Computational Flow and Thermal Analysis of Motorbike Exhaust Muffler

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Abstract

With the increasing demand for automobile vehicle and their usages its influence on environmental pollution and human health, it is very important to engineer it in the best optimum design with respect to its life, emissions and manufacturing cost. Also, with an increase in the maintenance of various components of vehicles demand new effective design and their analyses have increased. In this work, we focused on the life of the exhaust system of a motorbike in which high-temperature gases pass and get cool and also sound emissions are decreased and then released to the atmosphere. Gases stay more time in silencers than other parts of the exhaust system to reduce the noise level. The uniform heat distribution over the entire exhaust system is important for ensuring the enhanced life of elements in the sub-system. Therefore, uniform heat flow is necessary along the passage surface to minimise the harmful effect of hotspots over the length of the silencer, especially at the outer body of the silencer. We introduced that providing different types of patterns uniform over the surface of the muffler results in better heat dissipation throughout the surface, which will decrease the oxidation rate of metal with oxygen present in air and rust formation. So, we made CAD files using CREO Parametric of mufflers having different patterns on the surface. The pattern designs which can be manufactured easily are to be made. Further CAD models will be analysed in ANSYS by thermal analysis to observe which pattern is best among those made.

Keywords: - *Muffler, Silencer, Heat Flux, CFD*

INTRODUCTION

Mufflers or silencer in the exhaust system of every vehicle is an acoustic device to reduce the loudness of the sound pressure created by the engine. Straight-through design mufflers consist of an inner perforated tube, an outer solid tube and fibreglass insulation between the two tubes. They often have less back pressure than original equipment mufflers but are relatively ineffective at reducing sound levels. A chambered muffler consists of a series of concentric or eccentric pipes inside the expansion chamber cavity. Sound waves

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in pipes bounce off the closed, flat ends of the pipe. These reflections partially cancel each other and reducing the sound level.

B.S. Patel and Mahesh et al. [1,2] reviewed heat transfer analysis in the automotive exhaust system. It is found that the transfer in exhaust system plays a key role in the design of exhaust system components. Hot spots and corrosion on exhaust pipes and silencers can be controlled by exhaust system temperature. They found that reducing the number of iterations, product, development, time, and cost can improve. Baffle type, Absorption type, wave eliminating type, and resonance type of mufflers are explained.

Saravanan et al. [3] analysed exhaust manifold with ceramic coating to reduce heat dissipation. They found that the surface temperature, carbon monoxide emission, and nitrogen oxide emission are minimised by coating the exhaust manifold at rated load. VERONICA powder inside and ALUMINA-TITANIA coating is done outside. Venkata et al. [4] worked on the Design and Analysis of an Automobile Exhaust Muffler and investigated it. A double expansion chamber gives better results as compared to a single expansion chamber. The transmission loss of the dual expansion chamber is which is more than the requirement and satisfactory. Transmission loss is about 42.48%. Dhananjay et al. [5] studied muffler design and prototypes validation with consideration of time and. And design verification will always be necessary at the end of each step. Design for the desired frequency is given. Bharath al [6] done a thermal analysis of the motorbike silencer and conclude that by providing different patterns on the outer surface of the Muffler, the heat dissipation is found to be even all over the surface. Vinod Sherekar et al. [7] investigated that an automotive muffler should be designed to meet all requirements, like adequate insertion loss, minimal backpressure, space constraints, be durable, lightweight, be cost-effective. Christopher et al. [8] observed a wide scope or an unexplored area of open flow or straight-through Muffler, which are much more efficient in terms of minimised pressure drop, improved fuel efficiency, and increased power at the throttle.

Nitin Kumar et al. [9] studied the main source of vibration and noise in an engine are exhaust noise. He observed an acoustic performance of a reactive muffler with a side outlet using FEM and an analytical approach.

S. Rajadurai et al. [10] studied materials for automotive exhaust systems. They observed that thermal expansion is co-efficient, and service temperature for various materials is defined. In ferrite materials, SUS 441L has a high service temperature and austenitic materials. SUS 310 has a high service temperature, and in a special alloy, FeCr alloy has high conductivity.

Dattatray Dilipet al [11] worked on thermal analysis on motorbike silencer for reduced hotspots through design enhancement and research done by different methods like Mathematical method, Analytical Method, Computation approach, and Experimental set up is used to thermal analysis for motorbike exhaust silencer.

Dhiraj Kumar et al. [12] compare the result determined by analysis with the physical experimentation would be a good pointer to authenticate the design. The design said to be validated if the geometry of the silencer yields a

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result that displays a good competition within the analysis over the physical experimentation.

Province al [13] worked on the design and thermal analysis of motorbike silencers and found that the hotspots on the silencer surface due to non-uniform distribution of heat over the surface can significantly reduce by changing the profile of the silencer tube by providing dimples on the surface.

OBJECTIVES AND SCOPE OF THE STUDY

Automotive mufflers are designed considering various factors like exhaust gas emissions, sound emissions and Bharat Stage norms. Each vehicle's Muffler is different in geometry from inside as well as outside. There are baffles and walls in the inside geometry, which direct the exhaust gas and thus create hotspots at turning points, resulting in increased oxidation reaction with the atmosphere and thus resulting in corrosion. Increasing the life of Muffler and decreasing corrosion is our prime agenda.

REFERENCE TEST SPECIMENS:

It is best suited depending on the type of exhaust system present in the car or motorbike. You would need to check for the owner’s manual and other details of your product. Motorcycle exhausts come in many varieties depending on the type of engine and its intended use. A twin-cylinder bike may have independent exhaust sections, as seen in the Kawasaki EX250. Four-cylinder machines, super-sport bikes like Kawasaki's ZX series, Honda's CBR series often have a twin exhaust system. Depending on its layout, a "full system" may be bought as an aftermarket accessory, also called a 4-2-1 or 4-1. In the past, these bikes would come as standard with a single exhaust muffler, a practice that lasted until the early 2000s, when EU noise and pollution regulations mostly stopped this practice, forcing companies to use other methods to increase the performance of the motorcycle.

