Application of Gamma Ray Densitometry in Powder Metallurgy

by Georg Schlieper
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Abstract

The most important industrial application of gamma radiation in characterizing green compacts is the determination of the density. Examples are given where this method is applied in manufacturing technical components in powder metallurgy. The requirements imposed by modern quality management systems and operation by the workforce in industrial production are described. The accuracy of measurement achieved with this method is demonstrated and a comparison is given with other test methods to measure the density. The advantages and limitations of gamma ray densitometry are outlined.

The gamma ray densitometer measures the attenuation of gamma radiation penetrating the test parts (Fig. 1). As the capability of compacts to absorb this type of radiation depends on their density, the attenuation of gamma radiation can serve as a measure of the density. The volume of the part being tested is defined by the size of the aperture screeniing out the radiation. It is a channel with the cross section of the aperture whose length is the height of the test part. The intensity of the radiation identified by the detector is the quantity used to determine the material density.

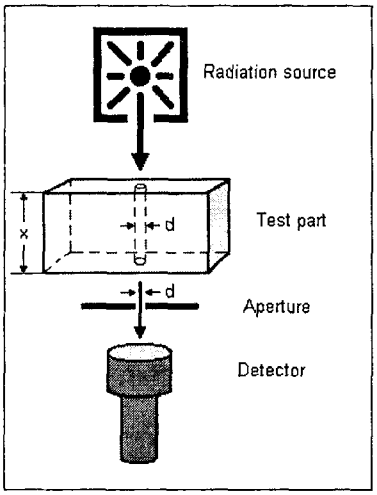

Fig. 1: Schematic of the gamma ray densitometer

Gamma ray densitometry can equally be performed on green compacts as well as on sintered components. Neither special preparation of test parts nor skilled personnel is required to perform the measurement; neither liquids nor other harmful substances are involved.

When parts are exhibiting local density variations, which is normally the case in powder compaction, sectional densities can be determined in different parts of the sample without cutting it into pieces. The test is non-destructive, i.e. the parts can still be used after the measurement and do not have to be scrapped.

The measurement is controlled by a special PC based software. All results are available for further processing by in-house quality documentation and supervision of measurements.

Tool setting for multi-level components can be much improved by using this test method. When a densitometer is installed on the press shop floor, it can be operated by

the tool setter himself. Then he can return to the press and immediately implement the corrections. Transfer of sample parts to the lab for density testing can be eliminated and results for the correction of tool settings are more readily available. This helps to reduce the time required for tool setting and clearly improves the productivity of powder presses.

The range of materials where this method can be successfully applied covers almost the entire periodic system of the elements. It reaches from the light elements such as graphite via light metals (Al, Mg, Li, Ti) and their alloys, ceramics (Al_2O_3, SiC, Si_3N_4, ZrO_2, ...), magnetic materials (hard and soft ferrites, AlNiCo, Nd-Fe-B, ...), metals including iron and alloy steels, Cu, Ni and Co based alloys to refractory and heavy metals (W, Mo,...) as well as hardmetals.

The gamma radiation required for the measurement is generated by radioactive sources which are produced by nuclear technology. These nuclear materials are safely encapsulated in stainless steel capsules so that no radioactive material can escape from the protective shielding container. The gamma ray densitometer is subject to the strict regulations for the use of radioactive materials.

The radiation shield is so effective that there is no elevation of the natural radiation level outside the instrument. Personal dosimetry by the operating personnel is not required. Even in case of malfunction, loss of power and incorrect operation, the escape of gamma radiation from the instrument is positively prevented.

Author's Profile

Dr. Georg Schlieper received his academic degree in 1979 from the University of Karlsruhe, Germany, at the institute of Prof. Thümmler, one of the most distinguished German powder metallurgists. From 1979 to 1994 he was employed as a R&D engineer at a leading German PM manufacturing plant. His work covered product and process development for ferrous structural parts and metal injection moulding. Since 1994 he is working as an independent engineer providing his services and special electronic products to the PM industry. From 1997 to 2000 he was the Technical Manager of a Thematic Network on European Standards for Metal Injection Moulding organized by the European Powder Metallurgy Association.

