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Research Article

Design and Analysis of Molybdenum Super Alloy FSW Tools

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Abstract

Friction stir welding is an exciting process for welding two pieces of material together as it doesn't require weld preparation, operates at low temperatures with absences of fumes, is environmentally friendly, energy efficient and can be used by only semi-skilled personnel to produce a satisfactory weld. This project emphasizes on some current uses, variations in tool design, improved welding techniques and new tool materials being developed for the welding of more difficult aluminium alloys to give increased tool life. The tool (made of molybdenum super alloy), its pin profile, shape and dimensions plays a vital role in making the weld joint. In FSW, the stress distribution of tool pin is affected by the thermo mechanical characteristics of the work piece. In this present work, three tools with different pin shapes (Conical, Cylindrical and Frustum) were designed with and without threads in their profiles. Initially the tools dimensions are based on the base material plate thickness taken in to consideration, the induced structural stresses were checked with in the permissible stress limits. The tools were modeled in CATIA and analysis is performed in ANSYS software for exploring stress distributions and displacement vector sum in the pin, at different speeds and temperatures. The frictional force between the tool shoulder and work piece is considered for simulating the stress and displacement vector in the pin profiles. The vonmises stress distributions in pin profiles, displacement vector sum of the pin profiles, are obtained from ANSYS software and the pin with optimum strength is determined.

Keywords: *CATIA, Molybdenum, ANSYS Software.*

1. Introduction

Friction stir welding (FSW) is a Solid-state joining technique invented in 1991, and it is initially applied to aluminum alloys. The concept of FSW is simple. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint.

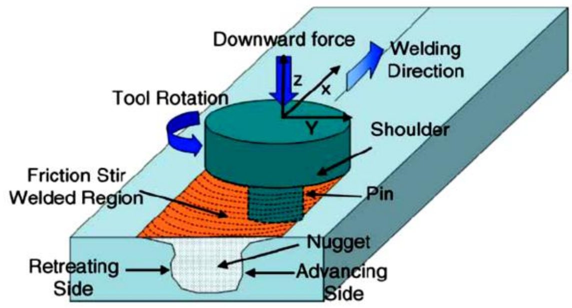

Fig.1 Principle of Operation of FSW

The tool serves as heating of work piece, and movement of material to produce the joint. The heating is accomplished by friction between the tool and the work piece and plastic deformation of work piece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front of the pin to the back of the pin. As a result of this process a joint is produced in 'solid state'. Because of various geometrical features of the tool, the material movement around the pin can be quite complex.

FSW is considered to be the most significant development in metal joining in a decade and is a ''green'' technology due to its energy efficiency, environment friendliness, and versatility.

2. Tool Geometry

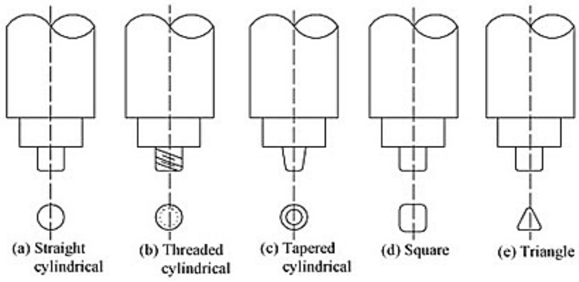

Fig.2 Basic pin profiles of FSW tool

Tool geometry is the most influential aspect of process development. The tool geometry plays a critical role in

*Corresponding author: **G.Afsar Hussain** is a M.Tech (CAD/CAM) student flow of material and in turn governs the traverse rate at which FSW can be conducted.

3. Parameters considered in this project

Molybdenum super alloy material is used for pin profile Material to be welded is aluminium alloys**.** Analysis is carried out for 600°c, 700°c, 800°c temperatures Analysis carried out for following speeds 1200 rpm, 1400 rpm, 1600 rpm. 50, 70, 90 m/min are the following welding speeds considered for the project.

