dimanfaatkan khususnya di bidang perpindahan panas. Stabilitas nanofluida merupakan suatu kondisi dimana belum terjadi aglomerasi dan sedimentasi karena nanopartikel melayang pada fluida dasarnya akibat gerak Brown. Aglomerasi dapat berdampak buruk karena dapat menyebabkan penurunan kemampuan nanofluida dalam menghantarkan panas, sehingga akan mengakibatkan penurunan nilai koefisien konveksi pada penukar kalor pipa ganda. Termoakustik adalah suatu bidang yang berhubungan dengan fenomena fisis di mana perbedaan suhu dapat membangkitkan gelombang bunyi, dan sebaliknya gelombang bunyi dapat menghasilkan perbedaan suhu. Pemakaian metode termoakustik dengan sonikasi gelombang akustik terbukti dapat menstabilkan dari efek gerak Brown di dalam aliran nanofluida. Hasil yang paling maksimal diperoleh dengan menggunakan gelombang akustik pada frekuensi 1000 Hz pada temperatur yang tinggi.



**Kata kunci**: Nanofluida, stabilitas, metode termoakustik.



## SUMMARY

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Astuti, Prof. Dr. Ir. Kaprawi, DEA dan Dr. RR. Sri Poernomo Sari, S.T., M.T.

iv+ 188 pages, 58 pictures, 25 Tables.

Nanofluids are a mixture of two phases where the phase is usually a liquid and the dispersed phase consists of very fine solid nanoparticles, smaller than 100 nm. Much research has been carried out in the field of nanofluids, especially in their

application as coolants in heat exchanger systems. Nanofluids have different properties from basic fluids so they have the potential to be utilized, especially in the field of heat transfer. Nanofluid stability is a condition where agglomeration and sedimentation have not occurred because the nanoparticles float in the underlying fluid due to Brownian motion. Agglomeration can have a bad impact because it can cause a decrease in the ability of nanofluids to conduct heat, which will result in a decrease in the convection coefficient value in the double pipe heat exchanger. Thermoacoustics is a field related to physical phenomena where temperature differences can generate sound waves, and conversely sound waves can produce temperature differences. The use of the thermoacoustic method with acoustic wave sonication has been proven to be able to stabilize the effects of Brownian motion in nanofluid flows. The maximum results are obtained by using acoustic waves at a frequency of 1000 Hz at high temperatures.

**Keywords**: Nanofluids, stability, thermoacoustic methods

Palembang, Agustus 2023

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Menyatakan bahwa Disertasi saya merupakan hasil karya sendiri didampingi oleh Promotor dan Ko Promotor. Apabila ditemukan Unsur Penjiplakan/ Plagiat dalam Disertasi ini, saya bersedia menerima sanksi akademik yang berlaku dari Universitas Sriwijaya.

Demikian pernyataan ini dibuat dengan sesungguhnya dan dengan sebenarnya.

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# DAFTAR ISI

# DAFTAR GAMBAR

# DAFTAR TABEL

# BAB 1

# PENDAHULUAN

## 1.1 Latar Belakang

Kemajuan teknologi industri saat ini yang makin meningkat akan memberikan dampak di dalam dunia industri. Industri yang memanfaatkan fenomena perpindahan kalor memanfaatkan teknologi yang mampu meningkatkan produktifitas dan efisiensi. Perpindahan kalor memegang peranan penting dalam banyak aplikasi. Heat exchanger, evaporator, condensor dan heat sink adalah peralatan yang menggunakan prinsip perpindahan kalor. Dalam dunia industri fenomena perpindahan kalor dimanfaatkan untuk suatu proses perpindahan kalor dengan menggunakan alat yang disebut heat exchanger atau alat penukar kalor [1].

