MARMARA UNIVERSITY
FACULTY OF ENGINEERING

DESIGN AND ANALYSIS OF AN EXTRUSION DIE HAVING A ROTATING BILLET

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GRADUATION PROJECT REPORT
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DESIGN AND ANALYSIS OF AN EXTRUSION DIE HAVING A ROTATING BILLET

by

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Head of the Department of Mechanical Engineering

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ABSTRACT

Design ana Analysis of an Extrusion Die Having a Rotating Billet

After a introduction about the purposes of the project and information about the process this project report starts with the explanation of design of the pieces which are mold, pusher and workpiece. It also gives the both the constant and variable parameters selected.

After that the method used which is computational analysis method is described with figures from the software used.

From then point selection is showed and results are given with graphs taken directly from the software DEFORM3D.With 2 variable parameters 15 different analyzes has been completed and their results are included in this project.

After the results part a discussion an conclusion part is given which sees the results in table format to make the comparing of the results so much easier.

SYMBOLS

ºC: Celsius Degree

sec: Seconds

rad: Radian

mm: Millimeters

MPa: Megapascal

ABBREVIATIONS

RPM: Revolutions per Minute

CAD: Computer Aided Design

3D : 3 Dimensional

WCS: World Coordinate System

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1.INTRODUCTION

Extrusion is one of the main production processes and being able to produce long goods continuously makes the process efficient and popular in industry. So, increasing efficiency of the process is one of the key areas among researchers. The one of the possible solutions is to change billet as a rotating one which will cause much more deformation in the same time interval. In this study, this process will be modelled in DEFORM3D and simulation results will be considered to check if the proposed method is feasible and which factor is much more affective.

In this project a simple mold that its parts can easily be replaced to change parameters has been designed using a CAD software. Alongside that a simple pusher has been designed and its design is changed to the needs of the user's parameters. The designed workpiece is same for all of the analyzes.

In this project effects of angular velocity and die diameter is researched in an extrusion die having a rotating billet. Traditional non- rotating extrusion is also compared with rotational extrusion with regards to load, strain rate, stress and total velocity.

2.MATERIAL AND METHOD

2.1. 3D CAD Design

Design of the mold that is used on this project is designed on 3D CAD software SiemensNX.

2.1.1. General Mold Design.

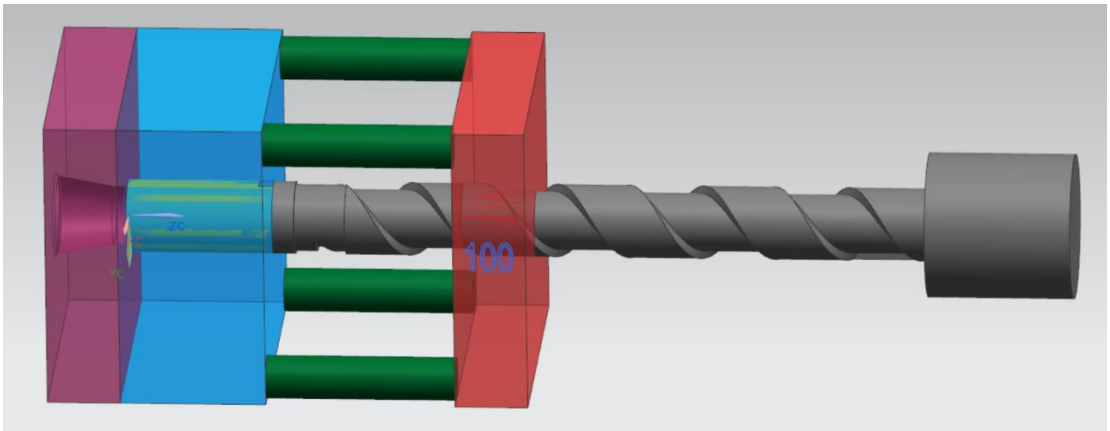

Figure 2.1. Mold Design

General Design of the mound is in figure 2.1. Mold design consists of mainly three parts and the parts are altered for the changing of parameters used in the analysis process.

2.1.2. Workpiece

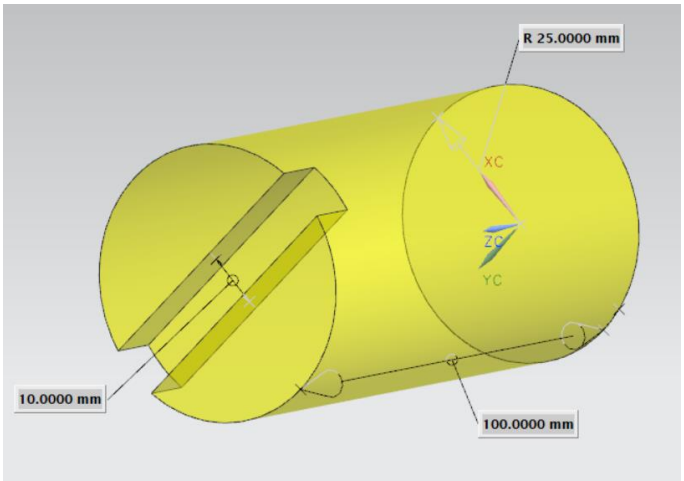

Figure 2.2. Workpiece

Design of the workpiece that is used is in Figure 2.2. It is a cylinder that has a 50mm diameter and a 100mm height that is cut on the back with a 10 mm through cut.

2.1.3. Pusher

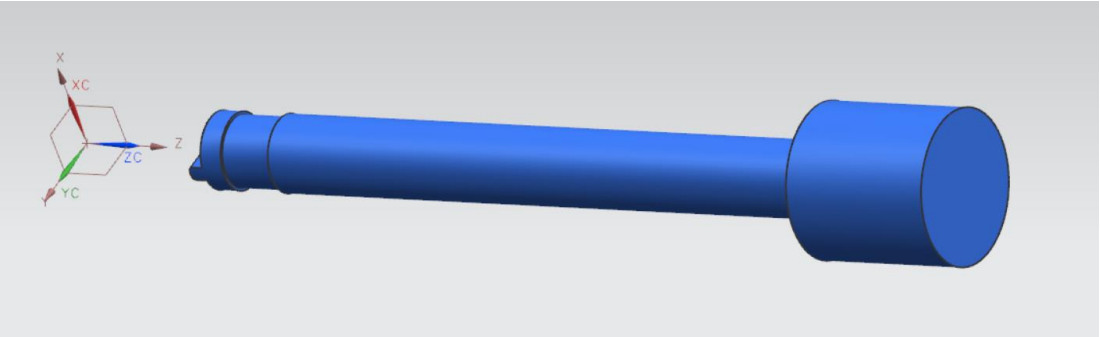

Figure 2.3. Non-rotating pusher

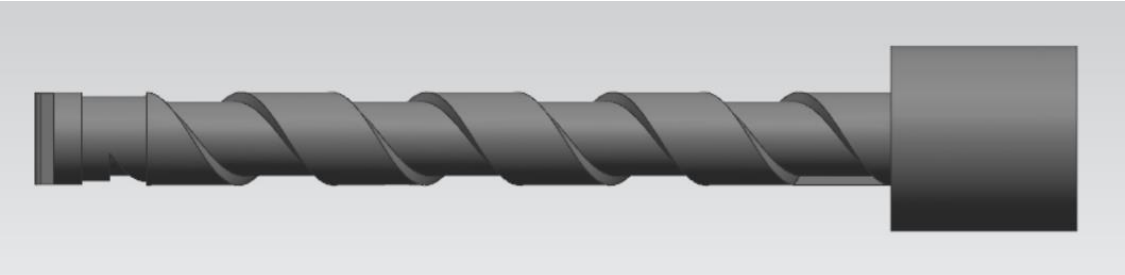

Figure 2.4. Rotating pusher with a step of 100 mm

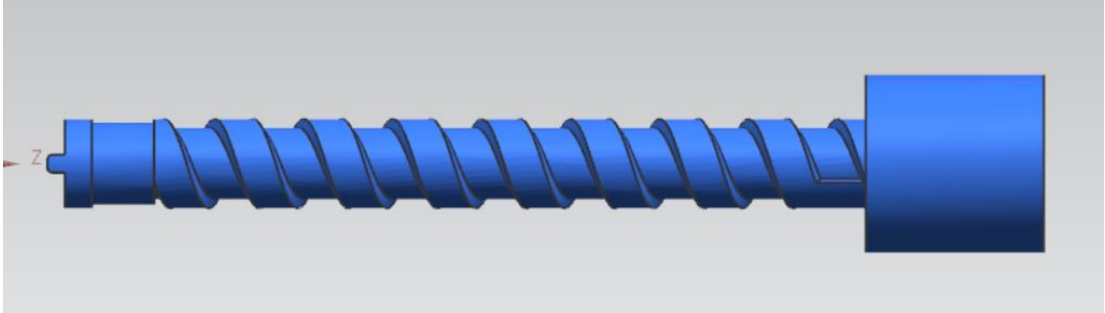

Figure 2.5. Rotating pusher with a step of 50 mm.

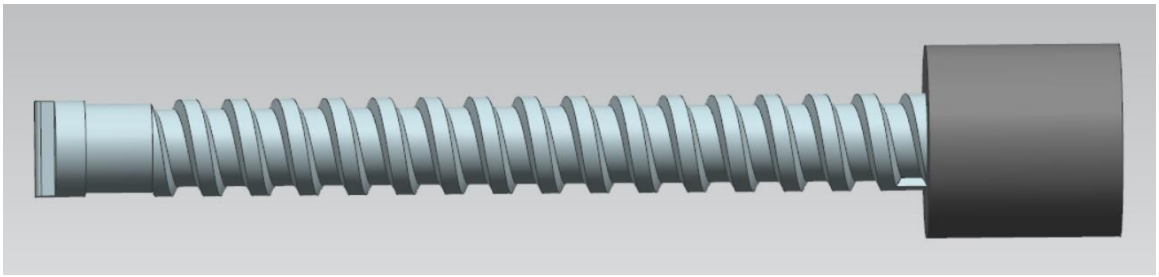

Figure 2.6. Rotating pusher with a step of 25 mm.

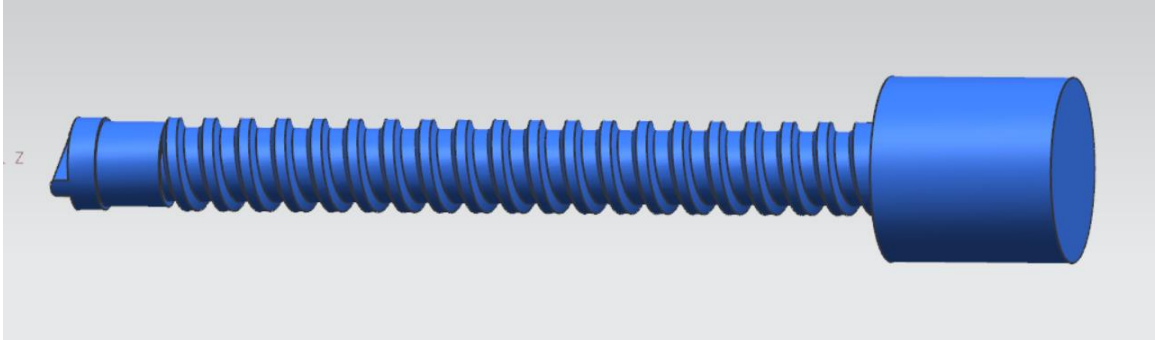

Figure 2.7. Rotating pusher with a step of 20 mm.

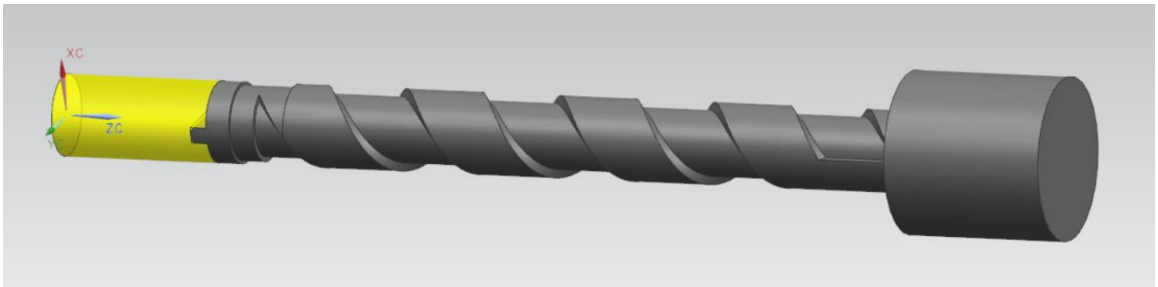

Figure 2.8. Positions of workpiece and pushers regarding to the WCS

Pushers seen in the above figures is used as top die for the analysis. Non-rotating pusher as the name suggests does not do rotational movement. 100mm Step means that the pusher turns 360 degrees one time on its axis while it translates 100mm on the Z direction. It is 2 times for Step of 50mm ,4 times for step of 25mm and 5 times for the step of 20mm respectively. The different design of pushers is used for changing the angular velocity without changing the stroke of the workpiece. WCS of the system can be seen in figure 2.2 and figure 2.3. It is important to note that origin of the system is at center of the flat upper face of the workpiece. At figure 2.8 the positions of workpiece and pusher can be seen regarding each other and the WCS.

2.1.4. Bottom Die

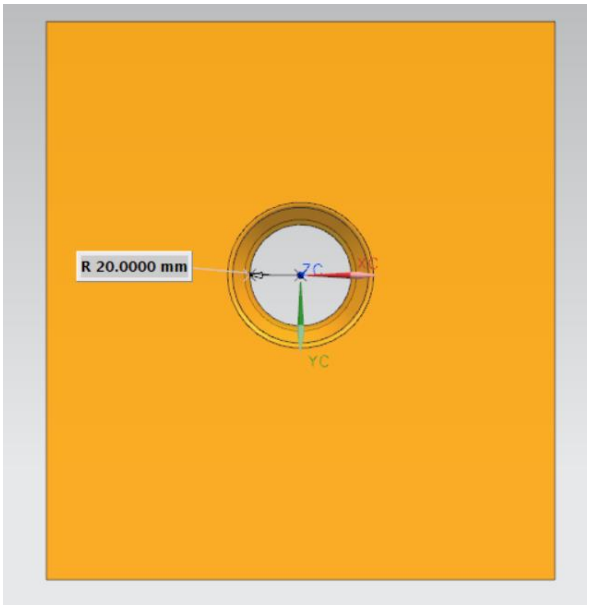

Figure 2.6. Die with a diameter of 40 mm

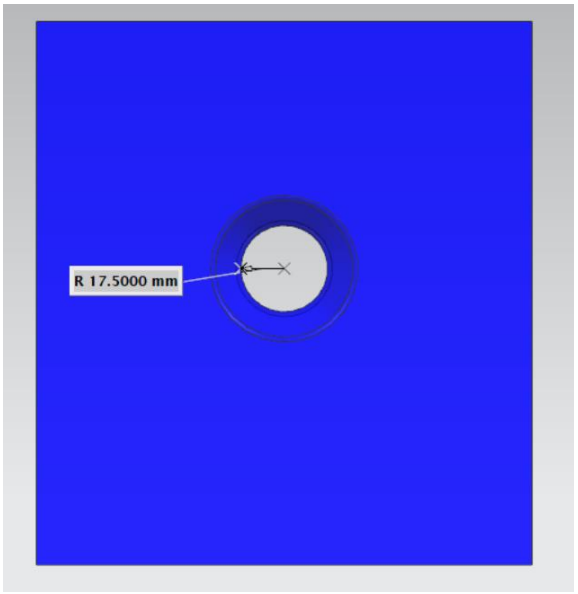

Figure 2.7. Die with a diameter of 35 mm

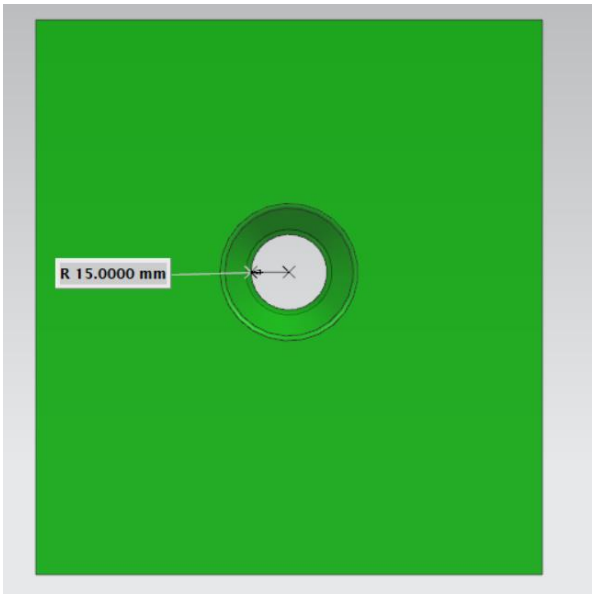

Figure 2.7. Die with a diameter of 30 mm

Shape-Forming parts of the bottom die are shown in the figures 2.6, 2.7 and 2.8. They are used for changing the diameter of the workpiece from 50mm to 40, 35 and 30 mm respectively.

2.2. Parameters

2.2.1. Constant parameters

2.2.1.1. Stroke

Stroke is a constant parameter that is same for all analysis performed for this project. Stroke of the extrusion is 89mm. Since the workpiece is 100mm and has a slot of 10mm the stroke is been selected as 89mm to avoid collision between the rotating pusher and bottom die.

2.2.1.2. Linear velocity

Linear velocity of the rotating pusher is a constant parameter for all analysis performed for this project. Linear velocity of the extrusion is selected as 40mm/s.

2.2.1.3. Time

As a result of stroke and linear velocity time is a constant calculated parameter for all analysis performed for this project.

$$\frac{89mm}{40\frac{mm}{s}} = 2.225sec$$

2.2.1.4. Temperature

Table 2.1. Temperature of the components of the mould

Temperature of the Components of the Mould		
Workpiece	Rotating Pusher	Bottom Die
450℃	500℃	400℃

Temperature that is used for the analysis performed for this project are shown on the table 2.1.

2.2.1.5. Material

Material of the workpiece is a constant parameter for the analysis performed for this project**.** Aluminum-1100 is the selected material for the workpiece for this project. Aluminum-1100 is selected due to wide variety of application field and it being the softest of the common aluminum alloys. Since the bottom die and rotating pusher are selected as rigid materials there is no need to select materials for them.

2.2.1.6. Shear friction factor

Friction factor is a constant parameter for the analysis performed for this project**.** Friction factor between the components of the mould is selected on the recommendation of the software as 0.3 for all analysis performed for this project.

2.2.1.7. Mesh number for the workpiece

Mesh number is a constant parameter for the analysis performed for this project**.** Mesh number for the workpiece is selected on the recommendation of the software as 32000 for all analysis performed for this project.

2.2.2. Variable parameters

2.2.2.1. Die diameter

As it has been stated in the design part of the document, die diameter is a variable parameter. There are 3 different die diameters that is used in the analysis which are 40mm,35mm and 30mm.

2.2.2.2. Angular Velocity

As it has been stated in the design part of the document, 3 different rotating pusher is used for the analyzes. The different design of pushers is used for changing the angular velocity without changing the stroke of the workpiece. The different step sizes are 100mm, 50mm and 25mm.Stroke is 89mm and the time is 2.25sec. If stroke had been 100mm the time would have been 2.5sec. So, it can be said that the workpiece rotates 1 time for every

2.5 sec for 100mm step size. Calculating the angular velocity for different sizes.

For 100mm step size;

$$\frac{60}{2.5} \times 1 = 24\, rpm = 2.5132\, rad/sec$$

For 50mm step size;

$$\frac{60}{2.5} \times 2 = 48\, rpm = 5.0265\, rad/sec$$

For 25mm step size;

$$\frac{60}{2.5} \times 4 = 96\, rpm = 10.0531\, rad/sec$$

For 20mm step size;

$$\frac{60}{2.5} \times 5 = 120\, rpm = 12.5664\, rad/sec$$

2.3. Analysis Method

Analyzes for this project are done using the DEFORM3D software. Analysis consists of three parts which are pre-processor, simulator and post-processor. In the preprocessor part the design and problem are introduced to the software.

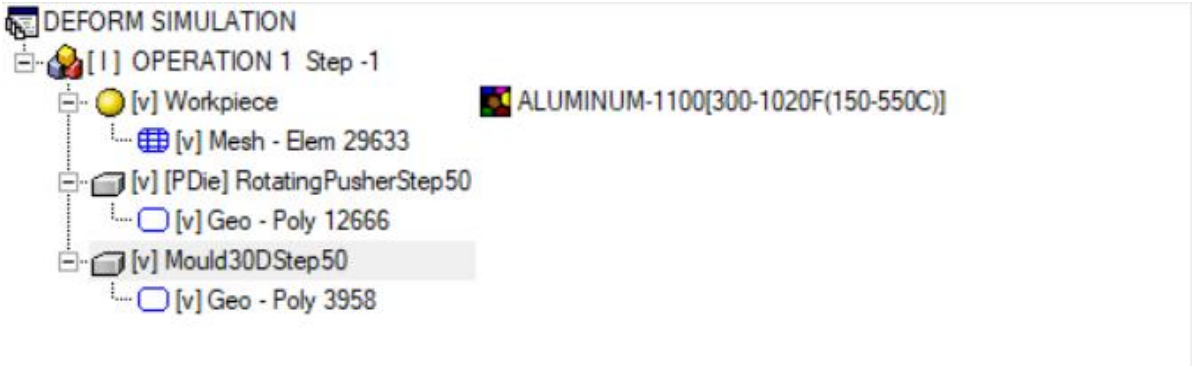

Figure 2.8. Pre-processor main window

Problems preprocess is started by selecting the number of components. Then they are renamed for as the user wants. After that geometry is imported. Then the material is selected from the material library for workpiece. After that the mesh for the workpiece is created. After that temperature for all components is inputted in to the system. After the main window of the preprocessor looks like the figure 2.8 and all the steps so has been done design window of the problem looks like figure 2.9

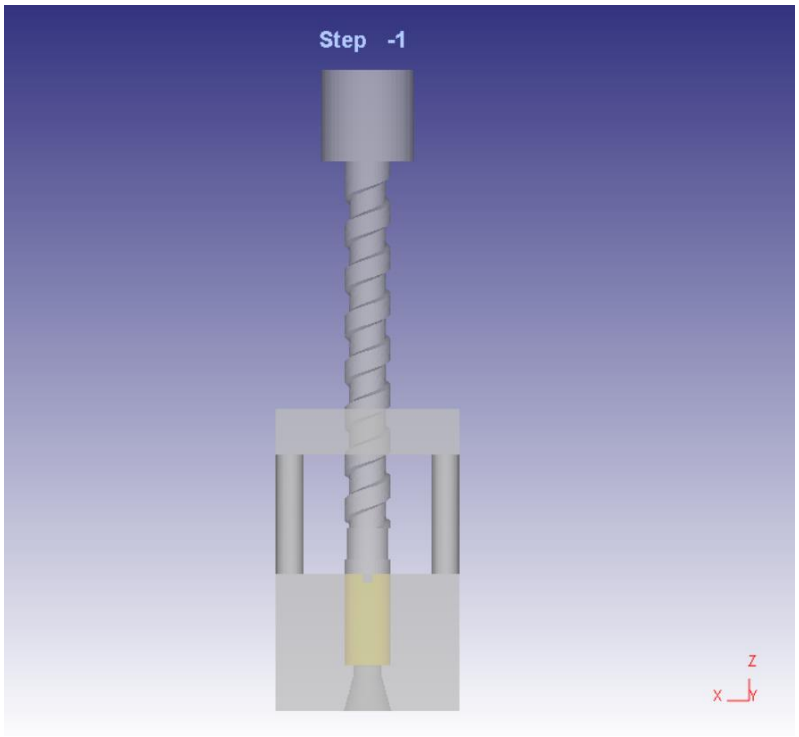

Figure 2.9. Pre-processor design window

After the design is completed, movement of the rotating pusher has to be inputted to the system for both translational and rotational velocities.

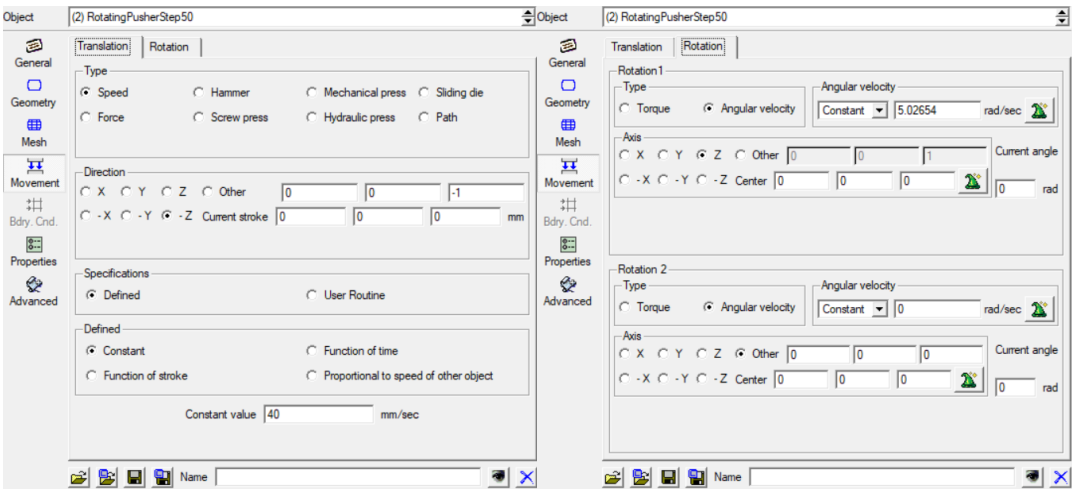

Figure 2.10. Translational and Rotational Movement Control

After the movement values and directions has been submitted to the system inter-

object relations need to be submitted. Master-Slave relationship between rotating pusher and workpiece is submitted to that the workpiece moves with the rotating pusher. This is also where the friction factor between components is selected. Inter-object controls window is in figure 2.10.

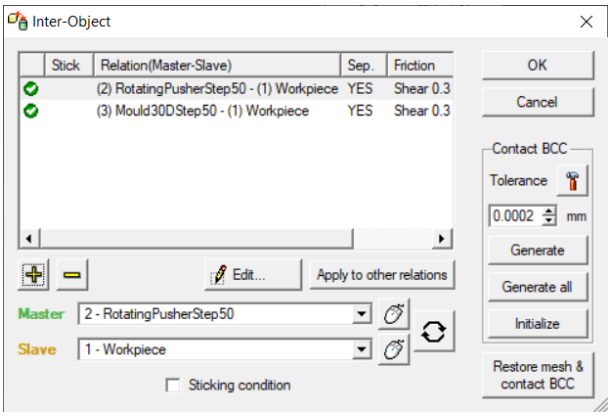

Figure 2.10. Inter-object controls window

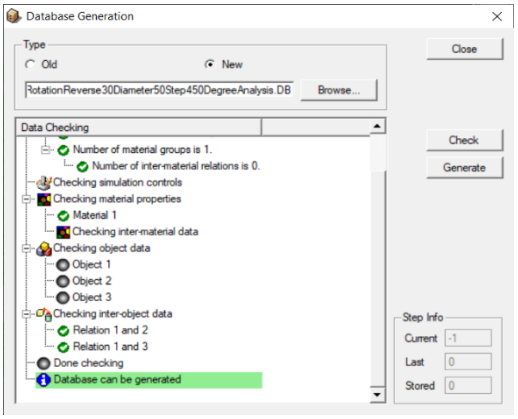

Figure 2.11. Database generation

Database generation window in figure 2.11 is used for creating the database for the problem. Before generating the database, it can be checked with the check button for errors.

Simulator part of the analysis is mainly consisting of waiting for the problem to be finished. After running the problem, the progression can be viewed using the simulation graphics option seen on figure 2.12. After the simulation is finished post processor can be used to view results and graphs, export results and many different uses.

Figure 2.12. Simulator Window

2.4.Points Selection

2.4.1. First selection of points

Four points on the workpiece is selected as seen in the figure 2.13 along z-axis. If P1 is accepted as origin, points are P1(0,0,0), P2(0,0,25), P3(0,0,50) and P4(0,0,75).

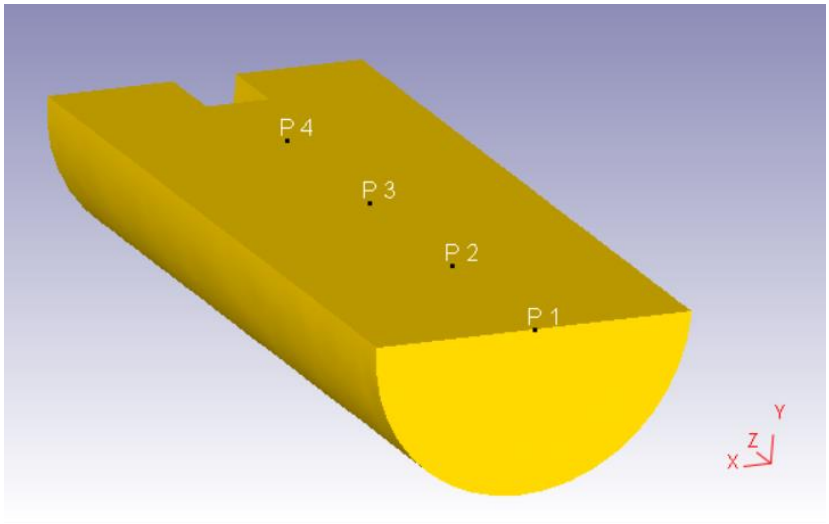

Figure 2.13. First Point Selection Figure

2.4.2.Second selection of points

Four different points on the workpiece is selected as seen in the figure 2.14. Points are P"1(0,0,50) , P"2(5,0,50), P"3(10,0,50) and P"4(15,0,50).

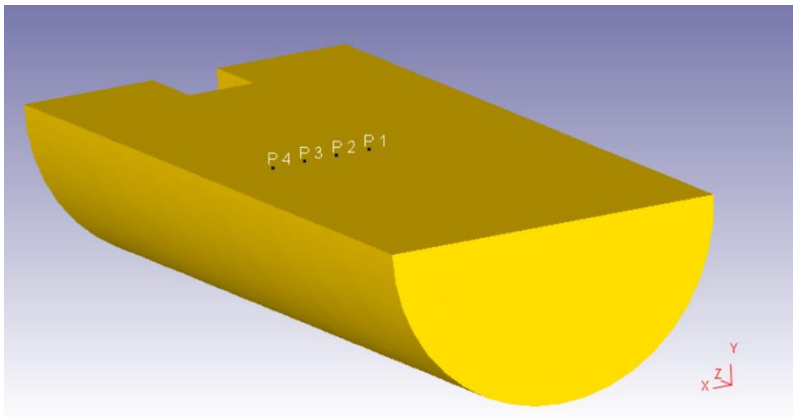

Figure 2.14. Second Point Selection Figure

3.RESULTS AND DISCUSSION

3.1. Results

3.1.1. First selection of points results

3.1.1.1. Load Prediction

40-Diameter and 0 Rpm Analysis Result

Average load for the 40 diameter and 0 Rpm is 85.491 kN.

Maximum load for the 40 diameter and 0 Rpm is 111.534 kN.

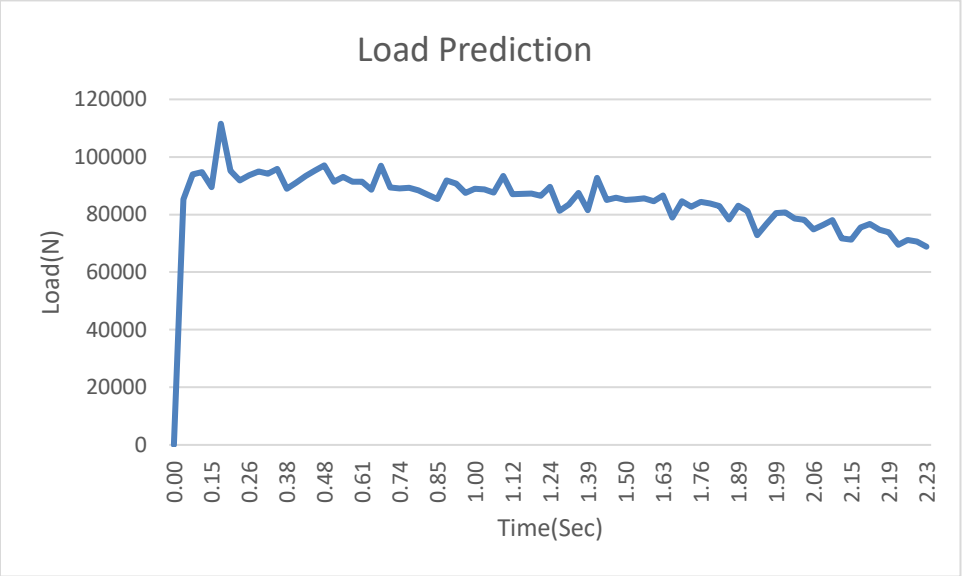

Figure 3.1. 40-Diameter and 0 Rpm Load Prediction Graph

As it can be seen in figure 3.1 load needed for the process is decreases with time which is expected since the material that is pressed on decreases. All load prediction graphs are expected to follow the same decrease with time as figure 3.1.

40-Diameter and 24 Rpm Analysis Result

Average load for the 40 diameter and 24 Rpm is 101.242 kN.

Maximum load for the 40 diameter and 24 Rpm is 129.657 kN.

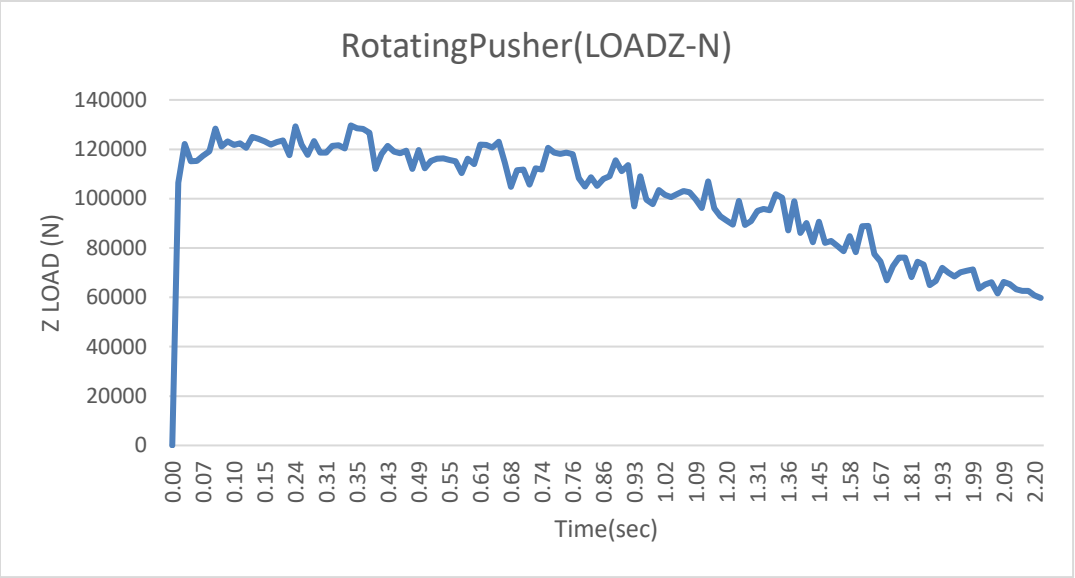

Figure 3.2. 40-Diameter and 24 Rpm Load Prediction Graph

40-Diameter and 48 Rpm Analysis Result

Average load for the 40 diameter and 48 Rpm is 97.201 kN.

