CHAPTER 5

INVESTIGATIONS ON RADIAL STRESSES IN MAGNESIUM ALLOYS BLANKS

5.1 INTRODUCTION

In this process radial stresses are produced in the blank in radial direction which is in between blank holder and die surface due to punch force applied on it. The radial stresses are higher causing higher draw ratios. In this process the automatic coordination is generated between the punch pressure and blank holder pressure. The frictional resistance between the blank and both blank holder and die surface is reduced due to the fluid film formed on the both sides of blank. In this process radial stresses are studied on blanks made of magnesium alloys at different radii of blanks with constant thickness and castor oil as medium.

5.2 RESULTS AND DISCUSSION

5.2.1 Radial Stresses

The radial stress distribution in the magnesium alloys blanks during the fluid assisted deep drawing process is given in eq.(3.17).The geometry of process, process parameters and yield strength of magnesium alloys are considered for evaluation of radial stresses with given fluid for successful formation of cup in fluid assisted deep drawing process.

The following parameters considered for the analysis.

Punch radius, r_p = 25 mm

Radius of die opening, r_d = 30mm

Punch speed, u = 10mm/sec

Pressure of fluid, P = 65 N/m^2

Blank holder pressure, P_h = 65 N/m^2

Thickness of blank, t = 1.5mm

Radius of blank, r_j = 90mm, 95mm and 100mm.

Fluid medium:

Castor oil, Viscosity μ = 0.985N–sec/m^2 , density ρ = 960 kg/m^3

and remaining various parameters of the process and yield stresses of magnesium alloys are shown in 3.16.The pressure of the fluid is obtained using Ansys Flotran CFD.

Substitute the process geometry and parameters in eq.(3.17), a generalized equation for results which is given in eq.(5.1), eq.(5.2) and eq.(5.3) with r_j = 90mm,95mm and 100mm respectively.

$$\sigma_r = \sigma_0 \ln\left(\frac{90}{r}\right) - 2.5[90 - r] \quad [5.1]$$

$$\sigma_r = \sigma_0 \ln\left(\frac{95}{r}\right) - 2.5[95 - r] \quad [5.2]$$

$$\sigma_r = \sigma_0 \ln\left(\frac{100}{r}\right) - 2.5[100 - r] \quad [5.3]$$

Fig.5.1 Shows the variation of radial stresses in blank made of magnesium alloys with castor oil obtained using theoretical and finite element simulation. From theoretical analysis the range of radial stresses for AZ61A-F, HK31A – H24 and AZ31B-0 alloys are 12574838.54N/m^2 – 152492267.2N/m^2, 11717462.34N/m^2 –

142095059.5N/m^2 and 8573749.576 N/m^2 – 103971964.6N/m^2 respectively.

From finite element analysis the range of radial stresses for AZ61A-F, HK31A-H24 and AZ31B-0 alloys are 13102983.06 N/m^2 – 160116892.4 N/m^2, HK31A – H24 is 12209597.06 N/m^2 – 149199824.3 N/m^2 and AZ31B–0 is 8933848.361 N/m^2 – 109170574.6 N/m^2 respectively.

