Laborbericht

BA-MECH-25

Elektrotechnik I

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Kapitel 1

Introduction

1.1 The Need for Speed

In recent years, improvements in manufacturing, transportation and process industry technologies bring about an increase in optimal operation speed in drive systems. In this respect, recently developed high speed gear-less or direct-drive electrical drives have seen an increase in interest based on the reduction in the total structural volume of the drive system. Due to the significant development of cost-effective, fast switching and compact variable frequency drives technology, wide speed range operations of different type AC motors has become feasible. The speed definition of an induction motor can be seen in Eq. 1.1

$$n = \frac{120f}{p}, \tag{1.1}$$

In literature, there are several descriptions for the term "high-speed". As a mechanical engineer, peripheral speed over $150\,\mathrm{m/s}$ is considered to be high speed **gieras2011performance**. From the motor manufacturer's point of view, a two-pole machine which is supplied higher than 50 to $60\,\mathrm{Hz}$, can be considered as a high-speed machine. However, the most important point of view for the high-speed term is explained by development at power electronics. Nowadays, up to few hundreds hertz frequencies can be produced by variable frequency drives. However, voltage qualities of these are not satisfactory due to limited switching frequency of high-power IGBT technology. Thus, high-speed levels might be calculated for frequencies in the range of 100 to $400\,\mathrm{Hz}$ are considered to be high-frequencies **pyrhonen1991high**. Owing to brush and commutator structure causing mechanical and electrical problems, DC drives are not allowed to be used for high-speed applications. In addition to the aforementioned statement, the structure is not appropriate for large centrifugal forces. Nevertheless, as high-speed drive applications, there are different type of AC motor concepts proposed in literature **gieras2011performance**, **pyrhonen1991high**, **lahteenmaki2002design**, **saari1998thermal**: Laminated/solid induction, permanent magnet synchronous and switched reluctance synchronous motors.

It is due to remarkable improvements of power electronics, frequency inverters and AC variable-speed drives, which allows a wider use of applications of solid-rotor induction motor (SRIM). SRIM's

Admission requirements for Mathematics (MSc)	**Courses completed before start**	**Date of completion**
Mathematical Analysis (30 ECTS)	Mathematical Analysis 1	22.04.2014
	Mathematical Analysis 2	15.02.2013
	Complex Analysis	01.07.2015
Algebra/Linear algebra (22.5 ECTS)	Advanced Algebra	17.02.2013
	Abstract Algebra	01.06.2015
Geometry/Topology (15 ECTS)	Topology	01.11.2014
	Vector Analysis	15.06.2015
	Differential Geometry	15.02.2013

Tabelle 1.1: As can be clearly seen, this table has absolutely no reason to be here aside from taking space. But it is a nice table to show how it should look and a template to write your own tables.

are used in drive application ranging from a few kW's to 10 MW's. Fans, compressors, pumps, gas turbines, sewing machines, space and aeronautics, auxiliary motors for starting turbo-alternators, eddy current brakes, two-phase servomotors are a few examples of its areas.

Below are the advantages of SRIM compared to CRIM:

- Structural and Mechanical integrity, Rigiditiy, Reliability and Strength of Material
- High thermal properties
- High speed in high power applications (high moment density)
- Low noise and vibrations in high speed applications
- Simple to protect against aggressive chemicals
- Ease of Manufacturing
- Low level of noise and vibrations (If the rotor has no slots)
- Linearity of torque-speed characteristics throughout the entire speed range
- The possibility of obtaining steady-state stability.

In 1950s, Solid-Rotor topologies for induction machines operating at high speeds have gained a lot of interest. From its inception to 1970s, various scientists and engineers have contributed to the development and the theory of solid rotor construction, where significant interest was seen the 1990s for using solid rotor structure for high speed applications.

As the rotor does not contain any trace of copper [1]windings, the eddy currents roam in the rotor without any conductive path restriction and cause the motor to have different characteristics compared to a Cage Rotor Induction motor (CRIM), an industry standard construction. While eddy currents are the main principle of its operation, these currents also causes the motor to have lower

[1]the rotor consists of a solid body of steel or similar ferromagnetic material

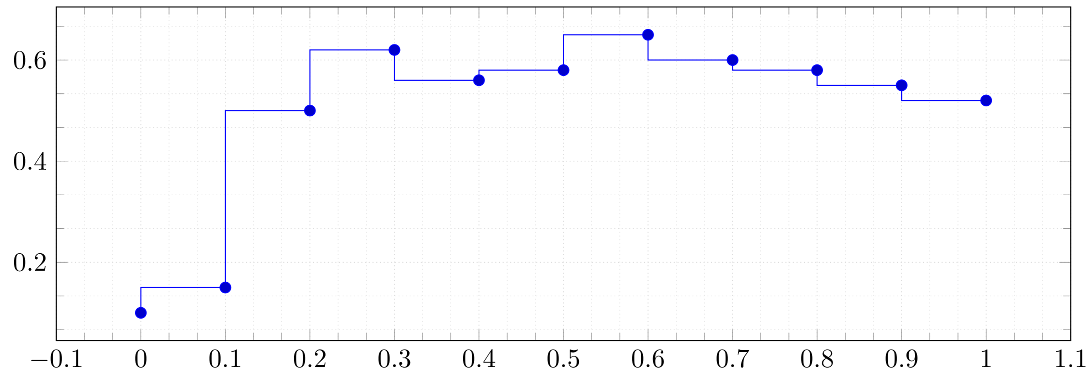

Abbildung 1.1: The authors interest in the topic as years go on.

efficiency in slow speed aplications and this indirectly decreases its power factor. But in high speed application where the speed is around 30000 rpm the losses become far less and SRIM becomes the better choice for high speed applications.