Thus an automobile muffler is used to reduce the noise and removing the gas. But the exhaust gas temperature is very high, as the exhaust gas doesn't pass uniformly throughout the Muffler. It just passes through some point of the Muffler. That part is called hotspots of Muffler. Hot-spot of the silencer body creates high-temperature oxidation that could lead to corrosion and mechanical breakage of the Muffler. Providing the patterns and different types of fins in the Muffler would help the Muffler uniformly distribute the temperature distribution.

DIFFERENT TYPE OF PATTERNS:

Pattern of longitudinal fin | Pattern of ribs | Pattern of longitudinal fins and ribs

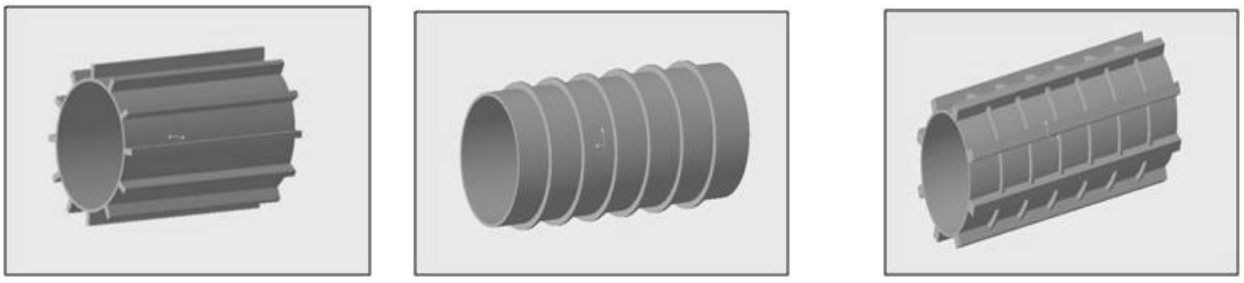
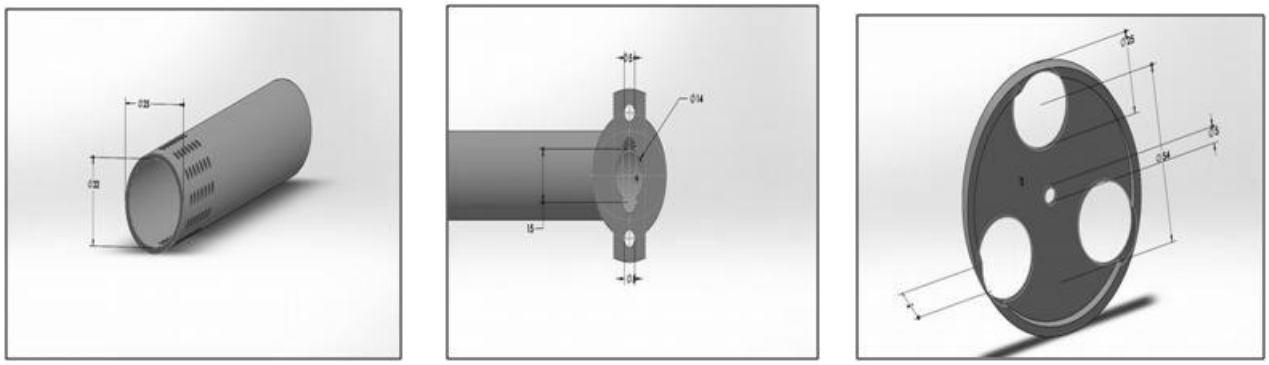


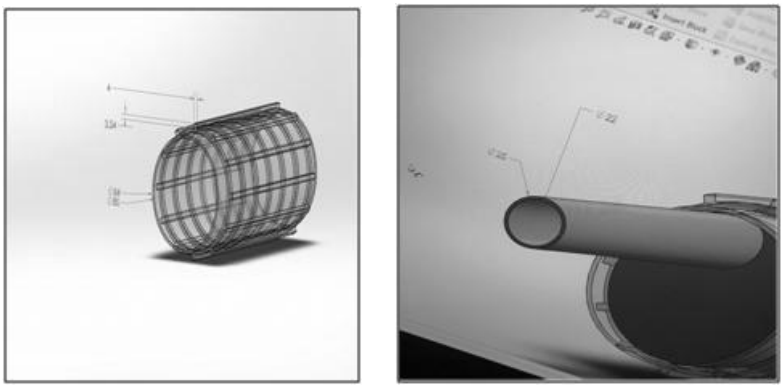
Figure 1: Different types of Pattern on Muffler

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GEOMETRIC MODELING OF MUFFLER



(a) (b) (c)



(e) (f)

PERFORMANCE OF FINITE ELEMENT MODEL

Velocity Analysis:

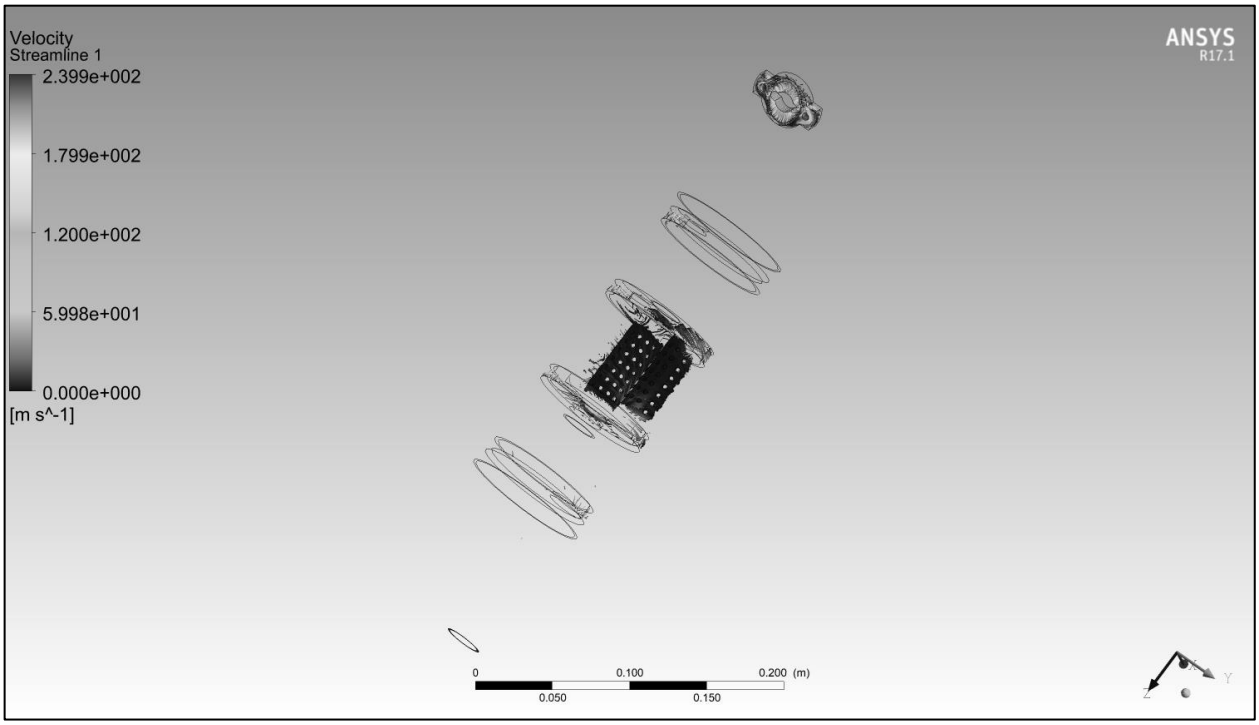


Figure 3: Velocity analysis in Simple Muffler

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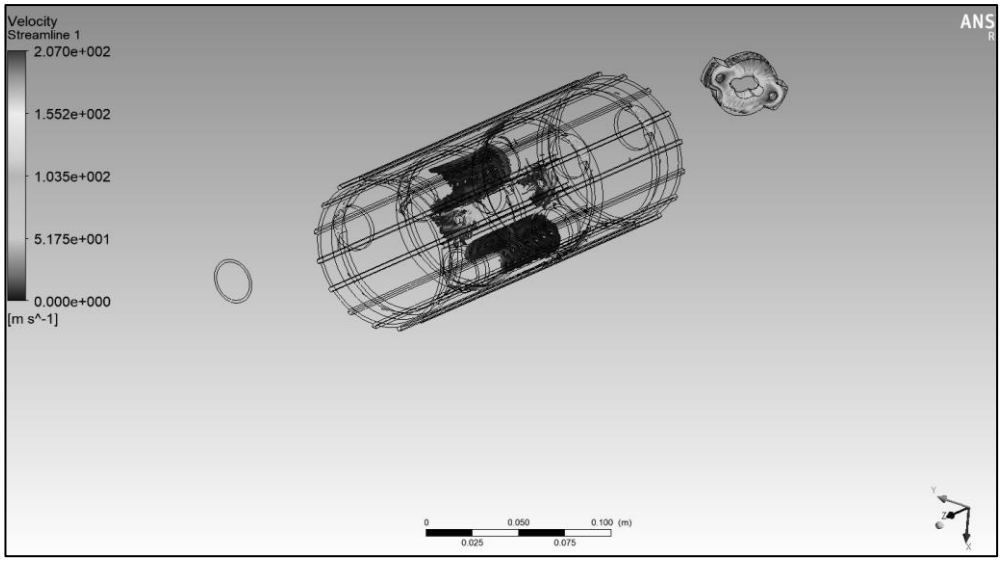


Figure 4: Velocity analysis in Muffler with Fins

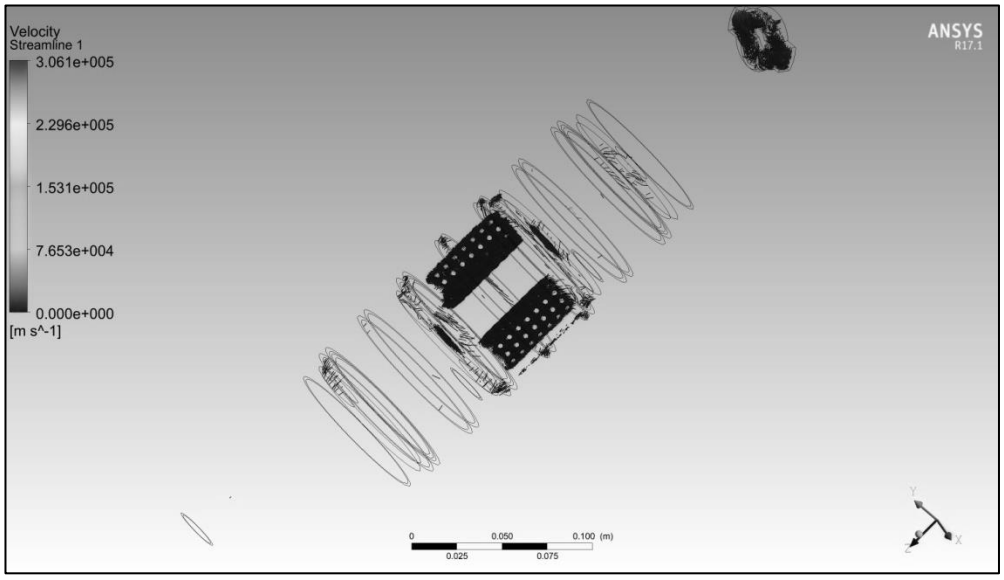


Figure 5: Velocity analysis in Muffler with Ribs

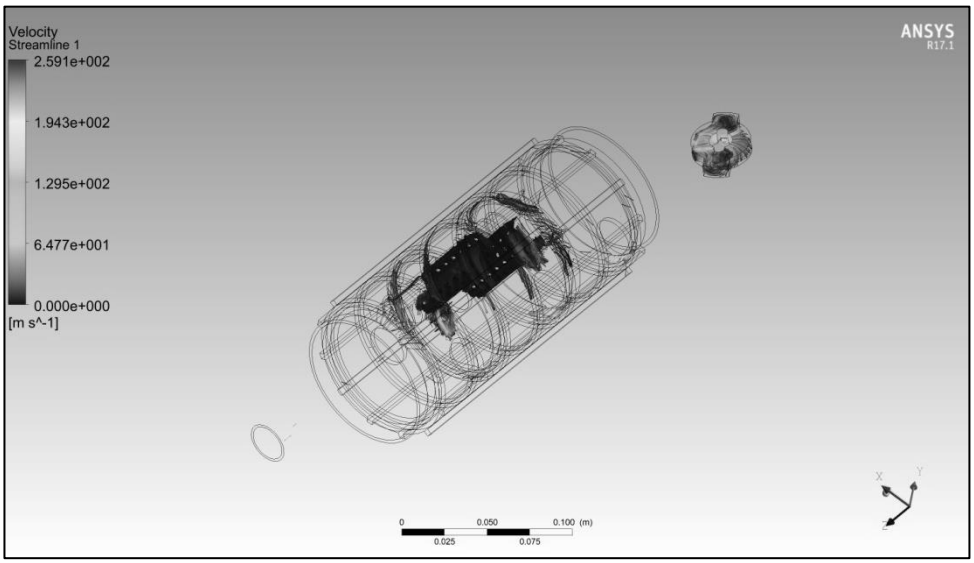


Figure 6: Velocity analysis in muffler with Fins and Ribs

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2) Wall Shear:

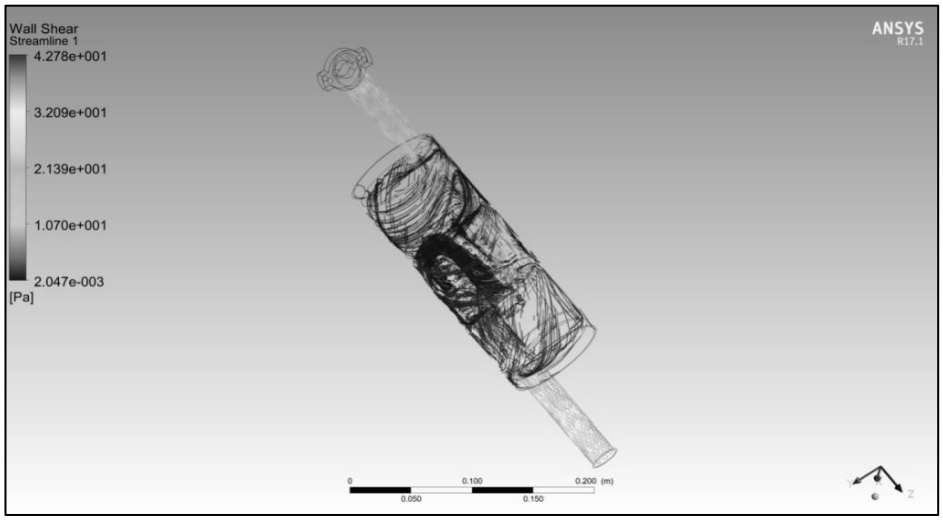


Figure 7: Wall Shear in Simple Muffler

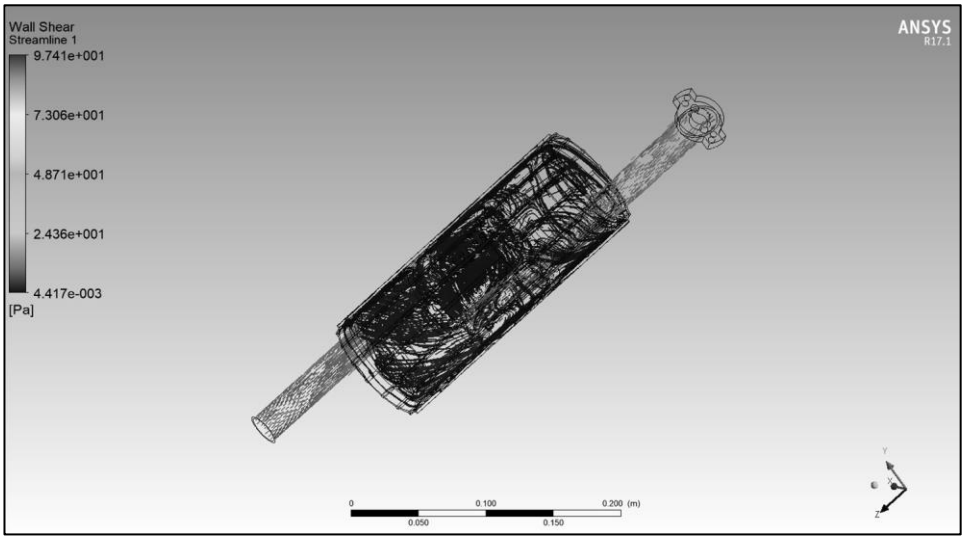


Figure 8: Wall Shear in Muffler with Fins

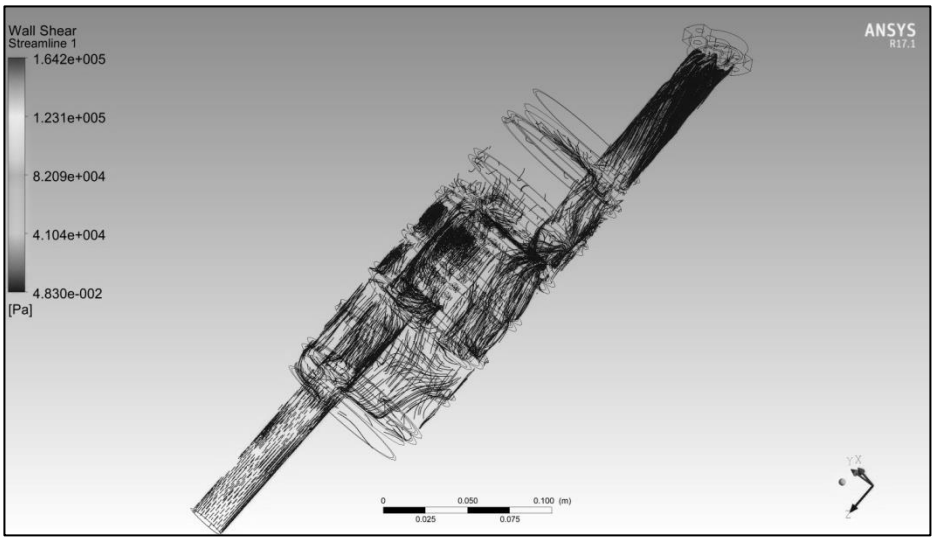


Figure 9: Wall Shear in Muffler with Ribs

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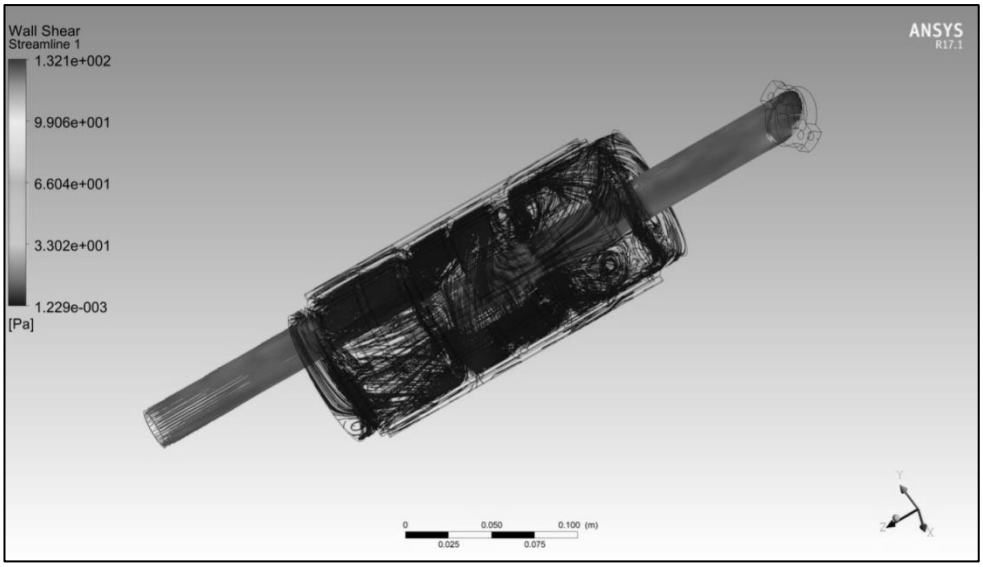