Maximum load for the 40 diameter and 48 Rpm is 121.958 kN.

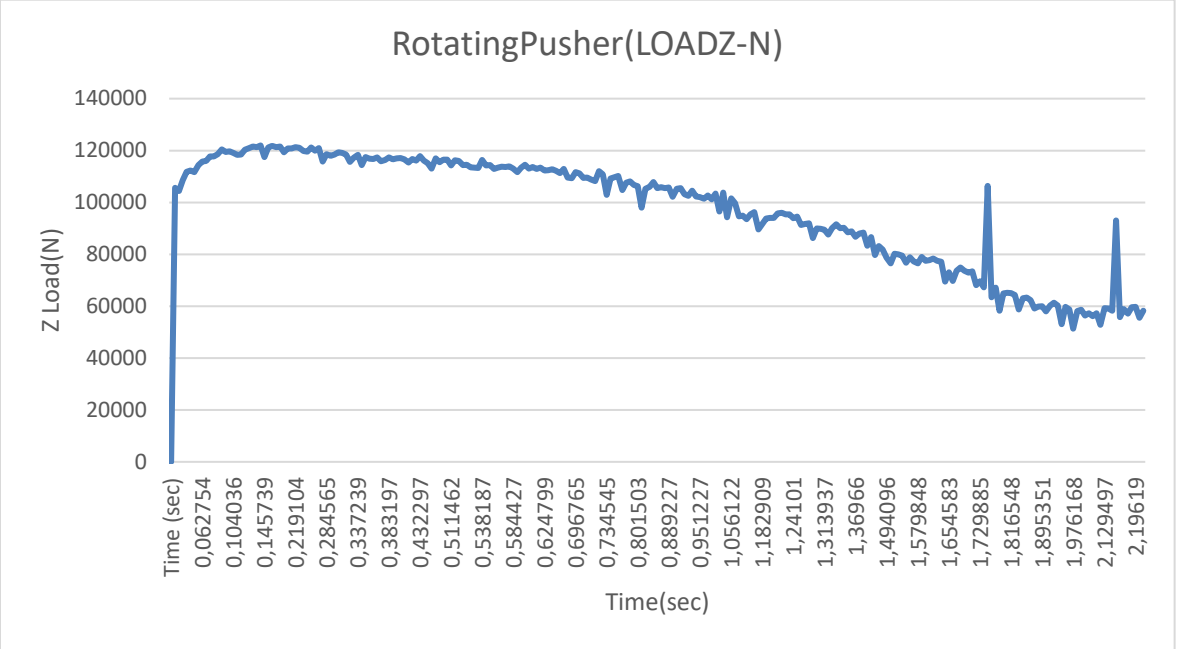

Figure 3.3. 40-Diameter and 48 Rpm Load Prediction Graph

40-Diameter and 96 Rpm Analysis Result

Average load for the 40 diameter and 96 Rpm is 95.653 kN.

Maximum load for the 40 diameter and 96 Rpm 122.079 kN.

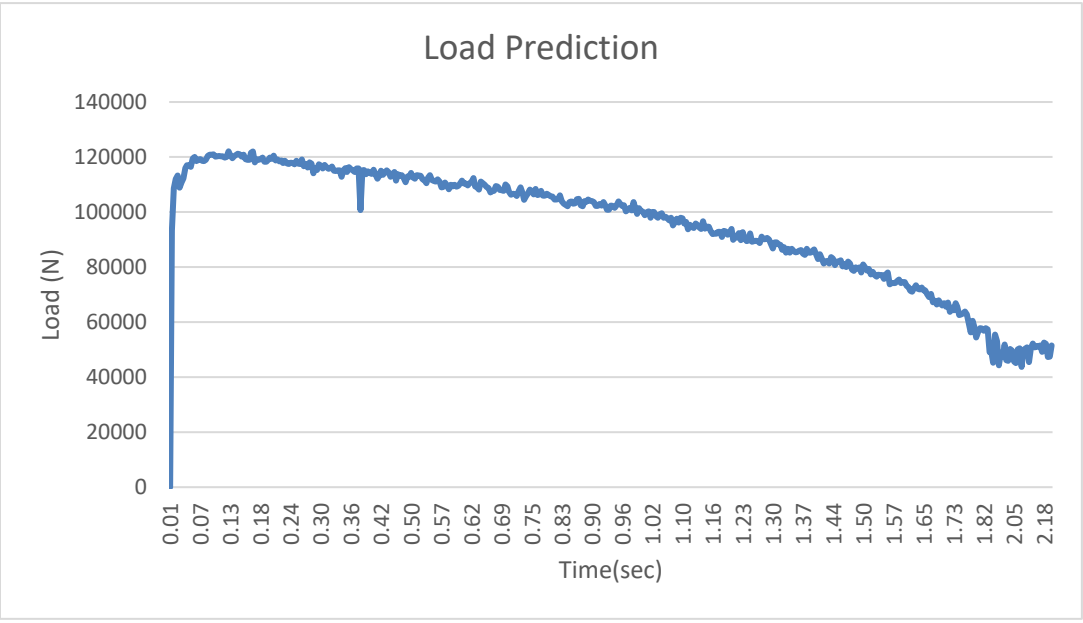

Figure 3.4. 40-Diameter and 96 Rpm Load Prediction Graph

40-Diameter and 120 Rpm Analysis Result

Average load for the 40 diameter and 120 Rpm is 96.025 kN

Maximum load for the 40 diameter and 120 Rpm is 120.161 kN

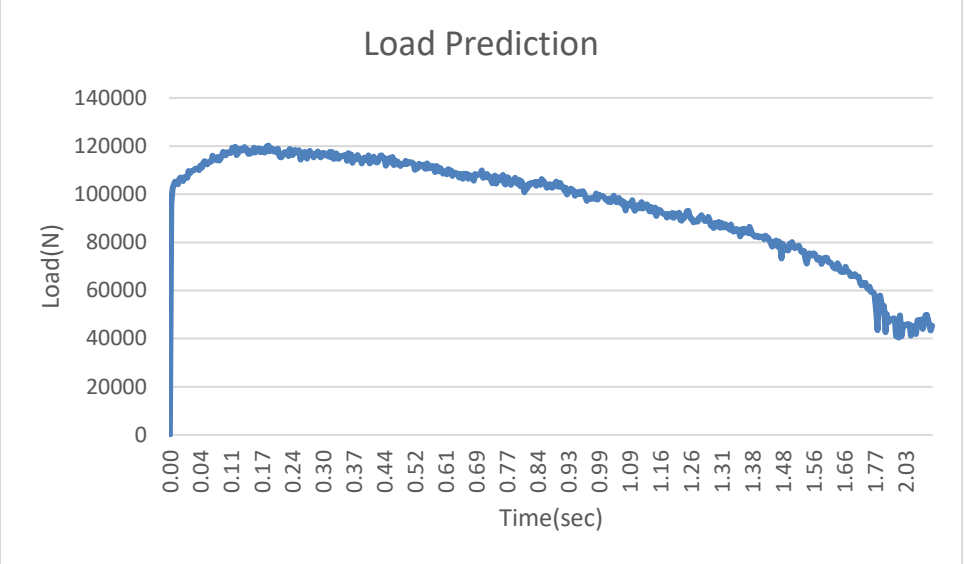

Figure 3.5. 40-Diameter and 120 Rpm Load Prediction Graph

35-Diameter and 0 Rpm Analysis Result

Average load for the 35 diameter and 0 Rpm is 121.465 kN

Maximum load for the 35 diameter and 0 Rpm is 155.876 kN

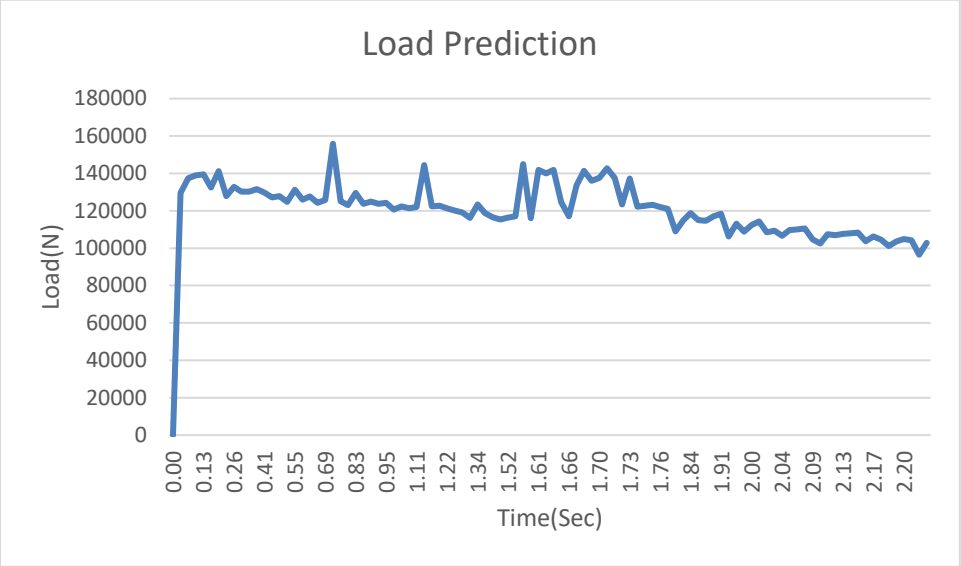

Figure 3.6. 35-Diameter and 0 Rpm Load Prediction Graph

35-Diameter and 24 Rpm Analysis Result

Average load for the 35 diameter and 24 Rpm is 131.707 kN

Maximum load for the 35 diameter and 24 Rpm is 169.492 kN

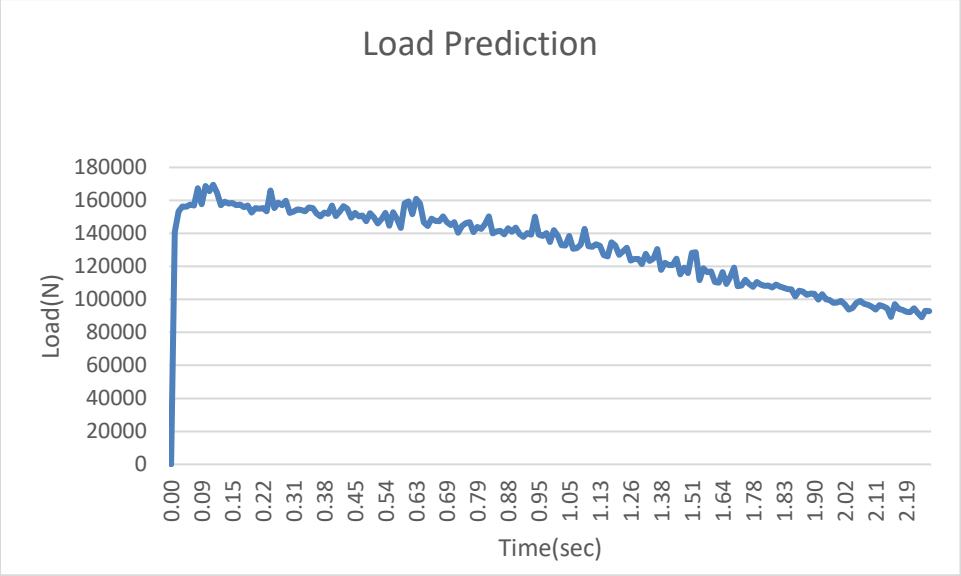

Figure 3.7. 35-Diameter and 24 Rpm Load Prediction Graph

35-Diameter and 48 Rpm Analysis Result

Average load for the 35 diameter and 48 Rpm is 127.6609 kN

Maximum load for the 35 diameter and 48 Rpm is 155.522 kN

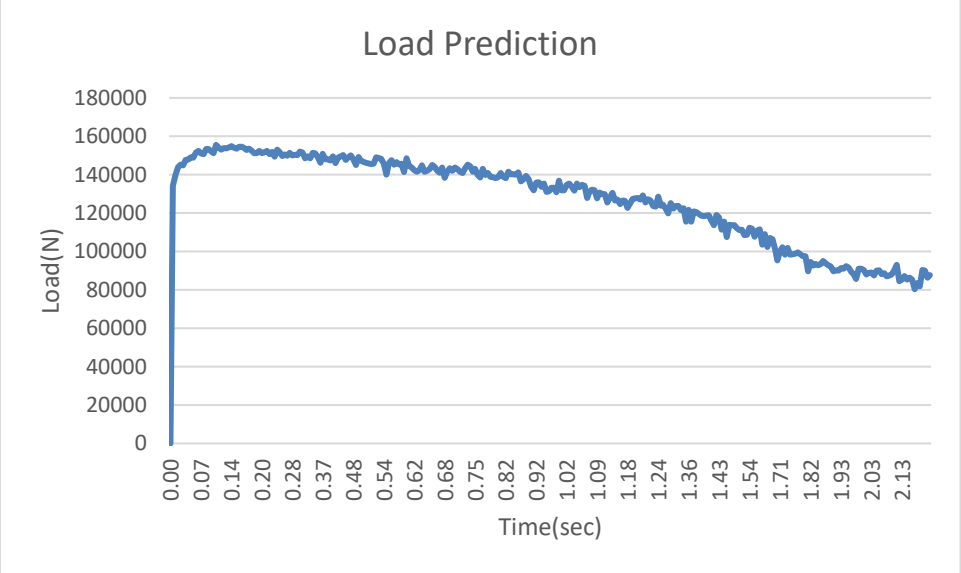

Figure 3.8. 35-Diameter and 48 Rpm Load Prediction Graph

35-Diameter and 96 Rpm Analysis Result

Average load for the 35 diameter and 96 Rpm is 125.265kN

Maximum load for the 35 diameter and 96 Rpm is 153.934kN

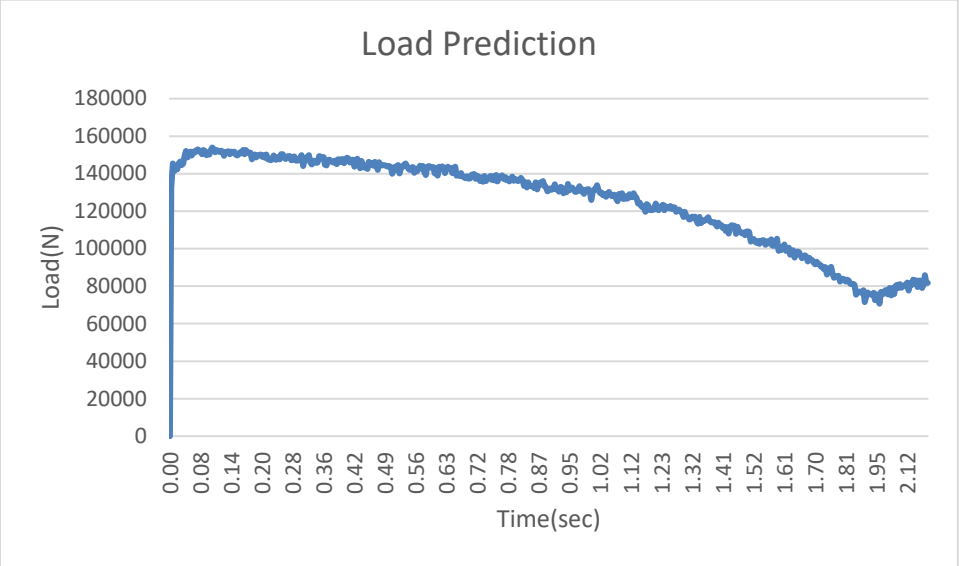

Figure 3.9. 35-Diameter and 96 Rpm Load Prediction Graph

35-Diameter and 120 Rpm Analysis Result

Average load for the 35 diameter and 120 Rpm is 121.797 kN

Maximum load for the 35 diameter and 120 Rpm is 151.384 kN

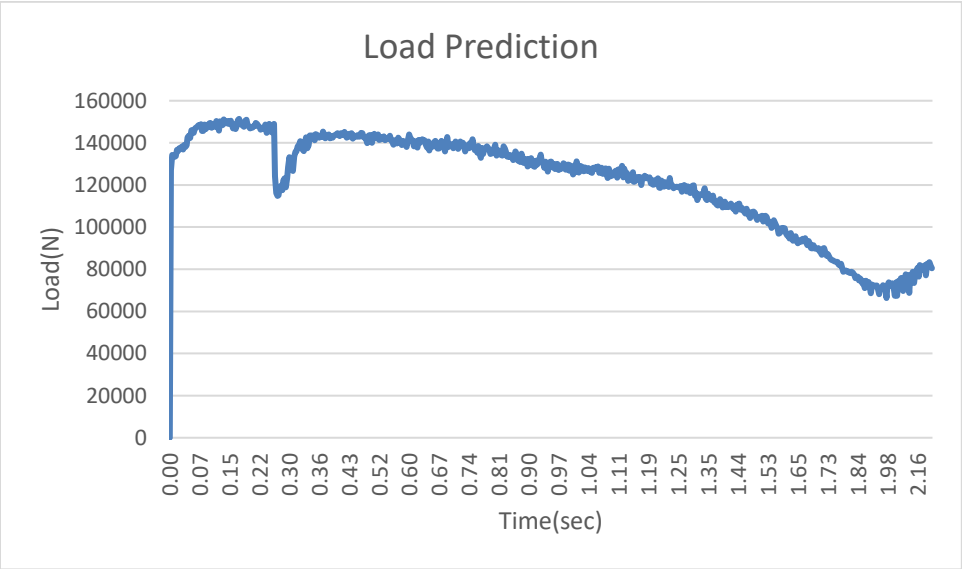

Figure 3.10. 35-Diameter and 120 Rpm Load Prediction Graph

30-Diameter and 0 Rpm Analysis Result

Average load for the 30 diameter and 0 Rpm is 153.776 kN

Maximum load for the 30 diameter and 0 Rpm is 182.804 kN

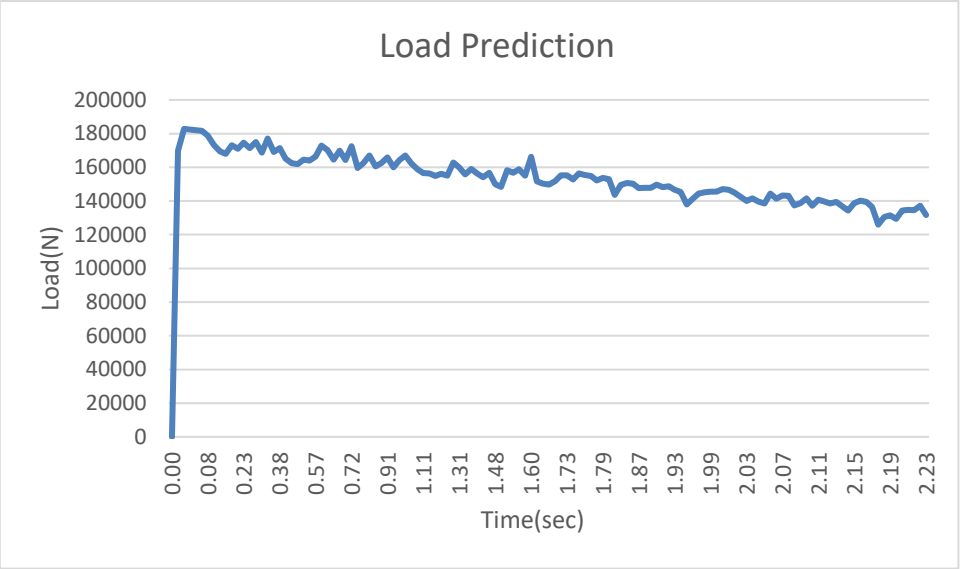

Figure 3.11. 30-Diameter and 0 Rpm Load Prediction Graph

30-Diameter and 24 Rpm Analysis Result

Average load for the 30 diameter and 24 Rpm is 161.974 kN

Maximum load for the 30 diameter and 24 Rpm is 189.751 kN

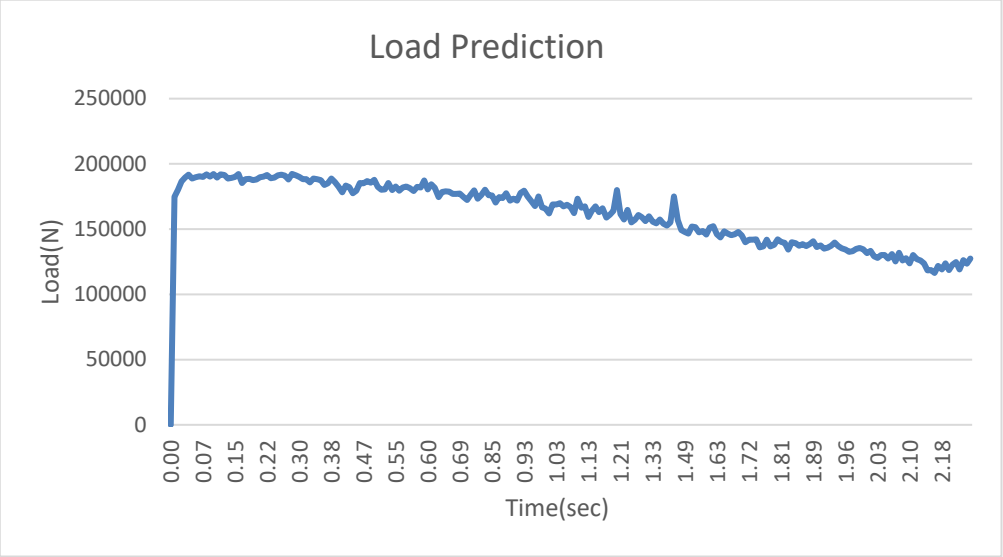

Figure 3.12. 30-Diameter and 24 Rpm Load Prediction Graph

30-Diameter and 48 Rpm Analysis Result

Average load for the 30 diameter and 48 Rpm is 162.206 kN

Maximum load for the 30 diameter and 48 Rpm is 192.313 kN

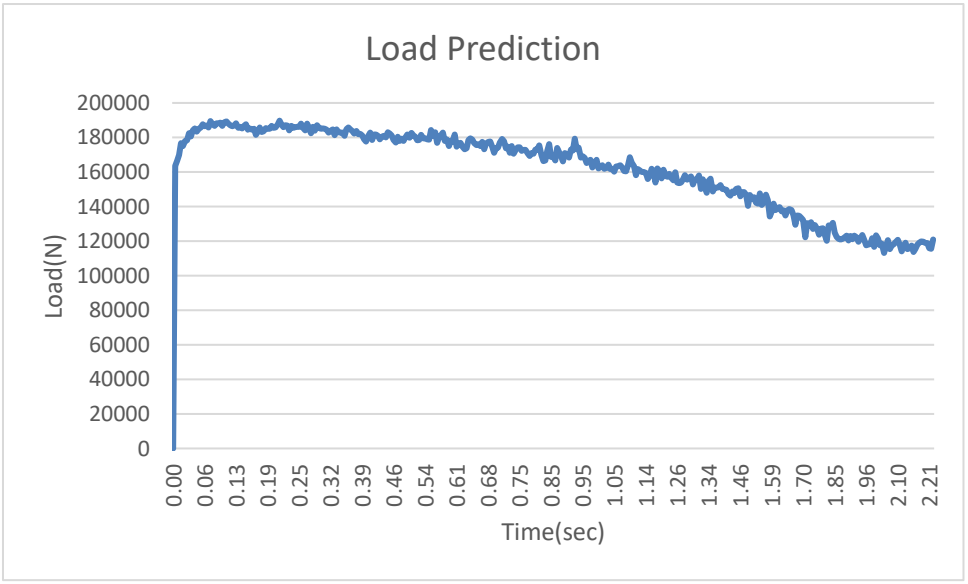

Figure 3.13. 30-Diameter and 48 Rpm Load Prediction Graph

30-Diameter and 96 Rpm Analysis Result

Average load for the 30 diameter and 96 Rpm is 162.206 kN

Maximum load for the 30 diameter and 96 Rpm is 185.662 kN

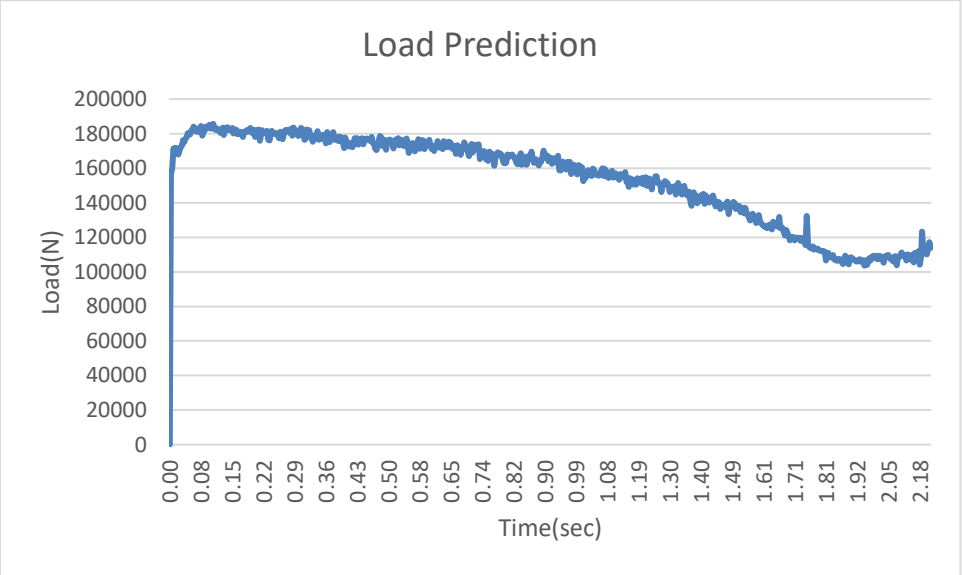

Figure 3.14. 30-Diameter and 96 Rpm Load Prediction Graph

30-Diameter and 120 Rpm Analysis Result

Average load for the 30 diameter and 120 Rpm is 152.372 kN

Maximum load for the 30 diameter and 120 Rpm is 184.439 kN

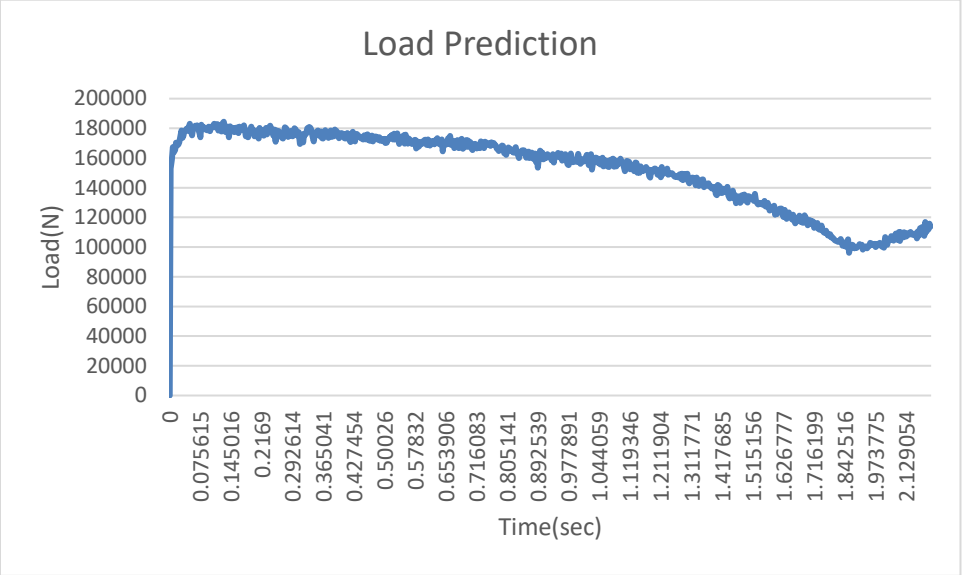

Figure 3.15. 30-Diameter and 120 Rpm Load Prediction Graph

3.1.1.2. Strain Rate Analysis Results

The reason the four points is selected is to increase the sample size and avoid the momentary extreme changes in data to affect the results. Final Results will be the average of the four points results and shown as one result.

40-Diameter and 0 Rpm Analysis Result

Average of the strain rate for P1 is 0.030713 (mm/mm)/sec.

Average of the strain rate for P2 is 0.128685 (mm/mm)/sec.

Average of the strain rate for P3 is 0.120448 (mm/mm)/sec.

Average of the strain rate for P4 is 0.115651 (mm/mm)/sec.

Average of the strain rate for all points is 0.098874 (mm/mm)/sec.

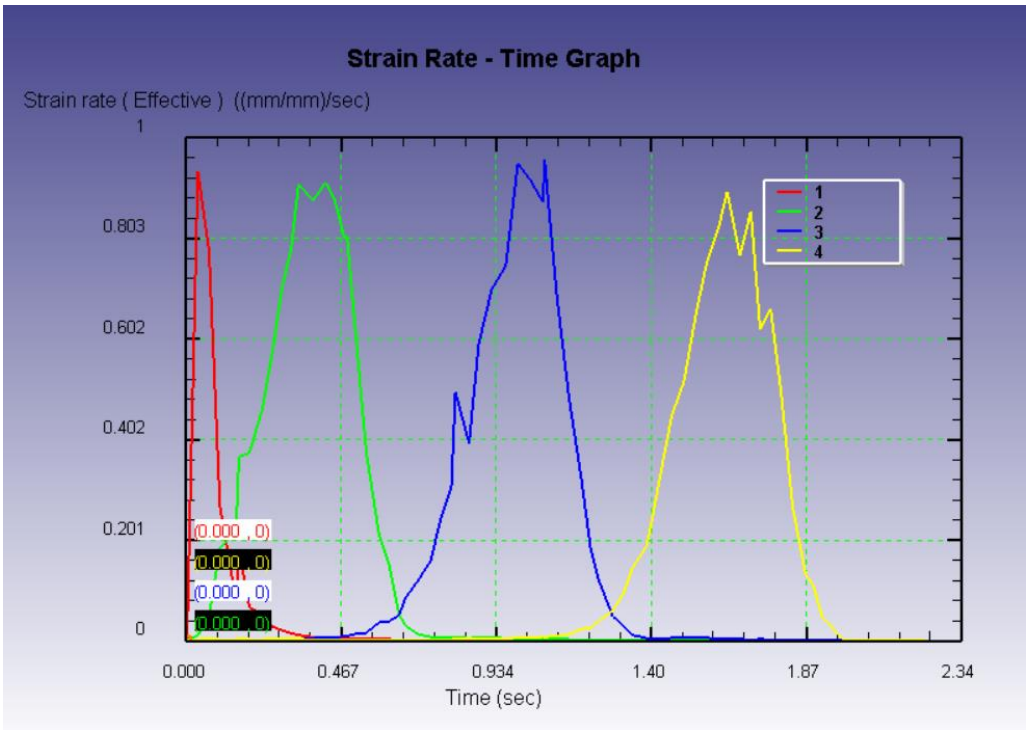

Figure 3.16. 40-Diameter and 0 Rpm Strain Rate Graph

40-Diameter and 24 Rpm Analysis Result

Average of the strain rate for P1 is 0.059682 (mm/mm)/sec.

Average of the strain rate for P2 is 0.197541 (mm/mm)/sec.

Average of the strain rate for P3 is 0.143150 (mm/mm)/sec.

Average of the strain rate for P4 is 0.140143 (mm/mm)/sec.

Average of the strain rate for all points is 0.135204 (mm/mm)/sec.

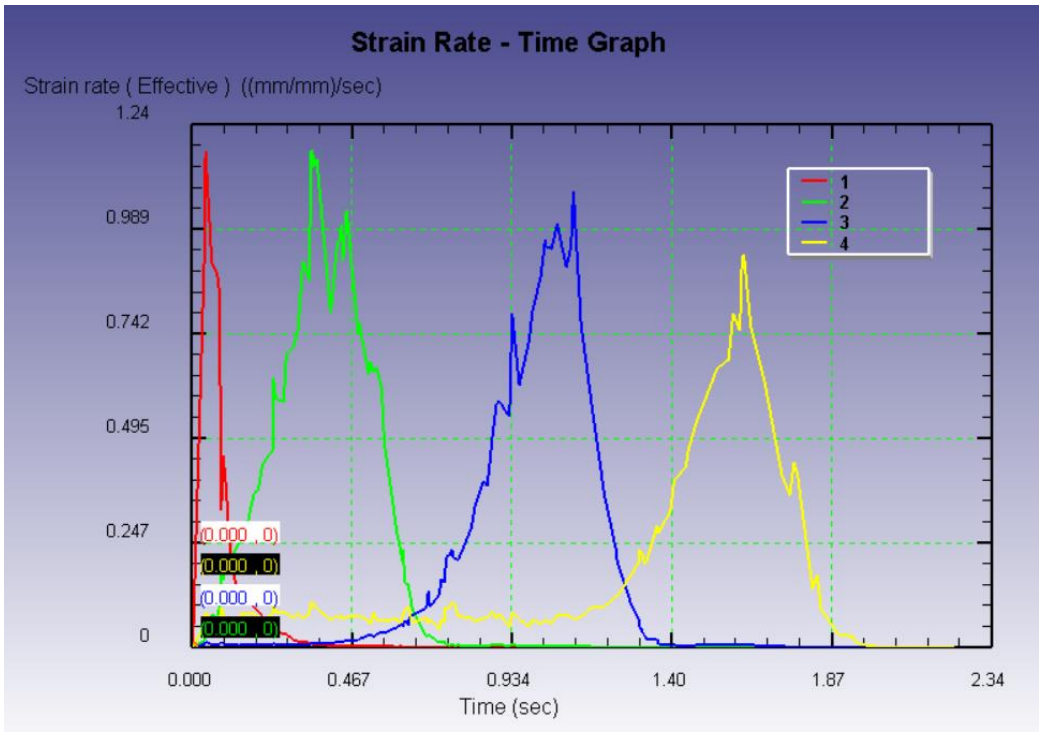

Figure 3.17. 40-Diameter and 24 Rpm Strain Rate Graph

40-Diameter and 48 Rpm Analysis Result

Average of the strain rate for P1 is 0.063157 (mm/mm)/sec.

Average of the strain rate for P2 is 0.208238 (mm/mm)/sec.

Average of the strain rate for P3 is 0.11065 (mm/mm)/sec.

Average of the strain rate for P4 is 0.18171 (mm/mm)/sec.

Average of the strain rate for all points is 0.140939 (mm/mm)/sec.

