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Comparison of local SME manufactured Al-alloy automotive piston in Bangladesh with imported counterparts by microstructural and chemical characterization

Fazle Rabbi [1], Md. Azizur Rahman[1], Md. Imtiaz Pathan[1], Safran Fazle Rahman[1], Shahnewaz Bhuiyan[1]

[1] *(Department of Mechanical and Production Engineering Ahsanullah University of Science and Technology, Bangladesh)*

Abstract

Engineering based SME is rapidly growing to be a key contributor to the national economy in Bangladesh by simultaneously creating jobs for the up-and-coming skilled labour forces, strengthening foreign currency resersve by reducing dependence on imported products for local industries and exporting high quality products. But growth of this promising field is often hinderd by the lack of internal R&D initiatives by the stakeholders. As a result, competing against international conterparts have become a struggle. In this work, we investigate widely used competeing automotive parts to identify parameters that contribute to the quality variation between local and imported components. We compare between automotive brake booster piston from local and imported manufacturers by studying their microstructural properties to identify the parameters that resulting in lower lifespan for the local parts compared to the imported ones.

Keywords*: SME, microstructure, automotive, aluminum, alloy*

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I. Introduction

In Bangladesh, SME have become significant contributors to overall national economy. They provide the prospect of creating jobs and strengthening local economy. Engineering based SME in the country has moved from humble beginning to technologically advanced state. Highly skilled labors with limited resource are producing high precision components catering to internal requirement in various fields such as automotive, industrial and consumer products [1]. But this development has now facing roadblocks due to the lack of research and development initiatives taken by both the government and private entrepreneurs. As a result, these manufactures are struggling to compete with imported counterparts in quality. Previous studies concentrated on several process variable in the manufacturing methods and their effect on mechanical properties [2]. In this paper, we investigate a common automotive part-clutch booster piston of Bedford truck, to identify parameters that contributes to the shorter lifespan of the locally made parts compared to the imported ones. Investigation was performed using microstructural and chemical characterization of the parts.

Booster piston in Bedford trucks is manufactured using aluminum alloys. Currently in Bangladesh, common practice is to use replacement piston from third party manufacturers of local or foreign origin due to their comparative lower price. For this study, we compared between locally manufacture piston with imported parts from Pakistan. Investigation of the manufacturing method of the locally made parts indicates several parameters that can contribute to the reduceced performance. Microstructural (SEM) and chemical (EDX) characterization showed presense of higher level of carbon and oxide in the locally made pistons compared to the imported ones.

II. Experimental Prcedure

The piston samples were collected after their service life. Survey of the personnel involved in automotive industy indicates that local samples had a much lower lifecycle compared to imported parts. The imported parts were more popular among users for their better performance and competitive price. Locally made parts are competing in the market by very low pricing. The collected samples were parted down into small pieces and then mounted bakelite substance by using mounting machine. The small pieces were placed in a mounting chamber and then filled with bakelite powder. The Preset temperature and pressure of the process was 50°C, 170 bars respectively for a time of 8 minutes operation. After mounting, the samples were polished using various grade emery paper. Since the sample is aluminium alloy it was polished using 600, 800, 1000, 1200 and 1500 grade paper respectively. To further remove tiny particles the samples were polished in a grinder machine using fine Alumina powder followed by diamond paste. The polished samples were cleaned using acetone. After the polishing process it was etched using Kroll's reagent (distilled water 92 ml, Nitric acid 6 ml, Hydrochloric acid 2 ml).

Brinell hardness test was performed to study comparative hardOptical microscopy, scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) spectroscopy were used for the identification of the phases. The results of the EDX semi-quantitative chemical analysis were compared with the results reported in the literature for alloys with similar composition.

III. Results and Discussion

Figure 01 shows new piston of two origin under investigation. The red box in the figure indicates the area of investigation due to the fact that most of the failure occurs in the top surfaces of the pistons.