4. Analysis of various profiles of FSW tools

4.1 Analysis of FSW tool with cylindrical pin

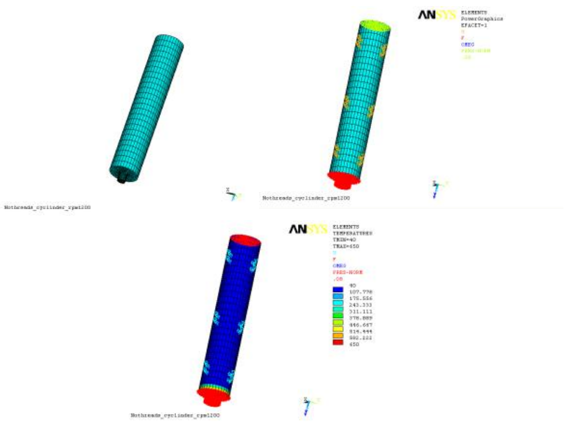

Fig. 3 meshed tool with loads and boundary conditions

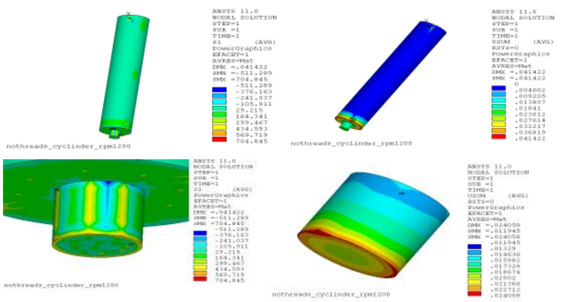

Fig.4 stress distribution and displacement vector sum at 1200 rpm

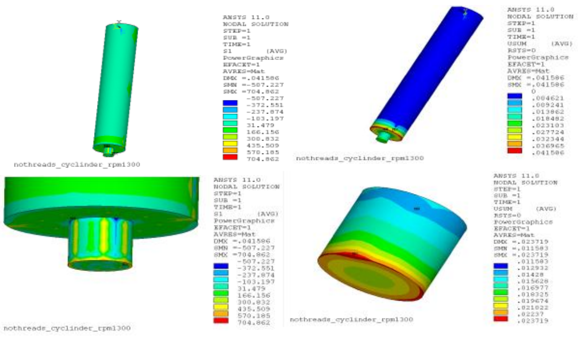

Fig.5 stress distribution and displacement vector sum at 1300 rpm

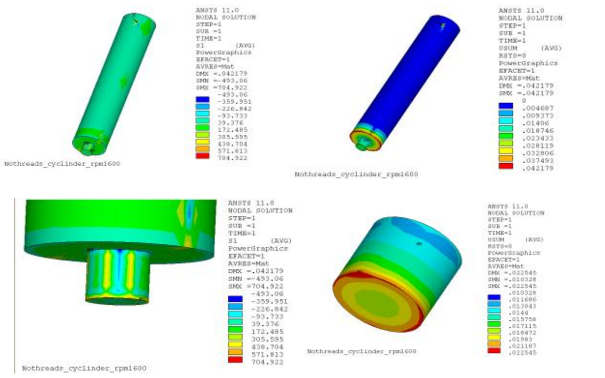

Fig.6 stress distribution and displacement vector sum at 1600 rpm

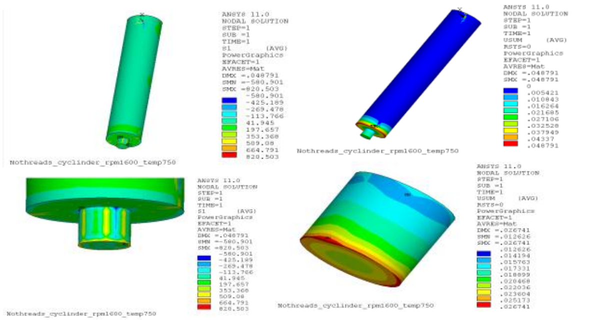

Fig.7 stress distribution and displacement vector sum at 700^{0}C

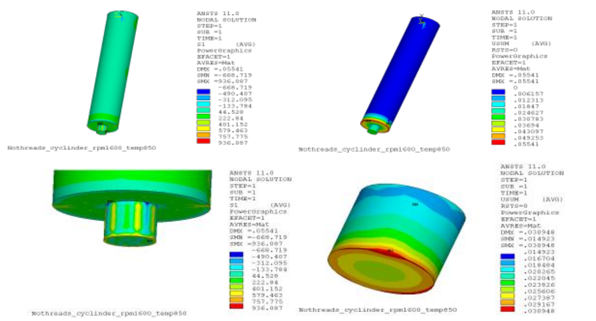