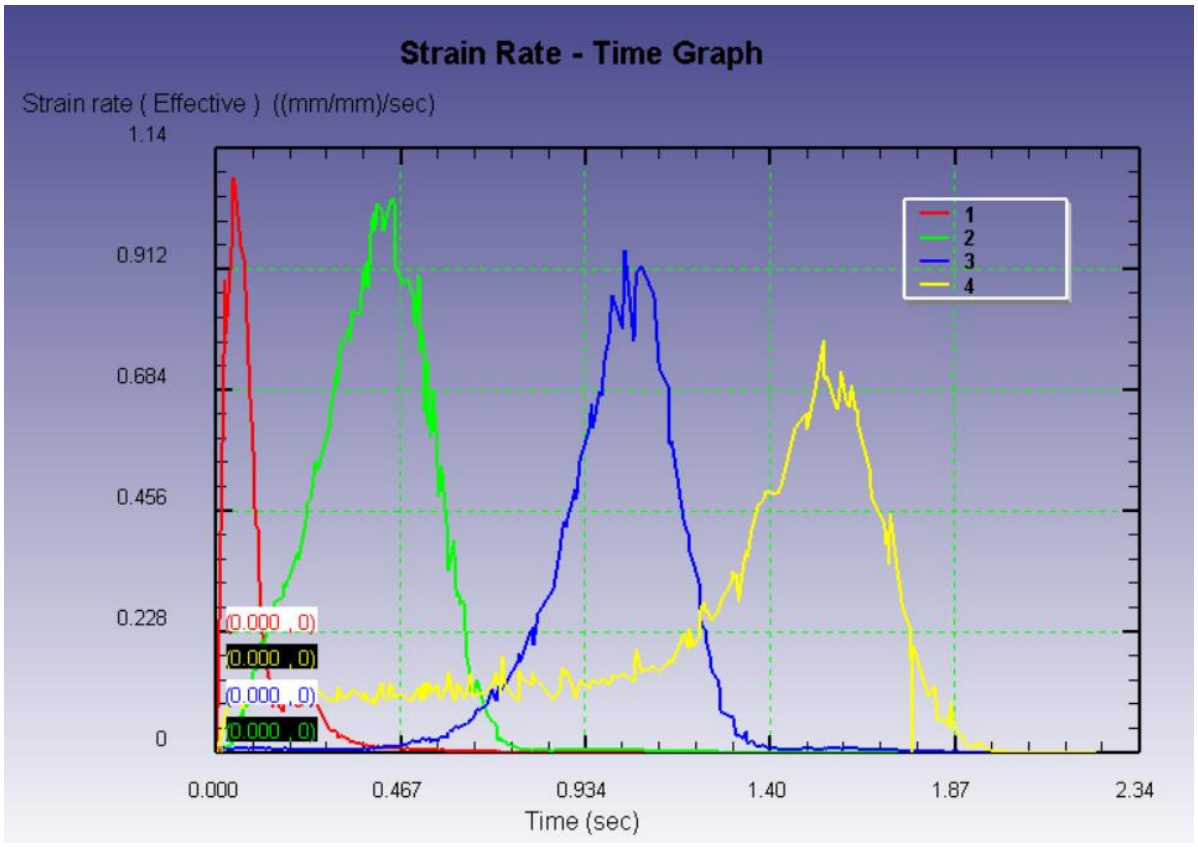

Figure 3.18. 40-Diameter and 48 Rpm Strain Rate Graph

40-Diameter and 96 Rpm Analysis Result

Average of the strain rate for P1 is 0.0547529 (mm/mm)/sec.

Average of the strain rate for P2 is 0.185541 (mm/mm)/sec.

Average of the strain rate for P3 is 0.139360 (mm/mm)/sec.

Average of the strain rate for P4 is 0.311152 (mm/mm)/sec.

Average of the strain rate for all points is 0.172701 (mm/mm)/sec.

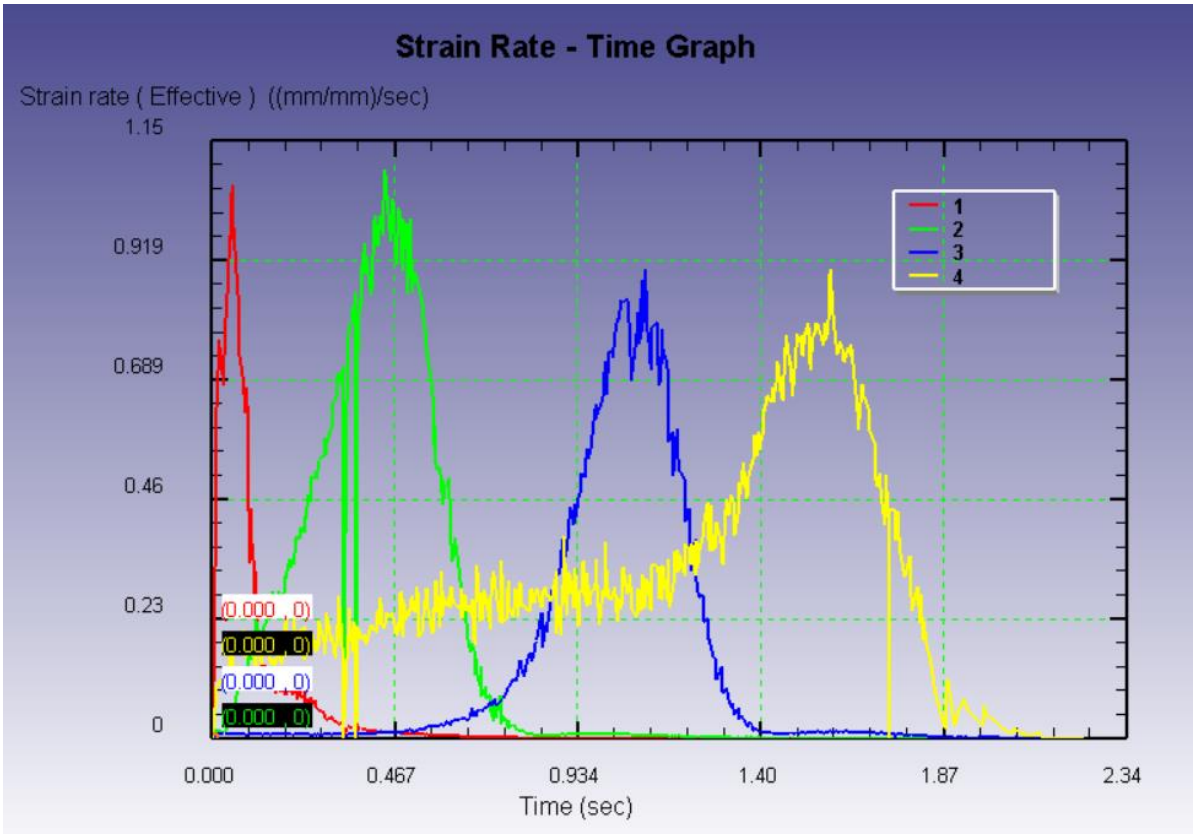

Figure 3.19. 40-Diameter and 96 Rpm Strain Rate Graph

40-Diameter and 120 Rpm Analysis Result

Average of the strain rate for P1 is 0.073970 (mm/mm)/sec.

Average of the strain rate for P2 is 0.197226 (mm/mm)/sec.

Average of the strain rate for P3 is 0.137628 (mm/mm)/sec.

Average of the strain rate for P4 is 0.378522 (mm/mm)/sec.

Average of the strain rate for all points is 0.196837 (mm/mm)/sec.

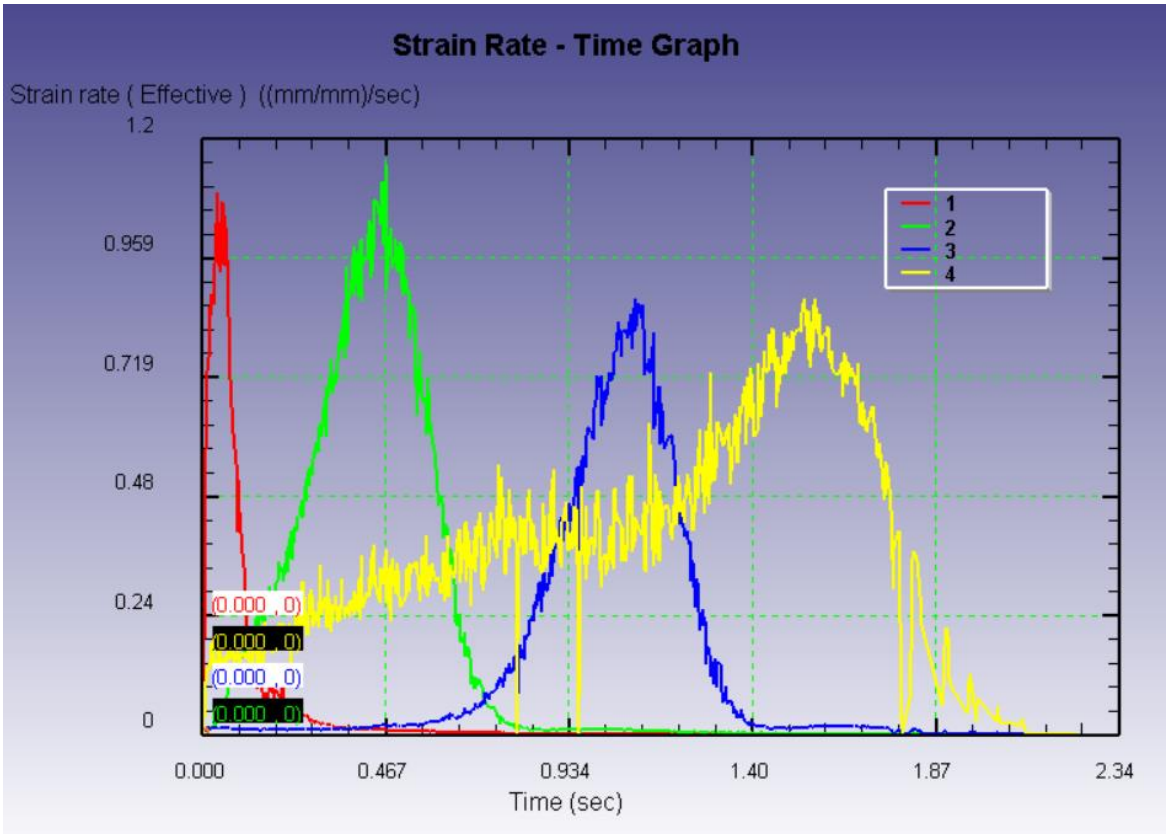

Figure 3.20. 40-Diameter and 120 Rpm Strain Rate Graph

35-Diameter and 0 Rpm Analysis Result

Average of the strain rate for P1 is 0.034458 (mm/mm)/sec.

Average of the strain rate for P2 is 0.165330 (mm/mm)/sec.

Average of the strain rate for P3 is 0.179812 (mm/mm)/sec.

Average of the strain rate for P4 is 0.363810 (mm/mm)/sec.

Average of the strain rate for all points is 0.185852 (mm/mm)/sec.

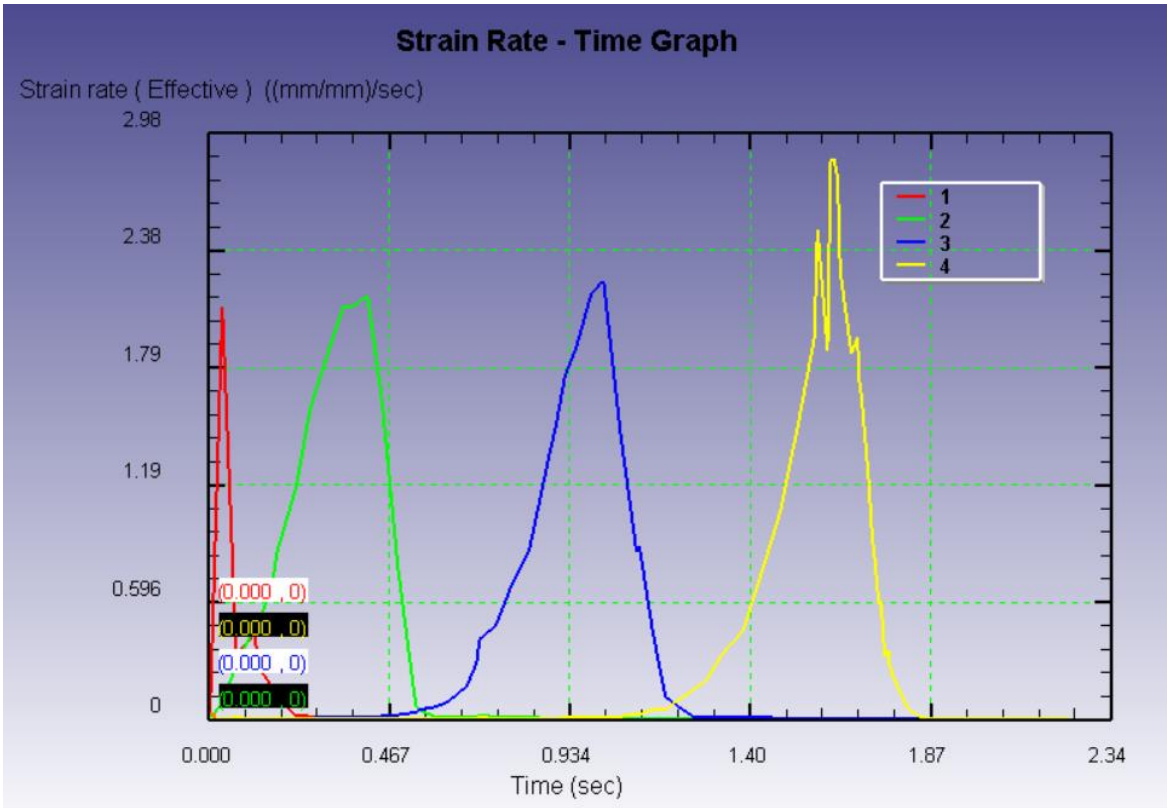

Figure 3.21. 35-Diameter and 24 Rpm Strain Rate Graph

35-Diameter and 24 Rpm Analysis Result

Average of the strain rate for P1 is 0.0392932 (mm/mm)/sec.

Average of the strain rate for P2 is 0.3334392 (mm/mm)/sec.

Average of the strain rate for P3 is 0.279820 (mm/mm)/sec.

Average of the strain rate for P4 is 0.219693 (mm/mm)/sec.

Average of the strain rate for all points is 0.218062 (mm/mm)/sec.

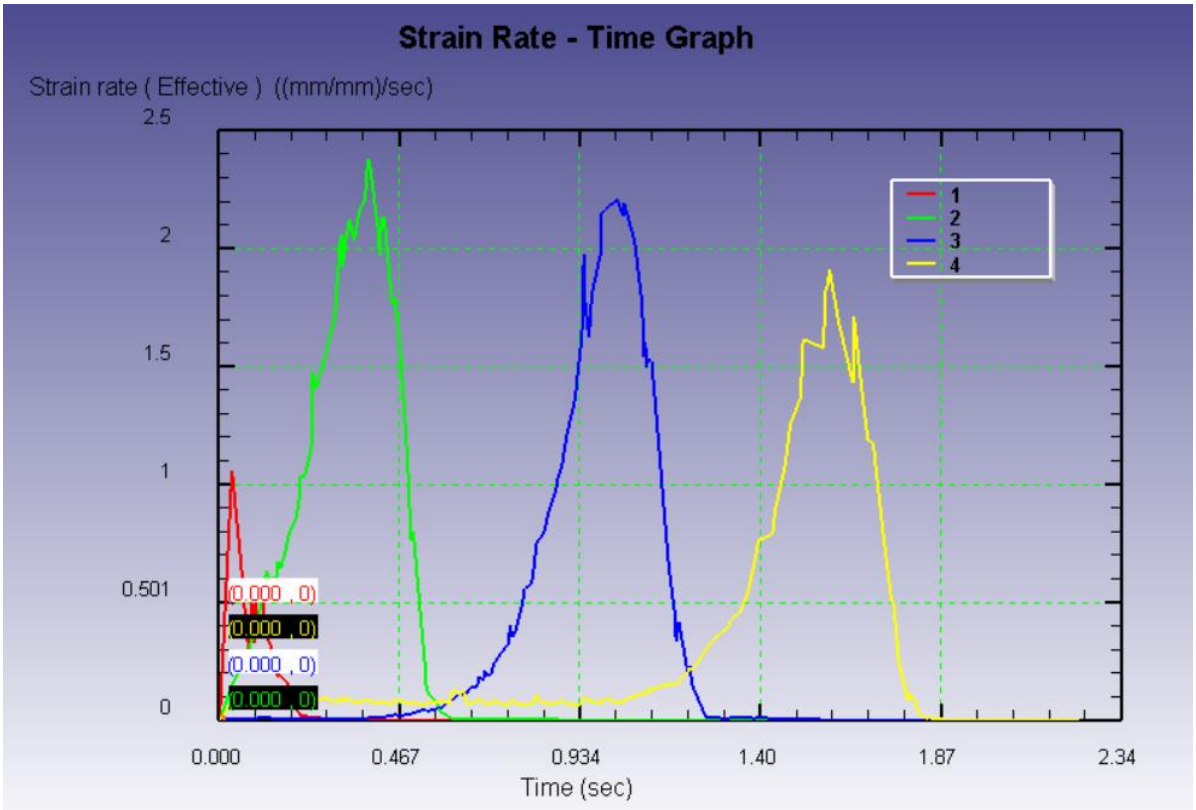

Figure 3.22. 35-Diameter and 24 Rpm Strain Rate Graph

35-Diameter and 48 Rpm Analysis Result

Average of the strain rate for P1 is 0.067543 (mm/mm)/sec.

Average of the strain rate for P2 is 0.284411 (mm/mm)/sec.

Average of the strain rate for P3 is 0.283904 (mm/mm)/sec.

Average of the strain rate for P4 is 0.278084 (mm/mm)/sec.

Average of the strain rate for all points is 0.228485 (mm/mm)/sec

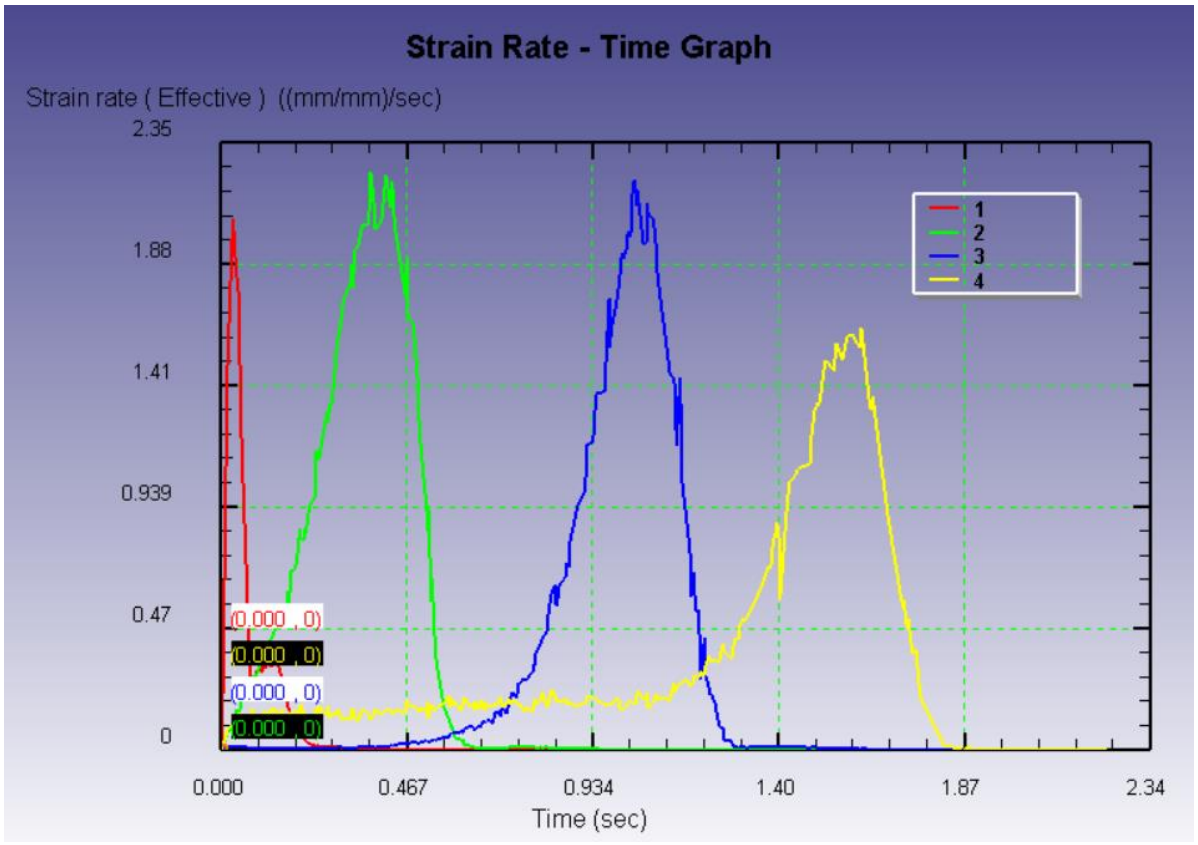

Figure 3.23. 35-Diameter and 48 Rpm Strain Rate Graph

35-Diameter and 96 Rpm Analysis Result

Average of the strain rate for P1 is 0.067979 (mm/mm)/sec.

Average of the strain rate for P2 is 0.548782 (mm/mm)/sec.

Average of the strain rate for P3 is 0.334011 (mm/mm)/sec.

Average of the strain rate for P4 is 0.653101 (mm/mm)/sec.

Average of the strain rate for all points is 0.400968 (mm/mm)/sec.

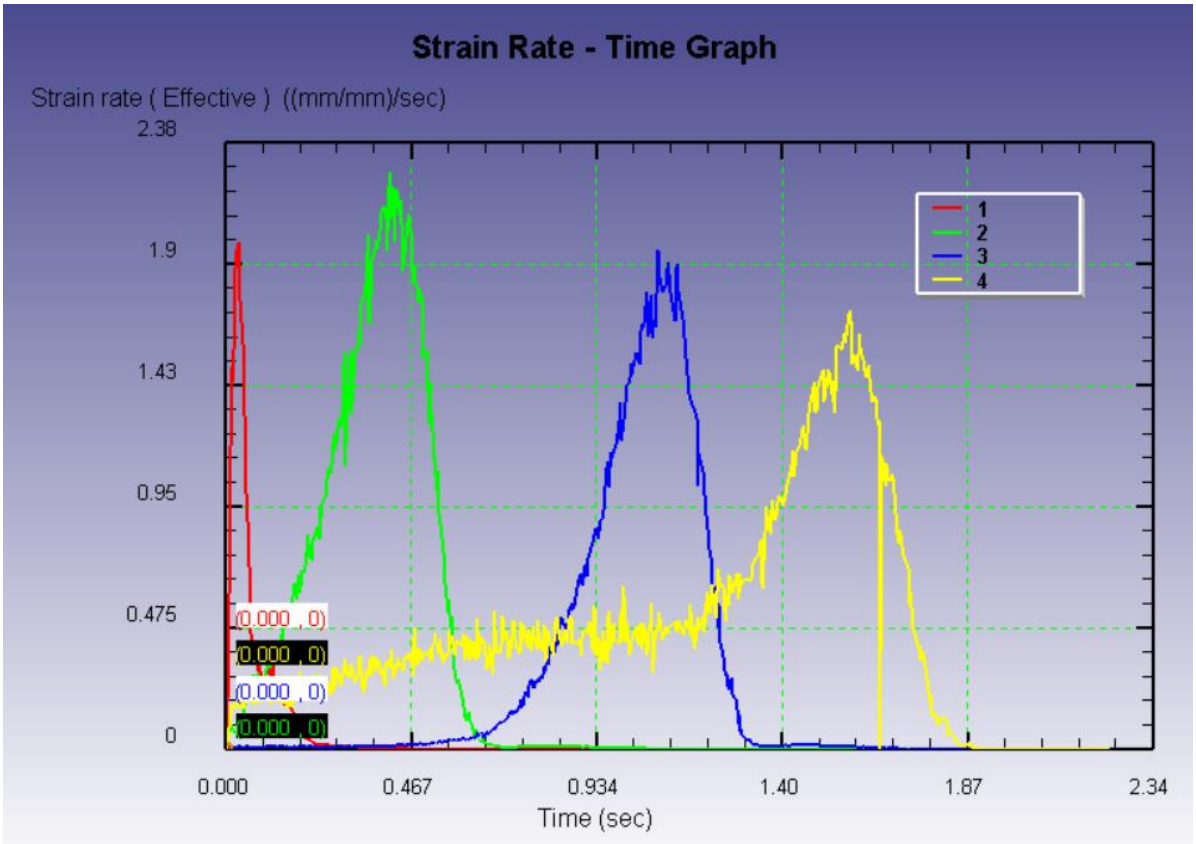

Figure 3.24. 35-Diameter and 96 Rpm Strain Rate Graph

35-Diameter and 120 Rpm Analysis Result

Average of the strain rate for P1 is 0.067230(mm/mm)/sec.

Average of the strain rate for P2 is 0.310496 (mm/mm)/sec.

Average of the strain rate for P3 is 0.264421 (mm/mm)/sec.

Average of the strain rate for P4 is 0.688516 (mm/mm)/sec.

Average of the strain rate for all points is 0.332666 (mm/mm)/sec.

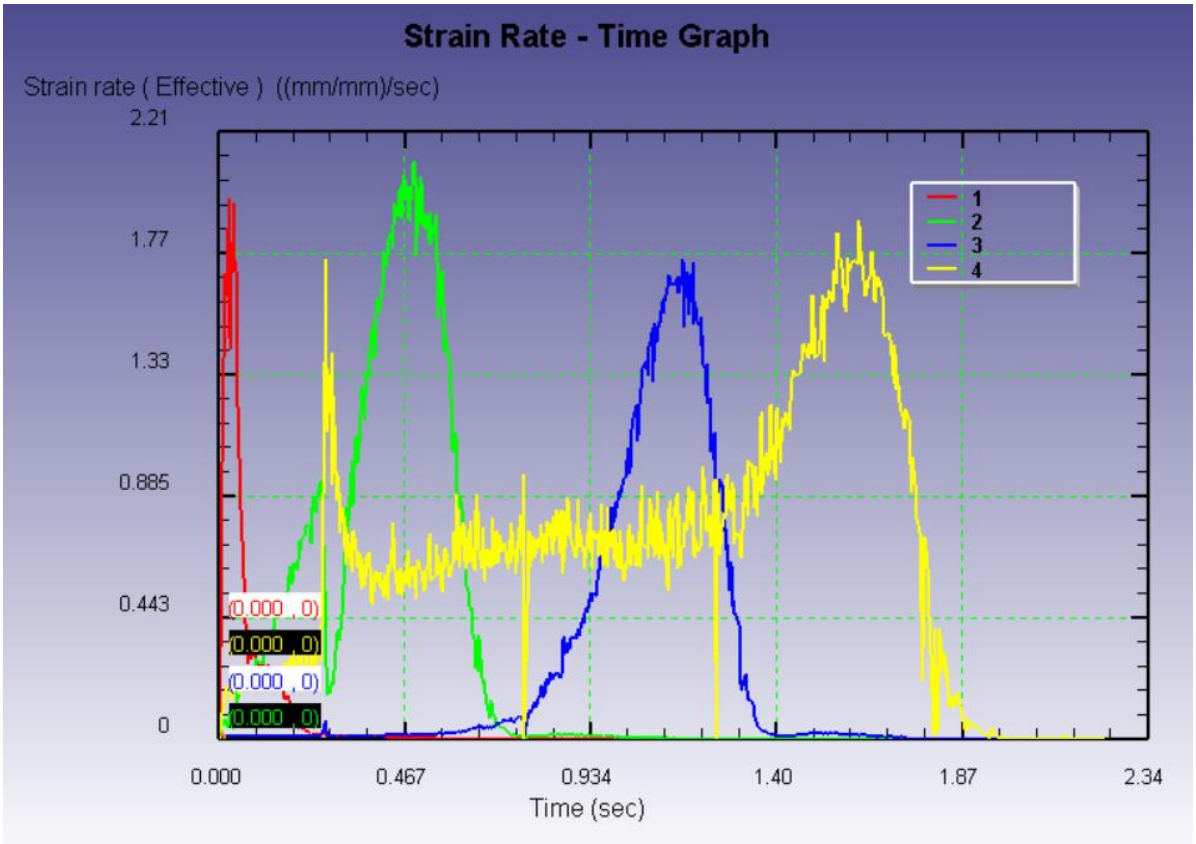

Figure 3.25. 35-Diameter and 120 Rpm Strain Rate Graph

30-Diameter and 0 Rpm Analysis Result

Average of the strain rate for P1 is 0.052653 (mm/mm)/sec.

Average of the strain rate for P2 is 0.296482 (mm/mm)/sec.

Average of the strain rate for P3 is 0.239112 (mm/mm)/sec.

Average of the strain rate for P4 is 0.311977 (mm/mm)/sec.

Average of the strain rate for all points is 0.225056 (mm/mm)/sec.

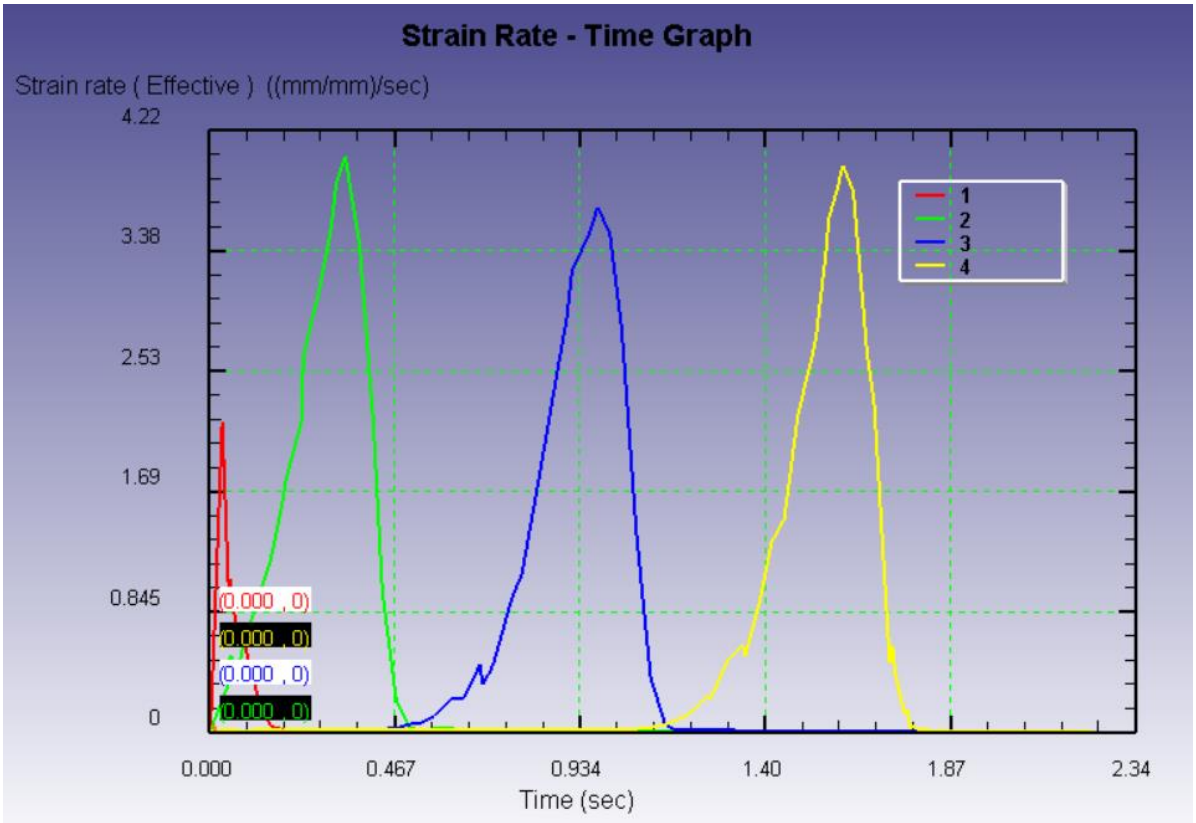

Figure 3.26. 30-Diameter and 24 Rpm Strain Rate Graph

30-Diameter and 24 Rpm Analysis Result

Average of the strain rate for P1 is 0.060673 (mm/mm)/sec.

Average of the strain rate for P2 is 0.457130 (mm/mm)/sec.

Average of the strain rate for P3 is 0.388705 (mm/mm)/sec.

Average of the strain rate for P4 is 0.318124 (mm/mm)/sec.

Average of the strain rate for all points is 0.306158 (mm/mm)/sec.

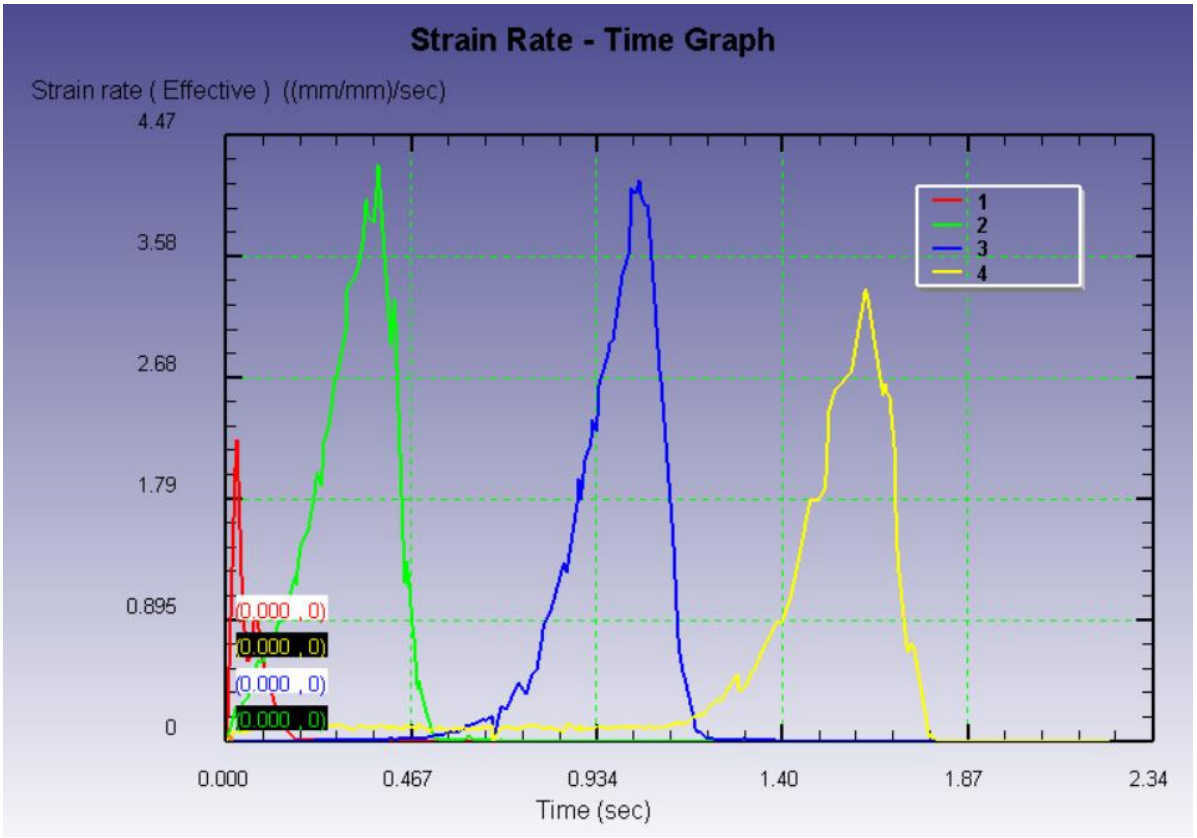

Figure 3.27. 30-Diameter and 24 Rpm Strain Rate Graph

30-Diameter and 48 Rpm Analysis Result

Average of the strain rate for P1 is 0.065525 (mm/mm)/sec.