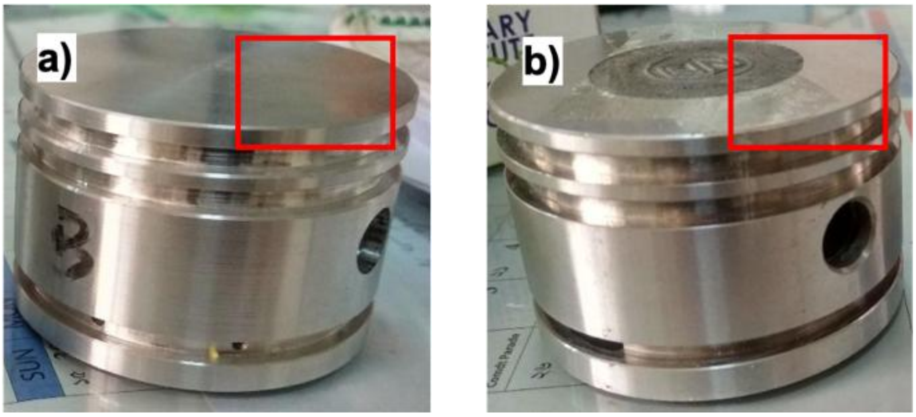

Fig 01. Clutch booster piston of a) Bangladesh and b) Pakistan country of origin. Red box indicating area of investigation

Table 01 and Figure 02 show comparative Brinell hardness test data of the two samples. It is clearly visible from Figure 02 is that the piston from Pakistan origin has significantly high hardness value compared to the Bangladesh origin sample. Materials with lower hardness value exhibit high wear rate resulting in deceased service life and diminishing efficiency of the component. [3–5].

Table 01
Brinell hardness test of sample from Bangladesh and Pakistan

Origin/Sample	Di	D	F	BHN
Bangladesh Sample-a	1.4	2.5	187.5	111
	1.39	2.5	187.5	113
	1.37	2.5	187.5	117
	1.38	2.5	187.5	115
	1.37	2.5	187.5	117
	1.36	2.5	187.5	119
Pakistan Sample-b	1.2	2.5	187.5	156
	1.21	2.5	187.5	153
	1.22	2.5	187.5	150
	1.25	2.5	187.5	143
	1.2	2.5	187.5	156
	1.24	2.5	187.5	145

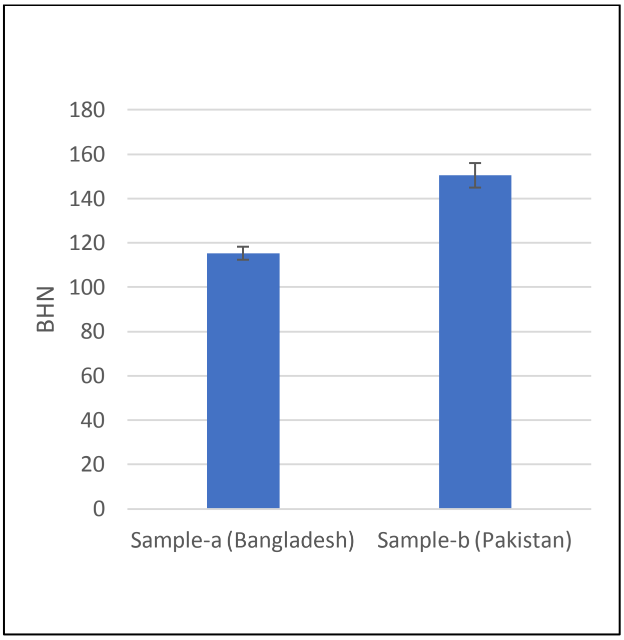

Fig 02. Comparative Brinell Hardness value of Sample of Bangladesh and Pakistan origin

Figure 03 and Figure 04 shows microscopic image of the two sets of samples with 20x, 50x and 100x magnification. From these figures we can see that sample-a (Bangladesh) has larger grain compared to sample-b (Pakistan). But we know that with decreasing grain size hardness of material increasing upto a certain size [6,7]. Below a certain size hardness decrease. This supports the hardness test result we have discussed above.

