Bibliography

[1] J S Smith and A P Watson, "Design, manufacture, and testing of a high speed 10 MW permanent magnet motor and discussion of potential applications," in *Proceedings of the thirty-fith turbomachinery symposium*, Texas, 2006, pp. 19-24.

[2] J Huppunen, *High-Speed Solid-Rotor Induction Machine – Electromagnetic Calculation and Design*. Lappeenrannan, Finland, 2004.

[3] R Larsonneur, *Design and Control of Active Magnetic Bearing Systems for High Speed Rotation*. Zurich, 1990.

[4] L M Mhango, The development of high-speed high power density induction machines with AMBs for high pressure high temperature gas processing applications, August 19, 2009, Paper presentation.

[5] K Kugeler, HTR Technology, 2009, NUCI 878 EB Study guide North West University.

[6] M Mekhiche et al., "High speed motor drive development for industrial applications," in *Electric Machines and Drives International Conference*, Seattle, 1999, pp. 244-248.

[7] W L Soong, G B Kliman, R N Johnson, R A White, and J E Miller, "Novel High-Speed Induction Motor for a Commercial Centrifugal Compressor," *IEEE Transactions on industry applications*, vol. 36, no. 3, pp. 706-713, MAY/JUNE 2000.

[8] N Bessinger, "The adaptation of a rotor for active magnetic bearing levitation and the corresponding auxiliary bearing design," North West University, Potchefstroom, M.Eng Thesis 2009.

[9] V. Lelos, and J.D. Herbst M.T. Caprio, "Design and stress analysis of a high speed rotor for an advanced induction motor," in *Electric Machine Technology Symposium (EMTS)*, Philadelphia, January 27-29, 2004.

[10] C P Brown, "Design for Manufacturability of a High-Performance Induction Motor Rotor," Massachusetts Institute of Technology, Massachusetts, Master of Science Dissertation 1996.

[11] J Lähteenmäki, "Design and Voltage Supply of High-Speed Induction Machines," Helsinki University of Technology, Helsinki, PhD Thesis 2002.

[12] A H Bonnett and T Albers, "Squirrel-Cage Rotor Options for AC Induction Motors," *IEEE Transaction on Industry Applications*, vol. 37, no. 4, pp. 1197-1209, July/Aug 2001.

[13] S Kalpakjian and S R Schmid, *Manufacturing Engineering And Technology*, 5th ed. New Jersey:

Pearson Prentice Hall, 2006.

[14] K G Budinski and M K Budinski, *Engineering Materials Properties and Selection*, 7th ed.: Pearson Prentice Hall, 2005.

[15] W R Finley and M M Hodowanec, "Selection of Copper versus Aluminum Rotors for Induction Motors," *IEEE Transaction on Industry Applications*, vol. 37, pp. 1563-1572, November/December 2001.

[16] W P Pizzichil, "High Mechanical Strength Electrical Connection System And Method," US 7,336,013 B2, Feb 26, 2008.

[17] D Bozkaya and S Muftu, "Efficiency Considerations for the Purely Tapered Interference Fit (TIF) Abutments Used in Dental Implants," *Journal of Biomechanical Engineering*, vol. 126, pp. 393-401, Aug 2004.

[18] D Bozkaya and S Muftu, "Mechanics of the tapered interference fit in dental implants," *Journal of Biomechanics*, vol. 36, pp. 1649-1658, April 2003.

[19] U. Gamer and F. G. Kollmann, "A theory of rotating elasto-plastic shrink fits," *Archive of Applied Mechanics*, vol. 56, no. 4, pp. 254-264, July 1986.

[20] W J Chen and E J Gunter, *Introduction to Dynamics of Rotor-Bearing Systems*. Victoria: Trafford Publishing, 2005.

[21] A SRINIVASAN, *The influence of internal friction on rotordynamic instability*. Texas, 2003.