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Gamma Ray Densitometry in Powder Metallurgy

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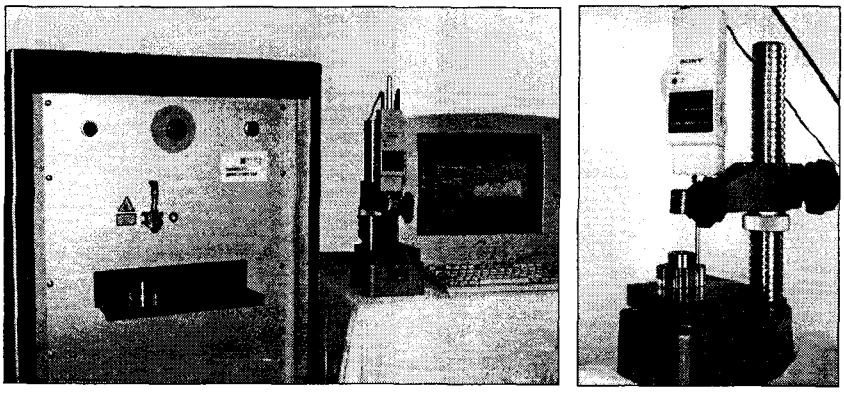

The GAMMATEC Densitometer

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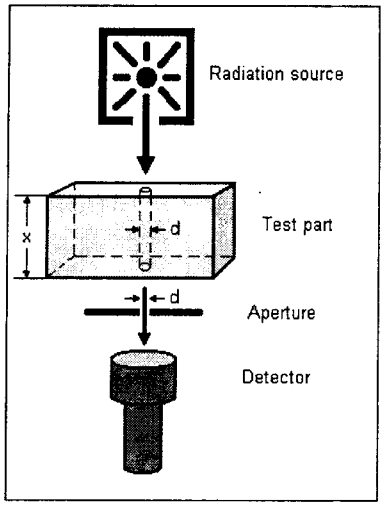

Measurement Principle

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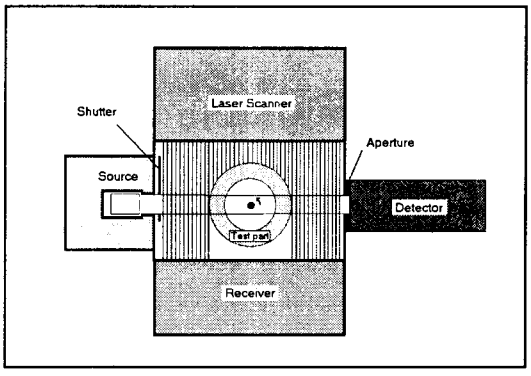
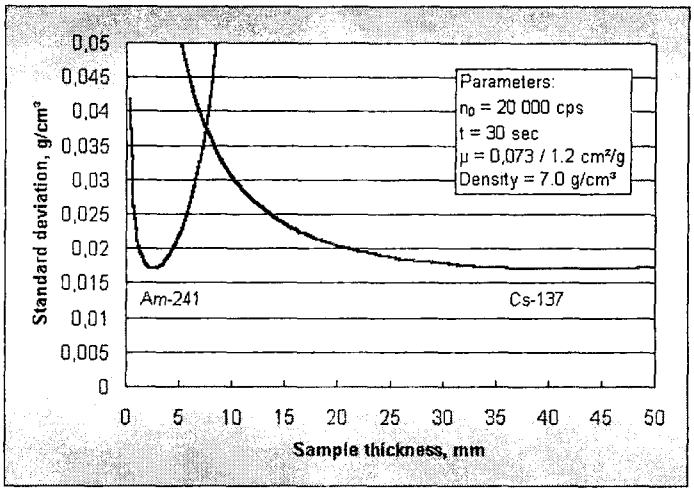


Densitometer for parts with rotational symmetry

DENSITOMETER



Accuracy of Measurement for Ferrous PM Parts

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Applicability of Gamma Ray Densitometry

- Applicable to ceramics, magnetic materials, PM steels, diamond tools, hardmetals, etc.
- Non-destructive test method: no preparation of test parts, no loss of test parts.
- Fast and accurate test, easy and safe operation.
- Fully automatic PC controlled instrument – eliminates the "human factor".
- Test results are available "online".

