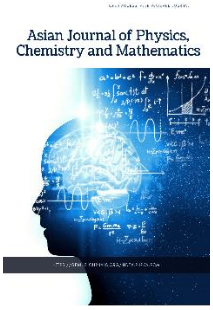

Study Some Differential Subordination and Superordination Results Involving of Certain Class

Mustafa I. Hameed[1]
[1]University of Anbar, College of Education for Pure Sciences, Department of Mathematics, Ramadi-Iraq,
mustafa8095@uoanbar.edu.iq

Shaheed Jameel Al-Dulaimi[2]
[2]Al- Maarif University College, Department of computer science, Ramadi – Iraq,
s .j kharbeet@uoa.edu.iq

ABSTRACT

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1. Introduction and Definitions

Assume $\mathcal{J} = \{t \in \mathbb{C} : |t| < 1\}$ be an open unit disc in $\mathbb{C}$. And assume $\mathcal{K}(\mathcal{J})$ be the class of analytic functions in $\mathcal{J}$ such that $\mathcal{J}[u, j]$ be the subclass of $\mathcal{K}(\mathcal{J})$ of

$$\mathcal{G}(t) = u + u_j t^j + u_{j+1} t^{j+1} + \cdots ,$$

where $u \in \mathbb{C}$ and $j \in \mathbb{N}$. Assume Σ be the class of all analytic functions of

$$\mathcal{G}(t) = t^{-1} + \sum_{j=0}^{\infty} u_j t^j, \qquad (1)$$

in the punctured unit disk

$$\mathcal{J}^* = \{t : t \in \mathbb{C} \text{ and } 0 < |t| < 1\} = \mathcal{J}\backslash\{0\}.$$

$\mathcal{S}$ alludes to the all functions is univalent in $\mathcal{J}$. Assume

$$\mathcal{S}^* = \left\{\mathcal{G} \text{ is univalent}, \Re e \frac{t\mathcal{G}'(t)}{\mathcal{G}(t)} > 0\right\},$$

alludes to the class of starlike functions in $\mathcal{J}$ and

$$K=\left\{\mathcal{G}\text{ is univalent}, \Re e\frac{t\mathcal{G}''(t)}{\mathcal{G}'(t)}+1>0\right\},$$

alludes to the class of convex functions in $\mathcal{J}$.
Assume that and $\mathcal{P}$ are members of $\mathcal{K}(\mathcal{J})$. If there exists a Schwarz function $\mathcal{V}$ analytic in $\mathcal{J}$, with $\mathcal{V}(0)=0$ and $|\mathcal{V}(t)|<1$, such that $\mathcal{G}(t)=\mathcal{P}(\mathcal{V}(t))$, the function is said to be subordinate to $\mathcal{P}$ or $\mathcal{P}$ is said to be superordinate to The term subordination is used to describe this relationship

$$\mathcal{G}(t)\prec\mathcal{P}(t)\text{ or }\mathcal{G}\prec\mathcal{P}.$$

In addition, if $\mathcal{P}$ is univalent in $\mathcal{J}$, we get the following equivalence [7, 14]

$\mathcal{G}(t)\prec\mathcal{P}(t)$ if and only if $\mathcal{G}(0)=\mathcal{P}(0)$, where $\mathcal{G}(\mathcal{J})\subset\mathcal{P}(\mathcal{J})$.

Bulboca [6] considered various kinds of first-order differential superordinations, as well as superordination preserving integral operators, based on Millir and Mocanu's [16] conclusions. Using the results of Bulboca [7], Ali [1] has found adequate requirements for certain normalized analytic functions $\mathcal{G}$ to satisfy:

$$\mathcal{L}_1(t)\prec\frac{t\mathcal{G}'(t)}{\mathcal{G}(t)}\prec\mathcal{L}_2(t),$$

where $\mathcal{L}_1,\mathcal{L}_2$ are univalent functions, such that $\mathcal{L}_1(0)=\mathcal{L}_2(0)=1$. Tuniski [27] obtained sandwich results for particular classes of analytic functions in order to satisfy the following conditions:

$$\mathcal{L}_1(t)\prec\frac{\mathcal{G}(t)}{t\mathcal{G}'(t)}\prec\mathcal{L}_2(t),$$

Shanmogam et al. [24] recently published sandwich results for analytic functions [2, 3, 4, 5, 8, 12, 15, 19, 20, 23, 26].
We'll look at some differential subordination and superordination results involving the operator $\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)$ in this paper.
Now we'll go over the definitions and lemmas we'll require in this work.