Perkembangan ilmu pengetahuan dan teknologi yang semakin pesat, ditandai dengan kecenderungan dimensi produk yang semakin kecil sekaligus peningkatan kemampuan perpindahan kalor yang tinggi sehingga fluks kalor yang dibangkitkan juga meningkat. Selama ini metode yang digunakan untuk mengatasi masalah pendinginan adalah dengan meningkatkan luas permukaan seperti sirip atau meningkatkan laju aliran fluida pendingin. Pada perpindahan kalor dengan intensitas tinggi hal tersebut mempunyai keterbatasan karena diperlukan luasan dan daya yang besar. Oleh karena itu, dibutuhkan sistem perpindahan kalor yang efisien dengan kemampuan yang tinggi [2].

Sifat termal dari fluida kerja memegang peran penting dalam upaya efisiensi energi pada peralatan perpindahan kalor. Fluida yang digunakan pada perpindahan kalor antara lain seperti air, ethylene glycol dan minyak pelumas mesin, secara umum memiliki sifat perpindahan kalor yang sangat rendah dibandingkan dengan kebanyakan benda padat. Sehingga dalam hal ini perlu adanya pengembangan untuk meningkatkan sifat perpindahan kalor fluida konvensional tersebut [3].

Salah satu cara yang dapat dilakukan untuk meningkatkan perpindahan kalor adalah memperbaiki sifat fluida pendingin, khususnya konduktivitas termal. Pada umumnya fluida yang digunakan memiliki konduktivitas termal yang rendah. Dengan menambahkan partikel padat ukuran nanometer diharapkan dapat memperbaiki sifat fluida tersebut [4].

Istilah nanofluida pertama kali diperkenalkan oleh Choi pada tahun 1995, yang didefinisikan sebagai fluida dasar yang ditambahkan partikel padat ukuran nanometer yang berfungsi untuk memperbaiki sifat fluida. Nanofluida merupakan dua campuran fase dimana fase yang biasanya cairan dan fase yang terdispersi terdiri dari nanopartikel padat yang sangat halus, berukuran lebih kecil daripada 100 nm [5].

Perkembangan teknologi material telah mampu memproduksi partikel dalam ukuran nanometer sehingga diharapkan partikel yang dicampurkan dalam fluida cair akan tersuspensi lebih baik, seperti dilakukan oleh Choi [6] yang mencampurkan partikel CuO dan $Al_2O_3$ dalam ukuran nanometer dengan fluida cair diantaranya air dan ethylene. Dari hasil penelitian diperoleh peningkatan perpindahan kalor konduksinya sebesar 20%.

Kemudian Eastman,et.al [7] menyatakan dari hasil penelitiannya diperoleh peningkatan sebesar 40% pada konduktivitas termal hanya dengan menambahkan 0,3% partikel Cu pada ethylene glycol.

Penelitian di atas telah banyak menginspirasi penelitian lebih lanjut terhadap sifat-sifat termal nanofluida serta untuk meyakinkan bahwa nanofluida sebagai media perpindahan kalor perlu diperhitungkan prospeknya.

Dalam perkembangannya saat ini dibutuhkan penukar kalor yang mempunyai bentuk kompak namun dengan perpindahan kalor yang tinggi. Hal tersebut dapat dicapai dengan menggunakan fluida kerja yang memiliki transfer kalor yang baik, yaitu dengan melakukan penambahan nanopartikel pada fluida dasar yang digunakan [8]. Penukar kalor yang digunakan pada penelitian ini adalah heat exchanger tipe counter flow yang merupakan pola aliran paling efisien. Diharapkan

tipe ini akan memberikan koefisien perpindahan kalor tertinggi keseluruhan untuk desain penukar kalor pipa ganda.

Nanopartikel adalah partikel yang berukuran antara 1-100 nanometer. Dalam nanoteknologi, suatu partikel didefinisikan sebagai objek kecil yang berperilaku sebagai satu kesatuan terhadap sifat dan transportasinya. Nanopartikel memiliki karakteristik yang berbeda-beda tergantung dari jenis, ukuran dan konsentrasi pencampuran dengan fluida lain. Konsentrasi dengan fraksi volume tertentu akan mempengaruhi dari karakteristik nanopartikel tersebut [9].