Average of the strain rate for P2 is 0.562304 (mm/mm)/sec.

Average of the strain rate for P3 is 0.378816 (mm/mm)/sec.

Average of the strain rate for P4 is 0.398620 (mm/mm)/sec.

Average of the strain rate for all points is 0.351316 (mm/mm)/sec.

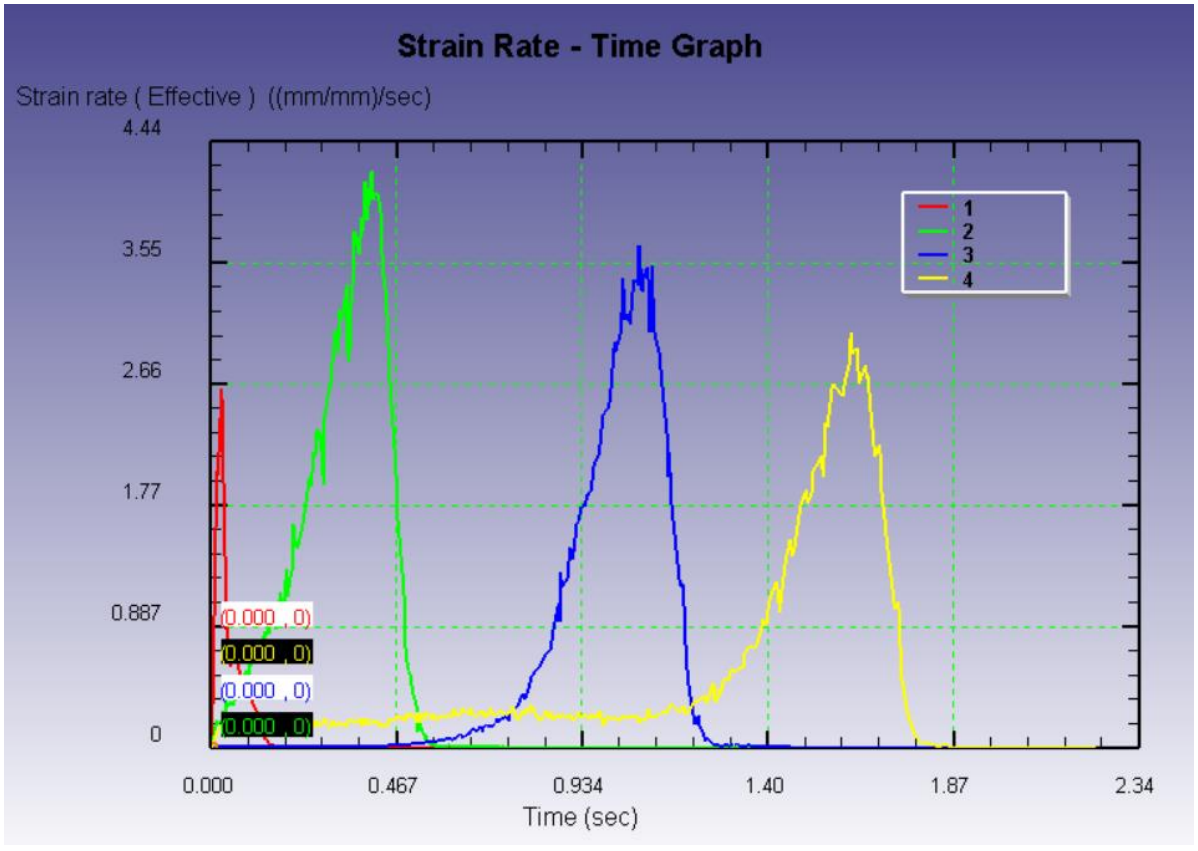

Figure 3.28. 30-Diameter and 48 Rpm Strain Rate Graph

30-Diameter and 96 Rpm Analysis Result

Average of the strain rate for P1 is 0.067989 (mm/mm)/sec.

Average of the strain rate for P2 is 0.548781(mm/mm)/sec.

Average of the strain rate for P3 is 0.3334011 (mm/mm)/sec.

Average of the strain rate for P4 is 0.653101 (mm/mm)/sec.

Average of the strain rate for all points is 0.400968 (mm/mm)/sec.

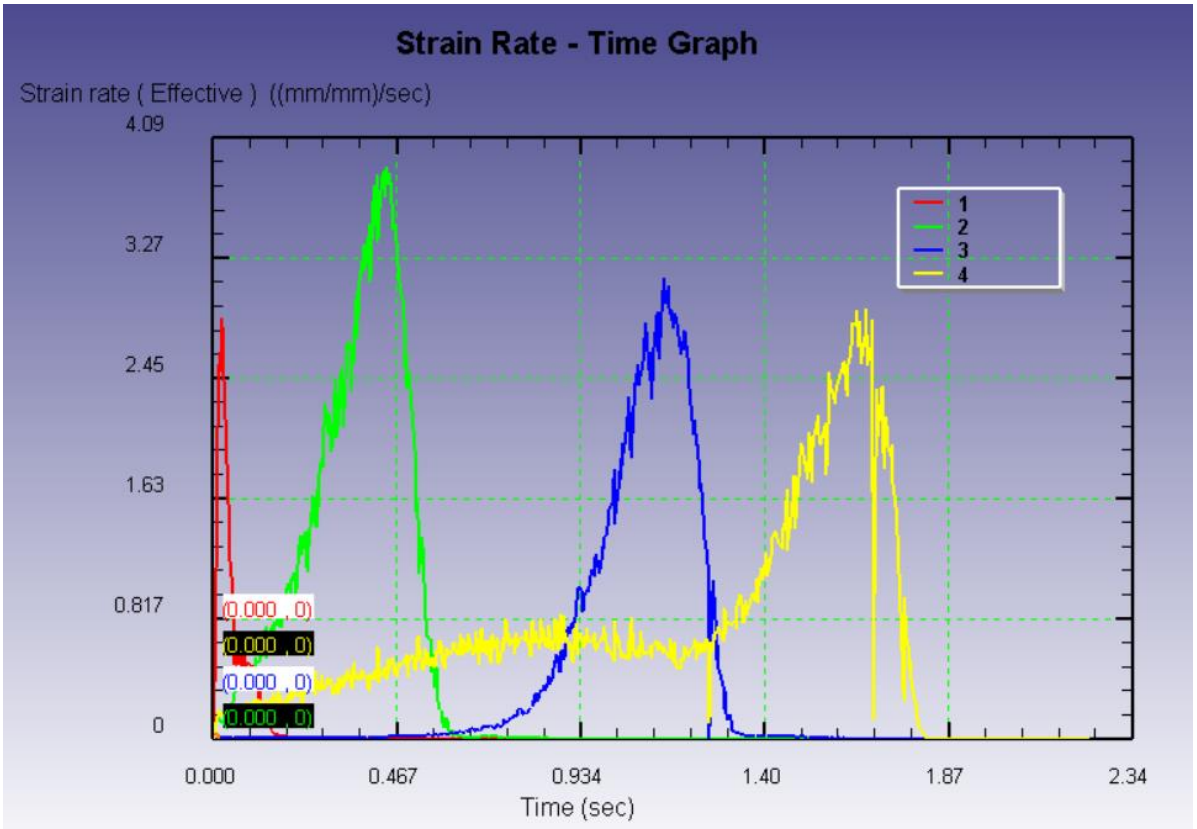

Figure 3.29. 30-Diameter and 96Rpm Strain Rate Graph

30-Diameter and 120 Rpm Analysis Result

Average of the strain rate for P1 is 0.067989 (mm/mm)/sec.

Average of the strain rate for P2 is 0.548781(mm/mm)/sec.

Average of the strain rate for P3 is 0.3334011 (mm/mm)/sec.

Average of the strain rate for P4 is 0.653101 (mm/mm)/sec.

Average of the strain rate for all points is 0.400968 (mm/mm)/sec.

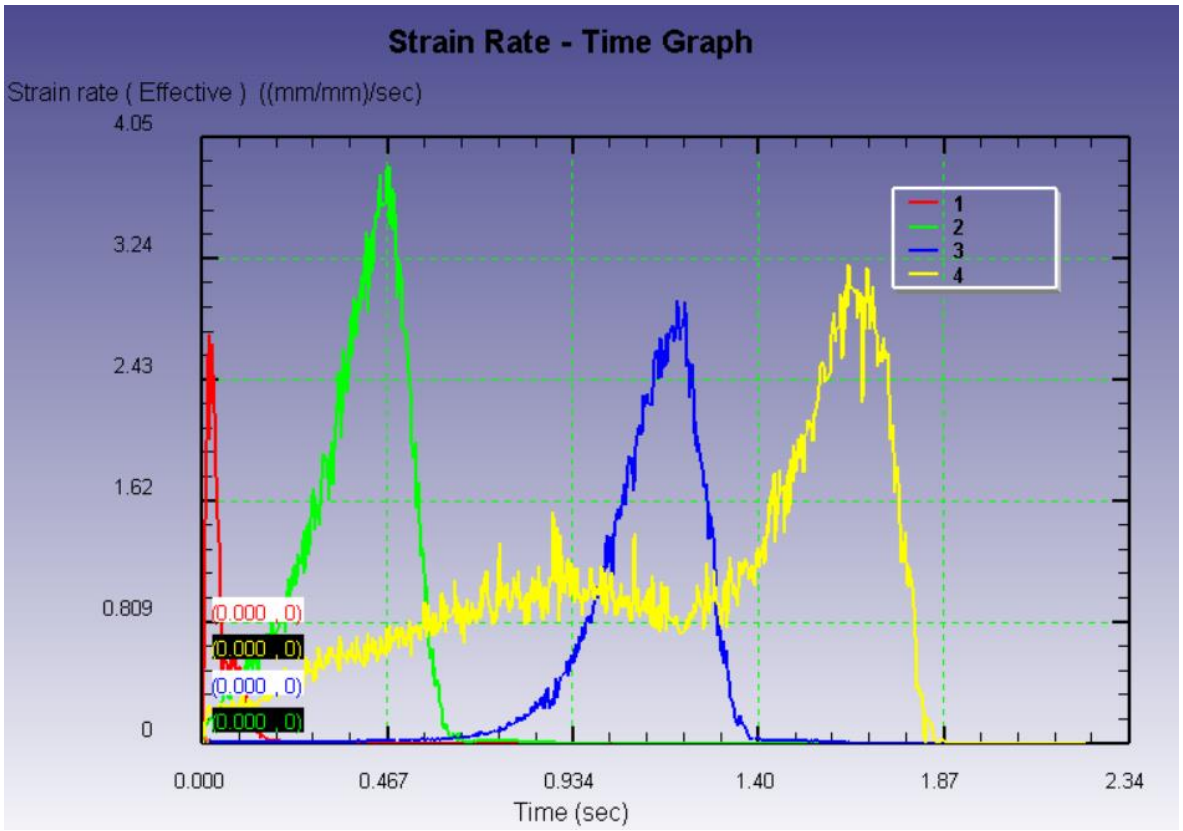

Figure 3.30. 30-Diameter and 120Rpm Strain Rate Graph

3.1.1.2. Stress Analysis Results

The reason the four points is selected is to increase the sample size and avoid the momentary extreme changes in data to affect the results. Final Results will be the average of the four points results and shown as one result.

40-Diameter and 0 Rpm Analysis Result

Maximum Tension Principal Stress 16.7789 MPa.

Maximum Compression Principal Stress -52.7563 MPa.

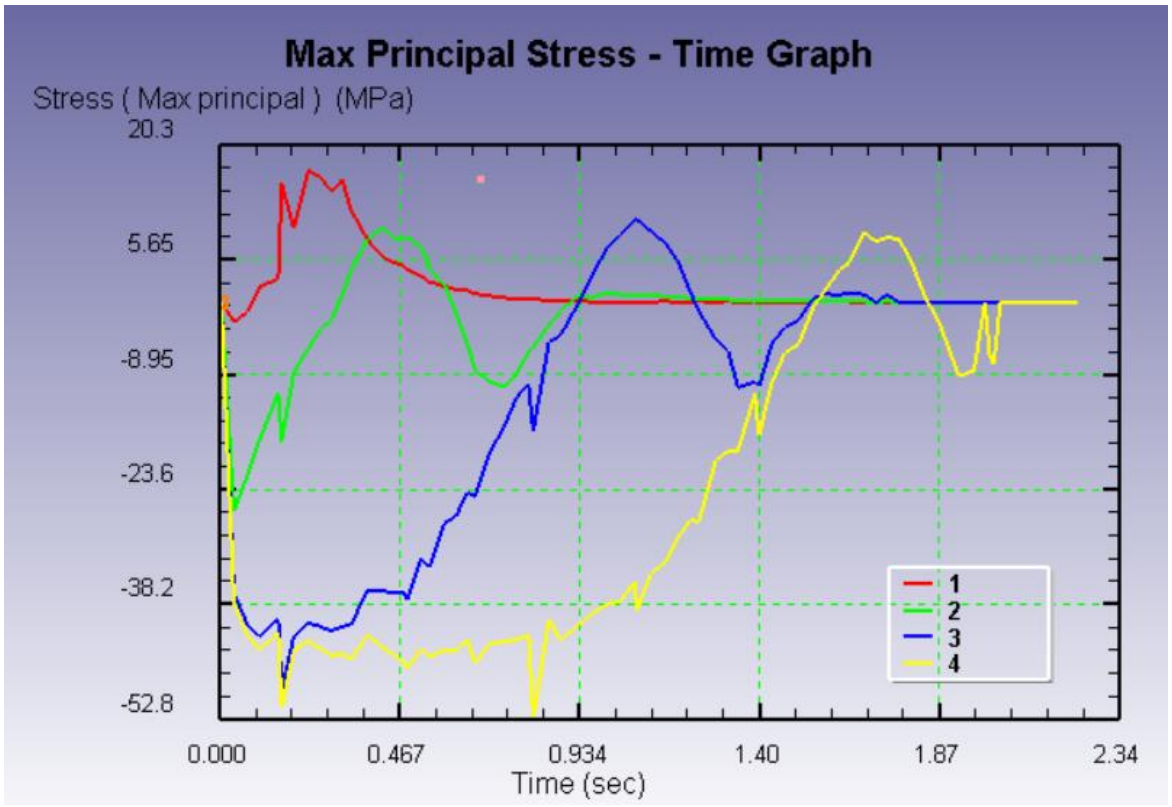

Figure 3.31. 40-Diameter and 0 Rpm Max Principal Stress - Time Graph

40-Diameter and 24 Rpm Analysis Result

Maximum Tension Principal Stress 17.2851 MPa.

Maximum Compression Principal Stress -54.0495 MPa.

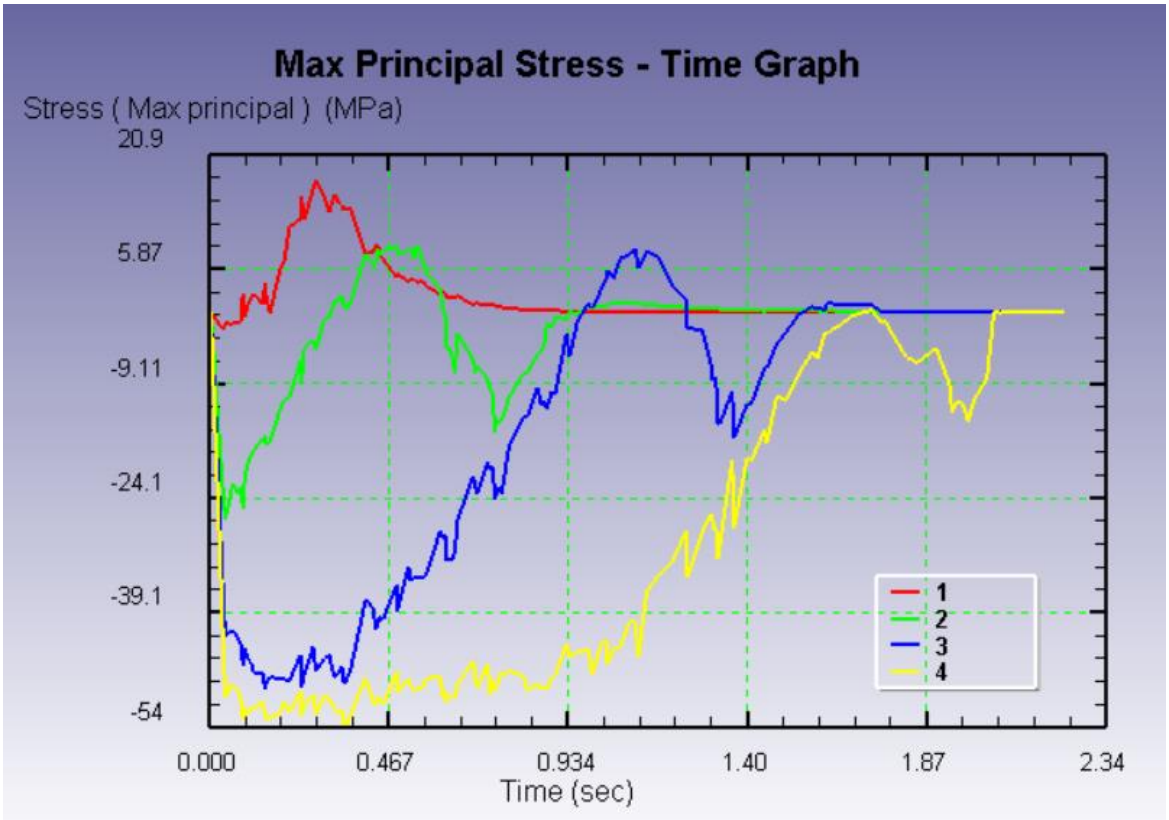

Figure 3.32. 40-Diameter and 24 Rpm Max Principal Stress - Time Graph

40-Diameter and 48 Rpm Analysis Result

Maximum Tension Principal Stress 21.0141 MPa.

Maximum Tension Principal Stress -51.9329 MPa.

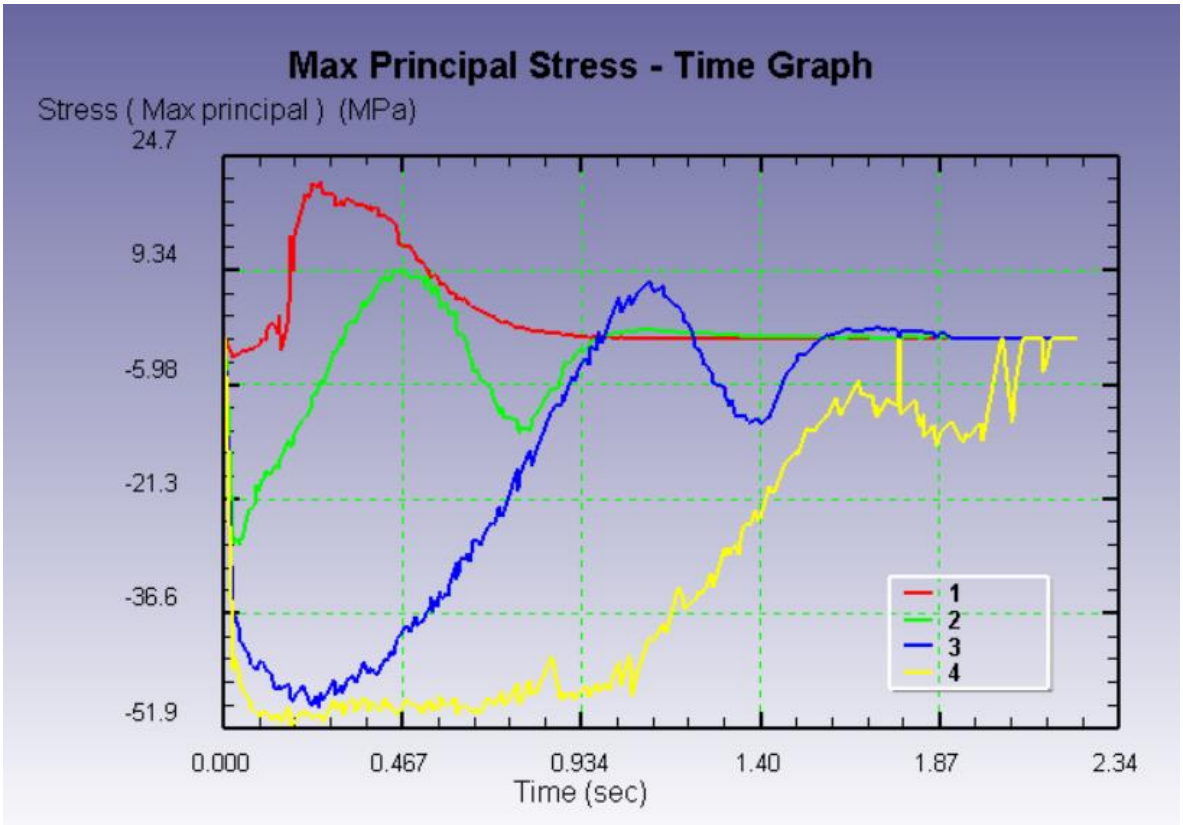

Figure 3.33. 40-Diameter and 48 Rpm Max Principal Stress - Time Graph

40-Diameter and 96 Rpm Analysis Result

Maximum Tension Principal Stress 19.2977 MPa.

Maximum Compression Principal Stress -51.8939 MPa.

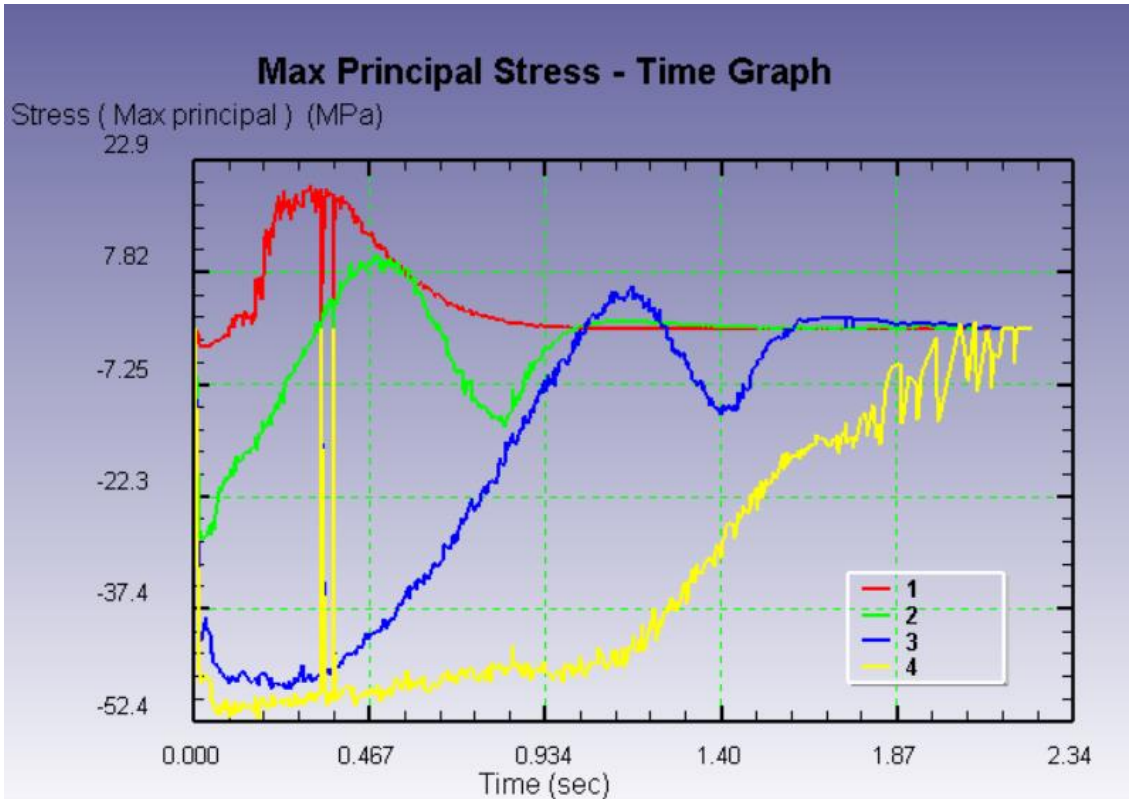

Figure 3.34. 40-Diameter and 96 Rpm Max Principal Stress - Time Graph

40-Diameter and 120 Rpm Analysis Result

Maximum Tension Principal Stress 15.4780 MPa.

Maximum Compression Principal Stress -51.6686 MPa.

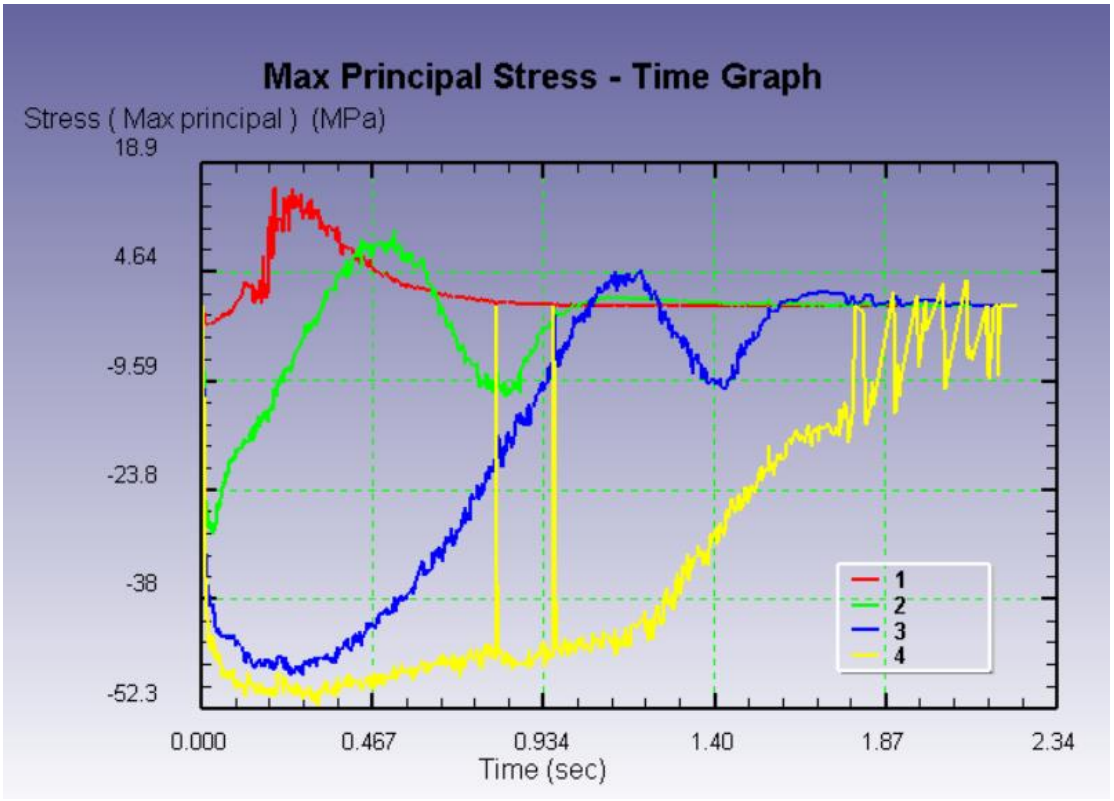

Figure 3.35. 40-Diameter and 120 Rpm Max Principal Stress - Time Graph

35-Diameter and 0 Rpm Analysis Result

Maximum Tension Principal Stress 20.6046 MPa.

Maximum Compression Principal Stress -73.1586 MPa.

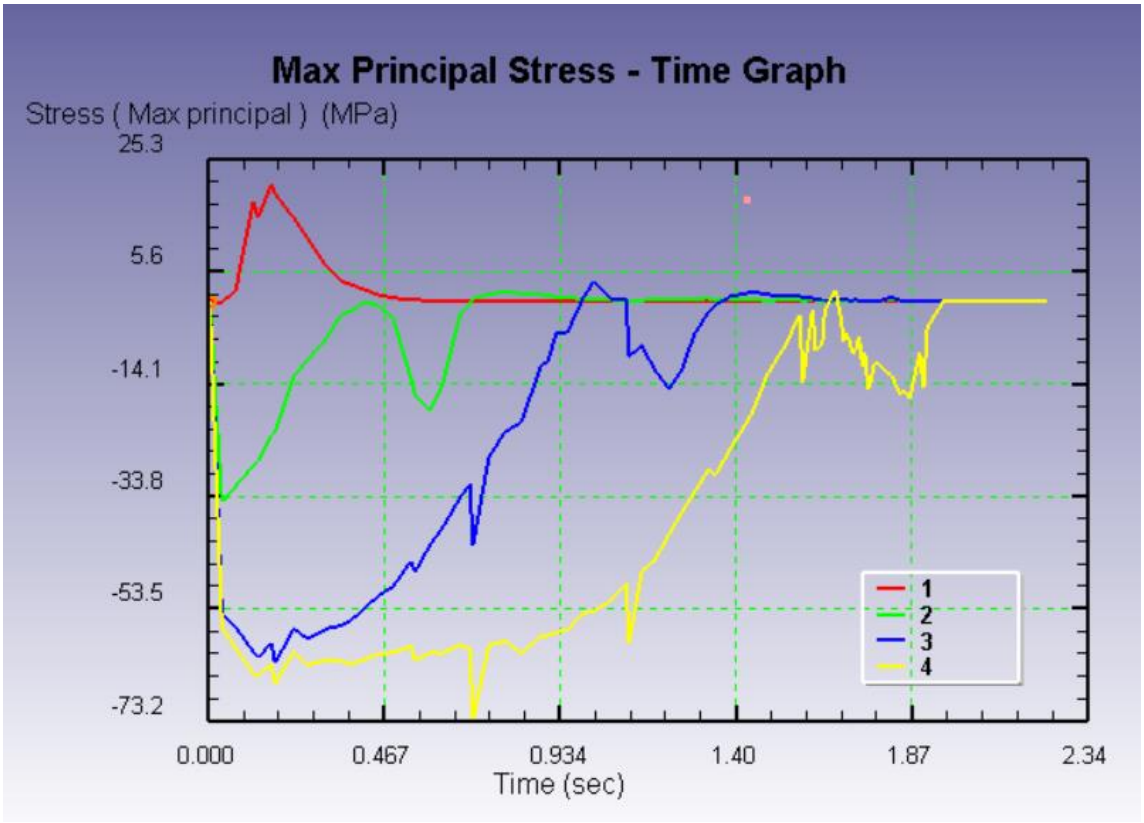

Figure 3.36. 35-Diameter and 0 Rpm Max Principal Stress - Time Graph

35-Diameter and 24 Rpm Analysis Result

Maximum Tension Principal Stress 24.1353 MPa.

Maximum Compression Principal Stress -73.8584 MPa.

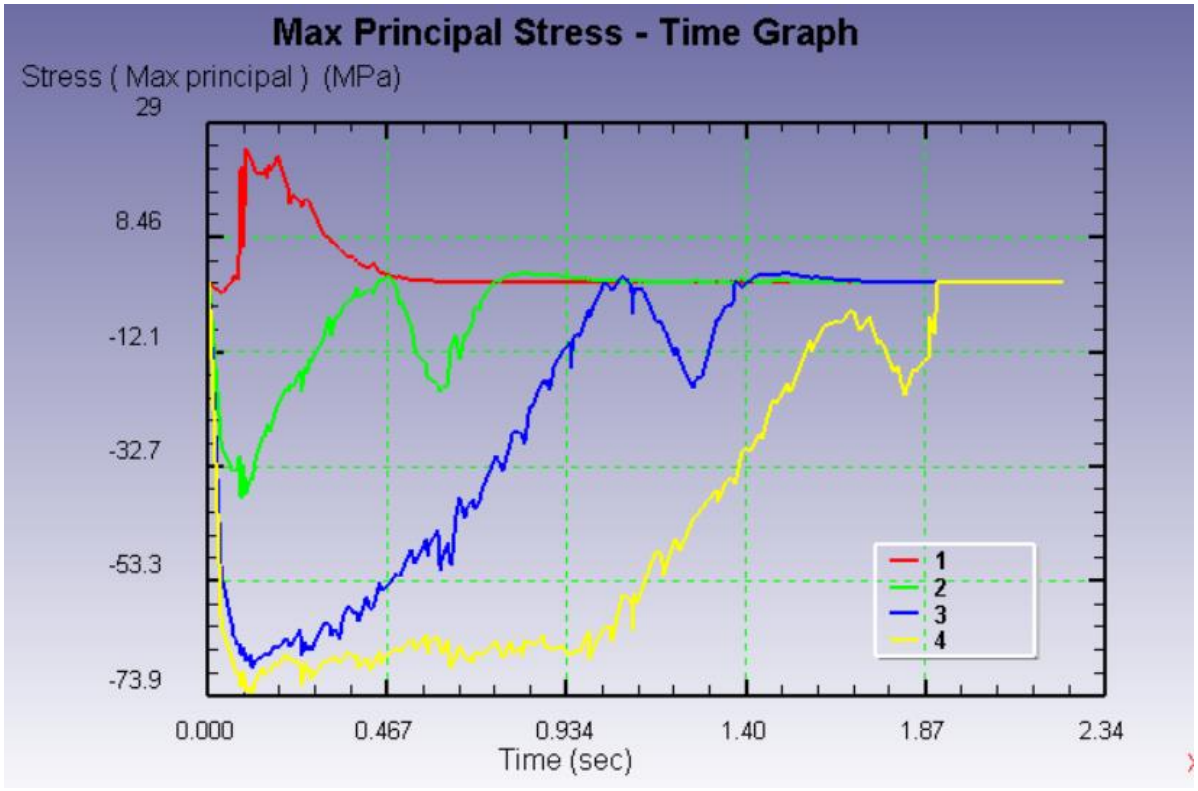

Figure 3.37. 35-Diameter and 24 Rpm Max Principal Stress - Time Graph

35-Diameter and 48 Rpm Analysis Result

Maximum Tension Principal Stress 22.6559 MPa.

Maximum Compression Principal Stress -69.3964 MPa.