Fig.8 Schematic viewof stress distribution and displacement vector sum at 800^{0}C.

4.2 Analysis of FSW tool with frustum pin

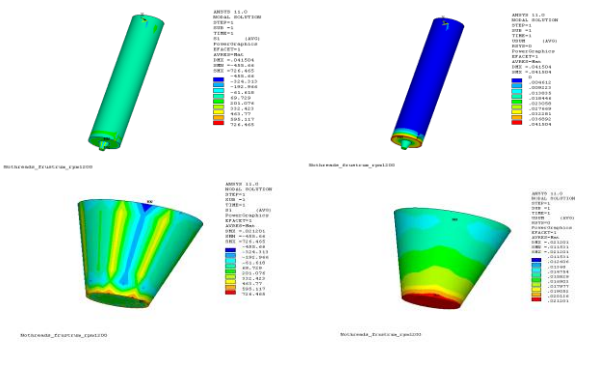

Fig.9 Schematic view of stress distribution and displacement vector sum

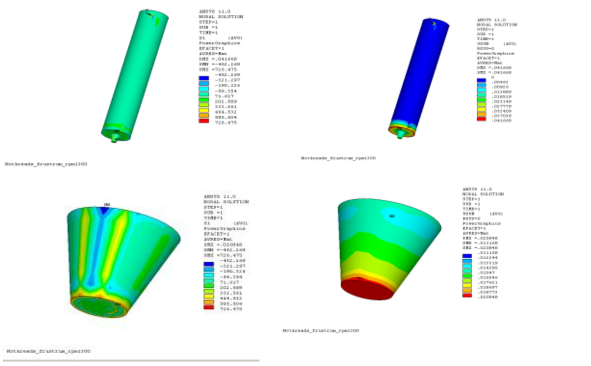

Fig.10 Schematic view of stress distribution and displacement vector sum at 1300 rpm

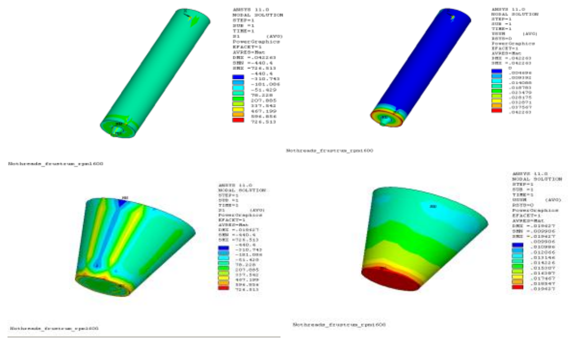

Fig.11 Schematic view of stress distribution and displacement vector sum at 1600 rpm

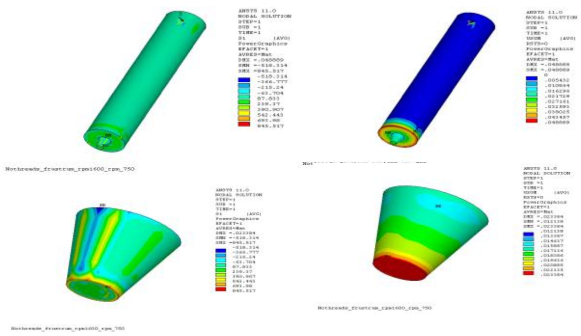

Fig.12 Schematic view of stress distribution and displacement vector sum at 700^{0}C