[22] Syed Muhammad Mohsin Jafri, *Shrink fit effects on rotordynamic stability: Experimental and theoretical study*. Texas, 2007.

[23] G Boothroyd, P Dewhurst, and W Knight, *Product design for manufacture and assembly*, 2nd ed., Ioan Marinescu, Ed. New York: Marcel Dekker Inc, 2002.

[24] H Zhou and F Wang, "Comparative study on high speed induction machine with different rotor structures," in *Electrical machines and systems*, Seoul, 2007, pp. 1009-1011.

[25] W A Mitchell, "Solid rotor shaft construction for alternating current induction motor," Mechanical 2003/0098627 A1, May 29, 2003.

[26] K Hasegawa, S Ozaki, T Takahashi, and N Sugitani, "Cage-type induction motor for high rotational speeds," Mechanical 6,556,778, May 20, 2003.

[27] P F Carosa and A G Cocconi, "Rotor construction for alternating current induction motor,"

Mechanical 5,642,010, Jun 24, 1997.

[28] (2009, November) DFMA Design for manufacture and assembly. [Online]. http://www.design-iv.com/

[29] M Zoche, G Zoche, and B Krasser, "Squirrel Cage Rotor," Mechanical 6,031,312, Feb 29, 2000.

[30] R A Lawrence, "Rotor assembly and method of manufacturing," Mechanical 6,304,009, Oct 16, 2001.

[31] (2009, October) Cogent - Surahammars Bruks AB. [Online]. http://www.sura.se/

[32] (2009, October) VAC Vacuumschmelze. [Online]. http://www.vacuumschmelze.de

[33] J A Moses and J G Thursby, "Improvement of magnetic properties of electrical steel using a surface diffusion technique," *Journal of materials science*, vol. 18, pp. 1657-1665, 1983.

[34] E L Owen, "Flexible shaft versus rigid shaft electric machines for petroleumand chemical plants," *IEEE Transaction on Industry Applications*, vol. 27, no. 2, pp. 245-252, 1991.

[35] (2009) Matweb Material Property Data. [Online]. http://www.matweb.com/

[36] D T Peters, J G Cowie, E F Brush Jr, and S P Midson, "Die-cast Copper Motor Rotors: Die Materials and Process Considerations for Economical Copper Rotor Production," Copper Development Association Inc, Hilton Head Island,.

[37] P E Hayes, B M Wood, and D G Horn, "Mechanical design of induction motors applied on adjustable speed drives," in *IEEE Industry Applications Society 44th Annual Petroleum and Chemical Industry Conference*, New York, 1197, pp. 139-149.

[38] F Armao. (2009, Oct) Metalforming web site. [Online]. www.metalforming.com

[39] T Paterson, Aluminium expert, 2009, Email correspondance.

[40] C Liu, D O Northwood, and S D Bhole, "Tensile fracture behavior in CO2 laser beam welds of 7075-T6 aluminum alloy," *Materials and Design*, vol. 25, pp. 573-577, Feb 2004.

[41] J E Shigley, C R Mischke, and R G Budynas, *Mechanical Engineering Design*, 7th ed. New York: McGraw-Hill, 2004.

[42] R C Hibbeler, *Mechanics Of Materials*, 6th ed.: Pearson Prentice Hall, 2005.

[43] C J Ranft, "Stress in a multi-ring high speed rotor of a permanent magnet synchronous machine,"

North West University, Potchefstroom, Dissertation 2008.

[44] U Gamer and Y Orcan, "On the Elastic-plastic shrink fit rotating with supercritical angular speed," *ZAMM - Journal of Applied Mathematics and Mechanics*, vol. 69, no. 8, pp. 219-226, Nov 1989.

[45] U Gamer and S Muftu, "On the Elastic-plastic shrink fit with supercritical interference," *ZAMM - Journal of Applied Mathematics and Mechanics*, vol. 70, pp. 501-507, Nov 1190.

[46] J G Bralla, *Design for manufacturability handbook*, 2nd ed. New York, USA: McGraw Hill, 1999.