Figure 10: Wall Shear in Muffler with Fins and Ribs

3) Pressure Gradient:

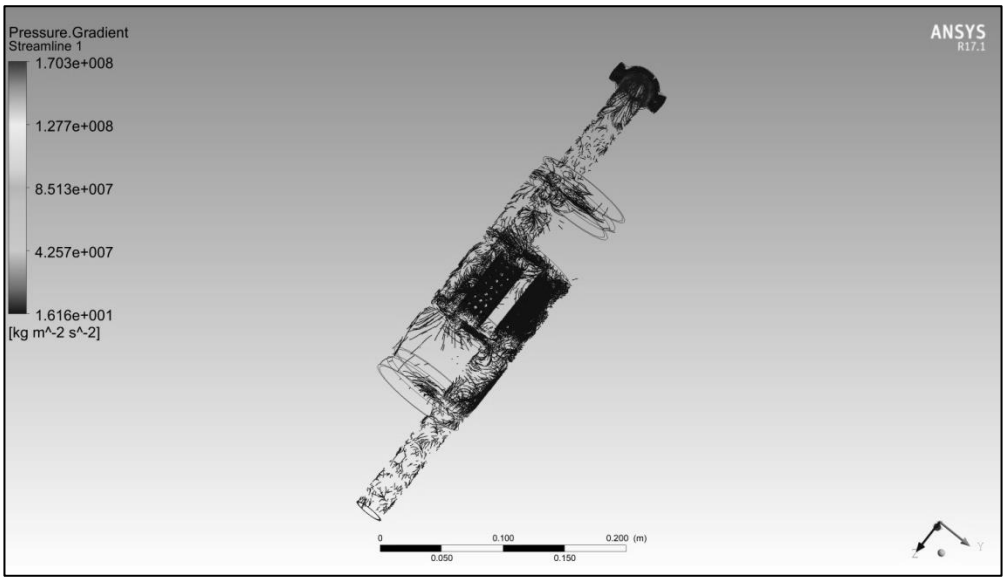


Figure 11: Pressure Gradient in Simple Muffler

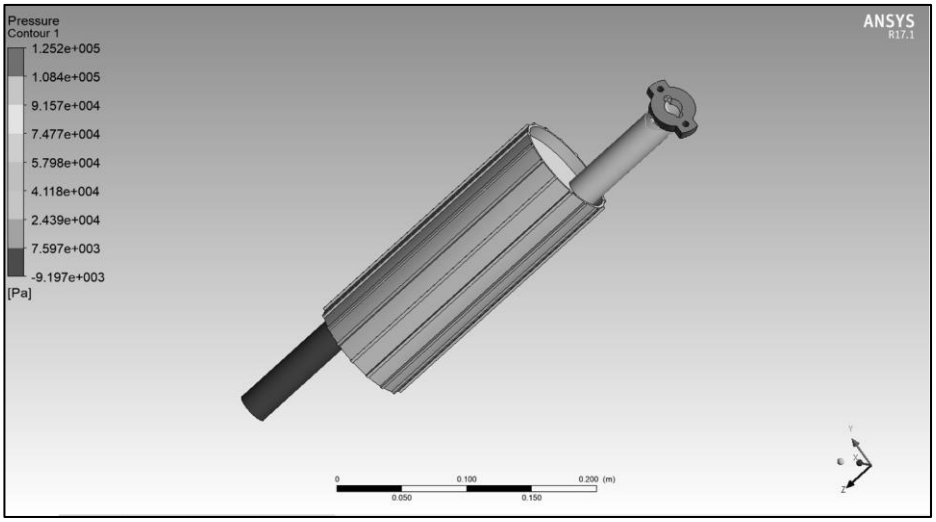


Figure 12: Pressure Gradient in Muffler with Fins

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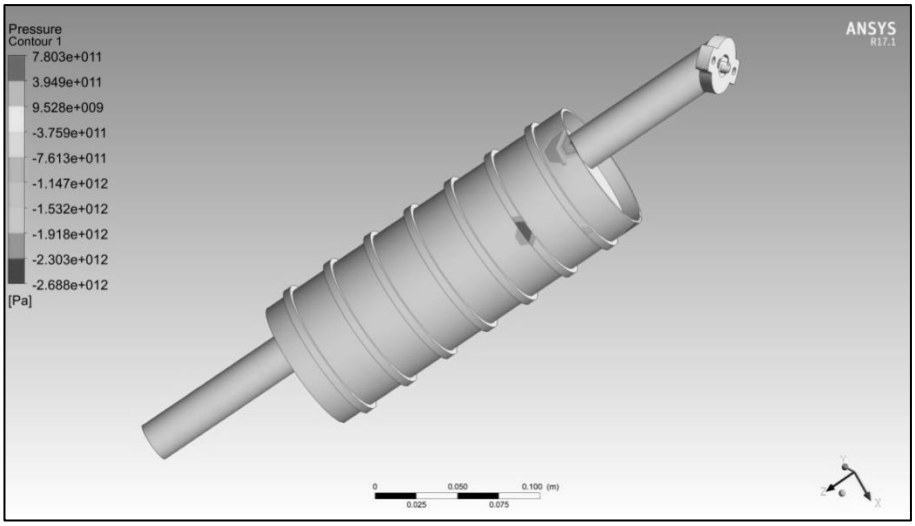