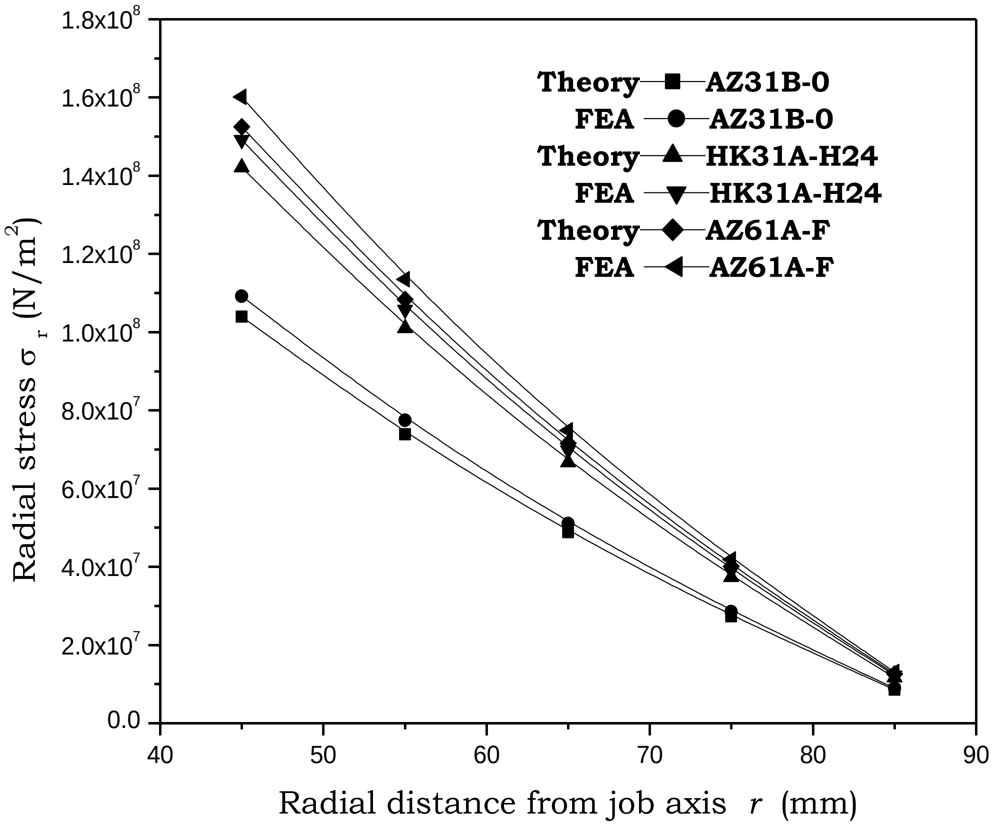

Fig.5.1. Variation of radial stresses in magnesium alloys blanks at r_j = 90mm

The radial stresses from theoretical analysis are maximum at r = 45mm for AZ61A-F alloy is 152492267.2 N/m^2 and in AZ31B-0 alloy which is 103971964.6N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is 12574838.54 N/m^2, AZ31B-0 alloy is 8573749.576N/m^2 .High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

A similar variation is observed from Finite element analysis, maximum at r = 45mm for AZ61A-F alloy is 160116892.4 N/m^2 and in AZ31B-0 alloy which is 109170574.6N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is13102983.06 N/m^2, AZ31B-0 alloy is 8933848.361N/m^2 . High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

The average percentage variation between the theoretical and finite element analysis is 4.395%. From this analysis, the order of radial stresses of magnesium alloys are AZ31B-0 < HK31A-H24 < AZ61A-F found.

Fig.5.2 Shows the variation of radial stresses in blank made of magnesium alloys with castor oil obtained using theoretical and finite element simulation. From theoretical analysis the range of radial stresses for AZ61A-F, HK31A–H24 and AZ31B–0 alloys are 24469614.72N/m^2 – 164387055.9N/m^2, 22801230.2N/m^2 – 153178839.9N/m^2 and 16683820.27N/m^2 – 112082047.8N/m^2 respectively.

From finite element analysis the range of radial stresses for AZ61A-F, HK31A-H24 and AZ31B-0 alloys are 25717567.1N/m^2 –