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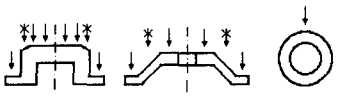
Limitations of Gamma Ray Densitometry



Geometrical limitations:

- Flat surfaces required on top and bottom.
- Not applicable on angles and inclined *surfaces.*
- Minimum wall thickness according to aperture size.
- Material composition and thickness have to match with the radiation energy.
  The choice of radiation sources (energies) is limited.

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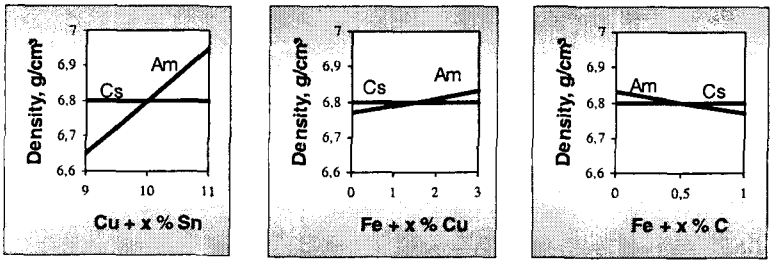
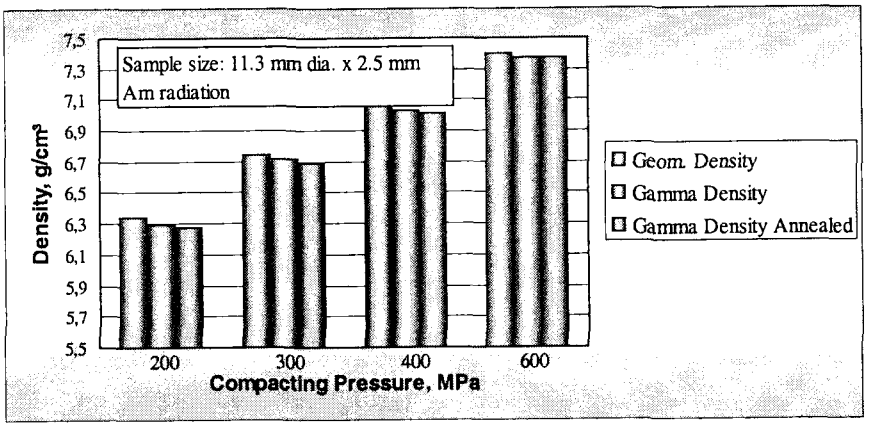