[47] T Marks, *Standard Handbook for Mechanical Engineering*, 8th ed. New York: McGraw-Hill, 1979.

[48] W D Pilkey, *Peterson's Stress Concentration Factors*, 2nd ed. USA: Wiley-Interscience, 1997.

[49] A L Window and G S Holister, *Strain gauge technology*, 1st ed. New York, USA: Applied science.

[50] M Liu, "A New Method for Measuring Contact Resistance," Beijing Orient Institute of Measurement & Test Chinese Academy of Space Technology, Beijing, Test and Measurement report.

[51] K Lingaiah, *Machine design databook*, 2nd ed. New York, United States of America: McGraw Hill, 2004.

[52] CMMI for development, version 1.2, 2006, CMMI is a process improvement maturity model for the development of products and services.

[53] C McCauley, Ed., *Machinery's Handbook*, 26th ed. New York, United States of America: Industrial Press, Inc.

[54] J D Edwards, D T Monk, and J W Tolbert, "Method of manufacturing a laminated rotor," 6,848,495 B2, February 1, 2005.

Appendix A : Matlab® program

```
% Rene' Larsonneur - PhD "Design and control of active magnetic bearing
% systems for high speed rotation" pp 11-31, pp146,147.

% Radial, tangential and Von Mises stress in two shrink-fitted rings

clear all;
clc;
format long e
tic;

% General Parameters ######################################################
Nsim    = 250;
rpm_min = 0;
rpm_max = 19000;
FS      = 2;
delta_T = 0;
% General Parameters ######################################################


% Material Data ###########################################################
% Shaft - AISI 4140 ####################
sigma_0_1   = 834e6;    % (N/m^2) Yeild strength
rho1        = 7.85e3;   % (kg/m^3)
E1          = 205e9;    % (N/m^2)
v1          = 0.285;    % Poisson's ratio
alpha1      = 12.6e-6;  % (m/m-C) Coef. of therm. expansion

% Laminations - M270-35A Silicon steel  ######################
sigma_0_2   = 450e6;    % (N/m^2) Yeild strength
rho2        = 7.65e3;   % (kg/m^3)
E2          = 185e9;    % (N/m^2)
v2          = 0.3;      % Poisson's ratio
alpha2      = 12e-6;    % (m/m-c) Coef. of therm. expansion

% Material Data ###########################################################


% Material Geometry #######################################################
% Inner ring ##############################################
ri1 = 0e-3;
ro1 = 40e-3 + alpha1*delta_T*(40e-3);

% Outer ring ##############################################
ri2 = 40e-3 - 25e-6 + alpha2*delta_T*(40e-3);
ro2 =61.5e-3+ alpha2*delta_T*(61.5e-3);
% Material Geometry #######################################################


r               = linspace(ri1+50e-6,ro2,Nsim);
```

```
rpm             = linspace(rpm_min,rpm_max,Nsim);
Ohmega          = rpm/60*2*pi;
u               = zeros(Nsim,1);
epsilon_r       = zeros(Nsim,1);
epsilon_t       = zeros(Nsim,1);
sigma_ref_max   = zeros(Nsim,1);