173592731 N/m², 23964095.5N/m² – 161756854.95N/m² and 17534697.73N/m² – 118358642.5N/m² respectively.

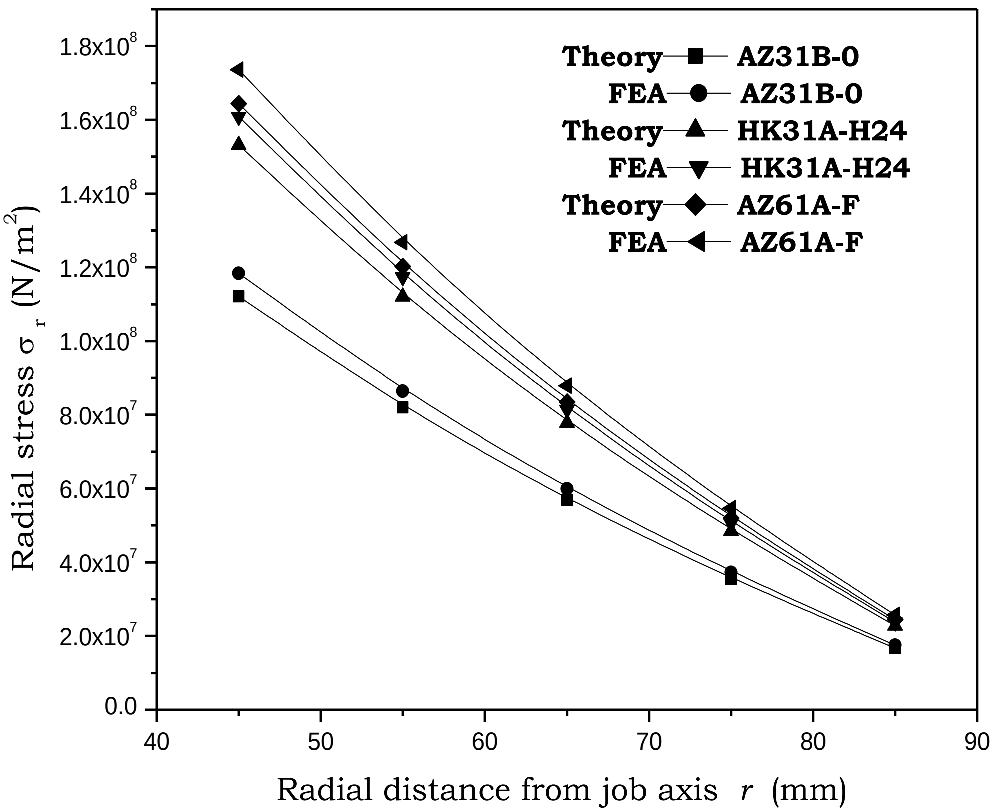

Fig.5.2. Variation of radial stresses in magnesium alloys blanks at r_j = 95mm

The radial stresses from theoretical analysis are maximum at r = 45mm for AZ61A-F is 164387055.9 N/m² and in AZ31B-0 alloy which is 112082047.8N/m². At r = 85mm the least variation is observed for AZ61A-F alloy is 24469614.72 N/m², AZ31B-0 alloy is 16683820.27 N/m².High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

A similar variation is observed from finite element analysis, maximum at r = 45mm for AZ61A-F alloy is 173592731N/m² and in

AZ31B-0 alloy which is118358642.5N/m^2. At r = 85mm the least variations is observed for AZ61A-F alloy is 25717567.1N/m^2, AZ31B-0 alloy is 17534697.73 N/m^2. High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

The average percentage variation between the theoretical and finite element analysis is 5.075%. From this analysis, the order of radial stresses of magnesium alloys are AZ31B-0 < HK31A-H24 < AZ61A-F obtained.

Fig.5.3 Shows the variation of radial stresses in blank made of magnesium alloys with castor oil obtained using theoretical and finite element simulation. From theoretical analysis the range of radial stresses for AZ61A-F, HK31A-H24 and AZ31B-0 alloys are 35754126.99N/m^2 – 175671555.7N/m^2, 33316343.05N/m^2 – 163693940.2N/m^2 and 24377801.92N/m^2 – 119776016.9N/m^2 respectively.

From finite element analysis the range of radial stresses for AZ61A-F, HK31A-H24 and AZ31B-0 alloys are 37613345.54N/m^2 – 186211863.6N/m^2, 35048796.83N/m^2 - 173515591.2N/m^2 and 25645451.56N/m^2 –126962592.5 N/m^2 respectively.