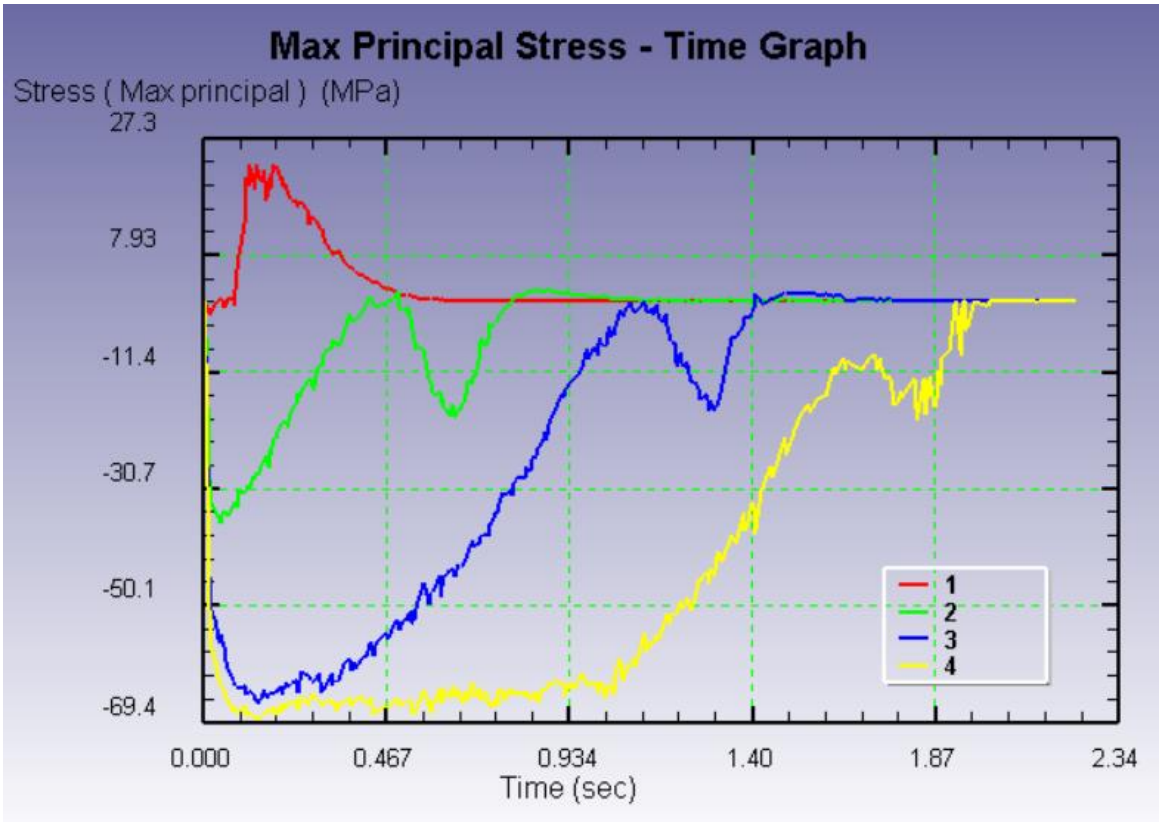

Figure 3.38. 35-Diameter and 48 Rpm Max Principal Stress - Time Graph

35-Diameter and 96 Rpm Analysis Result

Maximum Tension Principal Stress 21.4780 MPa.

Maximum Compression Principal Stress -69.1276 MPa.

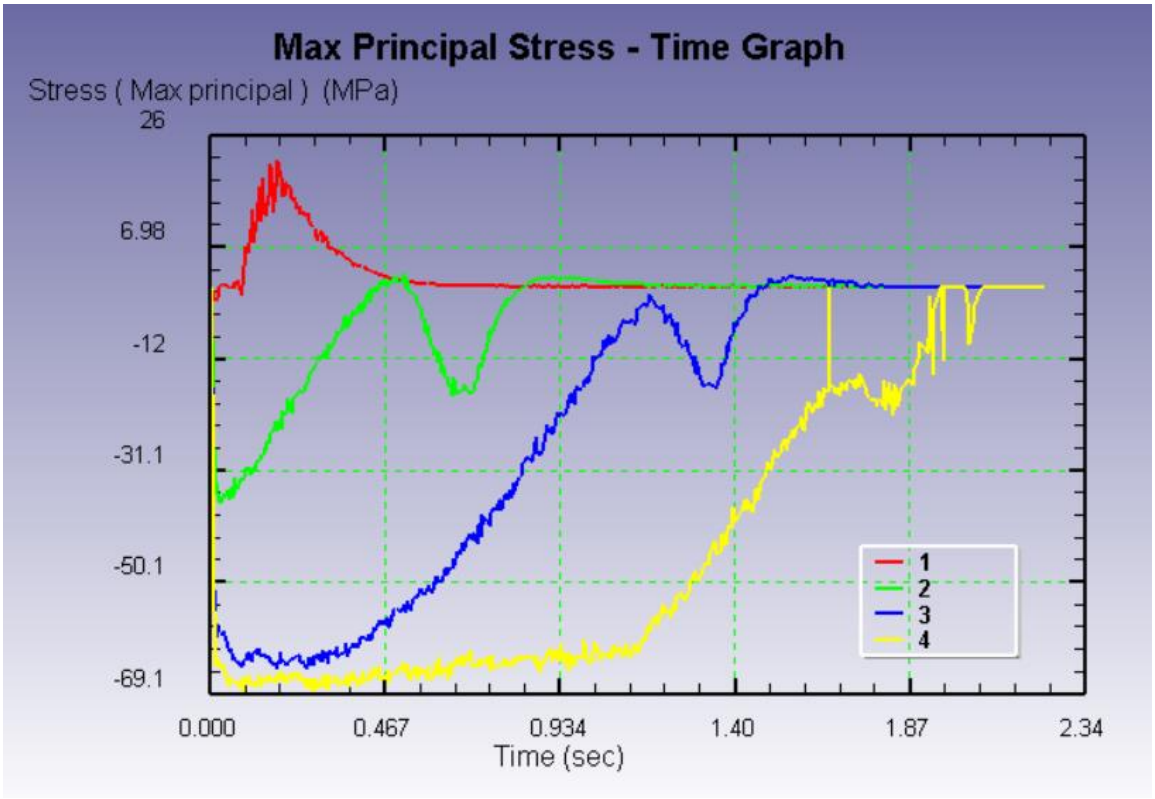

Figure 3.39. 35-Diameter and 96 Rpm Max Principal Stress - Time Graph

35-Diameter and 120 Rpm Analysis Result

Maximum Tension Principal Stress 20.4702 MPa.

Maximum Compression Principal Stress -68.2282 MPa.

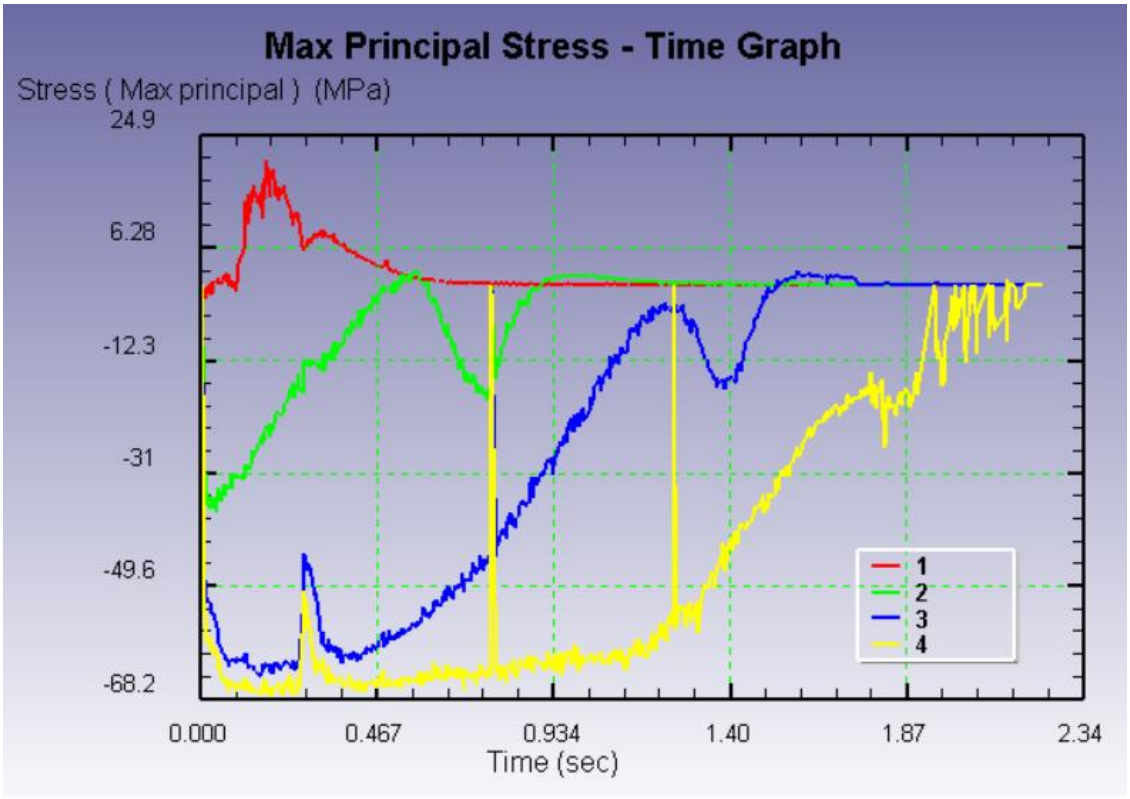

Figure 3.40. 35-Diameter and 120 Rpm Max Principal Stress - Time Graph

30-Diameter and 0 Rpm Analysis Result

Maximum Tension Principal Stress 21.0659 MPa.

Maximum Compression Principal Stress -90.8783 MPa.

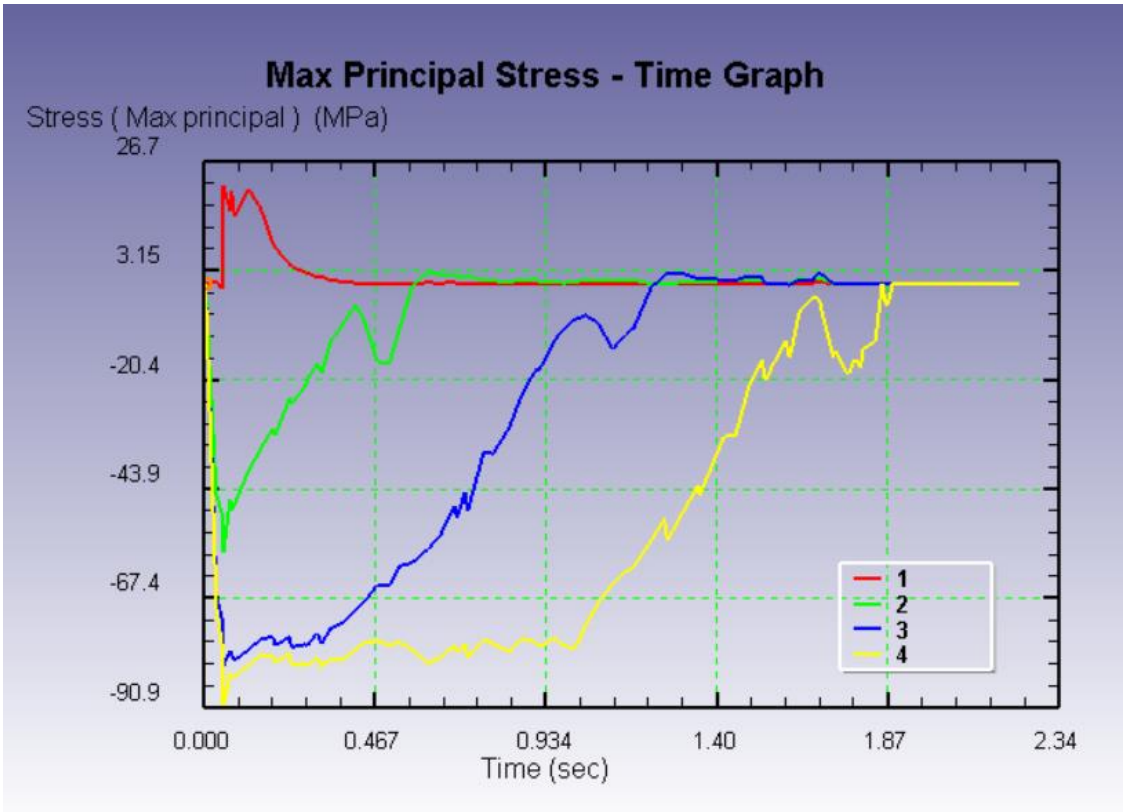

Figure 3.41. 30-Diameter and 0 Rpm Max Principal Stress - Time Graph

30-Diameter and 24 Rpm Analysis Result

Maximum Tension Principal Stress 27.8764 MPa.

Maximum Compression Principal Stress -88.4569 MPa.

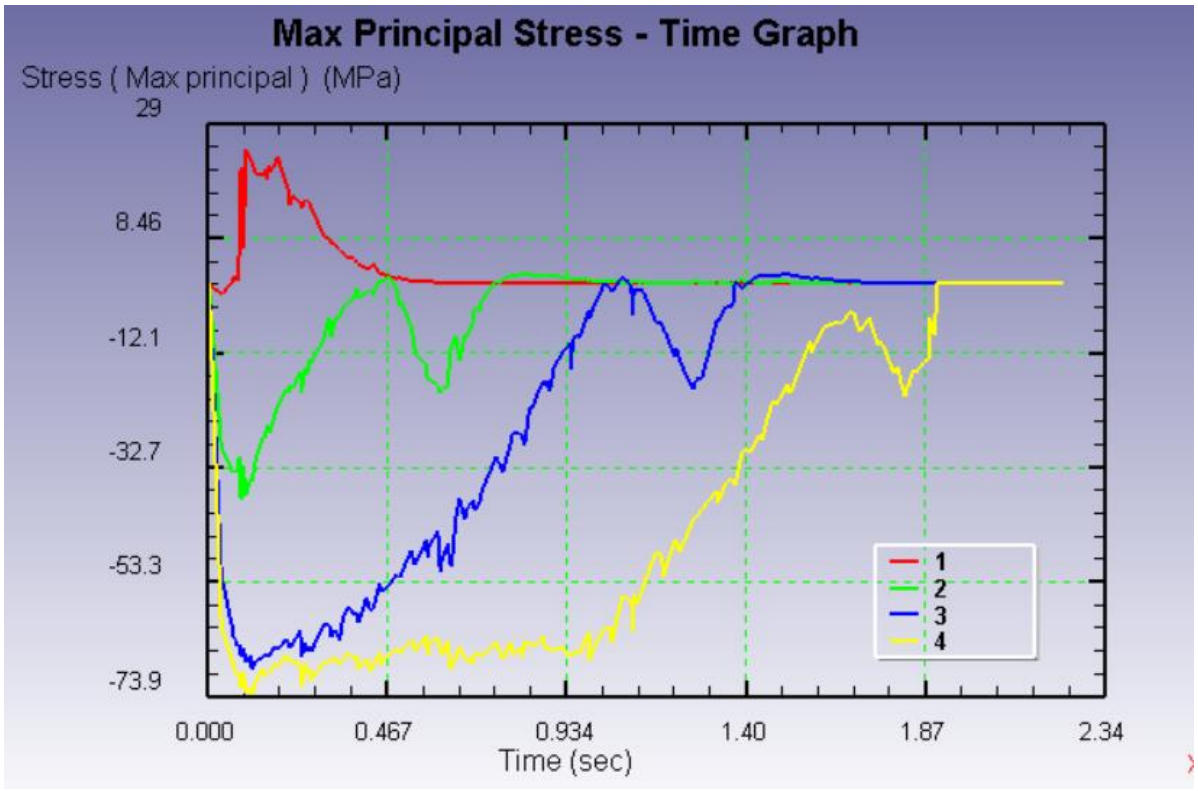

Figure 3.42. 30-Diameter and 24 Rpm Max Principal Stress - Time Graph

30-Diameter and 48 Rpm Analysis Result

Maximum Tension Principal Stress 26.8772 MPa.

Maximum Compression Principal Stress -86.8816 MPa.

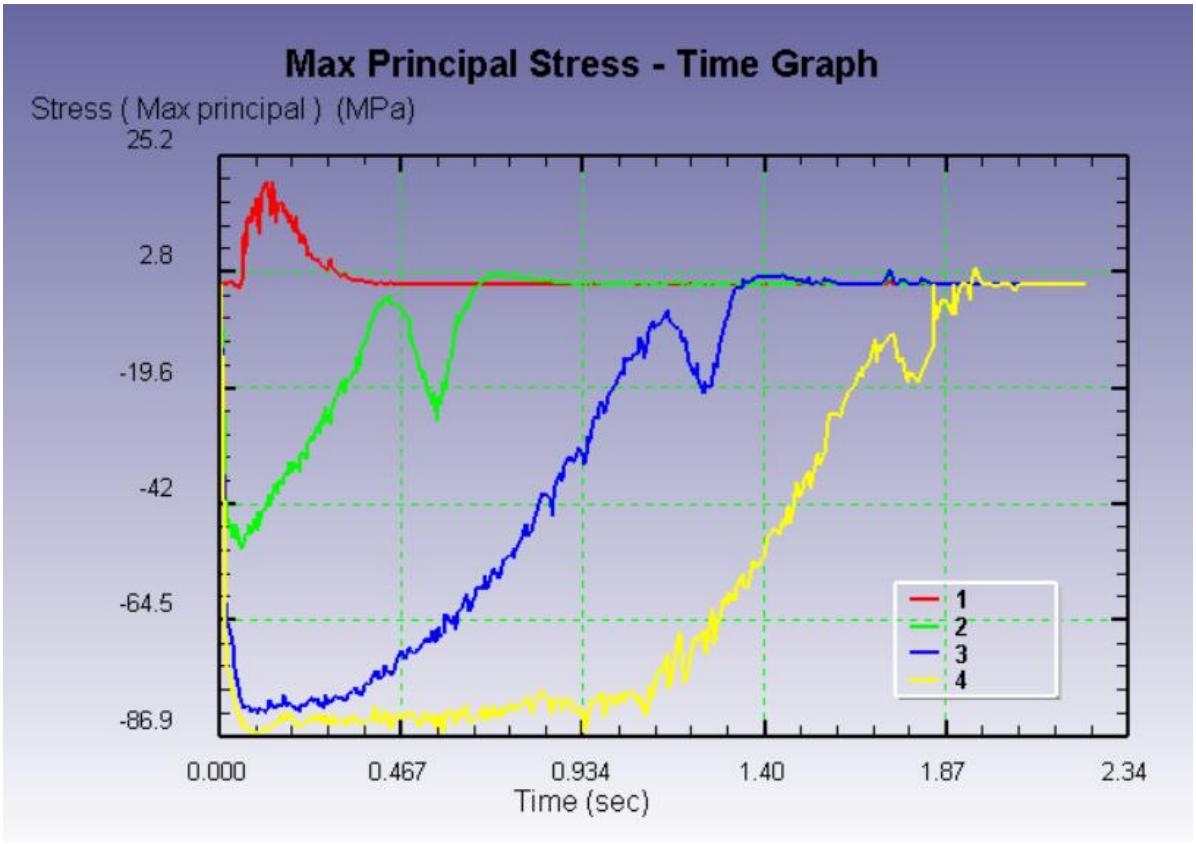

Figure 3.43. 30-Diameter and 48 Rpm Max Principal Stress - Time Graph

30-Diameter and 96 Rpm Analysis Result

Maximum Tension Principal Stress 24.9037 MPa.

Maximum Compression Principal Stress -85.8872 MPa.

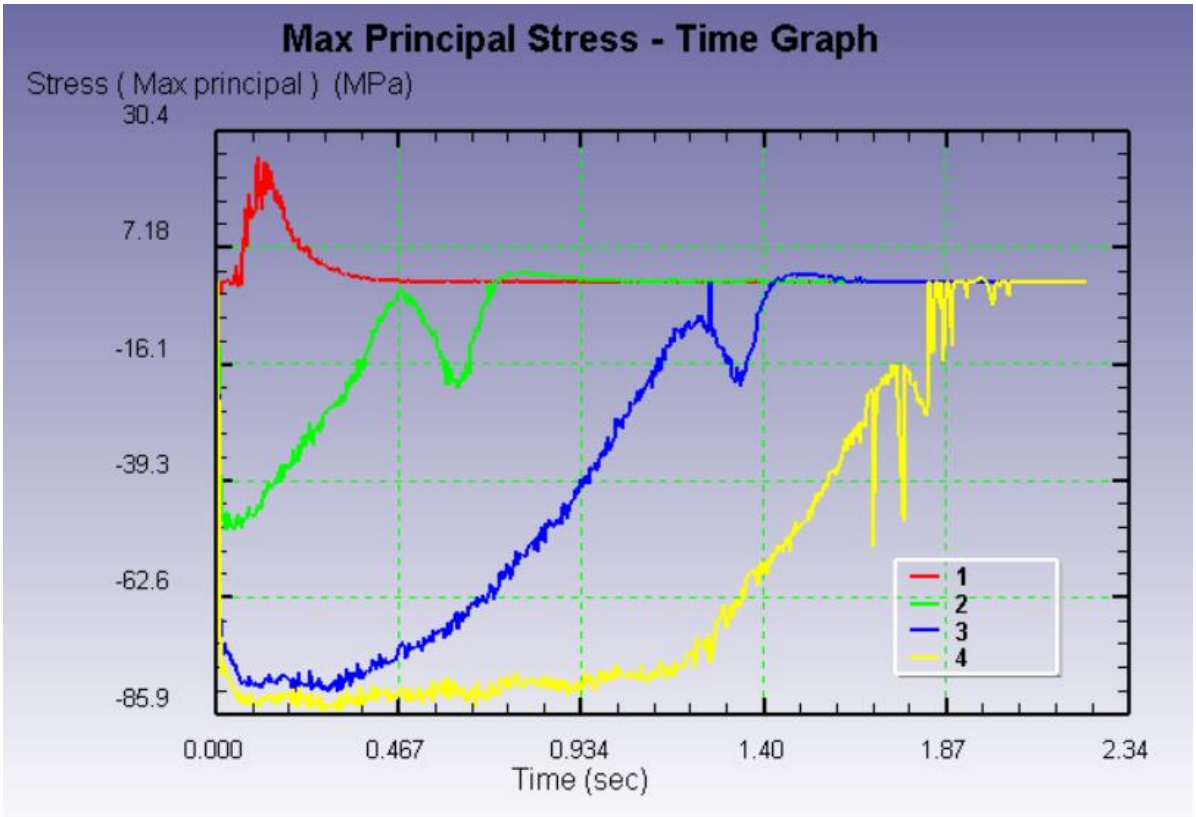

Figure 3.44. 30-Diameter and 96 Rpm Max Principal Stress - Time Graph

30-Diameter and 120 Rpm Analysis Result

Maximum Tension Principal Stress 20.4838 MPa.

Maximum Compression Principal Stress -85.5198 MPa.

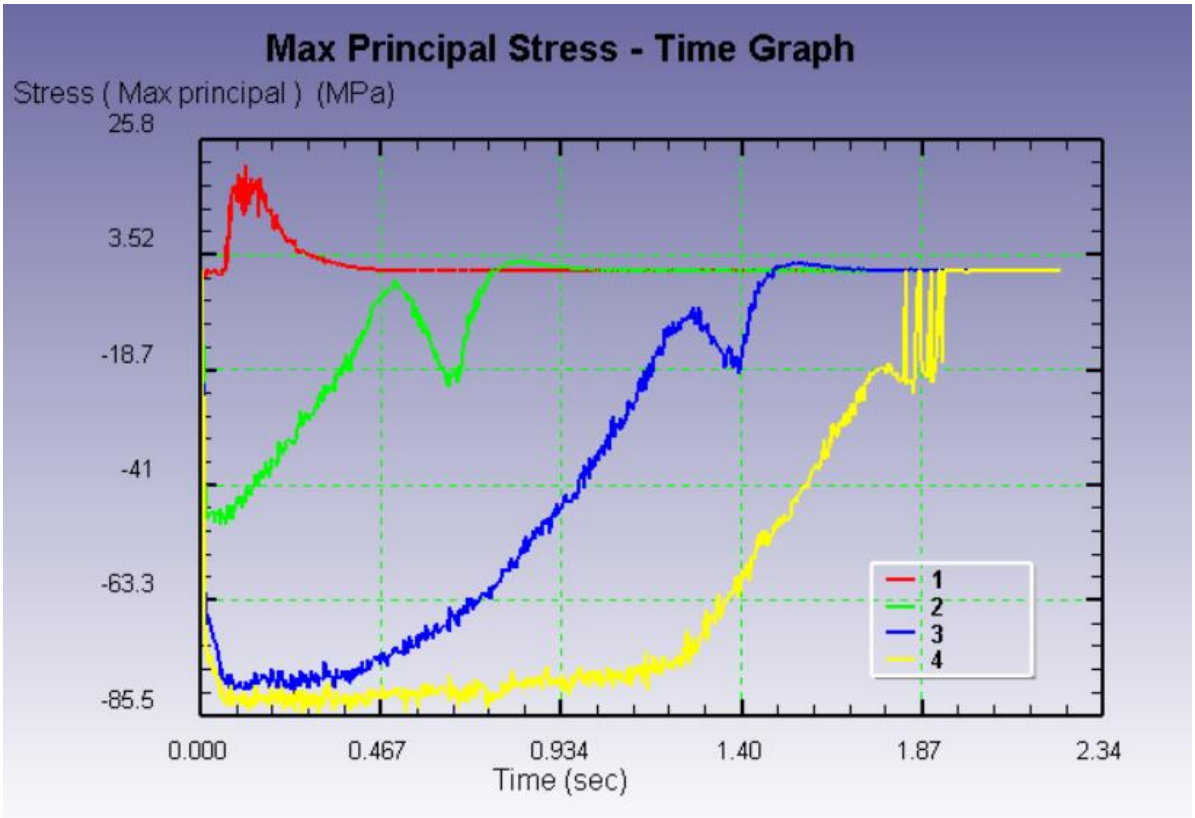

Figure 3.45. 30-Diameter and 120 Rpm Max Principal Stress - Time Graph

3.1.1.2. Total Velocity Analysis Results

The reason the four points is selected is to increase the sample size and avoid the momentary extreme changes in data to affect the results. Final Results will be the average of the four points results and shown as one result.

40-Diameter and 0 Rpm Analysis Result

Average of the total velocity for P1 is 54.83257 mm/sec.

Mean of the average total velocity for all points is 50.45926 mm/sec.

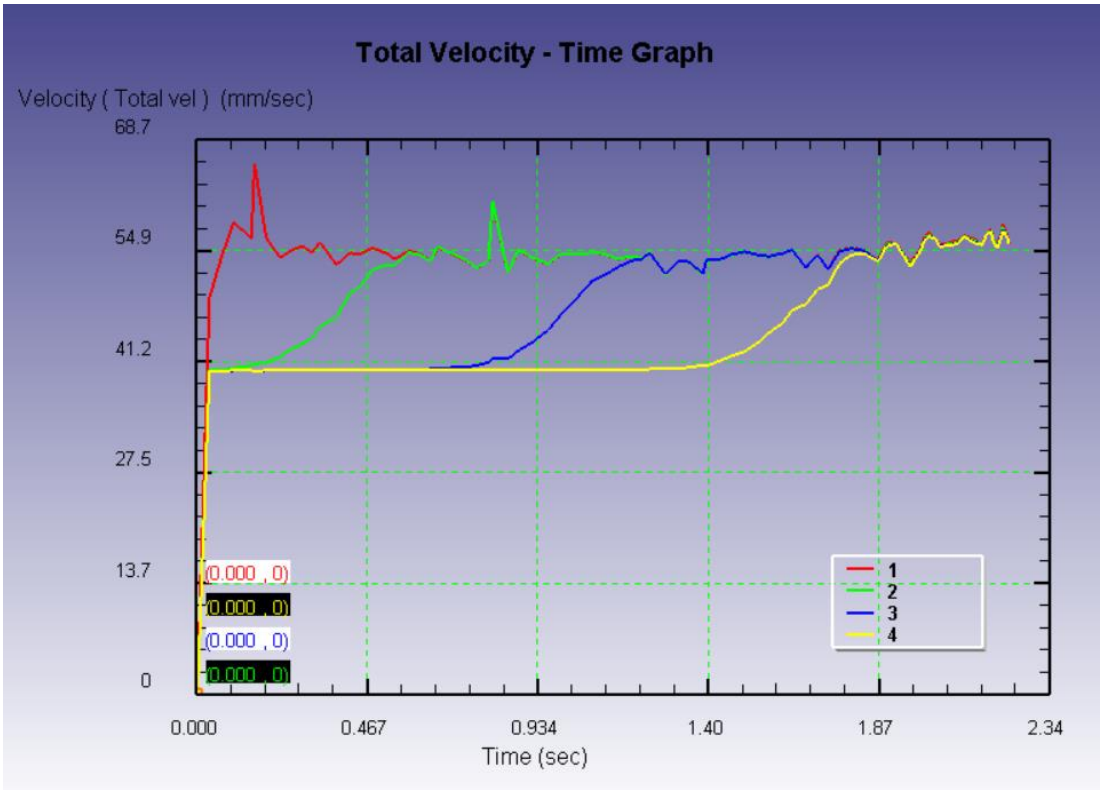

Figure 3.46. 40-Diameter and 0 Rpm Total Velocity- Time Graph

40-Diameter and 24 Rpm Analysis Result

Average of the total velocity for P1 is 54.95724 mm/sec.

Average of the total velocity for P2 is 51.09489 mm/sec.

Average of the total velocity for P3 is 45.58649 mm/sec

Average of the total velocity for P4 is 42.84232 mm/sec.

Mean of the average total velocity for all points is 48.62113 mm/sec.

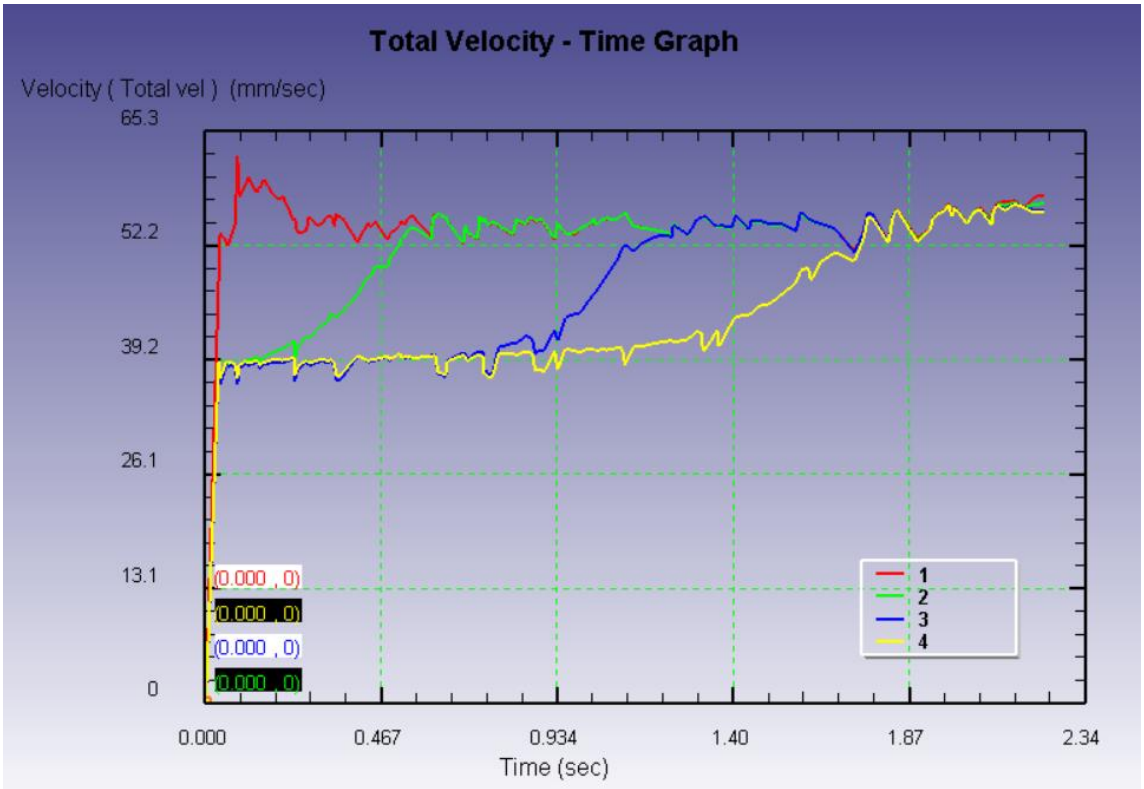

Figure 3.47. 40-Diameter and 24 Rpm Total Velocity- Time Graph

40-Diameter and 48 Rpm Analysis Result

Average of the total velocity for P1 is 53.69636 mm/sec.

Average of the total velocity for P2 is 50.03872 mm/sec.

Average of the total velocity for P3 is 45.01524 mm/sec.

Average of the total velocity for P4 is 42.83209 mm/sec.

Mean of the average total velocity for all points is 47.8956 mm/sec.

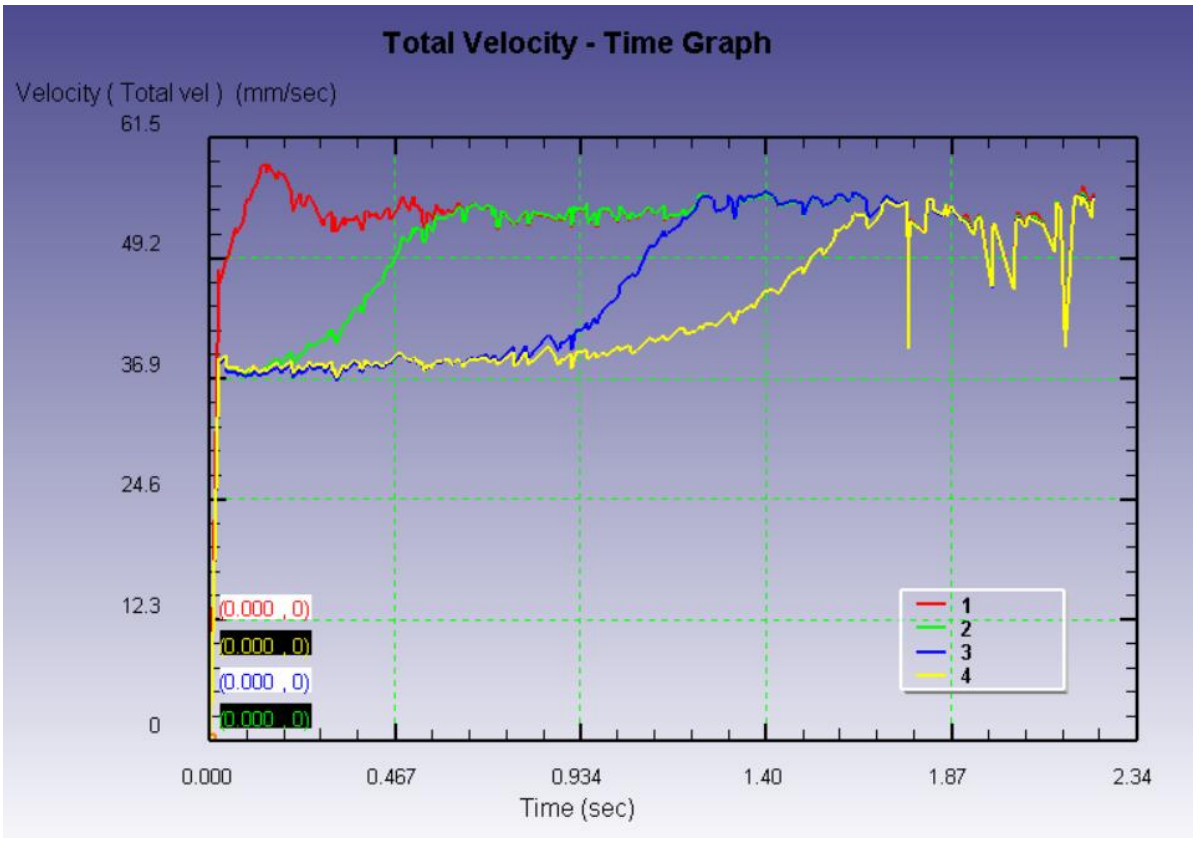

Figure 3.48. 40-Diameter and 48 Rpm Total Velocity- Time Graph

40-Diameter and 96 Rpm Analysis Result

Average of the total velocity for P1 is 51.99983 mm/sec.

