

## REFEREE'S REPORT

for the doctoral thesis of **Mukunda Bhimasena Rao Nagaraj**  
**„Role of Powder Characteristics in Metal Injection Molding Process“**

Doctoral programme: P3909 Process Engineering

Degree course: 3909V013 Tools and Processes

Supervisor: prof. Ing. Berenika Hausnerová, Ph.D.

The submitted thesis represents a contribution to the role of characteristics of metal powder applied in precision component manufacturing via metal injection molding (MIM). This work is focused on the interpreting the shape of the powder particles using a qualitative microscopic technique and development of quantitative approach based on the Euclidean distance mapping. Obtained results were compared with the commercially available dynamic image analyzer.

In generally the thesis is divided to parts corresponding with the common form of regular PhD. thesis, but this thesis represents a collection of thematically arranged papers devoted to the aim of the doctoral work. In submitted thesis main obtained results are briefly discussed and thesis content full text of four papers which were published by author in journals. Base on this fact it is possible to say, that practically all results were verified by independet reviewers too.

Theoretical background desrcibed basic principles of metal injection molding (MIM). Current status desrcibed various aspects concerning the MIM technology, powders and binder system and role of powder characteristics in metal injection molding. To this part I have one question:

- In first stage of debinding process part of the primary binders are removed through solvents, catalytic or thermal debinding. In this process usually creat crazes and pores in polymer binder. Which type of pores are create on dependence of type of debinding process?

The objectives of the thesis are clearly described based on the current state of art with importance of quantitative evaluation of powder morphology and its influence on rheological properties, injection molding parameter and mechanical properties after sintering.

The experimental part describes the characteristics of gas and water atomized powders materials used in experimental work and procedures applied for the research are summarized in Paper P- I – Papers P-IV. The part Results and discussion content of characteristics of gas

and water atomized powders, estimations of critical solid loading of metal powder, rheological properties affected by powder size and shape and quantification of metal particle shape. Chapter results and discussion is clear, the results are well presented and adequately discussed. The conclusions are sufficiently supported by experimental data.

I have few comments and questions which should be discussed during the defense:

- Knowledge of the particle size distribution plays a vital role in the production of feedstock and precision metal components in the MIM process. In all tables are summarized only data for  $D_{10}$ ,  $D_{50}$  and  $D_{90}$ . Please give full particle size distribution curve on the time of defence. Have author results of metal powders porosity too?
- For a critical solid loading is very important parameter particle size distribution to, not only different particle size. Have all types of powders which characteristics are in table 7 the same particle size distribution?
- From the experimental data is evident that the sensitivity of feedstock to temperature is similar for both gas– and water– atomized powders but only in solid loading to 30 wt %. Way is apparent flow activation energy the same in higher solid loading in all tested shear rate?
- In Figure 26 Mooney diagrams are presented as a linear fitting lines with coefficients of determination greater than 0,995. How many points were measured?
- Where parameters You recommended for reduce of wall slip and flow instabilities due to powder – binder separation for reduce of components defects in the MIM?
- Which parameter was applied as criterium for optimization metal injection molding of water atomized stainless steel feedstock? /Paper P-II/

These questions should be understood as a topics for discussion during the defense and they are not intended to decrease the level of the thesis.

**Conclusion:** Mukunda Bhimasena Rao Nagaraj has presented a PhD. thesis of high level. He has demonstrated the ability to identify the research problem and to analyze critically and clearly the experimental results. I suggest accepting the thesis for further procedure and after successful defense a I **recommend Mukunda Bhimasena Rao Nagaraj to be awarded the degree of Doctor of Philosophy.**