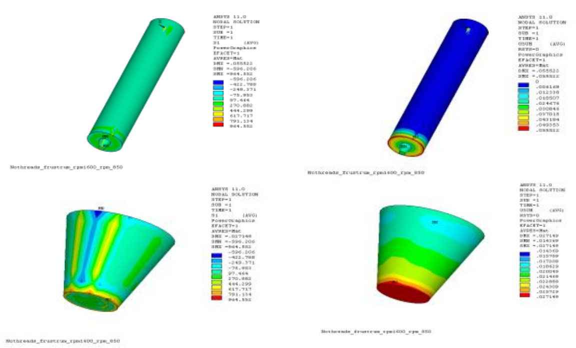

Fig.13 Schematic view of stress distribution and displacement vector sum at 800^{0}C

4.3. Analysis of FSW tool with conical pin

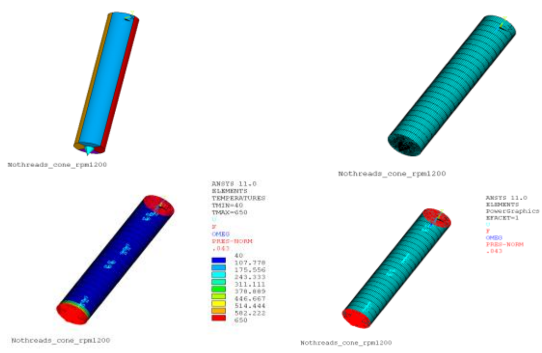

Fig.14 Schematic view of meshed tool with applied loads&boundary conditions

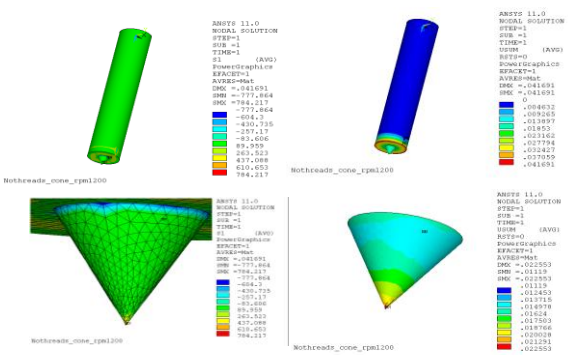

Fig.15 Schematic view of stress distribution and displacement vector sum at 1200 rpm

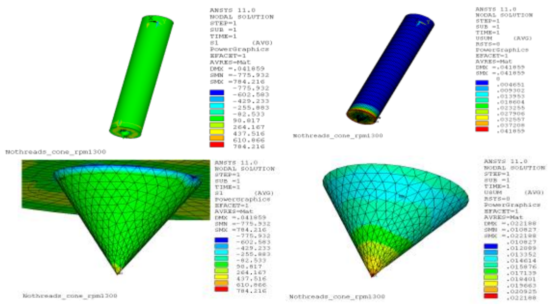

Fig.16 Schematic view of stress distribution and displacement vector sum at 1300 rpm

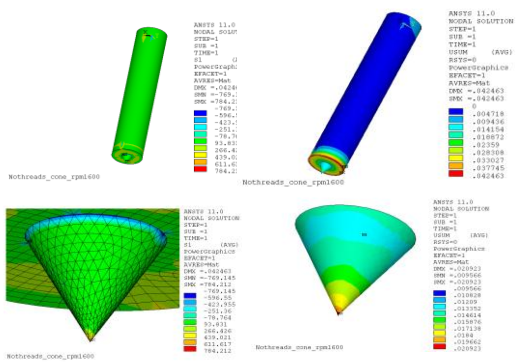

Fig.17 Schematic view of stress distribution and displacement vector sum at 1600 rpm