Average of the total velocity for P2 is 48.34904 mm/sec.

Average of the total velocity for P3 is 43.51533 mm/sec.

Average of the total velocity for P4 is 41.01974 mm/sec.

Mean of the average total velocity for all points is 46.22098 mm/sec.

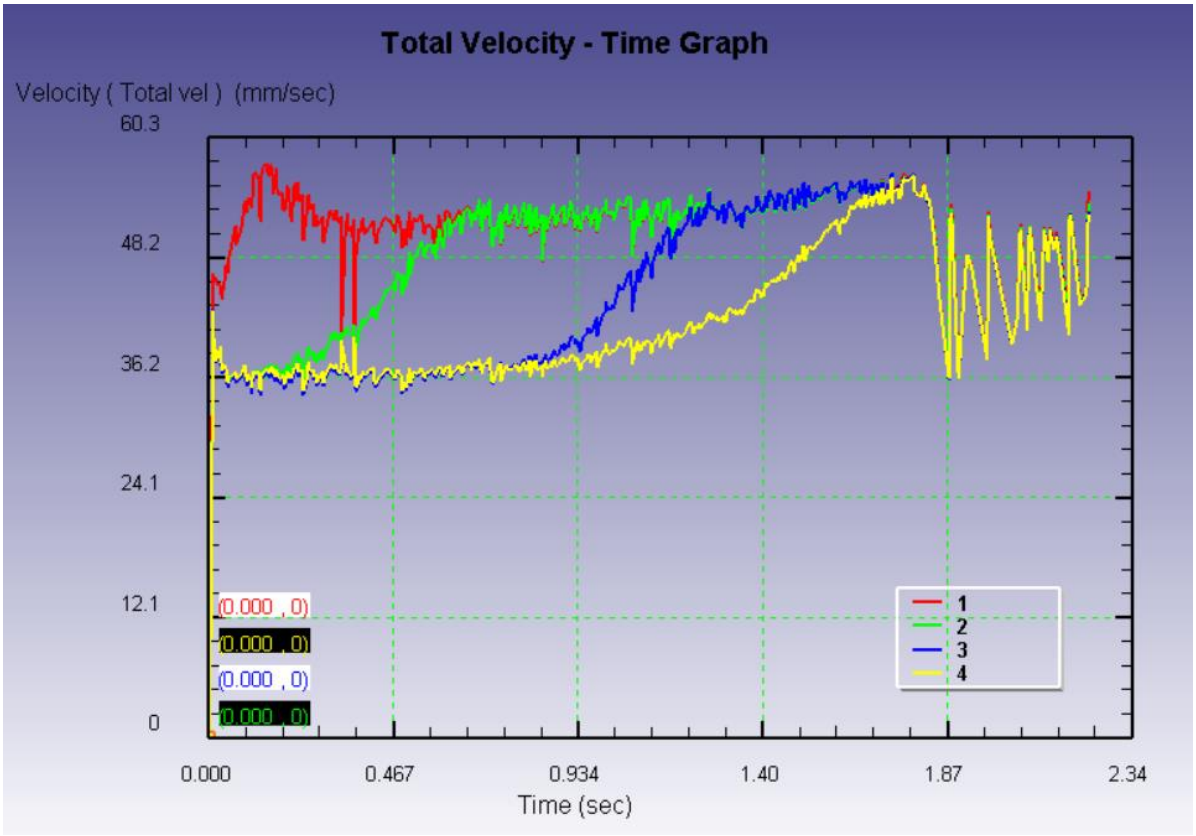

Figure 3.49. 40-Diameter and 96 Rpm Total Velocity- Time Graph

40-Diameter and 120 Rpm Analysis Result

Average of the total velocity for P1 is 51.50243 mm/sec.

Average of the total velocity for P2 is 47.41603 mm/sec.

Average of the total velocity for P3 is 42.64579 mm/sec.

Average of the total velocity for P4 is 40.20169 mm/sec.

Mean of the average total velocity for all points is 45.44194 mm/sec.

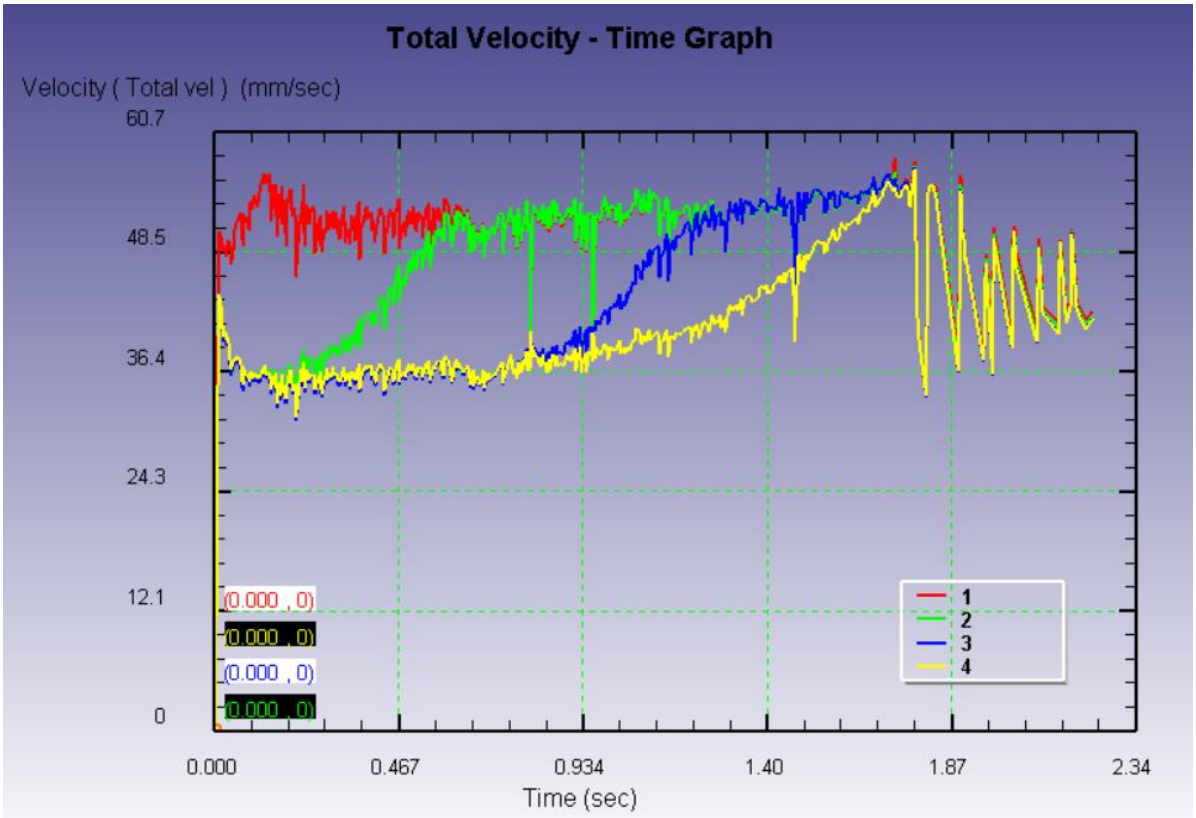

Figure 3.50. 40-Diameter and 120 Rpm Total Velocity- Time Graph

35-Diameter and 0 Rpm Analysis Result

Average of the total velocity for P1 is 74.57182 mm/sec.

Average of the total velocity for P2 is 70.68847 mm/sec.

Average of the total velocity for P3 is 64.22983 mm/sec.

Average of the total velocity for P4 is 57.58443 mm/sec.

Mean of the average total velocity for all points is 66.76864 mm/sec.

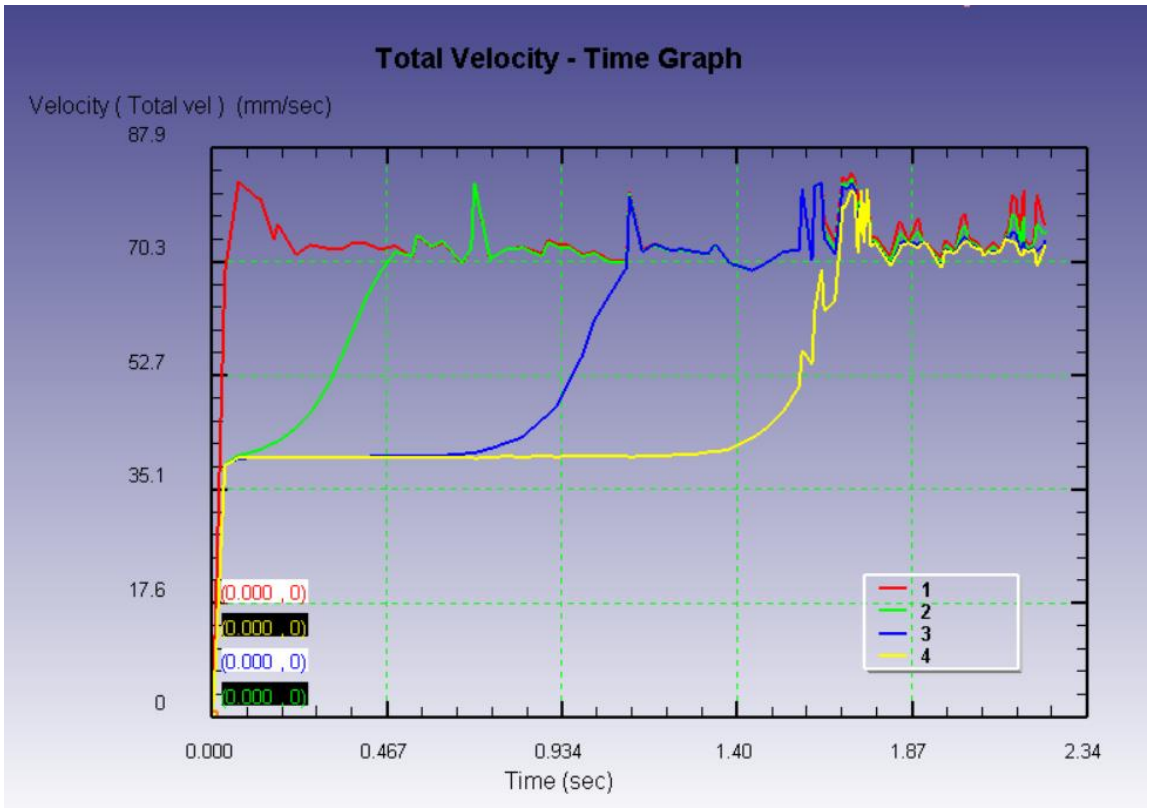

Figure 3.51. 35-Diameter and 0 Rpm Total Velocity- Time Graph

35-Diameter and 24 Rpm Analysis Result

Average of the total velocity for P1 is 72.9317 mm/sec.

Average of the total velocity for P2 is 65.64265 mm/sec.

Average of the total velocity for P3 is 54.95714 mm/sec.

Average of the total velocity for P4 is 48.89869 mm/sec.

Mean of the average total velocity for all points is 60.60754 mm/sec.

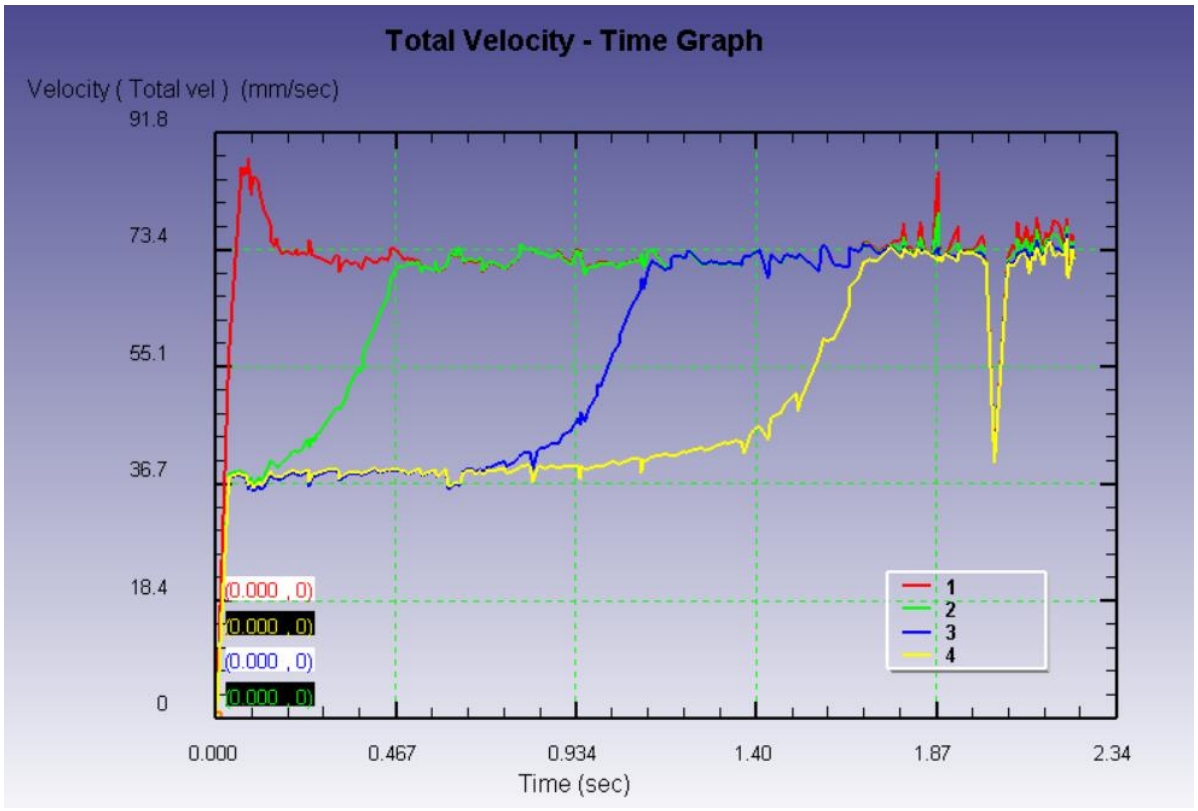

Figure 3.52. 35-Diameter and 24 Rpm Total Velocity- Time Graph

35-Diameter and 48 Rpm Analysis Result

Average of the total velocity for P1 is 71.02307 mm/sec.

Average of the total velocity for P2 is 63.93140 mm/sec.

Average of the total velocity for P3 is 53.02274 mm/sec.

Average of the total velocity for P4 is 46.64374 mm/sec.

Mean of the average total velocity for all points is 58.65524 mm/sec.

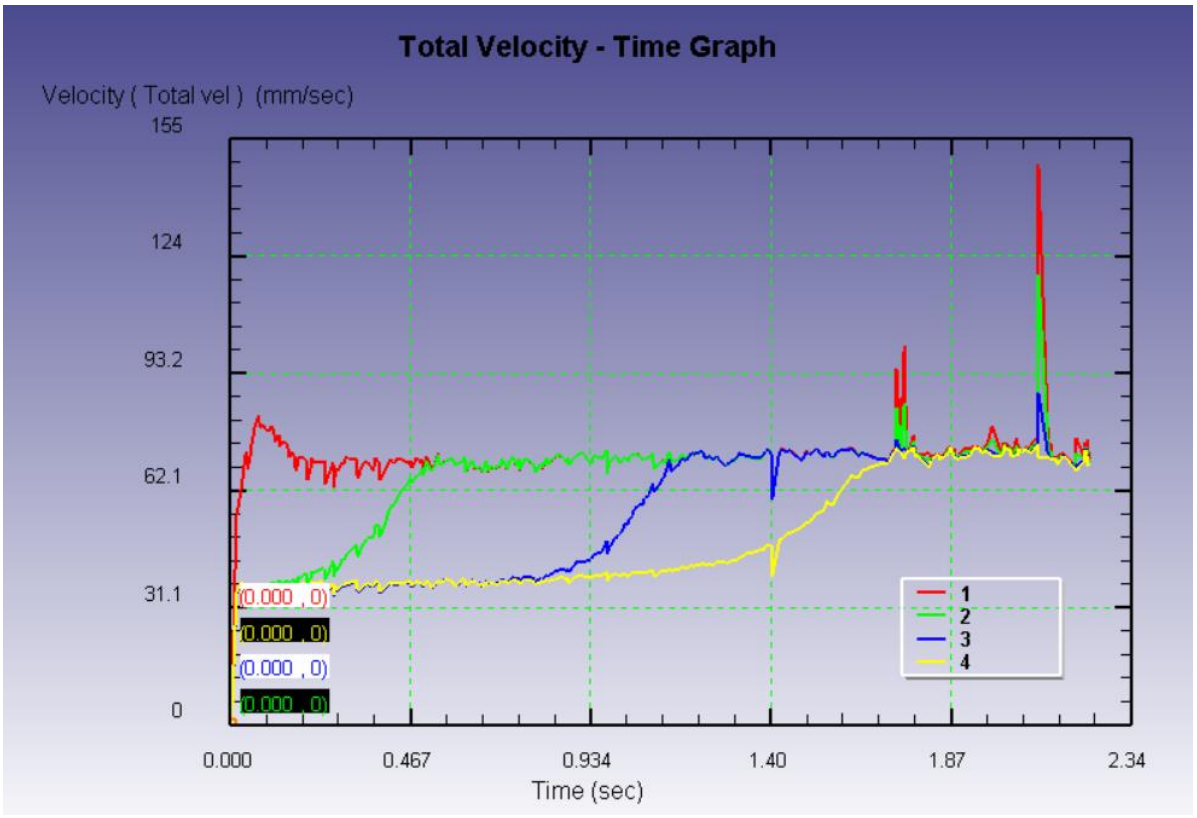

Figure 3.53. 35-Diameter and 48 Rpm Total Velocity- Time Graph

35-Diameter and 96 Rpm Analysis Result

Average of the total velocity for P1 is 67.18007 mm/sec.

Average of the total velocity for P2 is 59.76169 mm/sec.

Average of the total velocity for P3 is 49.02369 mm/sec.

Average of the total velocity for P4 is 44.05965 mm/sec.

Mean of the average total velocity for all points is 55.06274 mm/sec.

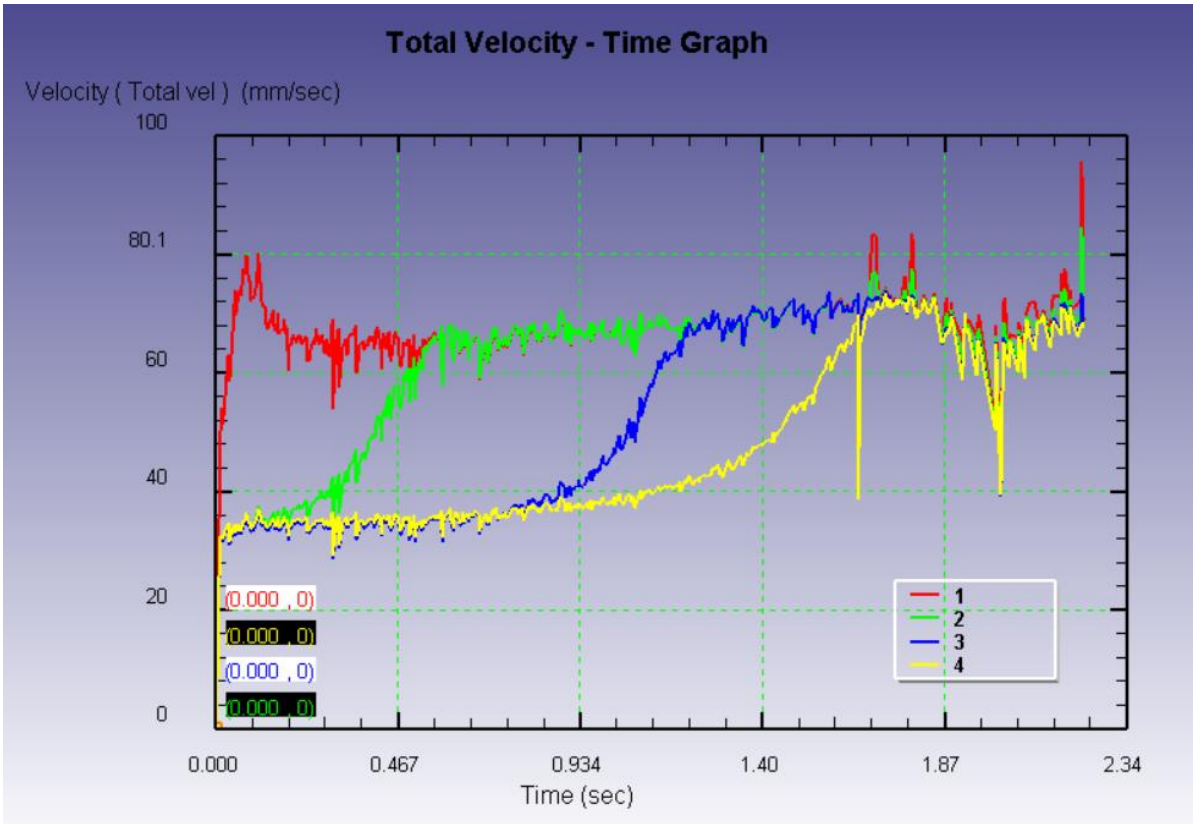

Figure 3.54. 35-Diameter and 96 Rpm Total Velocity- Time Graph

35-Diameter and 120 Rpm Analysis Result

Average of the total velocity for P1 is 63.55057 mm/sec.

Average of the total velocity for P2 is 56.98085 mm/sec.

Average of the total velocity for P3 is 46.79336 mm/sec.

Average of the total velocity for P4 is 42.10637 mm/sec.

Mean of the average total velocity for all points is 52.35779 mm/sec.

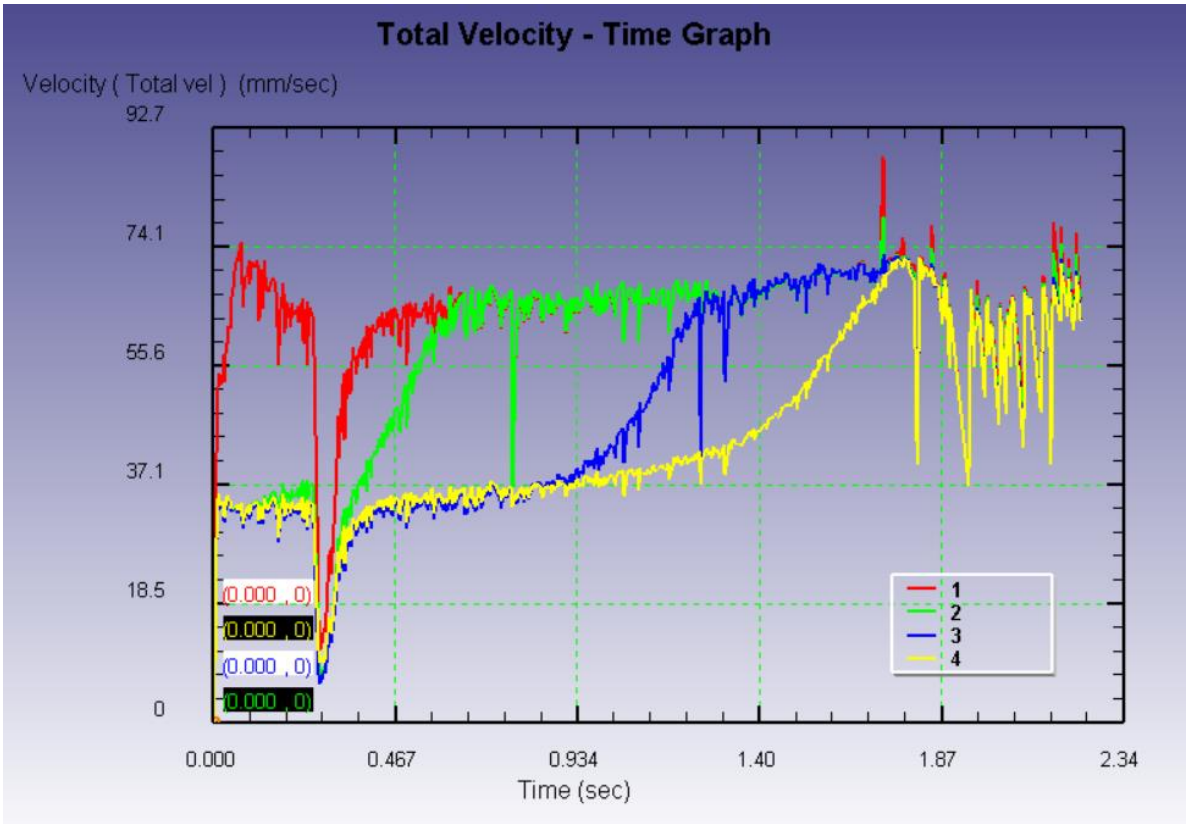

Figure 3.55. 35-Diameter and 120 Rpm Total Velocity- Time Graph

30-Diameter and 0 Rpm Analysis Result

Average of the total velocity for P1 is 105.61376 mm/sec.

Average of the total velocity for P2 is 94.34304 mm/sec.

Average of the total velocity for P3 is 80.33648 mm/sec.

Average of the total velocity for P4 is 69.32166 mm/sec.

Mean of the average total velocity for all points is 87.32380 mm/sec.

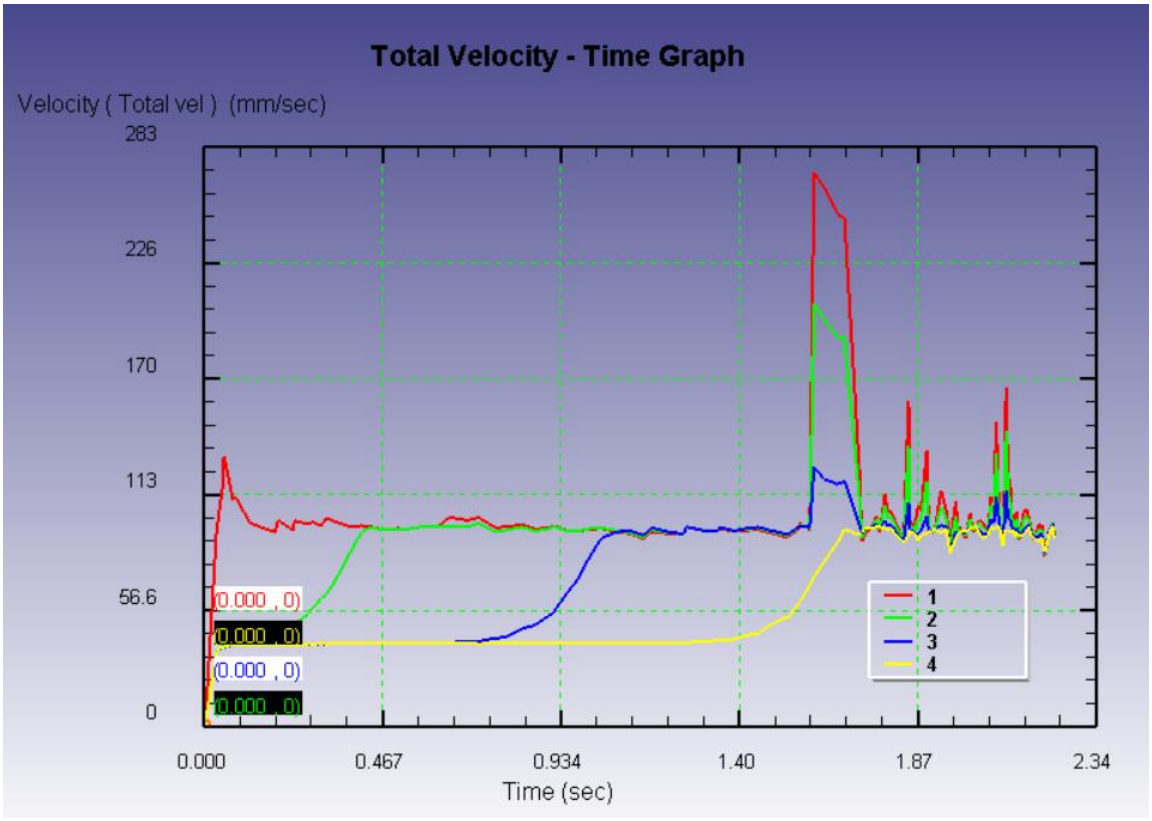

Figure 3.56. 30-Diameter and 0 Rpm Total Velocity- Time Graph

30-Diameter and 24 Rpm Analysis Result

Average of the total velocity for P1 is 96.99643 mm/sec.

Average of the total velocity for P2 is 84.94001 mm/sec.

Average of the total velocity for P3 is 67.48683 mm/sec.

Average of the total velocity for P4 is 56.83087 mm/sec.

Mean of the average total velocity for all points is 76.56353 mm/sec.

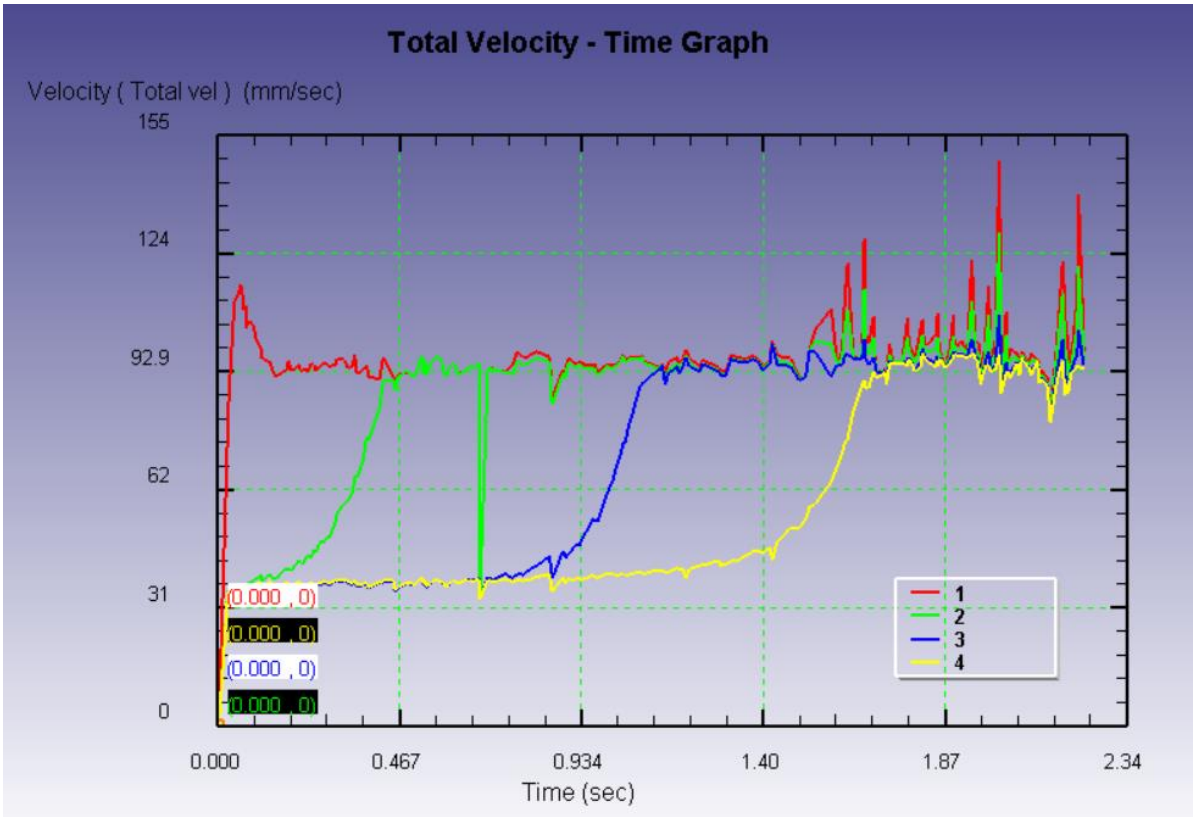

Figure 3.57. 30-Diameter and 24 Rpm Total Velocity- Time Graph

30-Diameter and 48 Rpm Analysis Result

Average of the total velocity for P1 is 94.28484 mm/sec.

Average of the total velocity for P2 is 79.71277 mm/sec.

Average of the total velocity for P3 is 59.25915 mm/sec.

Average of the total velocity for P4 is 49.02899 mm/sec.

Mean of the average total velocity for all points is 70.57144 mm/sec.

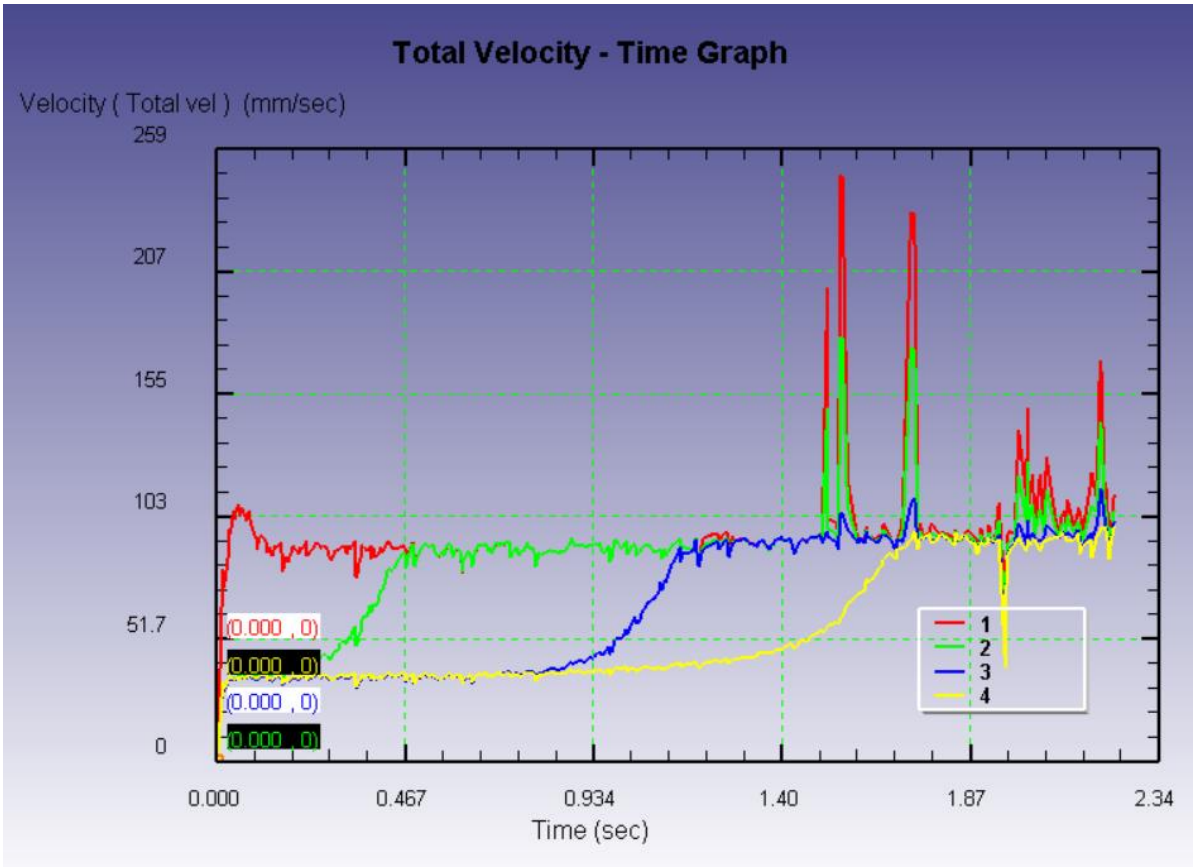

Figure 3.58. 30-Diameter and 48 Rpm Total Velocity- Time Graph

30-Diameter and 96 Rpm Analysis Result

Average of the total velocity for P1 is 85.273503 mm/sec.