Figure 13: Pressure Gradient in Muffler with Ribs

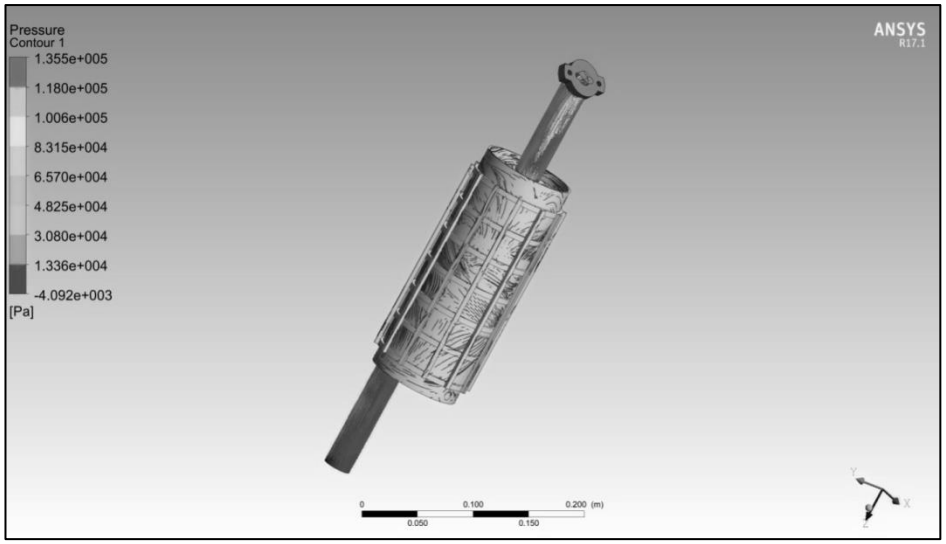


Figure 14: Pressure Gradient in Muffler with Fins and Ribs

4) Total Heat Flux

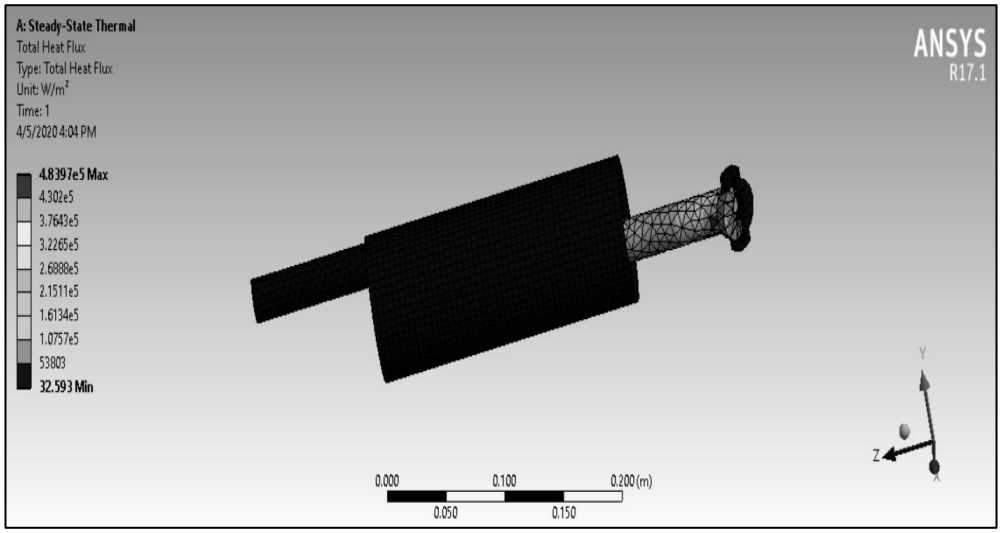


Figure15: Total heat flux in Simple Muffler

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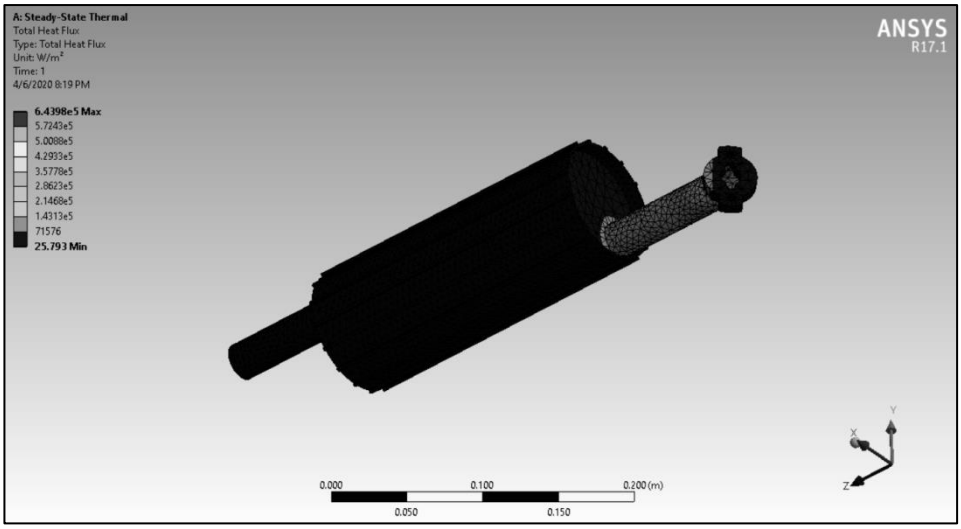