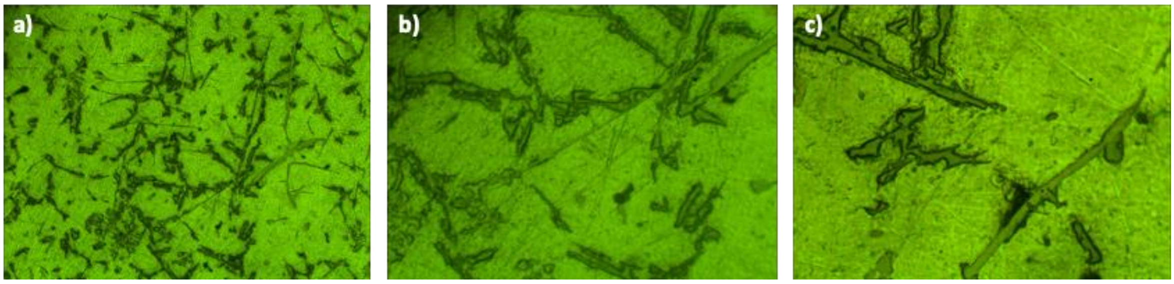

Fig 03. Microscopic image of clutch booster piston of Bangladesh origin. a) 20x, b) 50x and c) 100x magnification

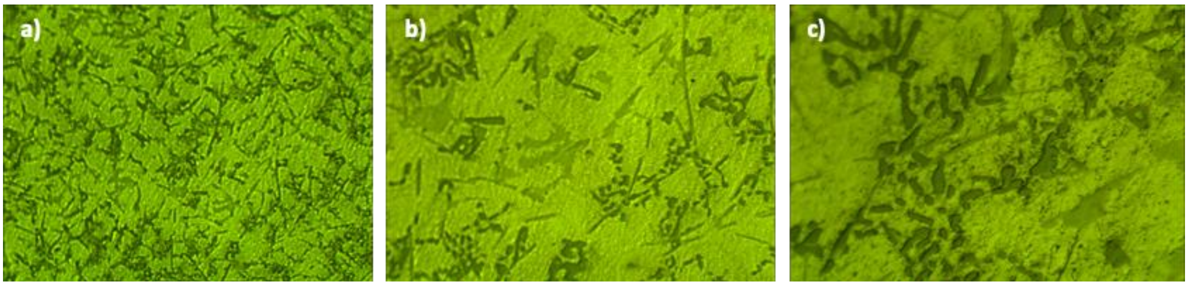

Fig 04. Microscopic image of clutch booster piston of Pakitan origin. a) 20x, b) 50x and c) 100x magnification

Figure 05 shows comparison SEM micrograph of clutch booster piston of sample-a (Bangladesh) and sample-b (Pakistan) with four and six phases respectively, identified using EDX and indicated by markers. Quantitative chemical analysis of each phases indicating composition of each constituents are shown in Table 02. For both cases phase 2 is the largest by wt.% compared to the other phases in the and has major effect on the performance of the whole alloy.

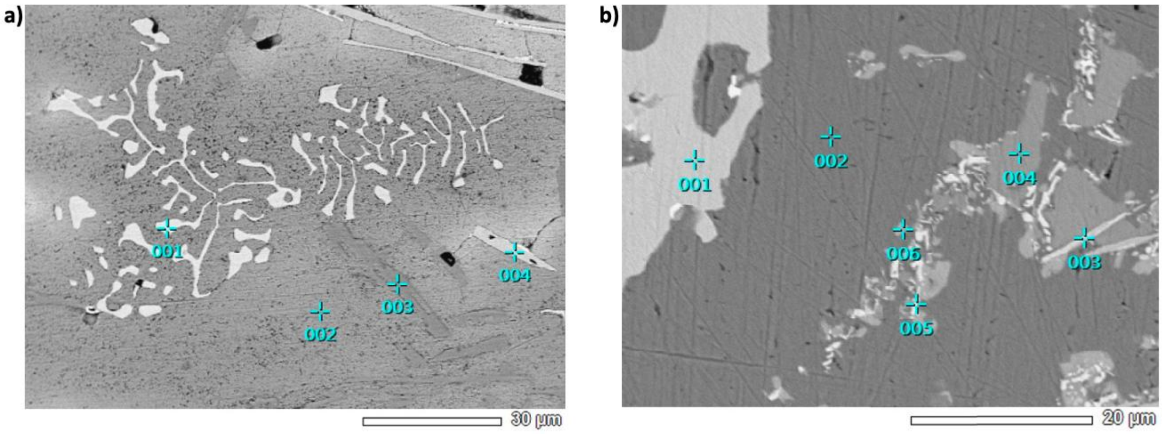

Fig 05. SEM micrograph of clutch booster piston of a) Bangladesh and b) Pakistan country of origin. Markers indicating each phase that being investigated whose composition is given in table 02