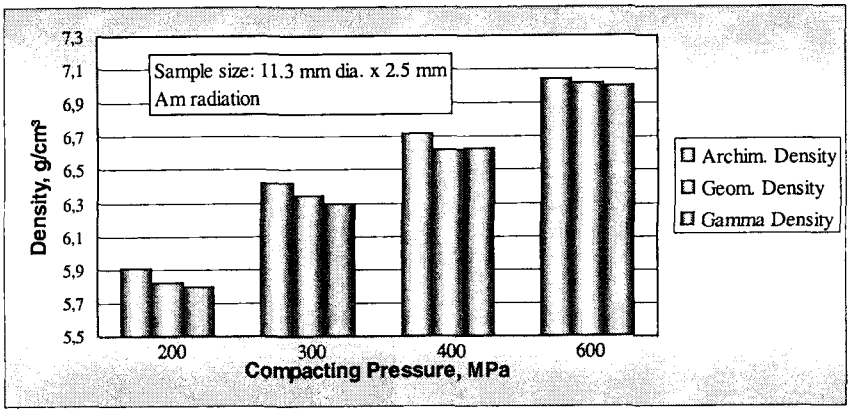
Effect of the chemical composition

DENSITOMETER



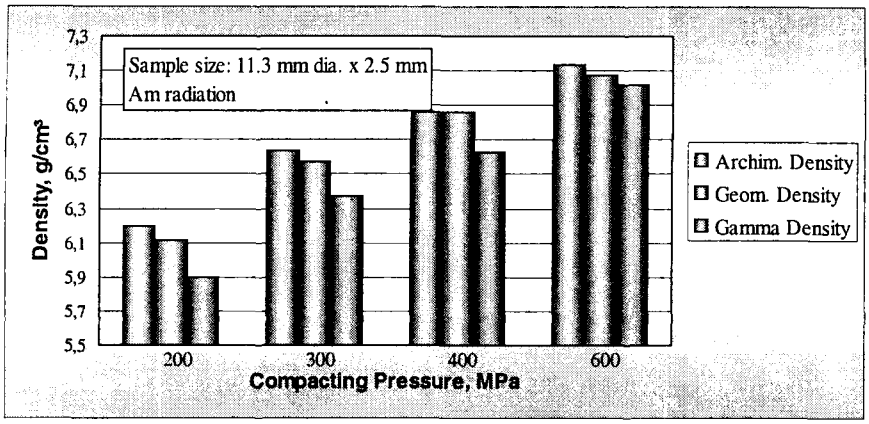
Density after sizing

DENSITOMETER



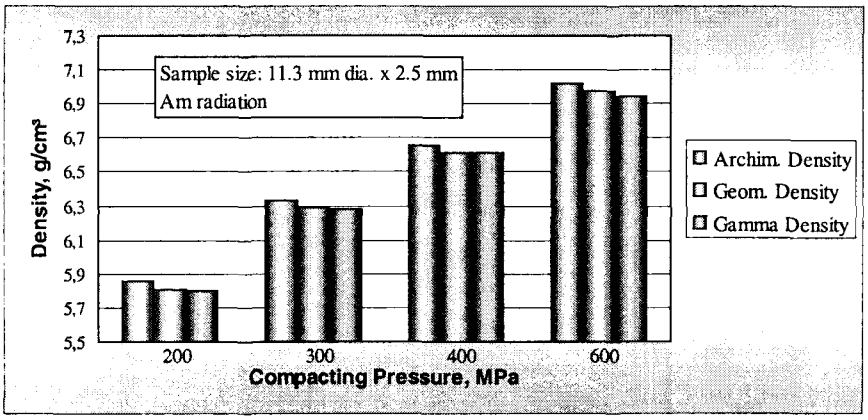
Impregnated with corrosion inhibiting fluid

DENSITOMETER



Effect of steam treatment

DENSITOMETER



Effect of case hardening

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Reasons for Using Gamma Ray Densitometry

- Accelerate tool setup procedures – reduce press idle times.
- Quality assurance in all manufacturing stages.
- The shrinkage can be predetermined from the density of the green compact when sintering to full density (e.g. ceramics).
- Green compact densities allow to determine local tool loading via the compressibility curve; this information can be used to avoid excessive local tool loading.
- Apply fully automatic density measurements to monitor and control the compaction process.
- Develop better die fill and press techniques;
  avoid excessive tool loading and reduce tool failures.

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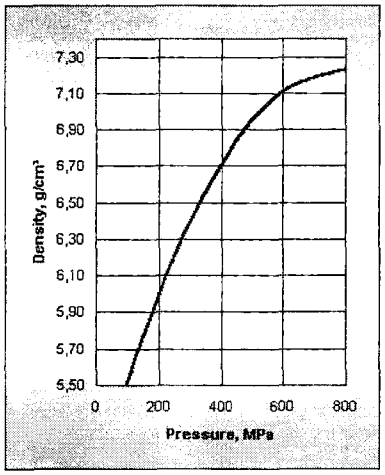