Proses pencampurannya dapat dilakukan dengan menggunakan magnetic stirer, yang akan mempengaruhi karakteristik nanopartikel tersebut. Tumbukan pada proses pencampuran tersebut akan mengalami suatu gejala momentum yang berbeda-beda sesuai kadar waktu dan jumlah pada proses pencampuran tersebut.

Proses pencampuran nanopartikel dengan fluida air juga akan menghasilkan efek gerak Brown di dalam nanofluida tersebut. Efek gerak Brown ini membuat partikel melayang di dalam fluida dalam waktu tertentu [10]. Dengan adanya efek gerak Brown ini partikel juga akan lebih banyak menyerap panas sehingga perlu dijaga kestabilannya agar tidak cepat terjadi aglomerasi.

Aglomerasi itu sendiri merupakan proses pengendapan partikel atau penggumpalan antar partikel yang disebabkan adanya gaya tarik menarik antar partikel tersebut. Sehingga menyebabkan adanya sebuah pengendapan yang terjadi pada fluida dasarnya. Hal ini tentu akan mempengaruhi kestabilan nanofluida dalam menyerap panas. Maka diperlukan perlakuan tambahan yaitu dengan adanya gelombang akustik yang dapat disebut dengan metode termoakustik.

## 1.2 Rumusan Masalah

Berdasarkan latar belakang yang telah diuraikan sebelumnya, maka dirasa perlu untuk melakukan studi eksperimen tentang pengaruh penggunaan nanofluida terhadap karakteristik koefisien perpindahan kalor konveksi dan juga akan diamati sejauh mana pengaruh geometri pipa circular dan konsentrasi nanofluida terhadap koefisien perpindahan kalor konveksi.

Adapun identifikasi masalah berdasarkan hasil identifikasi latar belakang penelitian di atas, antara lain:

1. Bagaimana pengaruh karakteristik nanofluida pada variasi konsentrasi dengan fraksi volume yang berbeda dengan nanopartikel $Al_2O_3$ ?
2. Bagaimana pengaruh penggunaan metode termoakustik dengan sonikasi gelombang akustik terhadap kestabilan nanofluida?
3. Bagaimana pengaruh efek gerak Brown terhadap hasil koefisien konveksi?

## 1.3 Batasan Masalah

Untuk pemahaman penelitian ini, perlu dilakukan pembatasan masalah agar pembahasan tidak meluas dan menyimpang dari tujuan. Adapun batasan masalah yang ditentukan adalah sebagai berikut :

1. Menggunakan nanopartikel $Al_2O_3$.
2. Nanofluida hanya menggunakan konsentrasi dengan fraksi volume 0,2%, 0,4%, 0,6% dan 0,8%.
3. Proses sonikasi dilakukan dengan frekuensi 100 Hz, 500 Hz dan 1000 Hz.
4. Penukar kalor yang digunakan adalah penukar kalor pipa ganda dengan pipa circular.

## 1.4 Tujuan Penelitian

Tujuan dari penelitian ini adalah sebagai berikut:

1. Menganalisis karakteristik nanofluida terhadap variasi konsentrasi dengan fraksi volume nanopartikel.
2. Membuktikan hasil metode termoakustik dengan sonikasi gelombang akustik terhadap nanofluida untuk stabilisasi efek gerak Brown.
3. Menganalisis stabilisasi efek gerak Brown untuk meningkatkan nilai koefisien konveksi dalam efektivitas perpindahan kalor.

## 1.5 Manfaat Penelitian

Pemanasan atau pendinginan fluida adalah suatu kebutuhan utama di dalam banyak sektor industri, termasuk transportasi, kebutuhan di bidang energi dan produksi serta bidang elektronika. Penelitian ini mempunyai manfaat atau menghasilkan keluaran yaitu :

1. Mengetahui pengaruh metode termoakustik dalam proses perpindahan kalor secara konveksi
2. Mengetahui pengaruh efek gerak Brown dalam proses aglomerasi pada nanofluida.

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