The radial stresses from theoretical analysis are maximum at r = 45mm for AZ61A-F alloy is 175671555.7 N/m^2 and in AZ31B-0 alloy which is 119776016.9N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is 35754126.99 N/m^2 , AZ31B-0 alloy is 24377801.92 N/m^2. High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

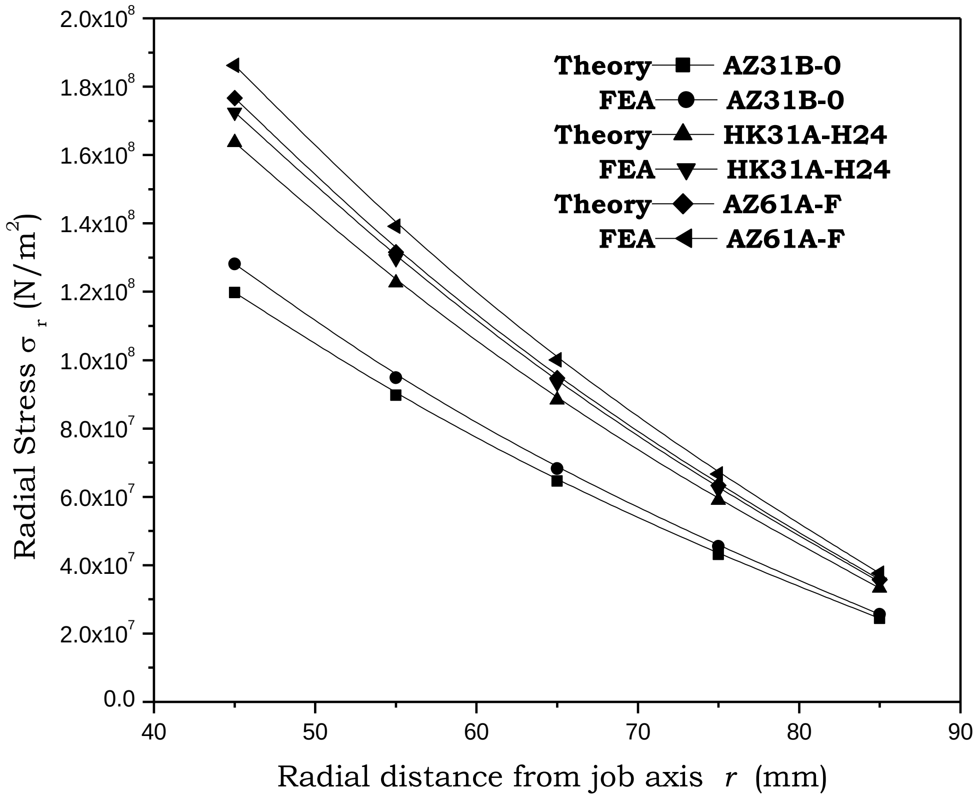

Fig.5.3 Variation of radial stresses in magnesium alloys blanks at r_j = 100mm

A similar variation is observed from finite element analysis, maximum at r = 45mm for AZ61A-F alloy is 186211863.6N/m^2 and in AZ31B-0 alloy which is 126962592.5 N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is 37613345.54 N/m^2, AZ31B-0 alloy is 25645451.56N/m^2. High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

The average percentage variation between the theoretical and finite element analysis is 5.3%. From this analysis, the order of radial stresses of magnesium alloys are AZ31B-0 < HK31A-H24 < AZ61A-F found. The nature of graphs is parabolic in shape.

The order of variation of radial stresses of magnesium alloys with castor oil as medium as follows.

$$\sigma_r \big|_{r_j=90mm} < \sigma_r \big|_{r_j=95mm} < \sigma_r \big|_{r_j=100mm}$$

The radial stresses increase with increase in the radius of blank and decrease with increase in the radial distance of the blank from the job axis. This is due to viscosity of fluid, the shear stresses and shear forces are acted on the blank surface during the fluid assisted deep drawing process. Radial stresses also depend up on process parameters, yield stress of alloys and fluid pressure.