Compressibility of Iron Powder

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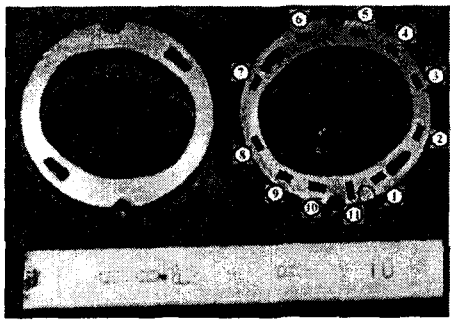
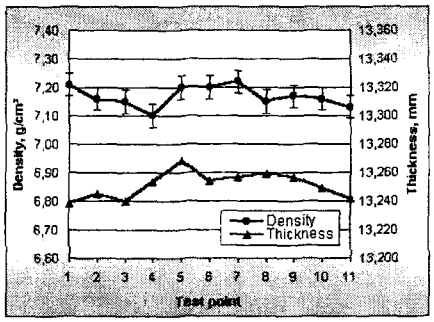
Curved ring



Test points



Green density profile

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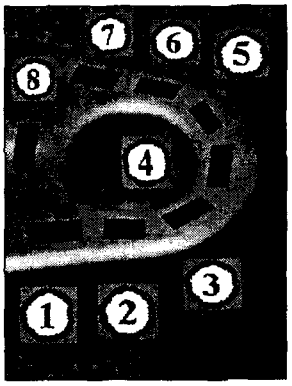
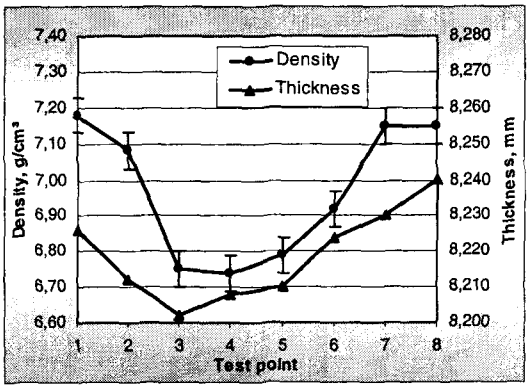
Density profile around a through hole



Test points



Green density profile

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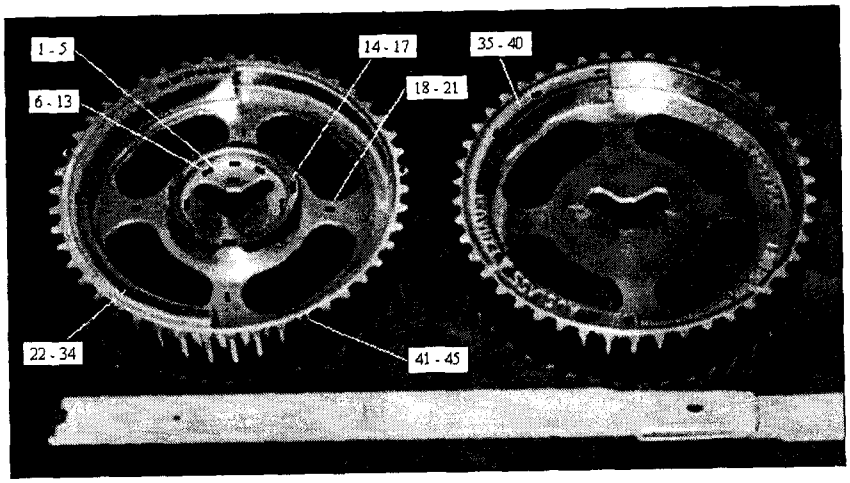
Camshaft pulley



Positions of test points

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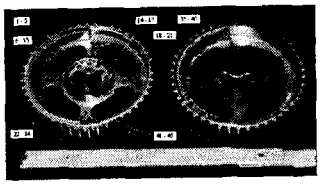
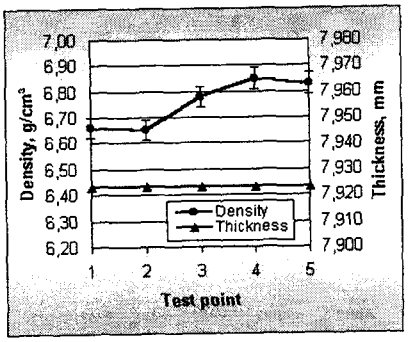
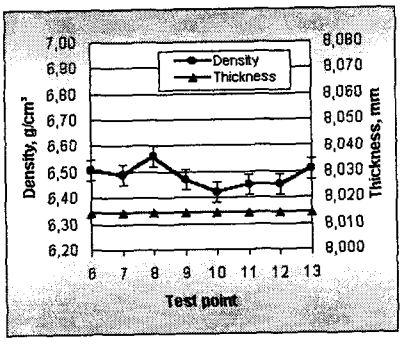
Camshaft pulley