Average of the total velocity for P2 is 73.543754 mm/sec.

Average of the total velocity for P3 is 55.49065 mm/sec.

Average of the total velocity for P4 is 47.197857 mm/sec.

Mean of the average total velocity for all points is 65.376441 mm/sec.

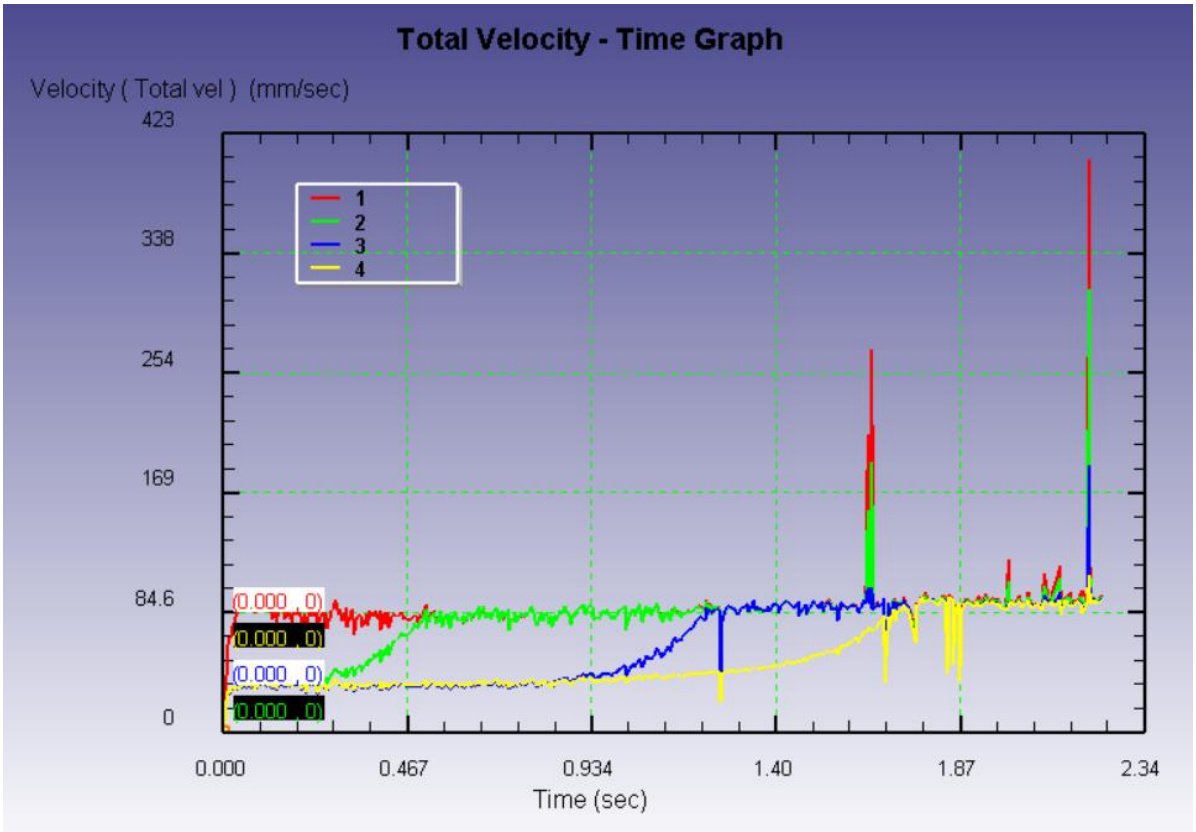

Figure 3.59. 30-Diameter and 96 Rpm Total Velocity- Time Graph

30-Diameter and 120 Rpm Analysis Result

Average of the total velocity for P1 is 81.88632 mm/sec.

Average of the total velocity for P2 is 70.53388 mm/sec.

Average of the total velocity for P3 is 52.47017 mm/sec.

Average of the total velocity for P4 is 45.06908 mm/sec.

Mean of the average total velocity for all points is 62.48986 mm/sec.

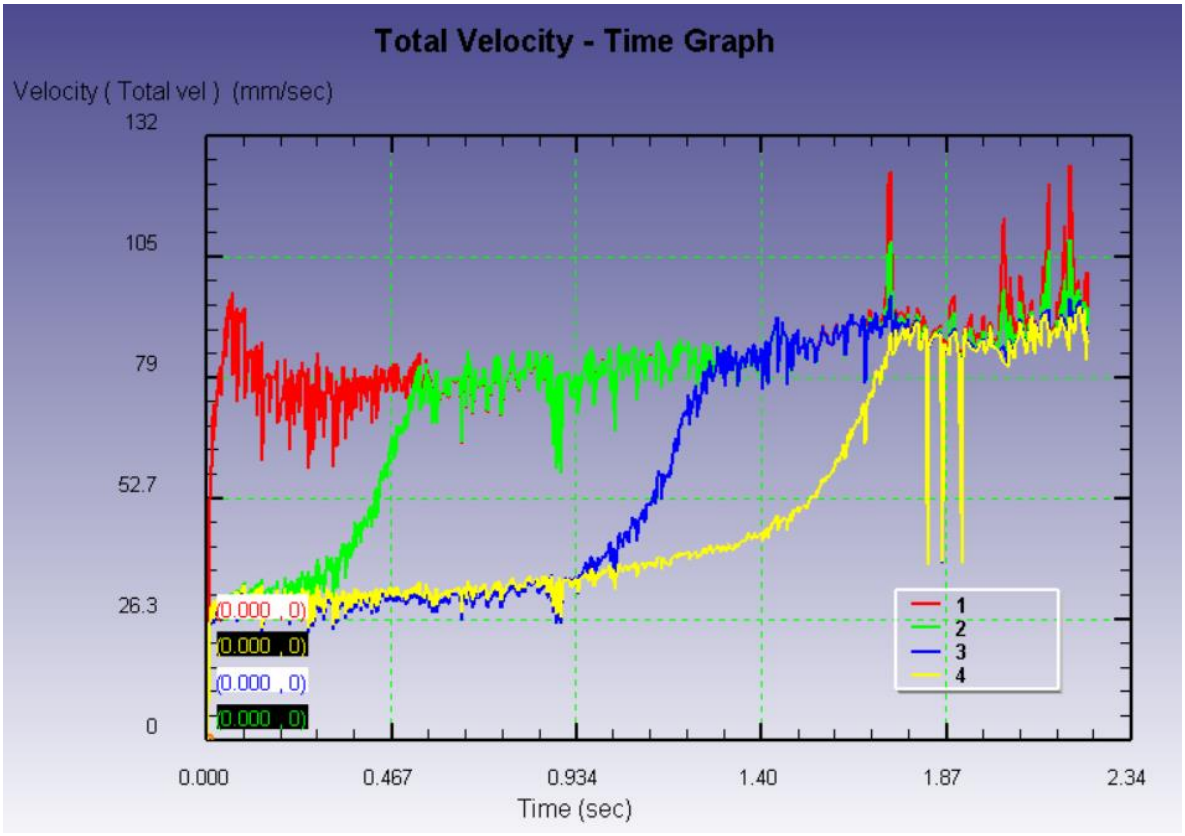

Figure 3.60. 30-Diameter and 120 Rpm Total Velocity- Time Graph

3.1.2. Second selection of points results

Since the effect of angular velocity was not clear on some of the results for the first selection of points second set of points is selected to see the effect of angular velocity more clearly.

3.1.2.2. Total velocity analysis results

P’4 will be used for the total velocity analysis results since it is the point closest to the outer surface of the workpiece

40-Diameter and 0 Rpm Analysis Result

Average of the total velocity for P’4 is 48.39640 mm/sec.

Maximum of the total velocity for P’4 is 57.79698 mm/sec.

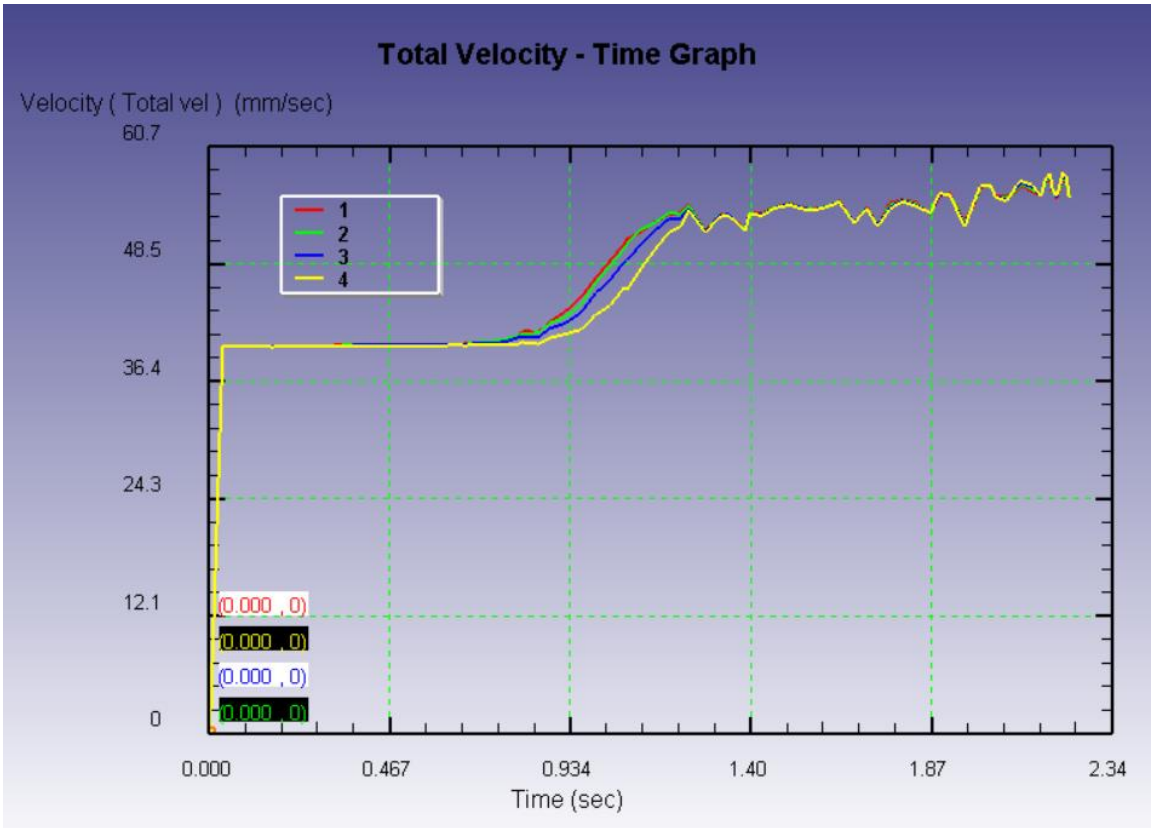

Figure 3.61. 40-Diameter and 0 Rpm Total Velocity- Time Graph

40-Diameter and 24 Rpm Analysis Result

Average of the total velocity for P’4 is 45.89806 mm/sec.

Maximum of the total velocity for P’4 is 65.34164 mm/sec.

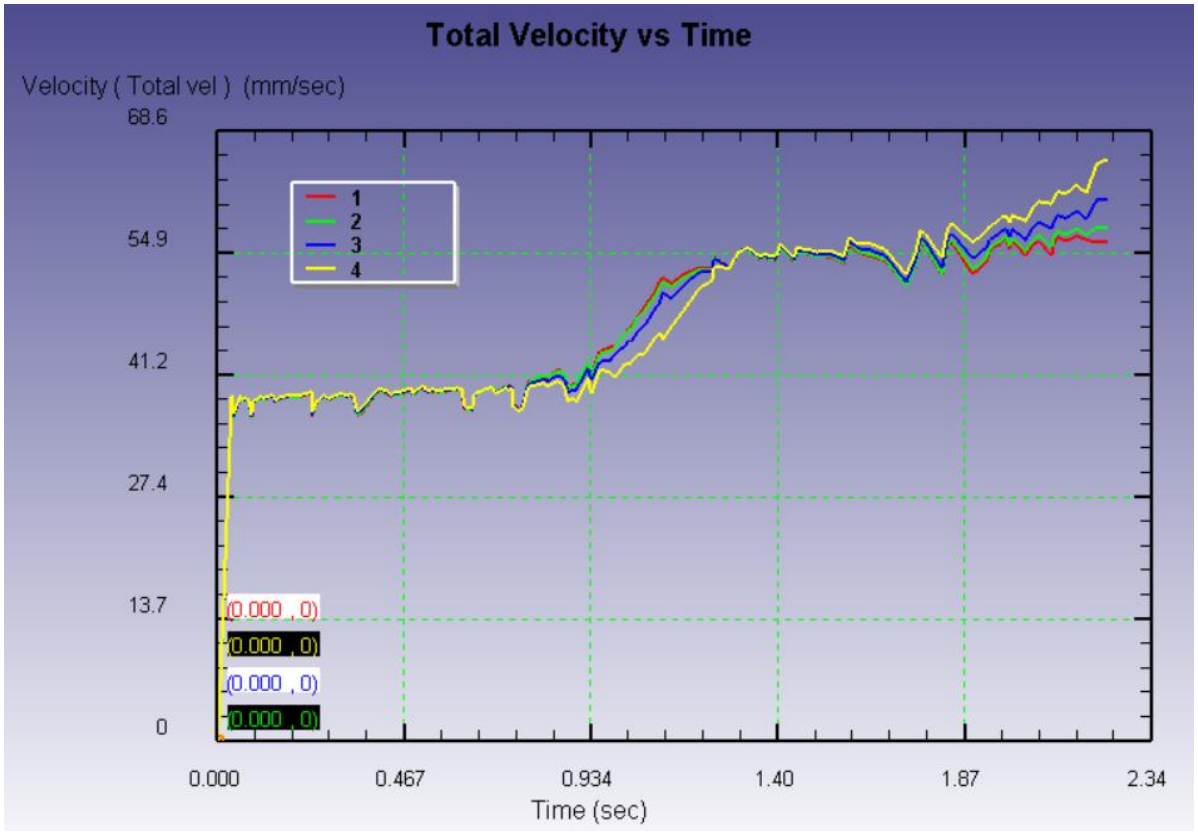

Figure 3.62. 40-Diameter and 24 Rpm Total Velocity- Time Graph

40-Diameter and 48 Rpm Analysis Result

Average of the total velocity for P'4 is 47.75524 mm/sec.

Maximum of the total velocity for P'4 is 83.45041 mm/sec.

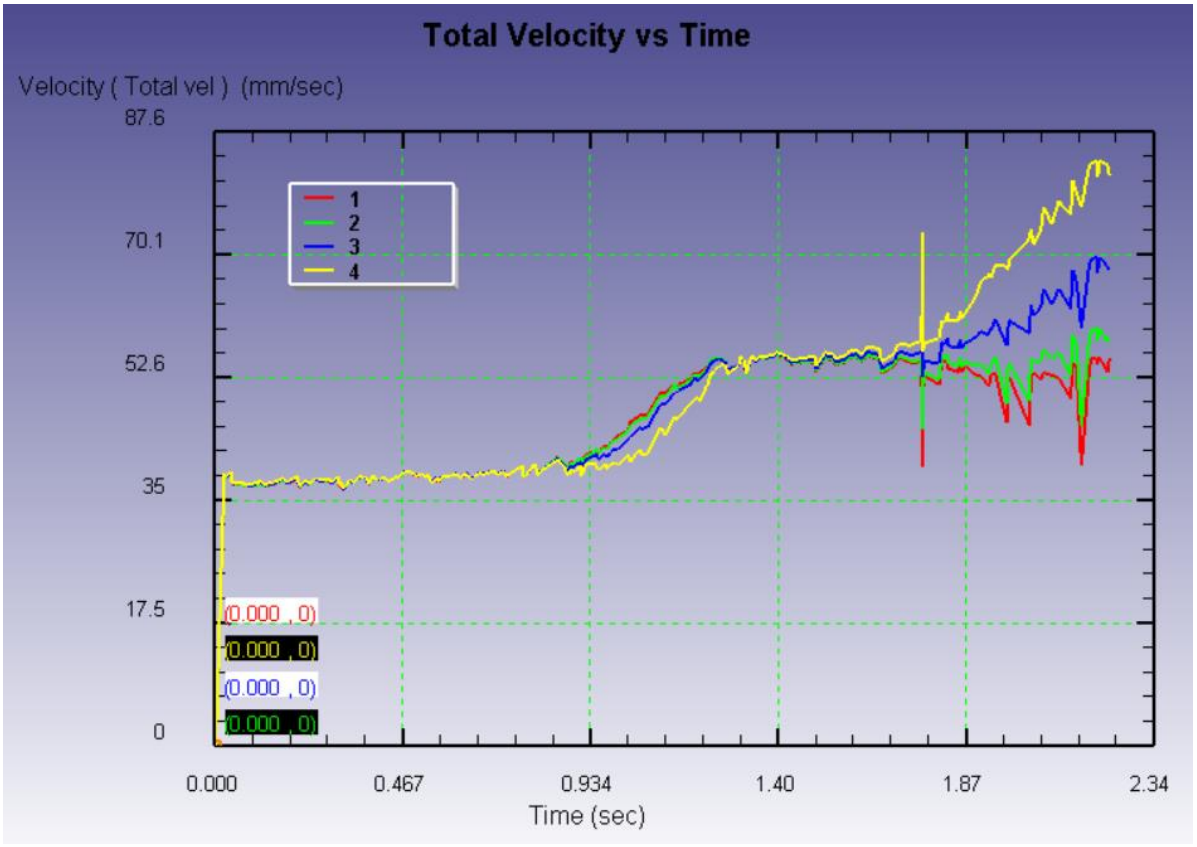

Figure 3.63. 40-Diameter and 48 Rpm Total Velocity- Time Graph

40-Diameter and 96 Rpm Analysis Result

Average of the total velocity for P'4 is 49.03761 mm/sec.

Maximum of the total velocity for P'4 is 142.7505 mm/sec.

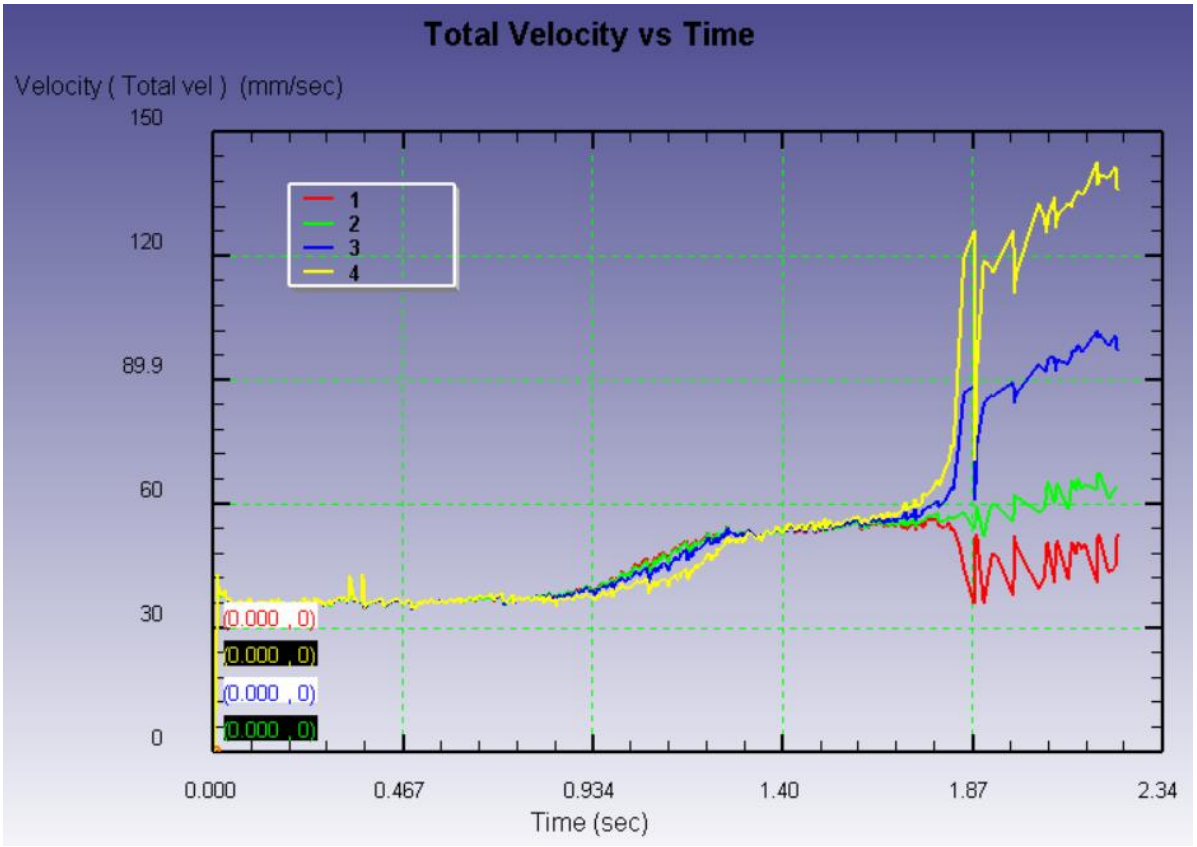

Figure 3.64. 40-Diameter and 96 Rpm Total Velocity- Time Graph

40-Diameter and 120 Rpm Analysis Result

Average of the total velocity for P'4 is 49.80733 mm/sec.

Maximum of the total velocity for P'4 is 175.32410 mm/sec.

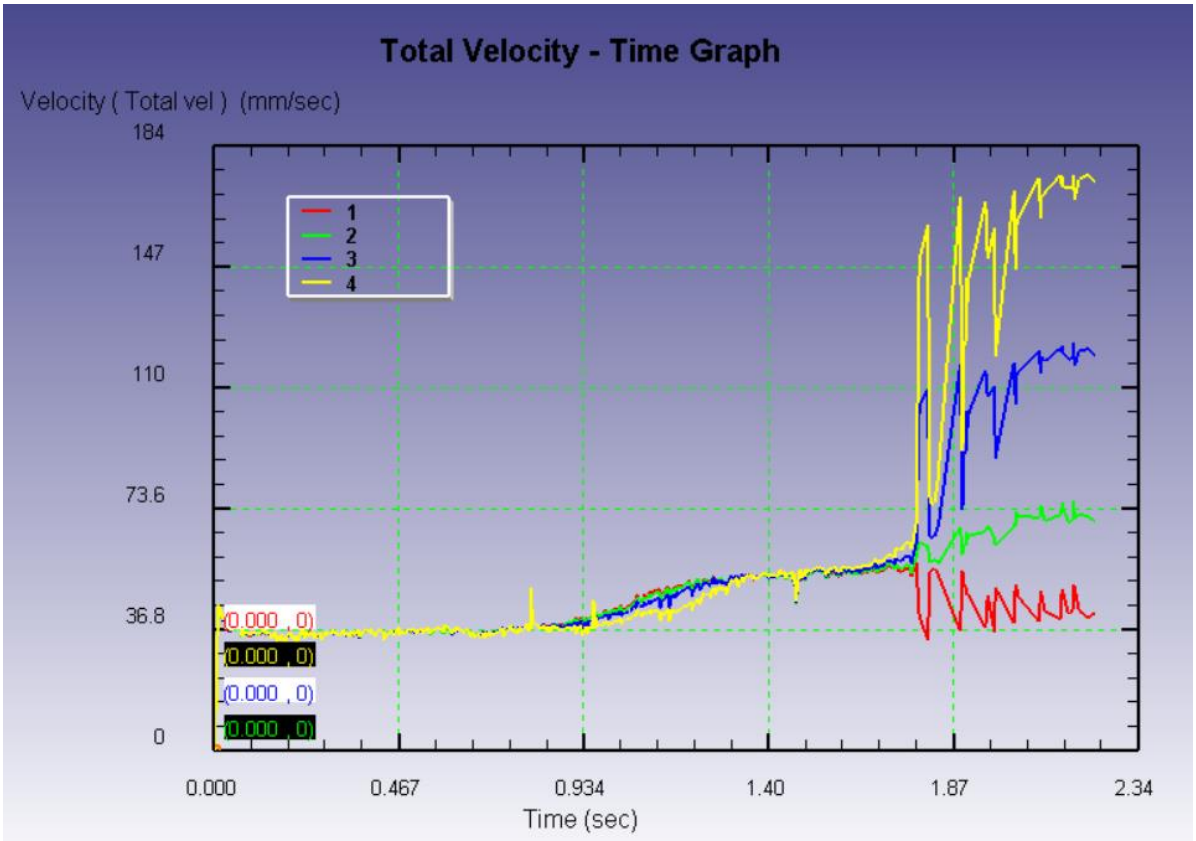

Figure 3.65. 40-Diameter and 120 Rpm Total Velocity- Time Graph

35-Diameter and 0 Rpm Analysis Result

Average of the total velocity for P'4 is 63.27247 mm/sec.

Maximum of the total velocity for P'4 is 82.17035 mm/sec.

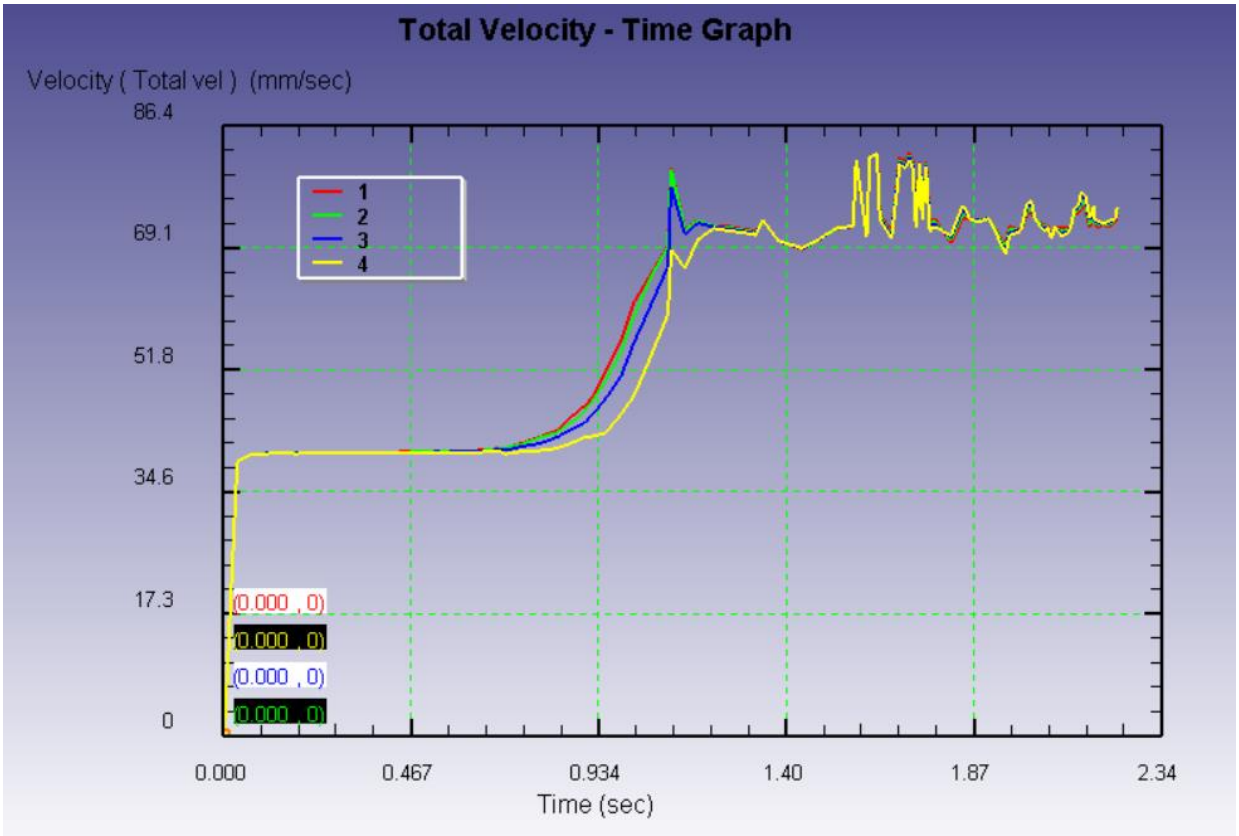

Figure 3.66. 35-Diameter and 0 Rpm Total Velocity- Time Graph

35-Diameter and 24 Rpm Analysis Result

Average of the total velocity for P'4 is 53.78819 mm/sec.

Maximum of the total velocity for P'4 is 79.41258 mm/sec.

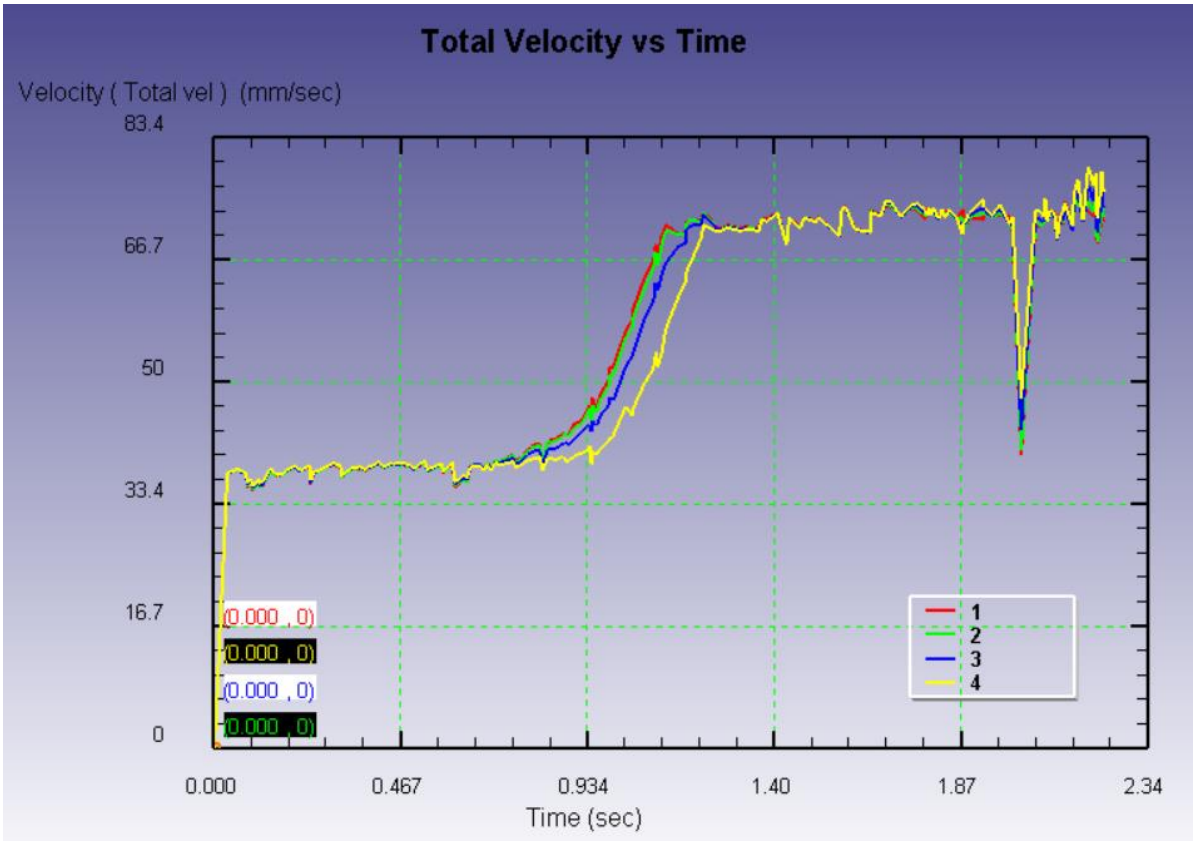

Figure 3.67. 35-Diameter and 24 Rpm Total Velocity- Time Graph

35-Diameter and 48 Rpm Analysis Result

Average of the total velocity for P'4 is 52.59501 mm/sec.

Maximum of the total velocity for P'4 is 112.06094 mm/sec.

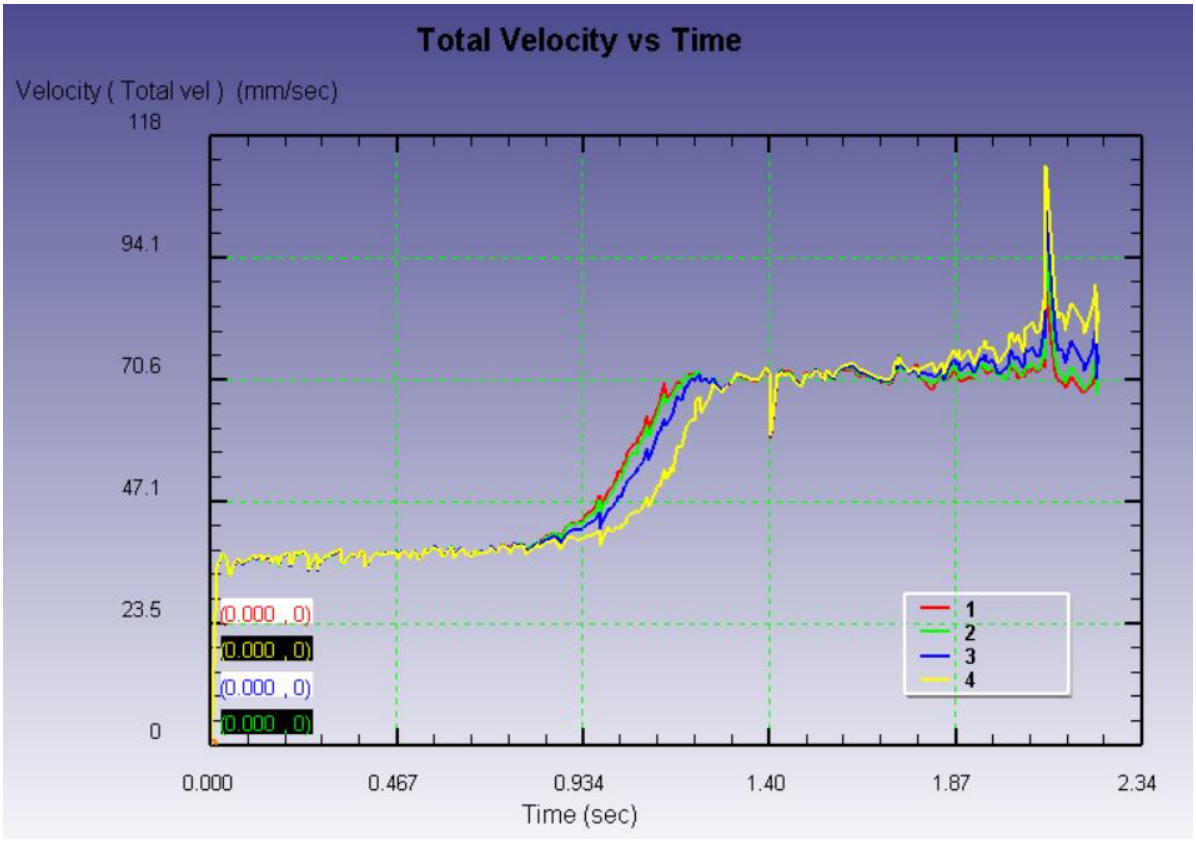

Figure 3.68. 35-Diameter and 48 Rpm Total Velocity- Time Graph

35-Diameter and 96 Rpm Analysis Result

Average of the total velocity for P'4 is 52.15174 mm/sec.