Figure 16: Total heat flux in Muffler with Fins

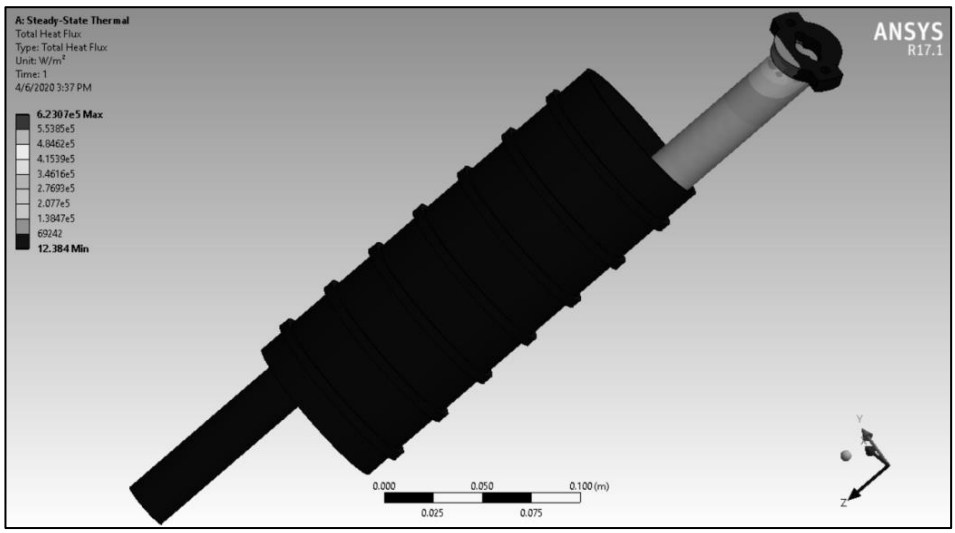


Figure 17: Total heat flux in Muffler with Ribs

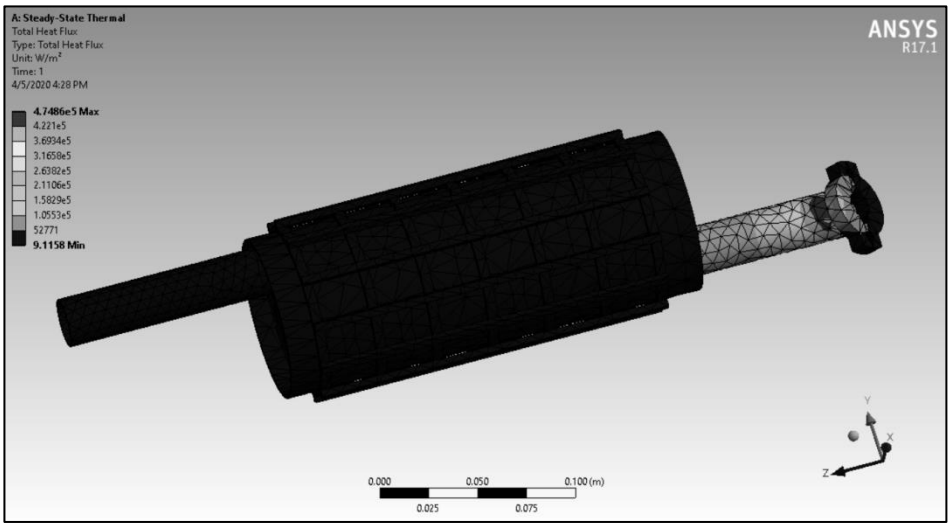


Figure 18: total heat flux in Muffler with Fins and Ribs

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5) Temperature

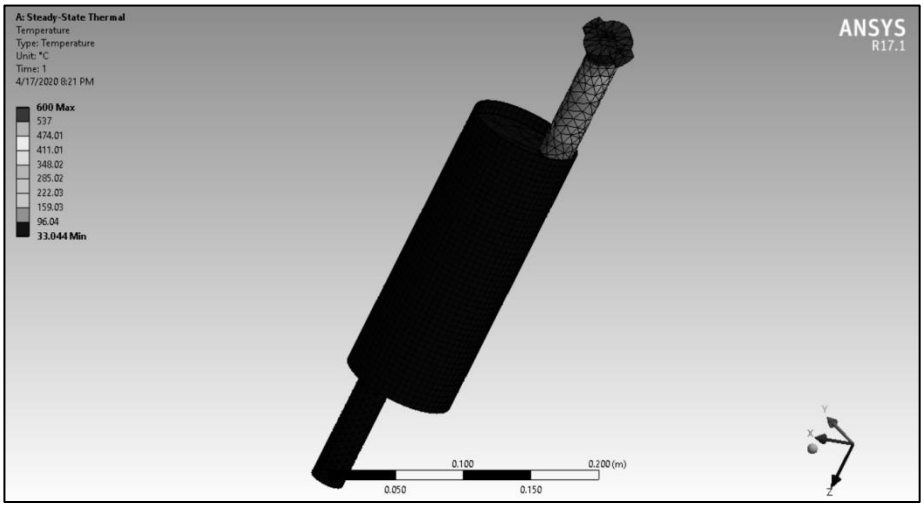


Figure 19: Temperature in Simple Muffler

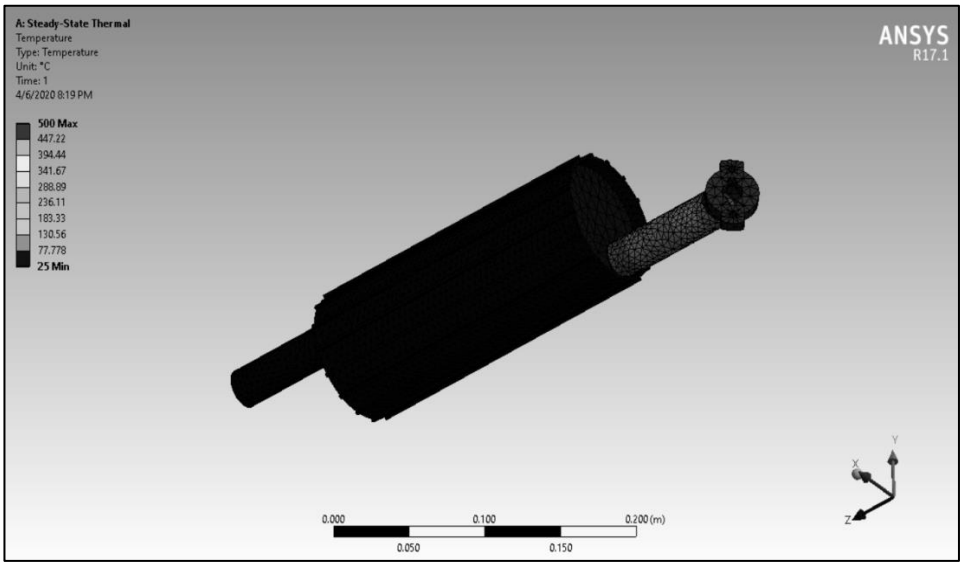


Figure 20: Temperature in Muffler with Fins

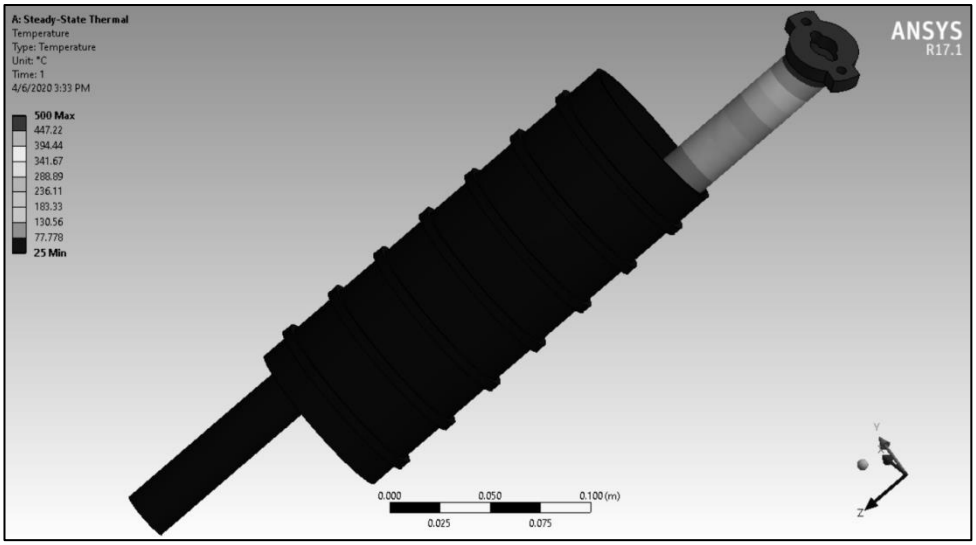


Figure 21: Temperature in Muffler with Ribs

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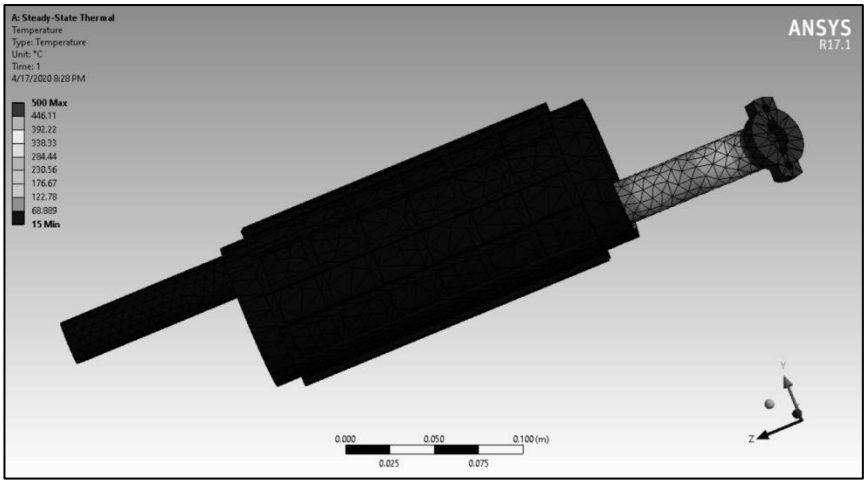


Figure 22: Temperature in Muffler with Fins and Ribs

RESULT AND DISCUSSION

- Velocity Analysis - velocity analysis, we observed that there is no significant change in velocity flow. Almost the same velocity flow is found in every design of mufflers. But you find minor up and downs in some velocity flow, like in simple Muffler, Muffler with fins and Muffler with fins and ribs, it's almost same, but in Muffler with ribs, we find that velocity flowing per second is more.
- Wall Shear – Wall shear means the shear force acting on the wall parallel to the gas flow. As we see from the analysis, there is some difference between the four designs. But we see the lowest value in the design of Muffler with rib and Muffler with fin and ribs, and that is a positive sign of analysis, but in Muffler, with fin, we see there is an increase of wall shear than the simple design of Muffler.
- Wall shear analysis in Ansys, we tested each of the Mufflers with modifications to increase heat dissipation. As a result, we found the slightest turbulence in design having a pattern on the surface of ribs and fins combined. There was more heat dissipation than other designs due to laminar flow and the pattern formed on the surface.
- Pressure Gradient –Pressure gradient is a physical quantity that describes the direction and rate of increase/decrease. In our analysis, we find that the pressure gradient didn't change, but we also see from the analysis that the design of Muffler with ribs has vast differences compared to pressure gradient than other designs.
- Total Heat flux-Total heat flux means flowing of heat in all the direction, and we see from the analysis that there is not much difference in the value of the heat flux in all the design.
- Temperature - In temperature analysis, we can say about the design of ribs and fins. We find outlet temperature is relatively low than all other designs, as there is less turbulence. As we know that, the hot spots created on the surface is due to the penetration of the gas on point, and this happens when turbulence is more, we needed to find the design in which there was the slightest turbulence than the standard Muffler.

CONCLUSIONS

In this computational flow and thermal analysis, different variables like velocity, wall shear, Pressure gradient, total heat flux were analysed

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with longitudinal fin, circular rib and a combination of fin and rib design. We observed that by changing the design of the outer surface of the Muffler of the motorbike, uniform heat flow distribution over the entire pipe of the silencer could be achieved. And also will prevent the hotspot on Muffler hence increase the life of the Muffler.

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