5.3 COMPARATIVE STUDIES ON RADIAL STRESSES WITH THREE DIFFERENT FLUID MEDIUM

The radial stresses of magnesium alloys are evaluated and compared at constant radius and constant thickness of blanks with using the fluids such as olive oil, heavy machine oil and castor oil as medium.

5.3.1 Results and Discussion

The radial stress distribution in the magnesium alloys blanks with different fluids are given in eq.(3.17). The various parameters and fluid properties are as shown in 3.16. The pressure obtained in Flotran CFD for different fluids olive oil, heavy machine oil and castor oil are 4 N/m^2, 29 N/m^2 and 65 N/m^2 respectively. This pressure of the fluid is applied radially on periphery of blank and also equal to blank holding pressure.

Substituting the geometry and process parameters in eq.(3.17), the generalized equation for evaluation of radial stresses at different viscosity of fluids for magnesium alloys are given in eq.(5.4) to eq.(5.6) at constant thickness t = 1.5mm and radius of blanks r_j = 90mm

at μ olive oil = 0.081N–sec/m^2

$$\sigma_r = \sigma_0 \ln\left(\frac{90}{r}\right) - 0.205[90 - r] \qquad [5.4]$$

at μ heavy machine oil = 0.453 N–sec/ m^2

$$\sigma_r = \sigma_0 \ln\left(\frac{90}{r}\right) - 1.15[90 - r] \qquad [5.5]$$

at μ castor oil = 0.985N–sec/ m^2

$$\sigma_r = \sigma_0 \ln\left(\frac{90}{r}\right) - 2.5[90 - r] \qquad [5.6]$$

Fig.5.4 Shows the variation of radial stresses in blank made of magnesium alloys with olive oil obtained using theoretical and finite element simulations. From theoretical analysis the range of radial stresses for AZ61A-F, HK31A-H24 and AZ31B-0 alloys are 12574850.02N/m^2 – 152492370.5N/m^2,11717473.81N/m^2–142095162.8N/m^2 and 8573761.051N/m^2 – 103972067.9N/m^2 respectively.

From finite element analysis the range of radial stresses for AZ61A-F, HK31A-H24 and AZ31B-0 alloys are 13228742.33N/m^2 – 161641913.7N/m^2, 12326782.55N/m^2 – 150620873.5N/m^2 and 9019596.731N/m^2 –110210392.9N/m^2 respectively.

The radial stresses from theoretical analysis are maximum at r = 45mm for AZ61A-F alloy is 152492370.5N/m^2 and in AZ31B-0 alloy which is 103972067.9N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is 12574850.02 N/m^2 , AZ31B-0 alloy is 8573761.051N/m^2.High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