Maximum of the total velocity for P'4 is 137.37737 mm/sec.

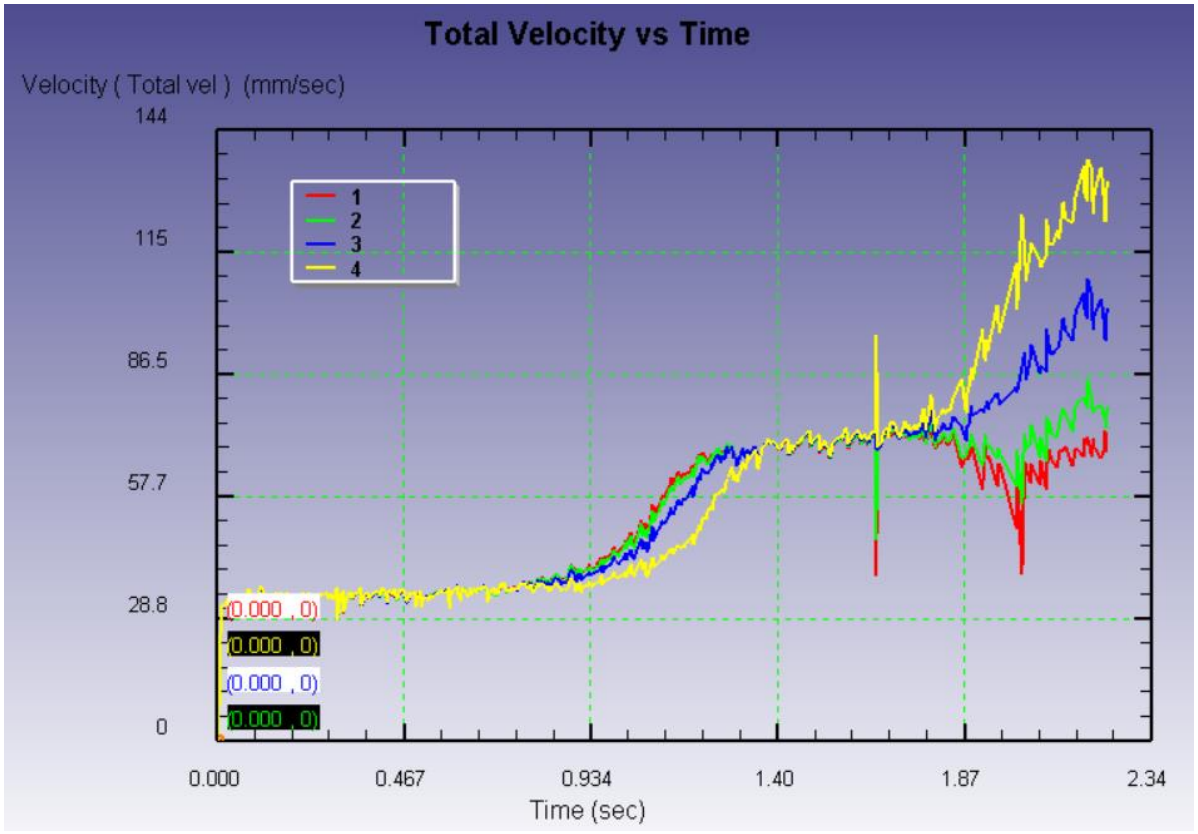

Figure 3.69. 35-Diameter and 96 Rpm Total Velocity- Time Graph

35-Diameter and 120 Rpm Analysis Result

Average of the total velocity for P'4 is 51.94124 mm/sec.

Maximum of the total velocity for P'4 is 163.29971 mm/sec.

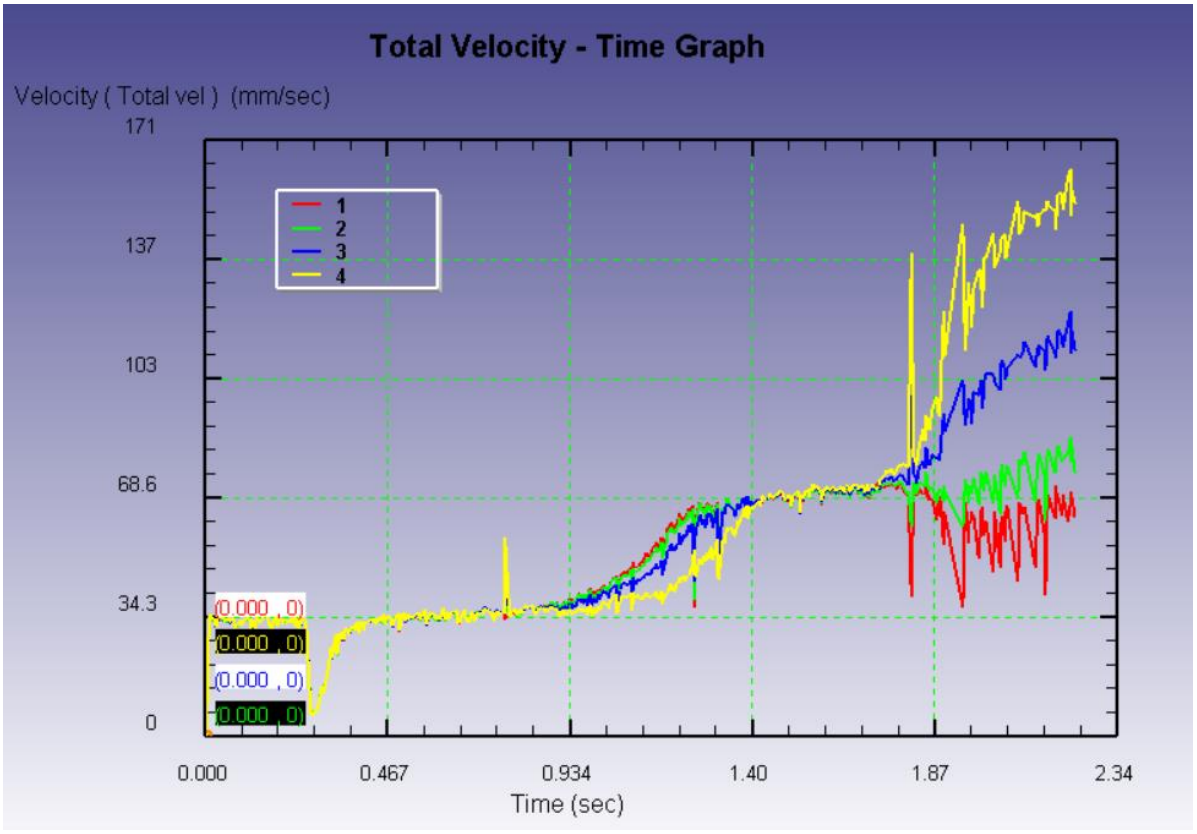

Figure 3.70. 35-Diameter and 120 Rpm Total Velocity- Time Graph

30-Diameter and 0 Rpm Analysis Result

Average of the total velocity for P'4 is 77.33127 mm/sec.

Maximum of the total velocity for P'4 is 106.64067 mm/sec.

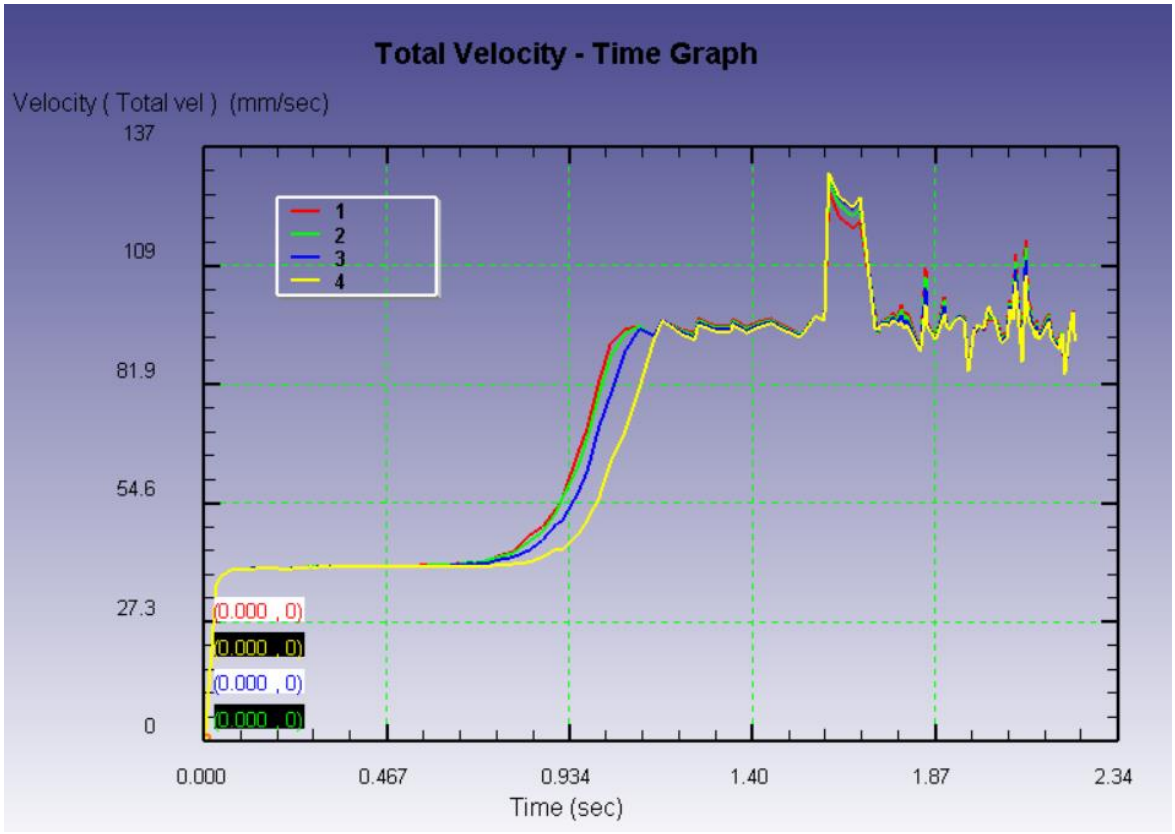

Figure 3.71. 30-Diameter and 0 Rpm Total Velocity- Time Graph

30-Diameter and 24 Rpm Analysis Result

Average of the total velocity for P'4 is 64.59691 mm/sec.

Maximum of the total velocity for P'4 is 111.15983 mm/sec.

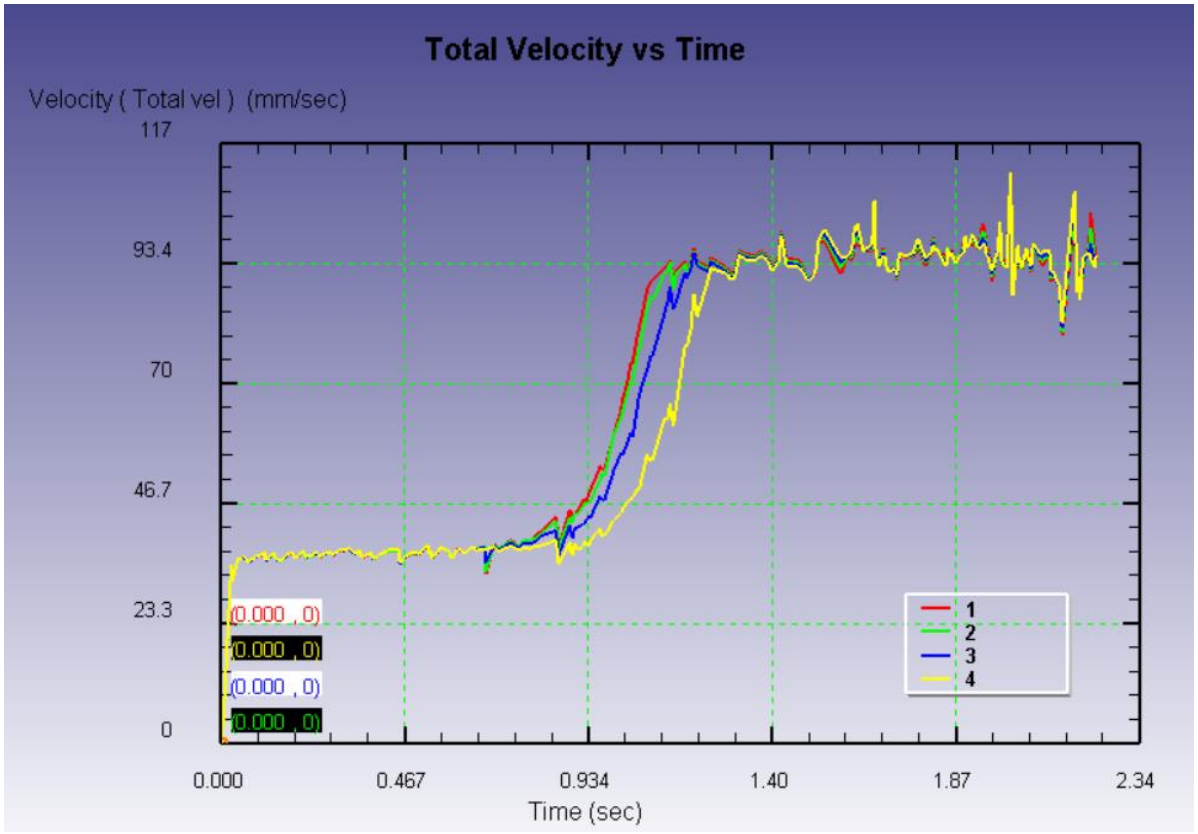

Figure 3.72. 30-Diameter and 24 Rpm Total Velocity- Time Graph

30-Diameter and 48 Rpm Analysis Result

Average of the total velocity for P'4 is 56.93521 mm/sec.

Maximum of the total velocity for P'4 is 136.34819 mm/sec.

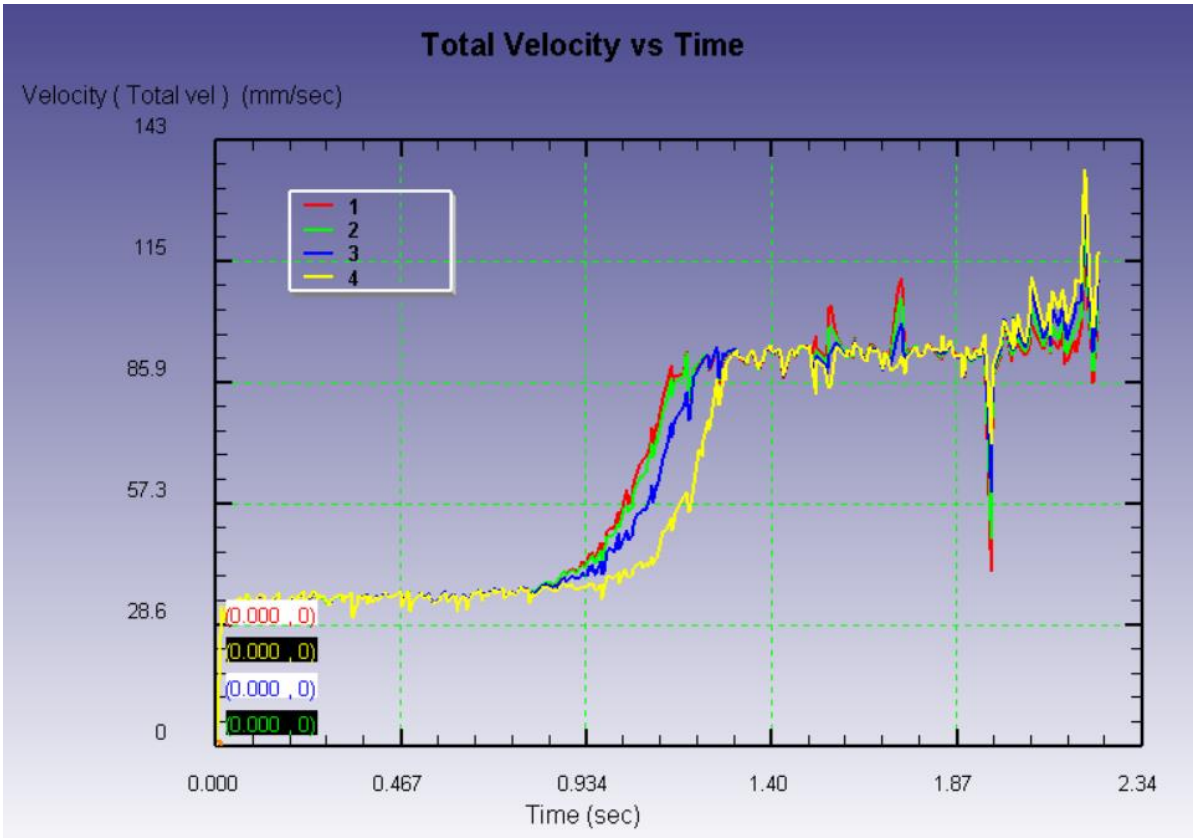

Figure 3.73. 30-Diameter and 48 Rpm Total Velocity- Time Graph

30-Diameter and 96 Rpm Analysis Result

Average of the total velocity for P'4 is 55.37364 mm/sec.

Maximum of the total velocity for P'4 is 141.70079 mm/sec.

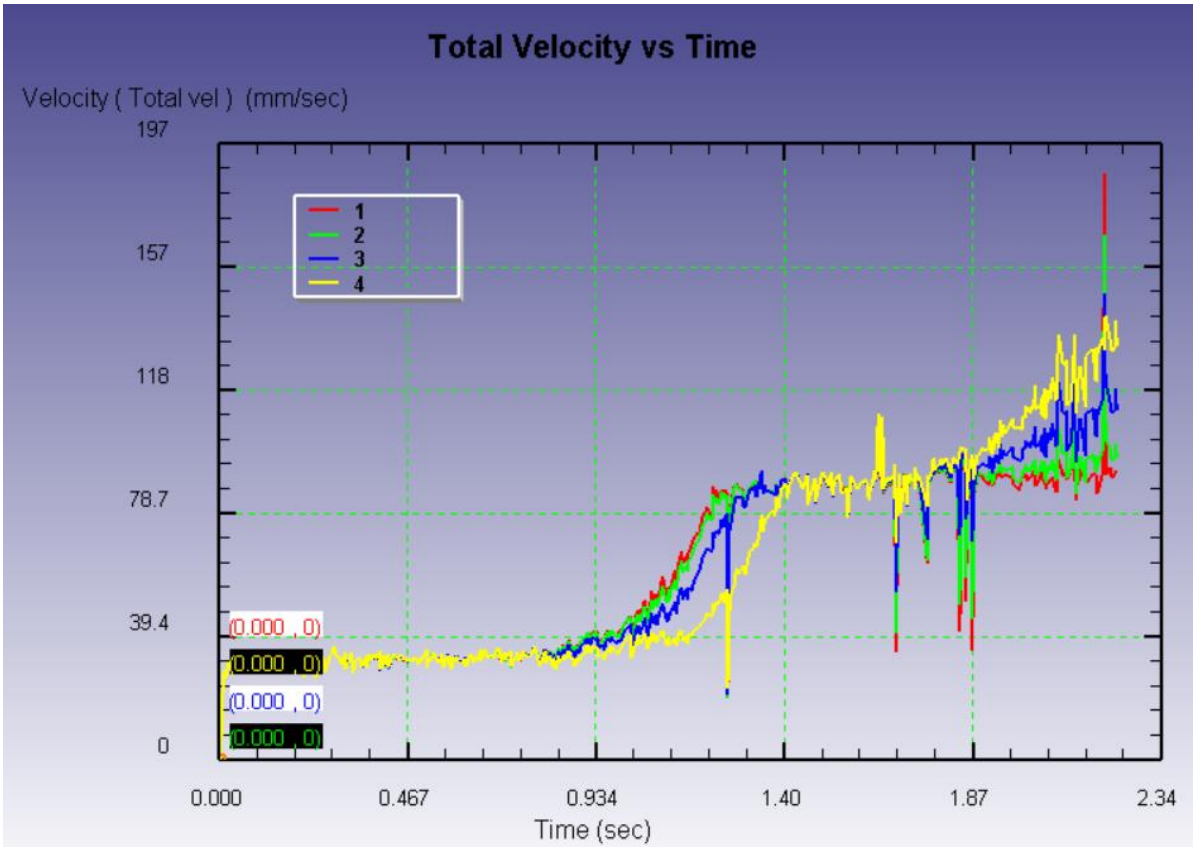

Figure 3.74. 30-Diameter and 96 Rpm Total Velocity- Time Graph

30-Diameter and 120 Rpm Analysis Result

Average of the total velocity for P'4 is 53.76087 mm/sec.

Maximum of the total velocity for P'4 is 167.06272 mm/sec.

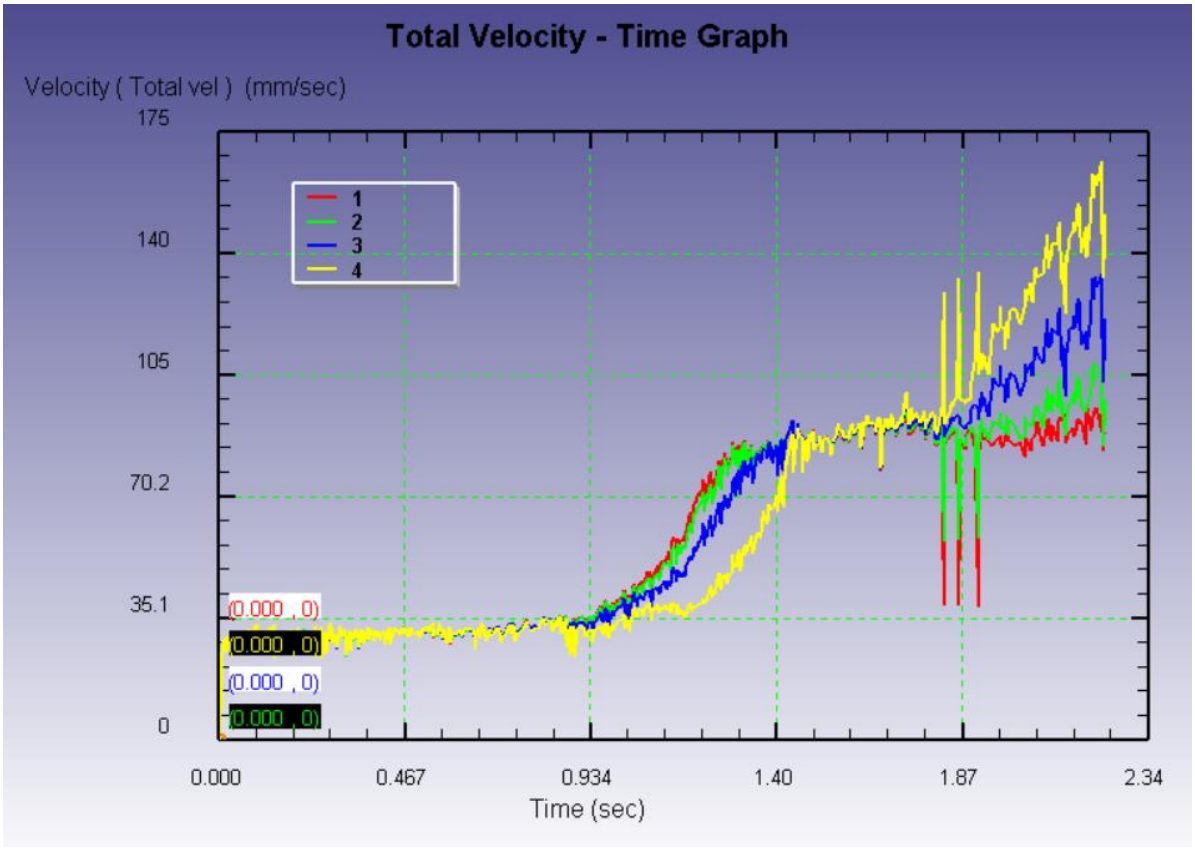

Figure 3.75. 30-Diameter and 120 Rpm Total Velocity- Time Graph

3.2. Discussions

3.2.1. First selection of points results discussions

3.2.1.1. Load prediction analyzes results discussion

Table 3.1. Maximum load table

Maximum Load Table			
	D=40mm	**D=35mm**	**D=30mm**
0	111.534 kN	155.876 kN	182.805 kN
24 Rpm	129.627 kN	169.492 kN	192.313 kN
48 Rpm	121.958 kN	155.522 kN	189.751 kN
96 Rpm	122.080 kN	153.934 kN	185.662 kN
120 Rpm	120.160 kN	151.384 kN	184.438 kN

As it can be seen in the table 3.1. with the decrease of die diameter there is a significantly high increase in maximum load for all Rpm values for the extrusion process of the workpiece. This result is expected since lowering the die diameter means that the workpiece and by extend the rotating pusher will encounter more resistance. That means that more force will need to be applied to the pushers as the diameter decreases.

First of all, As it can be seen in the table 3.1 we can see that the lowest load prediction for all diameter values regarding angular velocity is 0 rpm. Which means that translational movement was the easiest to perform at least in analyzed angular velocity range. But after a significant jump in load between 0 and 24 Rpm for the angular velocities that is selected which are arguably low rpm numbers increasing the angular velocity decreases the load that is needed. This decreasing trend may continue with the increase of angular velocity of 120 rpm. But it is not for sure. This is a good thing since lowering the load is preferable since less load will mean less energy used in the process. Decrease in the load can be due to more angular increasing the total energy of the workpiece by stimulating the particles of the workpiece in return making the workpiece more malleable.

3.2.1.2. Strain rate analyzes results discussion

Table 3.2. Strain rate comparison table

Strain Rate Table			
	D=40mm	**D=35mm**	**D=30mm**
0	0.098874 (mm/mm)/sec	0.185852 (mm/mm)/sec	0.225056 (mm/mm)/sec
24 Rpm	0.135204 (mm/mm)/sec	0.218062 (mm/mm)/sec	0.306158 (mm/mm)/sec
48 Rpm	0.140939 (mm/mm)/sec	0.228485 (mm/mm)/sec	0.351316 (mm/mm)/sec
96 Rpm	0.172701 (mm/mm)/sec	0.283860 (mm/mm)/sec	0.400968 (mm/mm)/sec
120 Rpm	0.196837 (mm/mm)/sec	0.332666 (mm/mm)/sec	0.455393 (mm/mm)/sec

Strain rate is the speed or velocity at which deformation of an object from its original shape occurs. Deformation can occur in any direction, depending on the way the force or stress is applied. Strain rate varies for different materials, and will often change at different temperatures and applied pressures. Since in this analysis materials and temperatures are is same for all analyzes the strain rate will changes will not be affected by those parameters. Instead, they will be affected by stress and force.

As it can be seen it table 3.2 decreasing of die diameter is increasing the strain rate. Since strain rate is deformation of an object form its original shape to a 30 mm diameter billet in the same amount of time should increase the strain rate compared to changing the workpiece to a 40 mm billet. And in the results, it can be seen that with the decrease of die diameter strain rate increases.

As it also can be seen from table 3.2 increase in angular velocity increases the strain rate for all analyzed die diameters. This may be due to increase in stress the workpiece goes through while increasing the angular velocity.

3.2.1.3. Stress analyzes results discussion

Table 3.3. Maximum tension principal stress comparison table

Maximum Tension Principal Stress comparison table			
	D=40mm	**D=35mm**	**D=30mm**
0	16.7789 MPa	20.6046 MPa	21.0659 MPa
24 Rpm	17.2851 MPa	24.1353 MPa	27.8764 MPa
48 Rpm	21.0141 MPa	22.6559 MPa	26.8772 MPa
96 Rpm	19.2977 MPa	21.4780 MPa	24.9037 MPa
120 Rpm	15.4780 MPa	20.4702 MPa	20.4838 MPa

Table 3.4. Maximum compression principal stress comparison table

Maximum Compression Principal Stress comparison table			
	D=40mm	**D=35mm**	**D=30mm**
0	-52.7563 MPa	-73.1586 MPa	-90.8783 MPa
24 Rpm	-54.0495 MPa	-73.8584 MPa	-88.4569 MPa
48 Rpm	-51.9328 MPa	-69.3964 MPa	-86.8816 MPa
96 Rpm	-51.8939 MPa	-69.1276 MPa	-85.8772 MPa
120 Rpm	-51.6686 MPa	-68.2282 MPa	-85.5198 MPa

If a component of brittle material is exposed to a multiaxial stress system, fracture will occur when the maximum principal stress anywhere in the component exceeds the local strength. Principal stress at location may have positive or negative sign but is dependent on the applied loading. The negative value of principal stress means the component is in compression and positive vale indicates tension.

It is desirable to have lower compression and tension principal stress to avoid fracture in the workpiece. It can be seen in the table 3.3 and 3.4 that increasing the angular velocity to 24 rpm from 0 rpm increases the principal stress for 40mm and 35 mm. But after that increasing the angular velocity further decreases the principal stress constantly. It can be seen that for 30mm diameter there is no increase in 0 to 24 rpm increase. So, it can be said that at

lower die diameters effect of angular velocity is more positive for principal stress.

To summarize, it can be said that increasing the angular velocity decreases max principal stress for both compression and tension. So increasing the angular velocity is desired for decreasing the maximum principal stress.

3.2.1.4. Total Velocity analyzes results discussion

Table 3.5. Total velocity comparison table

Total Velocity Table			
	D=40mm	**D=35mm**	**D=30mm**
0	50.45926 mm/sec	66.76864 mm/sec	87.32380 mm/sec
24 Rpm	48.62113 mm/sec	60.60754 mm/sec	76.56353 mm/sec
48 Rpm	47.89560 mm/sec.	58.65524 mm/sec	70.57144 mm/sec
96 Rpm	46.22098 mm/sec	55.06274 mm/sec	65.37644 mm/sec
120 Rpm	45.44193 mm/sec	52.35779 mm/sec	62.48986 mm/sec

As it can be seen in the table 3.4. with the decrease of die diameter there is a significantly high increase in average total velocity of the four points during the extrusion process. This increase is due difference in diameter increase of the raw workpiece and formed piece. So, the 30-diameter piece that is out of the mold is moving faster linearly than the 40-diameter piece.

As it also can be seen in the table with the increase of angular velocity total velocity of the points decreases. This is probably due to with the increase in speed the workpiece that comes out of the mold wobbles less and becomes more compact. But since the points selected are along the linear movement axis angular velocities effect on the total velocity is minimal. So, another set of points will be used for the purposes of seeing the effect of angular velocity on total velocity.

3.2.2. Second selection of points results discussions

3.2.2.1. Total Velocity analyzes results discussion

Table 3.6. Maximum of Total velocity-2 comparison table

Maximum of Total Velocity 2 Table			
	D=40mm	**D=35mm**	**D=30mm**
0	57.79698 mm/sec	82.17035 mm/sec	106.64067 mm/sec
24 Rpm	65.34164 mm/sec	79.41258 mm/sec	111.15983 mm/sec
48 Rpm	83.45041 mm/sec.	112.06069 mm/sec	136.34819 mm/sec
96 Rpm	142.13505 mm/sec	137.3774 mm/sec	141.70079 mm/sec
120 Rpm	175.32410 mm/sec	163.29971 mm/sec	167.06272 mm/sec

Table 3.7. Average of Total velocity-2 comparison table

Average of Total Velocity 2 Table			
	D=40mm	D=35mm	D=30mm
0	48.39640 mm/sec	63.27247 mm/sec	77.33127 mm/sec
24 Rpm	45.89806 mm/sec	53.78819 mm/sec	64.59691 mm/sec
48 Rpm	47.77524 mm/sec.	52.59501 mm/sec	56.93521 mm/sec
96 Rpm	49.03761 mm/sec	52.15174 mm/sec	55.37364 mm/sec
120 Rpm	49.80733 mm/sec	51.94124 mm/sec	53.76087 mm/sec

It can be seen from table 3.5 that closer to the outer surface of the workpiece effects of the angular velocity increases on the total velocity. It is pretty clear that angular velocity's effect on total velocity is higher closer to the surface.

3.2.3. Cost Analysis

Mold:

Mold raw material dimension for all their mold types is 220x220x330 mm.
Mold raw material mass for AISI 4140 steel for 220x220x330 mm is 132.65 kg.
1 kg of AISI 4140 steel is 3 € so 132.65 kg is

$$132.65 * 3 = 397.95€$$

Workmanship for mold is 1000 euro
Heat Treatment for mold is 400 euro

Pusher:

Pusher Raw material dimensions is radius is 50mm and height is 650 mm
Pusher raw material mass for AISI 4140 steel is 40 kg.
1 kg of AISI 4140 steel is 3 € so 40 kg is

$$40 * 3 = 120€$$

Workmanship for mold is 300 euro
Heat Treatment for mold is 100 euro

So, both mold pieces total cost is;

$$397.95€ + 1000€ + 400€ + 120€ + 300€ + 100€ = 2317.95€$$

Since all 9 different molds would have used same raw materials, material cost will not change. Any workmanship cost change can say to be negligible. So, mold cost would be like above. But it can be said that higher rpm pushers will be slightly more costly then the lower rpm pushers.

3.2.4. Energy Analysis

For energy analysis lower load basically means less energy spent. So decreasing the die diameter increases the energy spent while increasing the angular velocity decreases the energy spent. It is desired to have lower energy consumption. But since you will probably use the same extrusion machine for all of the different processes the energy spent will almost be equal to each other.

4.Conclusions

In conclusion, it can be said that for relatively low rpm values such as used in the analysis increasing the angular velocity of the rotation makes the extrusion process easier to perform. It can be seen from the results of load prediction that the translational extrusion may still be done with less force than the rotational extrusion. But rotational extrusion increases the strain rate. After all this increasing the angular velocity might be better if a rotational extrusion is performed. But translation extrusion may be preferred over rotational extrusion due to lower force requirement.

As can be expected decreasing the die diameter is makes the extrusion process harder. It increases the strain rate, maximum effective stress, maximum principal stress and also the average and maximum total velocities. All of these results are expected with regarding the decreasing of the die diameter. We can most definitely say that decreasing the die diameter further will increase the mentioned values even more.

With this project the effects of a rotating billet on extrusion process are researched using computational analysis method. As the computational analysis is without real time errors and changes and all parameters are perfect the results may not give us an accurate reading on what the results will be if same performed on real life with a molds and machines. But we can say that with the analyzes there is a definite increasing or decreasing pattern and same patterns will be in a experimental result

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