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Innovative changes in the cylinder liners surface shaping methods

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Abstract*: The main directions of changes in new internal combustion engine designs are determined not only by legislation on the toxic components emission in the exhaust gases, but also by the changes resulting from technological development, which are the results of research and development activities. One of the basic systems that has undergone intensive development recently is the piston-rings-cylinder (PRC) node. This article contains an original analysis of the direction of changes in cylinder surface shaping in terms of the cylinder's main functional features in the PRC system (the casting material and the opening surface topography after the finishing process). The results of the research on cast iron materials for cylinder liner castings with a strength of R_m> 300 MPa were analyzed based on the centrifugal casting method and their finishing stage in the finishing process meeting the criteria for reduction of oil consumption and particle emissions for new HDD type engine designs. The author also points to innovations in surface structure metrology based on new 3D optical measurement methods and the quality rating method by Mercedes company.*

Key words: cylinder liner, development, new technologies

1. Directions of changes in cylinder liners casting shape

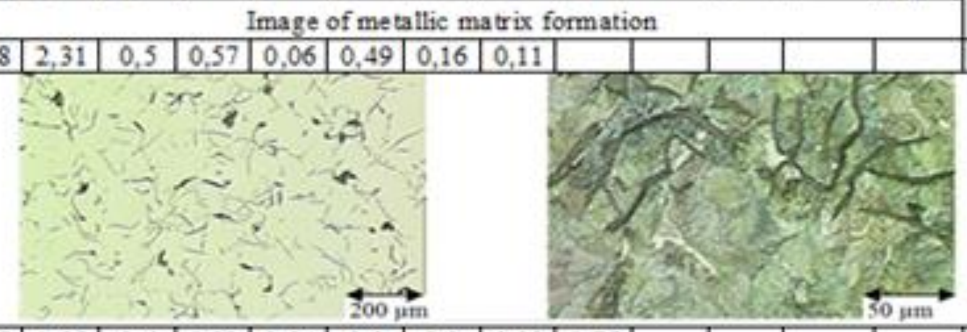
Research and analysis of new cast iron groups based on available literature data,cylinder liner manufacturers findings (FM, GKN and MAHLE) as well as own research have shown that new construction materials in order to meet the increased requirements of tensile strength limit (Rm> 300 MPa) belong to the cast iron group: - with flake graphite (EN-GJL 300),- with vermicular graphite (EN-GJV 450), -cast iron with ball graphite (EN-GJS 600), whose basic properties are listed in Table 1 and 2 against the background materials used for cylinder blocks and cylinder liner castings

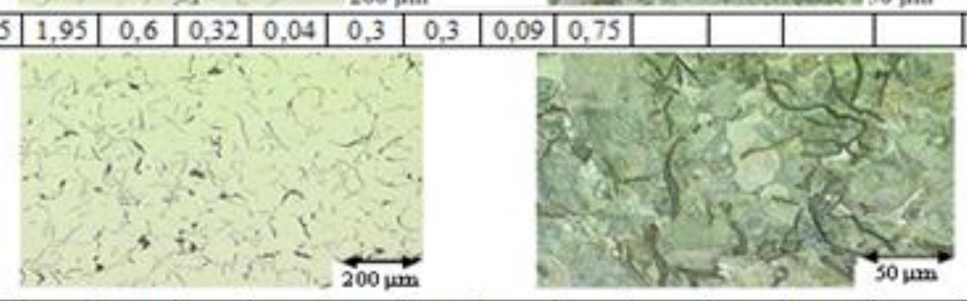
Table 1. Comparison of basic properties of cast iron for cylinder blocks and cylinder liners