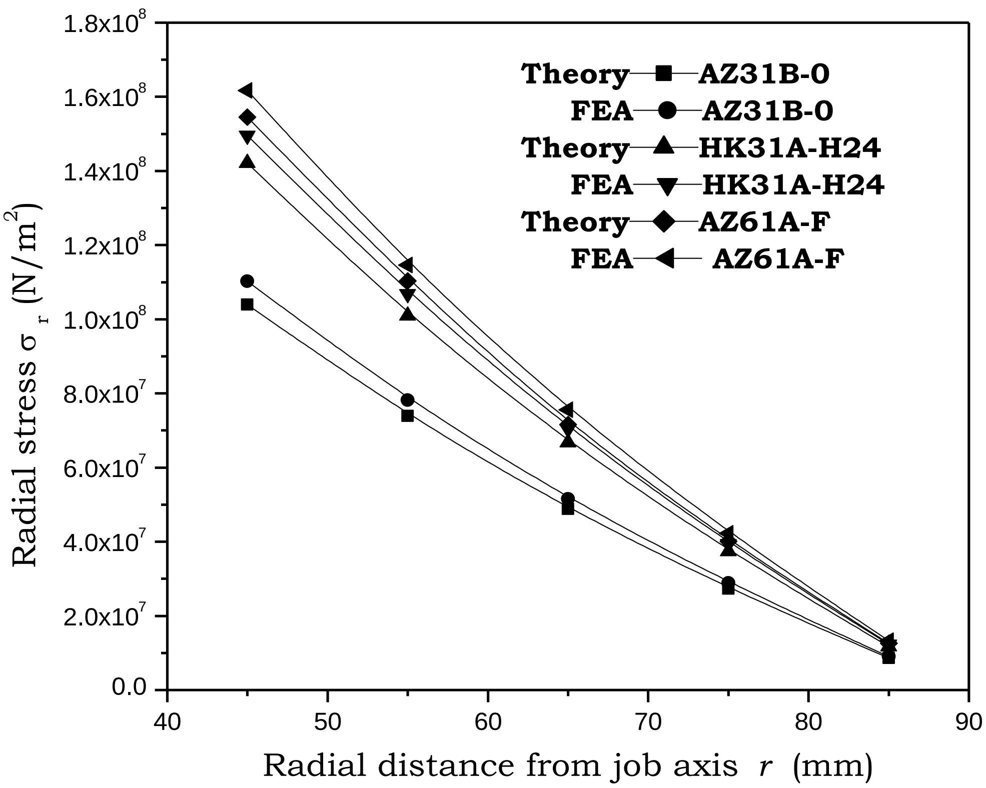

Fig.5.4. Variation of radial stresses in magnesium alloys blanks at olive oil medium

A similar variation is observed from finite element analysis, maximum at r = 45mm for AZ61A-F alloy is 161641913.7 N/m^2 and in AZ31B-0 alloy which is 110210392.9 N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is 13228742.33N/m^2, AZ31B-0 alloy is 9019596.731 N/m^2. High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

The average percentage variation between the theoretical and finite element analysis is 5.3%. From this analysis, the order of radial stresses of magnesium alloys are AZ31B-0 < HK31A-H24 < AZ61A-F found.

Fig.5.5 Shows the variation of radial stresses in blank made of magnesium alloys with heavy machine oil obtained using theoretical and finite element simulations. From theoretical analysis the range of radial stresses for AZ61A-F, HK31A-H24 and AZ31B-0 alloys are 12574845.29N/m^2 – 152492328.0N/m^2,11717469.09N/m^2– 142095120.3N/m^2 and 8573756.326 N/m^2 – 103972025.3N/m^2 respectively.

From finite element analysis the range of radial stresses for AZ61A-F, HK31A-H24 and AZ31B-0 alloys are 13203588.16N/m^2 – 161184396N/m^2, 12303343.14N/m^2 – 150194547.5N/m^2 and 9002444.746N/m^2 – 109898436.2N/m^2 respectively.

The radial stresses at from theoretical analysis are maximum at r = 45mm for AZ61A-F alloy is 152492328.0 N/m^2 and in AZ31B-0 alloy which is 103972025.3N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is 12574845.29N/m^2 , AZ31B-0 alloy is 8573756.326N/m^2.High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

A similar variation is observed from finite element analysis, maximum at r = 45mm for AZ61A-F alloy is 161184396.0 N/m^2 and in AZ31B-0 alloy which is 109898436.2 N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is 13203588.16N/m^2, AZ31B-0 alloy is 9002444.746 N/m^2. High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