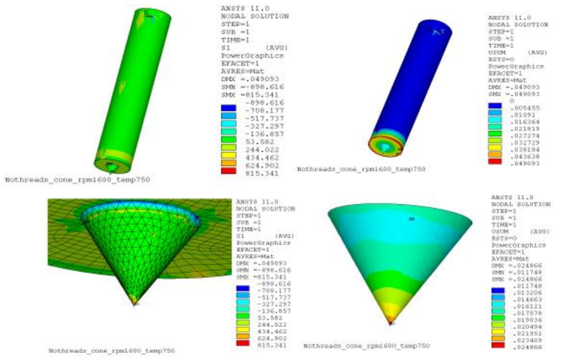

Fig.18 Schematic view of stress distribution and displacement vector sum at 700^0C

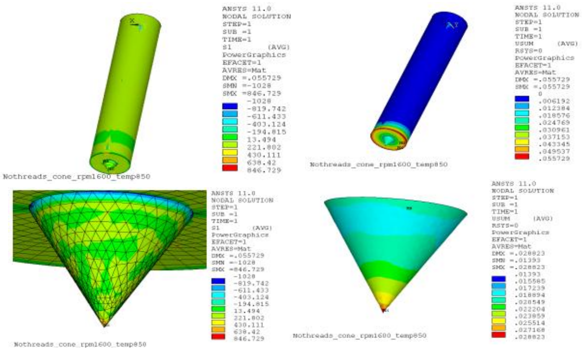

Fig.19 Schematic view of stress distribution and displacement vector sum at 800^0C

4.4. Analysis of FSW tool with threaded frustum pin

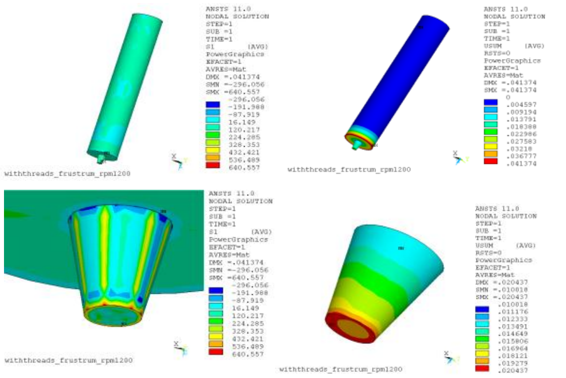

Fig.20 Schematic view of stress distribution and displacement vector sum at 1200 rpm

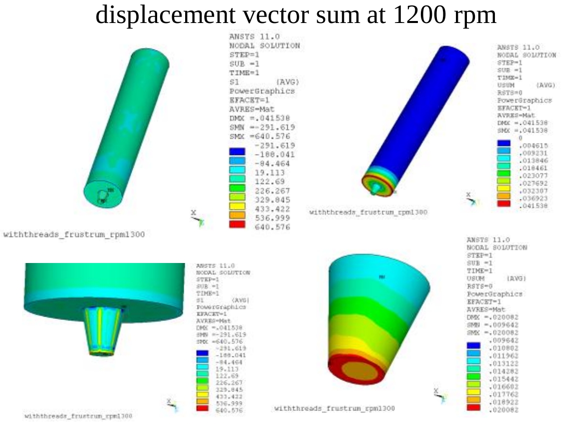

Fig.21 Schematic view of stress distribution and displacement vector sum at 1300 rpm

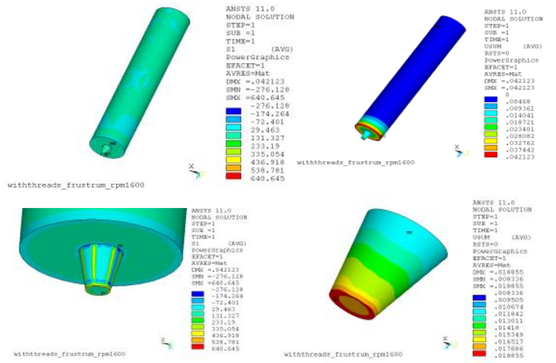

Fig.22 Schematic view of stress distribution and displacement vector sum at 1600 rpm