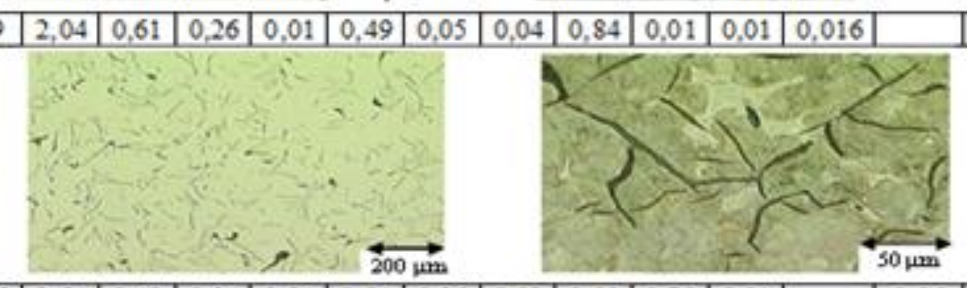
Properties	Unit	Material property					
		A 390	EN-GJL 250	EN-GJL 300	EN-GJV 450	EN-GJS 600	42CrMo
Tensile strength Rm	MPa	275	250	300-375	450–525	> 600	900-1150
Elastic modulus Eo	GPa	80	105	115	145	170	210
Elongation at break point Amin	%	1	1,5	1,5	1,0	0,5	(10)
Fatigue strength ($20^0 – 225^0$C)	MPa	100-35	110-100	125-120	210-205	-	(280)
Thermal conductivity λ (20^0C)	$W \cdot m^{-1}K^{-1}$	130	33-34		30-37	28-35	(50)
Thermal expansion α (20°-200°C)	$10^{-6}K^{-1}$	18	12,5		12,3	12	11-12
Density	g/cm^3	2,6-2,7	7,1-7,3				7,7
Hardness	HB	110-150	260-310		260-310	280-330	240
Structure			Pearlitic with ferrite				Marten-sitic
Graphite form			Flake		Vermicular	Ball	
Technological process		Casting	Centrifugal casting				Forging
Material availability		Base materials in production	Developing materials partly in production				

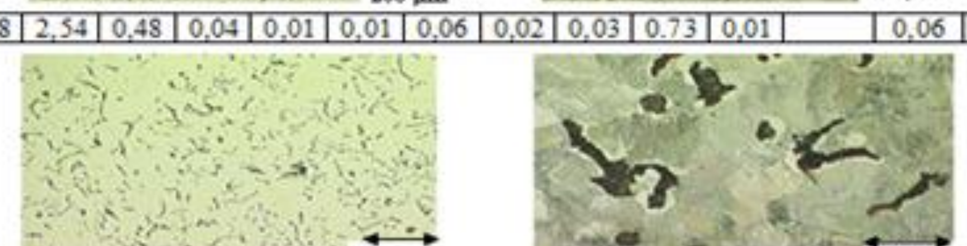
Table 2 Comparison of cast iron properties tested

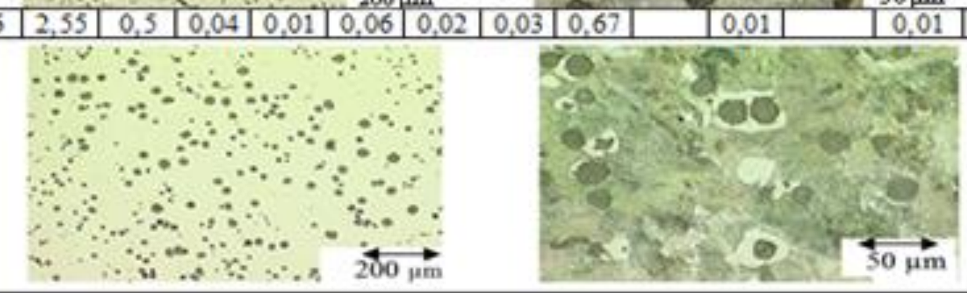
Type of material	Chemical composition [%]													Mechanical properties	
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	V	Ti	N	Mg	Rm [MPa]	HBW
	Image of metallic matrix formation														
Standard cast iron	3,28	2,31	0,5	0,57	0,06	0,49	0,16	0,11						255	244
Cast iron with Mo, Cu addition	2,95	1,95	0,6	0,32	0,04	0,3	0,3	0,09	0,75					320	264
Cast iron with N addition	2,9	2,04	0,61	0,26	0,01	0,49	0,05	0,04	0,84	0,01	0,01	0,016		347	265
Cast iron with Mg addition	3,38	2,54	0,48	0,04	0,01	0,01	0,06	0,02	0,03	0.73	0,01		0,06	660	266
Cast iron with Mg addition	3,6	2,55	0,5	0,04	0,01	0,06	0,02	0,03	0,67		0,01		0,01	842	286