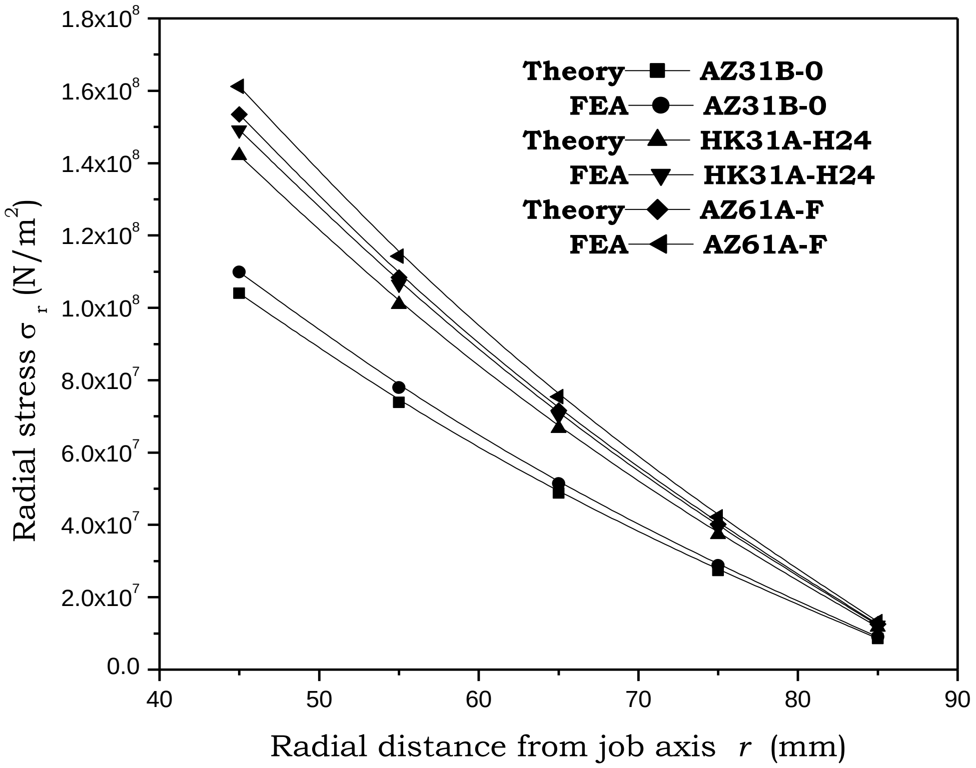

Fig.5.5 Variation of radial stresses in magnesium alloys blanks at heavy machine oil medium

The average percentage variation between the theoretical and finite element analysis is 5.075%. From this analysis, the order of radial stresses of magnesium alloys are AZ31B-0 < HK31A-H24 < AZ61A-F obtained.

Fig.5.6 Shows the variation of radial stresses in blank made of magnesium alloys with castor oil obtained using theoretical and finite element simulation. From theoretical analysis the range of radial stresses for AZ61A-F, HK31A – H24 and AZ31B-0 alloys are is 12574838.54N/m^2 – 152492267.2N/m^2, 11717462.34N/m^2 – 142095059.5N/m^2 and 8573749.576 N/m^2 – 103971964.6N/m^2 respectively.