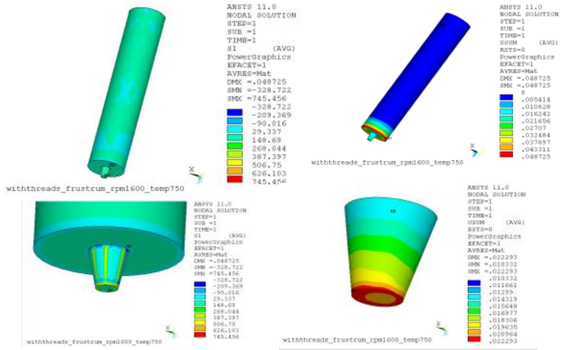

Fig.23 Schematic view of stress distribution and displacement vector sum at 700^0C.

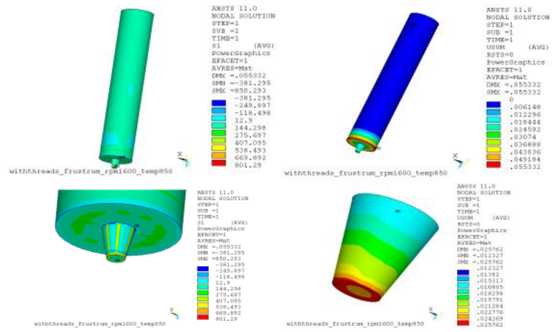

Fig.24 Schematic view of stress distribution and displacement vector sum at 800^0C.

4.6. Analysis of FSW tool with threaded conical pin

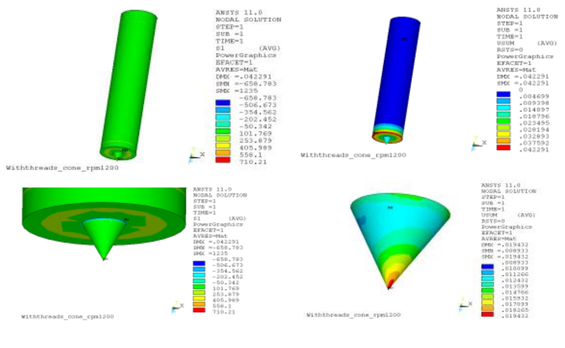

Fig.25 Schematic view of stress distribution and displacement vector sum at 1200 rpm

Table 1 Stress distribution and Displacement vector sum of various tool profiles for without and with thread

	Cylindrical pin		**Frustum pin**		**Conical Pin**	
Speed (rpm)	**Stress Distribution (N/mm²)**	**Displacement Vector Sum (mm)**	**Stress Distribution (N/mm²)**	**Displacement Vector Sum(mm)**	**Stress Distributio n (N/mm²)**	**Displacement Vector Sum(mm)**
1200	704.847	0.0414	726.465	0.0415	784.217	0.0416
1300	704.86	0.0415	726.475	0.0416	784.216	0.0418
1600	704.922	0.0421	726.513	0.0422	784.212	0.0426
Temp(⁰C)						
700	704.922	0.0421	726.513	0.0422	784.212	0.0426
800	820.541	0.047	845.517	0.048	815.341	0.049
900	936.08	0.0554	964.55	0.0555	846.721	0.0556
	Threaded Cylindrical pin		**Threaded Frustum pin**		**Threaded Conical Pin**	
Speed(rpm)	**Stress Distribution(N/ mm²)**	**Displacement Vector Sum (mm)**	**Stress Distributio n(N/mm²)**	**Displacement Vector Sum (mm)**	**Stress Distributio n(N/mm²)**	**Displacement Vector Sum (mm)**
1200	544.8	0.0413	640.557	0.0413	710.21	0.0415
1300	544.9	0.0415	640.576	0.0415	710.24	0.0416
1600	545.15	0.042	640.64	0.0421	710.25	0.0423
Temp(⁰C)						
700	545.15	0.042	640.64	0.0421	710.25	0.0423
800	634.35	0.0486	745.45	0.0487	782.31	0.0491
900	723.56	0.0552	801.29	0.0553	825.12	0.0554