Table 02
Chemical composition (in wt.%) of the alloys used in the experimental study

Sample	**Sample**	**Phase**	**Element, wt-%**							
Origin	**Name**		**C**	**O**	**Mg**	**Si**	**Fe**	**Ni**	**Ag**	**Al**
Bangladesh	Sample-a	1	15.03	4.07		14.27	0.7		0.62	Bal.
		2	8.81	6.04	0.12	1.47	0.6	1.89	0.11	Bal.
		3	16.47	9.22	0.07	1.49	0.32		0.17	Bal.
		4	13.82	5.32	0.21	0.69		1.52	0.24	Bal.
Pakistan	Sample-b	1	7.36	2.35		13.05	4.18	7.69		Bal.
		2	5.52	2.19	0.2	0.95			0.38	Bal.
		3	5.49	1.24	16.32	23.9	2.01	10.29		Bal.
		4	5.27	1.85	16.02	25.77	1.49	6.7	0.03	Bal.
		5	8.34	3.8	0.73	1.26			0.47	Bal.
		6	7.92	2.46	0.21	0.82	0.49			Bal.

First, we compare the amount of Mg present in phase 2 of each sample, 0.12wt.% and 0.2wt.% respectively. According to literature, finer grain size can be obtained by increasing mg content in Al alloys [8]. Finer grain results in effecting the mechanical properties of the alloy by contributing to microstructural stability which significantly enhances fatigue properties [9]. Sample-b has almost twice amount of Mg content compared to sample-a indicating sample-b had more stable microstructure with enhanced mechanical properties resulting in longer life span compared to sample-a.

Presense of iron always poses detrimental effect to aluminum alloys. Ductility and tensile strength of aluminum alloy decreases with increasing Fe content. Particularly, ductility of aluminum alloy decreases after a critical Fe content is surpassed [10]. Phase 2 of sample-a contains 0.6wt.% and sample-b is Fe free. Source of Fe in sample-a can be attributed to the synthesis process where raw materials used during casting were scrap alumium alloy from old pistons along with other sourced alloys. Aluminum recycling comes with the challenge of controlling the composition for the required application [11]. Fe in particular poses a serious challenge due to its gradual accumulation during recurring scrap recycling process [12]. Removal process of Fe from recycled aluminum alloy becomes complex and costly with decreasing Fe content [13]. Almost all the local manufacturers forego this refining process, resulting in presence of Fe, causing reduction of operation life of the components.

Oxygen in aluminum alloy influence mechanical properties. Addition of oxygen slightly increases tensile strength but causes large reduction of yield strength of the aluminum alloy [14]. Phase 2 of sample-a had almost three times more oxygen content compared to sample-b, 6.04 wt.% to 2.19 wt.%.

Carbon/graphite content is generally undesirable in aluminum alloy as it is detrimental to the tensile and compressive strength [15]. Sample-a has comparatively high C content, 8.81 wt.% compare to sample-b, 5.52 wt.%. The source of this C content can be attributed to the recycled aluminum alloys as recycle piston may contain carbon residue from previous application which are generally not removed before recycling.

Second largest phase based on wt.% is phase 1 for both sample-a and sample-b. Phase 1 has a very high wt.% of Si content and characterized by dendritic strcutures [16]. Al-Si alloy has outstanding influence in the improvement of casting characteristic, physical and mechanical properties and corrosion resistance [17]. Since both the sample has similar wt.% (14.27 wt.% and 13.05 wt.%) of Si, it will have less impact on the comparative performance of the components based on their chemical composition.