Definition 1.1.([21]) For functions$\mathcal{G}\in\Sigma$, such that $\alpha\geq\tau\geq0$ *and* $m\in\mathbb{N}=\{1,2,3,\dots\}$, consider the following operator:

$$\mathfrak{D}_{\alpha,\tau}^{m}\mathcal{G}(t)=t^{-1}+\sum_{j=0}^{\infty}\mathcal{H}(\alpha,\tau,n)^{m}\,u_j\,t^{j},\quad(t\in\mathcal{J}^{*}),\qquad(2)$$

where

$$\mathcal{H}(\alpha,\tau,j)=[(j+2)\alpha\tau+\alpha-\tau](j+1)+1$$

and

$$\mathfrak{D}_{\alpha,\tau}^{0}\mathcal{G}(t)=\mathcal{G}(t)$$

$$\mathfrak{D}_{\alpha,\tau}^{1}\mathcal{G}(t)=\mathcal{N}_{\alpha,\tau}\mathcal{G}(t)$$

$$\mathfrak{D}_{\alpha,\tau}^{m}\mathcal{G}(t)=\mathfrak{D}_{\alpha,\tau}\left(\mathfrak{D}_{\alpha,\tau}^{m-1}\,\mathcal{G}(t)\right),\qquad(t\in\mathcal{J}^{*}).$$

We get the differential operator given in [11] for $\alpha=1,\tau=0$. Using the operator $\mathfrak{D}_{\alpha,\tau}^{m}\mathcal{G}(t)$ to its full potential.
The linear operator $\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)$ on Σ is now defined as follows:

$$\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)=D_{\alpha,\tau}^{m}\mathcal{G}(t)*\omega(u,e;t),\quad(t\in\mathcal{J}^{*}),$$

where

$$\omega(u,e;t)=t^{-1}+\sum_{j=0}^{\infty}\frac{(u)_{j+1}}{(e)_{j+1}}u_j\,t^j\quad,\qquad u\in C^*,e\in C\backslash\{0,-1,-2,\dots\},$$

then

$$\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)=t^{-1}+\sum_{j=0}^{\infty}\mathcal{H}(\alpha,\tau,n)^m\ \frac{(u)_{j+1}}{(e)_{j+1}}u_j\,t^j. \tag{3}$$

The fact that (3) is easily verifiable is obvious

$$t\big(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\big)'=u\mathcal{N}_{\alpha,\tau}^{m}(u+1,e;t)\mathcal{G}(t)-(u+1)\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t), \tag{4}$$

and

$$t\big(\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\big)'=\alpha\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)-(\alpha+1)\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t). \tag{5}$$

Lemma 1.2. ([25]) Assume $\mu,\beta\in\mathbb{C}$ such that $\beta\neq0$ and assume w be a convex function in $\mathcal{J}$ with

$$\Re e\left\{1+\frac{tw''(z)}{w'(z)}\right\}>max\left\{0;\,-\Re e\left(\frac{\mu}{\beta}\right)\right\},\qquad(z\in\mathcal{J}). \tag{6}$$

If p is analytic in $\mathcal{J}$ and

$$\mu p(t)+\beta tp'(t)\prec\mu w(t)+\beta tw'(t), \tag{7}$$

then $p(\mathrm{t})\prec w(t), w$ is the best dominant of the subordination (7).

Lemma 1.3. ([17]) Assume w be univalent in $\mathcal{J}$

$$w(t)=\frac{1+lt}{1-lt},\text{with } l\in(-1,0)\cup(0,1), \tag{8}$$

such that

$$\frac{2\mu}{\sigma}\frac{1+l}{1-l}+\frac{\beta}{\sigma}\frac{1+l}{1-l}>0,\quad(\sigma\in(0,1],\mu,\beta>0).$$

If p univalent in $\mathcal{J}$ and $p(0)=w(0)=1$,

$$\mu p^2(t)+\beta p(t)+\sigma tp'(t)\prec\mu\left(\frac{1+lt}{1-lt}\right)^2+\beta\left(\frac{1+lt}{1-lt}\right)+\sigma\frac{2lt}{(1-lt)^2}\,, \tag{9}$$

then

$$p(t)\prec w(t).$$

Lemma 1.4. ([22]) If

$$w(t)=\frac{1}{(1-t)^{2bc}}$$

is univalent in $\mathcal{J}$ if and only if $|2bc-1|\le1\ or\ |2bc+1|\le1.$

2. Main results

Theorem 2.1. If p be univalent and $p(0)=1$ such that

$$\Re e\left\{1+\frac{tp''(t)}{p'(t)}\right\}>max\left\{0;\,-\alpha\nu\Re e\left(\frac{1}{\mu}\right)\right\},\qquad0<\nu<1,\alpha\ge1\,,\mu\in\mathbb{C}\backslash\{0\}, \tag{10}$$

and $\mathcal{G}\in\Sigma, t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\neq0$, if the following differential subordination

$$\left(\frac{\alpha+\mu}{\alpha}\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu-1}+\frac{t\mu}{\alpha}\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu} \prec p(t)-\frac{t\mu p'(t)}{\nu}, (11)$$

then

$$\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu} \prec p(t).$$

Proof. Assume

$$\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu} = g(t),$$

we obtain

$$\left(\frac{\alpha+\mu}{\alpha}\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu-1}+\frac{t\mu}{\alpha}\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu} = g(t)-\frac{t\mu g'(t)}{\nu},$$