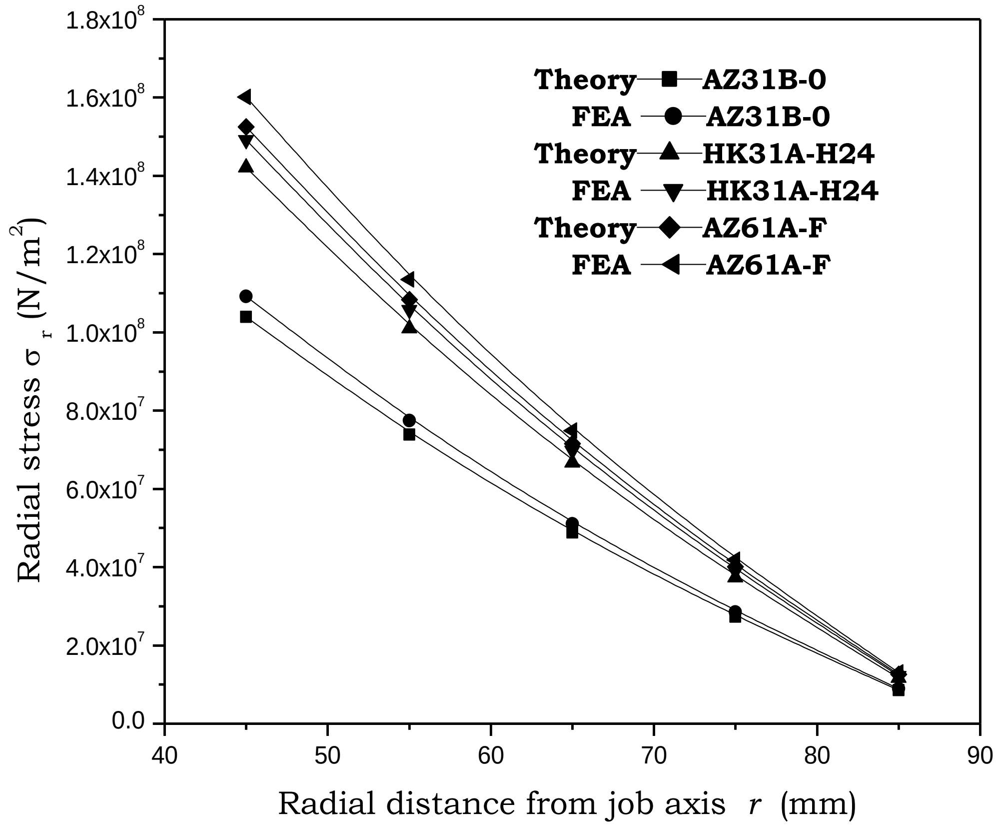

Fig.5.6 Variation of radial stresses in magnesium alloys blanks at castor oil medium

From finite element analysis the range of radial stresses for AZ61A-F, HK31A-H24 and AZ31B-0 alloys are 13102983.06 N/m^2 – 160116892.4 N/m^2, HK31A – H24 is 12209597.06 N/m^2 –

149199824.3 N/m^2 and AZ31B–0 is 8933848.361 N/m^2 – 109170574.6 N/m^2 respectively.

The radial stresses from theoretical analysis are maximum at r = 45mm for AZ61A-F alloy is 152492267.2 N/m^2 and in AZ31B-0 alloy which is 103971964.6N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is 12574838.54 N/m^2, AZ31B-0 alloy is 8573749.576N/m^2 .High radial stresses are found in AZ61A-F magnesium alloy and least inAZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

A similar variation is observed from Finite element analysis, maximum at r = 45mm for AZ61A-F alloy is 160116892.4 N/m^2 and in AZ31B-0 alloy which is 109170574.6N/m^2. At r = 85mm the least variation is observed for AZ61A-F alloy is13102983.06 N/m^2, AZ31B-0 alloy is 8933848.361N/m^2 . High radial stresses are found in AZ61A-F magnesium alloy and least in AZ31B-0 magnesium alloy and within these HK31A-H24 magnesium alloy are observed.

The average percentage variation between the theoretical and finite element analysis is 4.395%. From this analysis, the order of radial stresses of magnesium alloys are AZ31B-0 < HK31A-H24 < AZ61A-F obtained. The nature of graphs is parabolic in shape.

The order of viscosity of fluids as

$\mu_{\text{castor oil}} > \mu_{\text{heavy machine oil}} > \mu_{\text{olive oil}}$, then the order of variation of radial stresses of magnesium alloys with different fluids as medium is as follows

$$\sigma_r\Big|_{casteroil} < \sigma_r\Big|_{heavymachineoil} < \sigma_r\Big|_{oliveoil}$$

From this analysis, when the shear stresses, shear forces and viscosity are acted on the blank surface during the fluid assisted deep drawing process the radial stresses decrease with increase in the radial distance of the blank from the job axis. The observations obtained for magnesium alloys is that the radial stresses increase with decrease in the viscosity of oils and also radial stresses increase with decrease in the pressure of oils. These radial stresses also depend up on yield stress of alloys, fluid pressure and process parameters.

The higher radial stress minimize the drawing time and also forming limits are high. These radial stresses are used to get good results of formability of magnesium alloys.