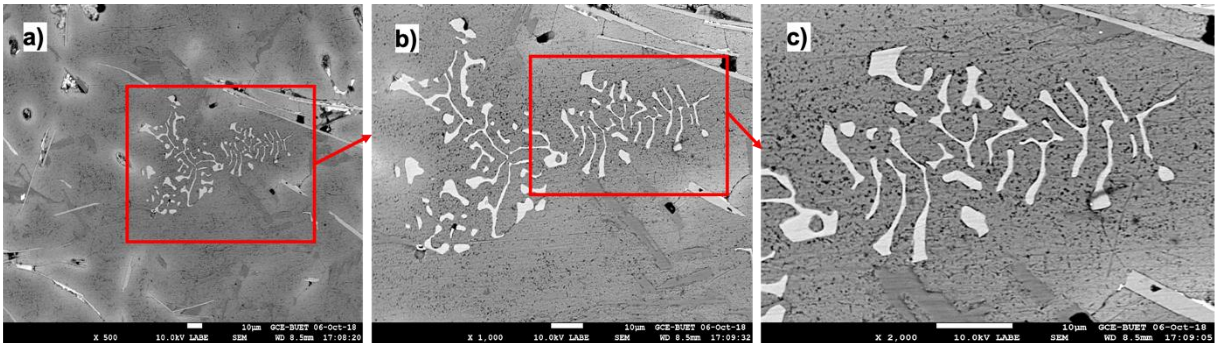

Fig 06. SEM micrograph of clutch booster piston of Bangladesh origin. a) 500x, b) 1000x and c) 2000x magnification

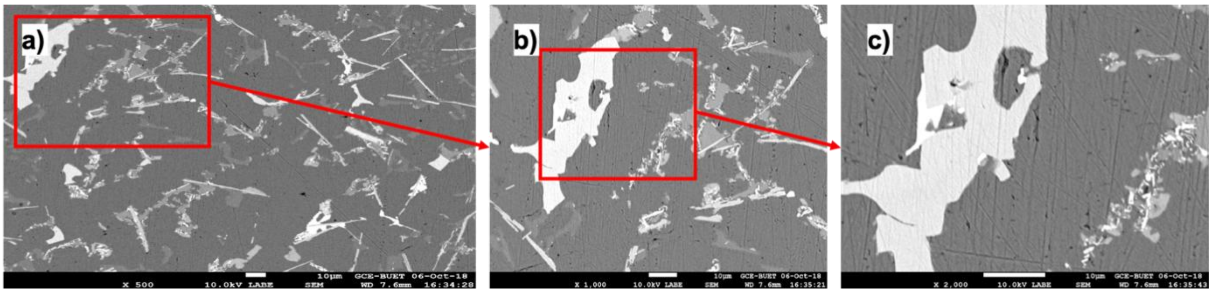

Fig 07. SEM micrograph of clutch booster piston of Pakistan origin. a) 500x, b) 1000x and c) 2000x magnification

But Figure 06 and Figure 07, showing SEM image of several magnification of the two specimens clearly indicate that phase 1 for each case has different morphology where phase 1 in sample-a is dendritic and in sample-b is agglomerate. Shape and size of these dendiritc structure influence the mechanical properties of aluminum alloys [18].

IV. Conclusion

To identify the factors that contribute to the quality variation between local and imported automotive parts, we investigate automotive clutch booster piston by microstructural characterization and quantitative chemical analysis. Brinell hardness test indicates that sample of Pakistan origin has significantly higher hardness value compared to Bangladesh origin. Literature suggests that material with higher hardness value will be more resistant to wear and degradation increasing operating life. Our hardness result is in agreement with this. Also, microscopic image shows finer grain size for Pakistan sample. According to literature, finer grain contributes to higher hardness in materials. Mg content that enhances microsturcural stabitliy in aluminum alloy were found to be in higher wt.% in the major phases in the imported components. Fe, O and C-elements, detrimental to the material strength and stability were found to be in higher wt.% in the local manufactured components resulting in its poor performance. Presence of these undesirable elements can be attributed to the manufacturing process where scrap aluminum from different automotive components is used as raw materials. Also, lack of use of refining method to remove these unwanted elements to reduce manufacturing price may also be responsible.

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