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2. The directions of changes in shaping the topology of the liner opening surface after the finishing process

In the new solutions, the formation of the cylindrical surface topography is a trend towards the method of multi-step finishing, taking into account the dependence of the Rk parameter on the exhaust emission standard, as illustrated in the data presented in figure 2.

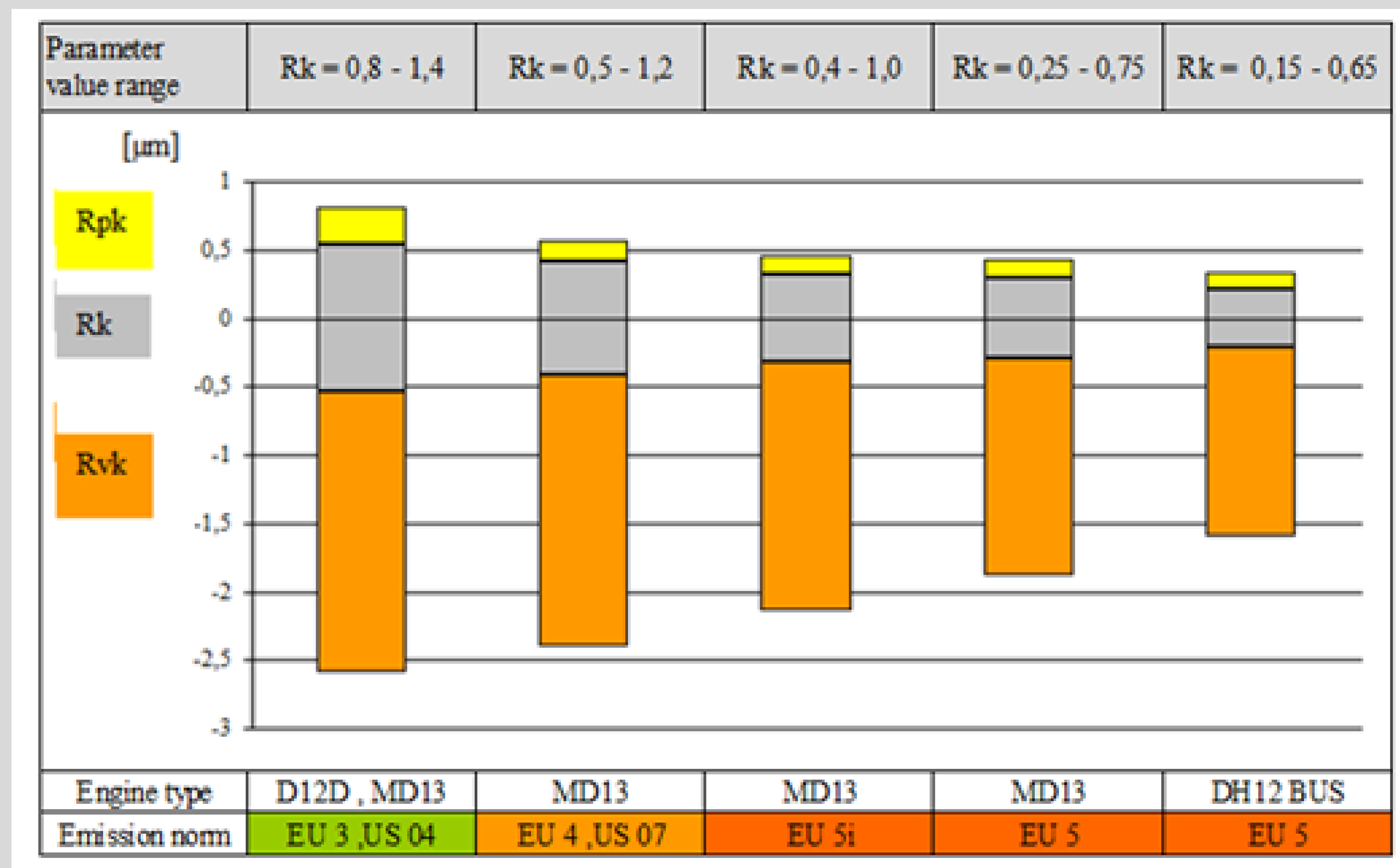

Fig. 2. Cylinder liners surface roughness parameters test results according to the purpose of the liner for the VOLVO HDEP type of engine.

3. New methods of optical 3D measurements (WLI) using the MBN 37800 standard

The use of white light inferometry (WLI) is new in surface metrology, as illustrated in the data presented in figure 3.

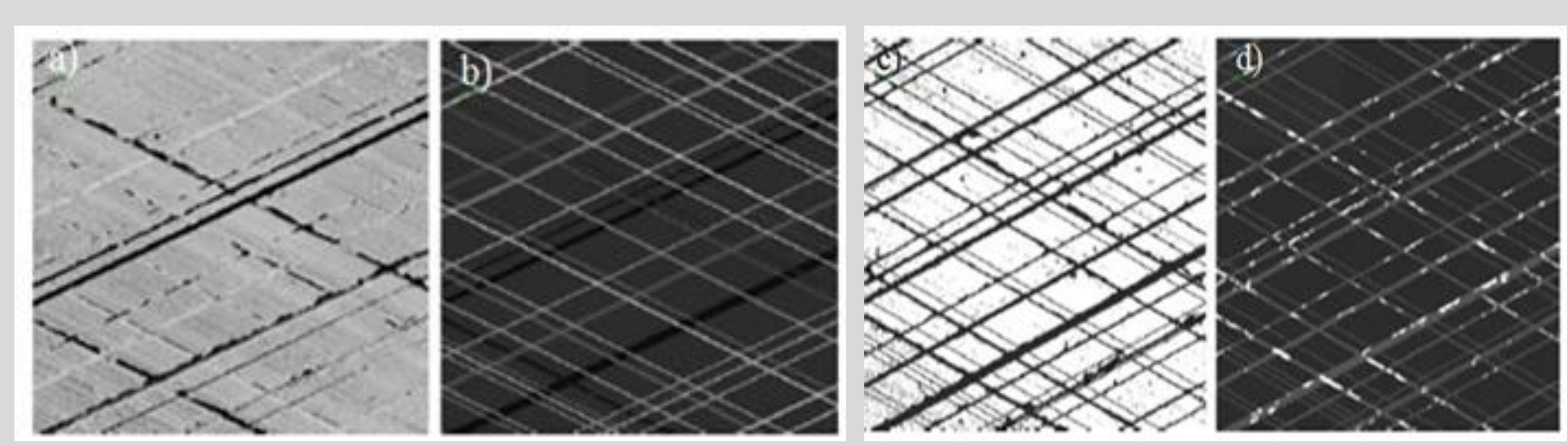

Fig. 3. Honing structure according to MBN 37800-1. From left (a) to right (d): original topography after the F-operator application, raster image, contact surface (white), undesired surface structures on the sheet metal part (white).

4. Conclusions

- Compliance with the new design requirements of the type HDD/HDEP internal combustion engines (increase of maximum combustion pressures exceeding P_{max} = 23-25 MPa) requires the construction of cylinder liners that can meet the strict criteria of material strength (R_m > 300 MPa) and the surface topography to meet the requirements of standards related to reduction of oil consumption and particulate emissions.
- New methods of optical 3D measurements (WLI) using the MBN 37800-1 standard will requirethe implementation of research methodology and international benchmarking and comparative studies with the round-robin method based on the instrument used (Talysurf CCI 600 or WLICyl-S).