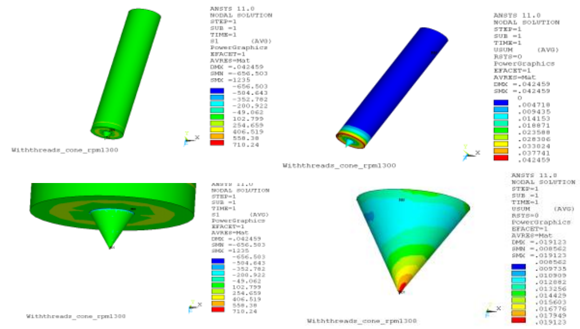

Fig.26 Schematic view of stress distribution and displacement vector sum at 1300 rpm

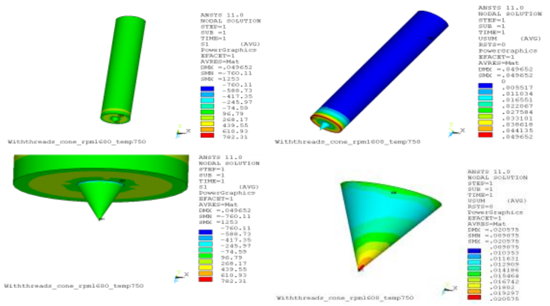

Fig.28 Schematic view of stress distribution and displacement vector sum

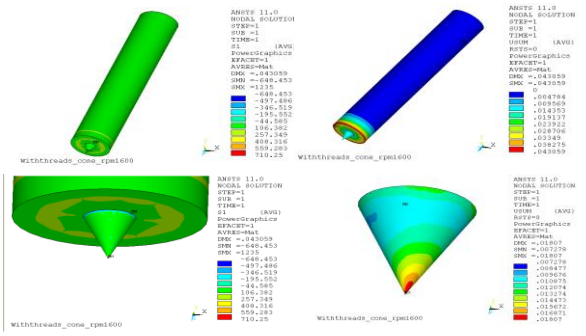

Fig.27 Schematic view of stress distribution and displacement vector sum at 1600 rpm

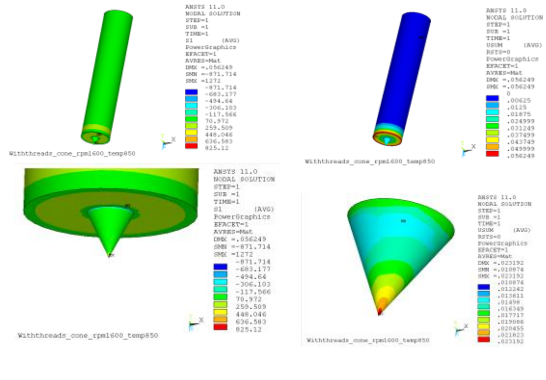

Fig.29 Schematic view of stress distribution and displacement vector sum

Conclusions

From the above results it can be concluded that, among all profiles in the tool with cylindrical profile with threads is preferable because the maximum stress distribution and displacement vector sum are very less.

As the temperature in the welding zone increases in the profiles for with and without threads, the stress distribution and displacement vector sum are observed to be increased and it is maximum in the tool with conical profile.

If the results of profiles with and without threads are compared, the stress distribution and displacement vector sum are observed to be maximum in the tool profiles without threads.

Among all the profiles, the maximum stress distribution and displacement vector sum are maximum in the FSW tool with conical profile and is observed that by increasing the rotational speed there is not much change in the maximum stress distribution and displacement vector sum.

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