1.1.1 Report Structure

In this report for Drive Technologies, the high-speed performance of the four different types of rotors are investigated and compared using finite element analysis: cage, smooth solid, axially slitted, coated is designed using a finite-element analysis (FEA). All rotors are designed with similar geometries and construction parameters to minimise the effect of unwanted effects.

```
// C++ program to find all string
// which are greater than given length k

#include <bits/stdc++.h>
using namespace std;

// function find string greater than
// length k
void string_k(string s, int k)
{
  // create an empty string
  string w = "";
  // iterate the loop till every space
  for (int i = 0; i < s.size(); i++) {
    if (s[i] != ' ')

      // append this sub string in
      // string w
      w = w + s[i];
      else {

        // if length of current sub
```

```
        // string w is greater than
        // k then print
        if (w.size() > k)
        cout << w << " ";
        w = "";
      }
    }
  }
```

The number of turns per stator slot is selected so as to obtain the same stator current in rated operation. All four motors were analyzed using FEA tools for 20 different speeds in order to obtain the combined torque-speed characteristics. To illustrate visually the differences in the distributions of the magnetic flux and the eddy current the results for 11300 rpm are presented and the core loss, the total loss and the efficiency for the specific speed are compared for all the motors. The designed four motors will be also compared for winding currents, induced voltages, flux linkages, electromagnetic torque, copper losses, iron losses, solid rotor losses and efficiency.

Kapitel 2

Gleichstromtechnik

2.1.2 Ohmsches Gesetz

Die Erdbeschleunigung beträgt $9{,}81\,\mathrm{m/s^2}$.
Wie in Abbildung 2.1 gezeigt, ...

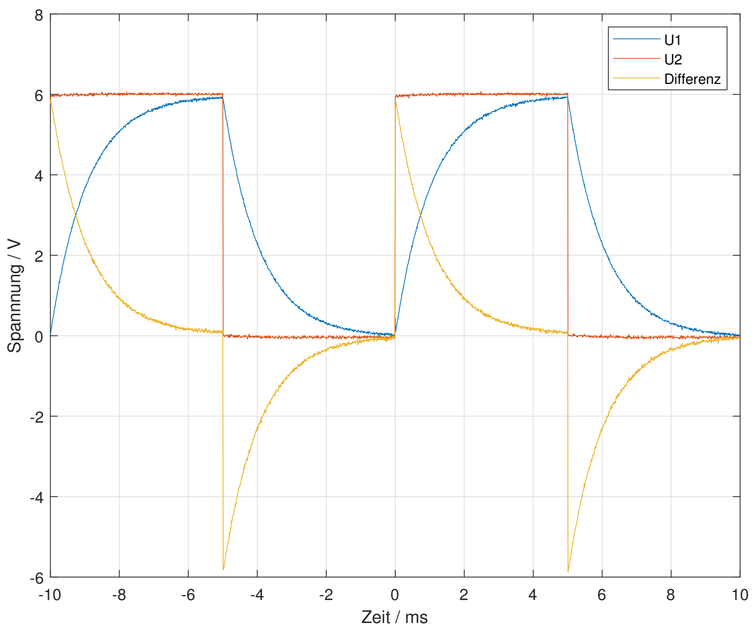

Abbildung 2.1: Meine Bildbeschreibung

Ergebnisse

Diskussion

2.2.2 Mischen von Reihen- und Parallelschaltungen

Ergebnisse

Diskussion

2.3.2 Unbelasteter Spannungsteiler

Ergebnisse

Diskussion

2.4.2 Belasteter Spannungsteiler

Ergebnisse

Diskussion

2.5.2 Spannungsrichtige und stromrichtige Messung

Ergebnisse

Diskussion

2.6.2 Ersatzspannungsquelle

Ergebnisse

Diskussion

2.7.2 Reihenschaltung von Spannungsquellen

Ergebnisse

Diskussion

2.8.2 Parallelschaltung von Spannungsquellen

Ergebnisse

Diskussion

Kapitel 3

Kondensator im Wechselstromkreis

3.2.2 Lade- und Entladevorgang eines Kondensators

Ergebnisse

Diskussion

3.3.2 Phasenverschiebung zwischen Strom und Spannung am Kondensator

Ergebnisse

Diskussion

3.4.2 Kapazitiver Blindwiderstand eines Kondensators

Ergebnisse

Diskussion

3.7.2 Blindleistung eines Kondensators

Ergebnisse

Diskussion

Kapitel 4

Spule im Wechselstromkreis

4.2.2 Ein- und Ausschaltvorgang an einer Spule

Ergebnisse

Diskussion

4.3.2 Phasenverschiebung zwischen Strom und Spannung an einer Spule

Ergebnisse

Diskussion

Kapitel 5

Zusammenschaltung von Widerstand, Kondensator, Spule

5.5.2 Parallelschaltung von Widerstand und Spule

Ergebnisse

Diskussion

5.2.2 Reihenschaltung von Widerstand und Kondensator

Ergebnisse

Diskussion

5.10.2 Wirk-, Blind- und Scheinleistung

Ergebnisse

Diskussion