Density profiles



a) Hub inside



b) Hub outside

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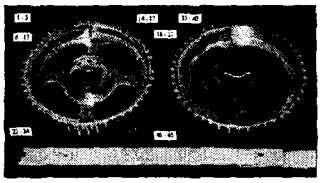
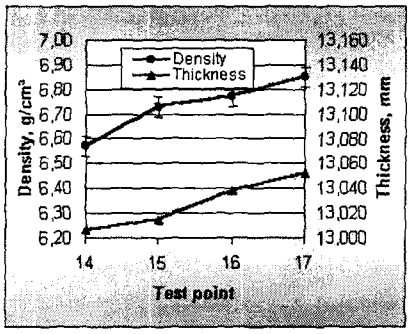
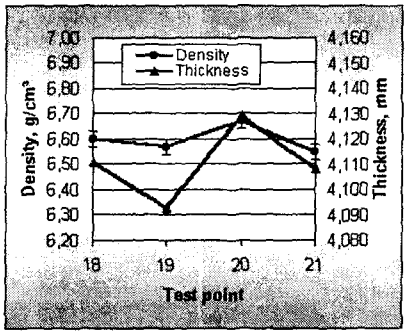
Camshaft pulley



Density profiles



c) Elevation



d) Ribs

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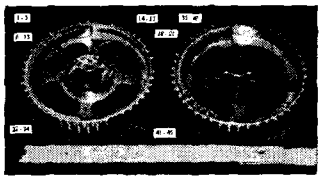
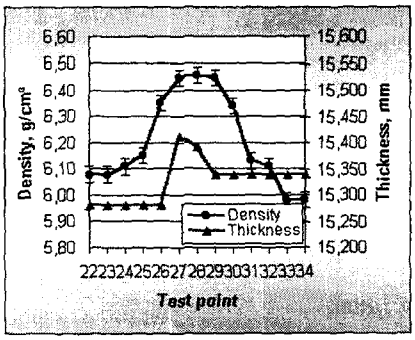
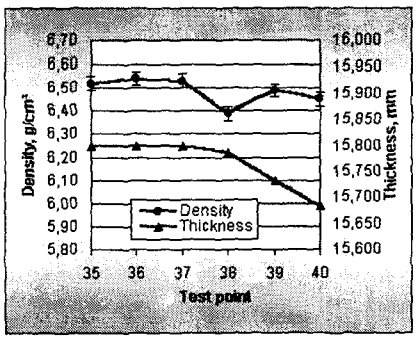
Camshaft pulley



Density profiles



e) Reinforcement INTAKE



f) Reinforcement EXHAUST

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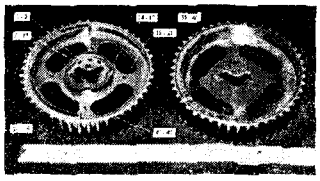
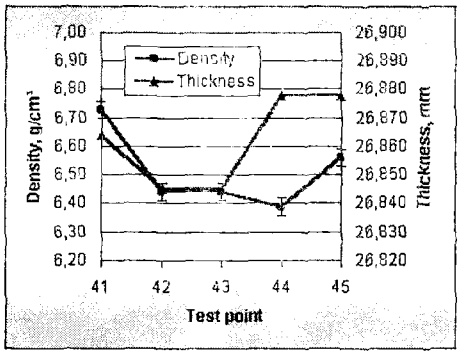
Camshaft pulley



Density profiles



g) Toothing

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Conclusions

- Green compacts and other manufacturing stages can be tested.
- The accuracy of measurement is high and can be adjusted according to requirements (time, aperture size).
- The local resolution is much better than with other methods.
- Density profiles by gamma ray densitometry can provide a comprehensive image of the density in a component.
- Test points for routine measurements should be selected with care in order to obtain representative results with only a few measurements.

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