A = [ 0                 1                             0                    0;
    E1*(1+v1)/(1-v1^2) -E1*(1-v1)/((1-v1^2)*ro1^2) -E2*(1+v2)/(1-v2^2) E2*(1-v2)/((1-
v2^2)*ri2^2);
    ro1                 1/ro1                         -ri2                 -1/ri2;
    0                   0                             (1+v2)               -(1-v2)/ro2^2];

x = zeros(4,1);
A_inv = inv(A);

for cntr1 = 1:Nsim % Speed loop

    F = [ 0;
        Ohmega(cntr1)^2/8*(rho1*(v1+3)*ro1^2 - rho2*(v2+3)*ri2^2);
        Ohmega(cntr1)^2/8*(rho1*(1-v1^2)*ro1^3/E1 - rho2*(1-v2^2)*ri2^3/E2) - ro1 +
ri2;
        rho2*Ohmega(cntr1)^2*(1-v2^2)*(v2+3)*ro2^2/8/E2];

    x = A_inv*F;

    for cntr2 = 1:Nsim % Radius loop
        if r(cntr2) <= ro1
            u(cntr2) = x(1)*r(cntr2) + x(2)/r(cntr2) - (1-
v1^2)/8/E1*rho1*r(cntr2)^3*Ohmega(cntr1)^2;
            epsilon_r(cntr2) = x(1) - x(2)/r(cntr2)^2 - 3*(1-
v1^2)/8/E1*rho1*r(cntr2)^2*Ohmega(cntr1)^2;
            epsilon_t(cntr2) = x(1) + x(2)/r(cntr2)^2 - (1-
v1^2)/8/E1*rho1*r(cntr2)^2*Ohmega(cntr1)^2;
            sigma_r(cntr1,cntr2) = E1/(1-v1^2)*(epsilon_r(cntr2) +
v1*epsilon_t(cntr2));
            sigma_t(cntr1,cntr2) = E1*epsilon_t(cntr2) + v1*sigma_r(cntr1,cntr2);
        else
            u(cntr2) = x(3)*r(cntr2) + x(4)/r(cntr2) - (1-
v2^2)/8/E2*rho1*r(cntr2)^3*Ohmega(cntr1)^2;
            epsilon_r(cntr2) = x(3) - x(4)/r(cntr2)^2 - 3*(1-
v2^2)/8/E2*rho2*r(cntr2)^2*Ohmega(cntr1)^2;
            epsilon_t(cntr2) = x(3) + x(4)/r(cntr2)^2 - (1-
v2^2)/8/E2*rho2*r(cntr2)^2*Ohmega(cntr1)^2;
            sigma_r(cntr1,cntr2) = E2/(1-v2^2)*(epsilon_r(cntr2) +
v2*epsilon_t(cntr2));
            sigma_t(cntr1,cntr2) = E2*epsilon_t(cntr2) + v2*sigma_r(cntr1,cntr2);
        end

         sigma_tresca(cntr1,cntr2) = max([abs(sigma_t(cntr1,cntr2)-
sigma_r(cntr1,cntr2)),abs(sigma_r(cntr1,cntr2)),abs(sigma_t(cntr1,cntr2))]);
        sigma_von_mises(cntr1,cntr2) = sqrt(sigma_r(cntr1,cntr2)^2 -
sigma_t(cntr1,cntr2)*sigma_r(cntr1,cntr2) + sigma_t(cntr1,cntr2)^2);
    end

end
toc

for k = 1:Nsim
```

```
    if r(k) <= ro1
        sigma_0(k) = sigma_0_1/FS;
    else
        sigma_0(k) = sigma_0_2/FS;
    end
    sigma_0_a(k) = sigma_0_2/FS;
end


rpm_plot = Nsim;
figure
plot(r*1e3,sigma_r(rpm_plot,:)/1e6,'k')
ylabel('\sigma_r (MPa)')
xlabel('Radius r (mm)')
grid on

figure
plot(r*1e3,sigma_t(rpm_plot,:)/1e6,'k')
ylabel('\sigma_t (MPa)')
xlabel('Radius r (mm)')
grid on

figure
plot(r*1e3,sigma_von_mises(rpm_plot,:)/1e6,'k')
hold on
plot(r*1e3,sigma_0/1e6,'-.k','linewidth',2)
legend('\sigma_v_o_n_m_i_s_e_s','\sigma_0')
ylabel('\sigma_v_o_n_m_i_s_e_s (MPa)')
xlabel('Radius r (mm)')
grid on
```

Appendix B : Data CD

A digital copy of the dissertation, all the detail drawings, analytical calculation using Matlab and EES as well as material data and other relevant documents and files of interest are found on the data CD.