Hence, by (11) gives

$$g(t)-\frac{t\mu g'(t)}{\nu} \prec p(t)-\frac{t\mu p'(t)}{\nu}.$$

Then

$$\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu} \prec p(t).$$

Corollary 2.2. If $\mathcal{G} \in \Sigma$ and

$$\left(\frac{\alpha+\mu}{\alpha}\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu-1}+\frac{t\mu}{\alpha}\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu} \prec \frac{2t(t\mu+t^2\mu)}{(\nu-t\nu)(1-t)^2}. (12)$$

Then

$$\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu} \prec \frac{1+t}{1-t}.$$

Theorem 2.3. If $\mathcal{G} \in \Sigma$ and p is univalent such that $p(0)=1,\ p(t)\neq 0, \pi,\rho \in \mathbb{C}, \tau,\alpha \in \mathbb{C}\backslash\{0\}, \pi+\rho \neq 0$. Suppose that $\mathcal{G}$ and p satisfy the following conditions:

$$\left\{\frac{t\{\pi\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)+\rho\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\}}{\rho-\pi}\right\} \neq 0, \quad (13)$$

with

$$\Re e\left\{1+\frac{tp''(t)}{p'(t)}-\frac{tp'(t)}{p(t)}\right\} > 0. \quad (14)$$

If

$$\left[\alpha-\frac{\pi t\left(\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)'-\rho t\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)'}{\pi\left(\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)-\rho\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)}\right] \prec \frac{tp'(t)}{p(t)}, \quad (15)$$

then

$$\left(\frac{t\pi\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)-\rho t\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)}{\rho-\pi}\right)^{\nu} \prec p(t).$$

Proof. Assume

$$\left(\frac{t\pi\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)-\rho t\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)}{\rho-\pi}\right)^{\nu}=g(t), \tag{16}$$

By (16), we obtain

$$\left[\alpha-\frac{\pi t\left(\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)'-\rho t\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)'}{\pi\left(\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)-\rho\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)}\right]=\frac{tg'(t)}{g(t)}.$$

If w is analytic in $\mathbb{C}$ with $\eta(u)\neq 0,\eta(u)=\frac{\tau}{u}$ is analytic in $\mathbb{C}^{*}$. Suppose that

$$W(t)=tp'(t)\eta(p(t))=\frac{tp'(t)}{p(t)},$$

since $W(0)=0$ and $W'(0)\neq 0$,then (14) would yield that W is a starlike function in $\mathcal{J}$. From (14), we have

$$\Re e\frac{th'(t)}{W(t)}=\Re e\left\{1+\frac{tp''(t)}{p'(t)}-\frac{tp'(t)}{p(t)}\right\}>0,$$

we get,

$$g(t)\prec p(t).$$

Corollary 2.4. If $\mathcal{G}\in\Sigma$, and assume $\pi=0,\rho=\tau=1,\ -1\leq\mathcal{A}<\mathcal{B}\leq 1, p(t)=\frac{1+\mathcal{A}t}{1+\mathcal{B}t},-1\leq\mathcal{A}<\mathcal{B}\leq 1$, such that

$$\left[\nu-\frac{t\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)'}{\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)}\right]\prec\frac{(\mathcal{A}+\mathcal{B})t}{(1-\mathcal{A}t)(1-\mathcal{B}t)}, \tag{17}$$

then

$$\left(t\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)^{\nu}\prec\frac{1+\mathcal{A}t}{1+\mathcal{A}t}.$$

Theorem 2.5. If $\mathcal{G}\in\Sigma$ and p is univalent such that $p(0)=1,\ p(t)\neq 0,\pi,\rho\in\mathbb{C},\tau,\alpha\in\mathbb{C}\backslash\{0\},\pi+\rho\neq 0$. Suppose that $\mathcal{G}$ and p satisfy the following conditions:

$$\left(t\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)^{\nu}\in G[p(0),1]\cap W.$$

$$\left(\frac{\alpha+\mu}{\alpha}\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu-1}+\frac{t\mu}{\alpha}\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu}$$

is univalent in $\mathcal{J}$, and

$$p(t)-\frac{t\mu p'(t)}{\nu}\prec\left(\frac{\alpha+\mu}{\alpha}\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu-1}+\frac{t\mu}{\alpha}\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu}, \tag{18}$$

then

$$p(t)\prec\left(t\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)^{\nu}.$$

Proof. Let

$$\left(t\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)^{\nu}=g(t),$$

we obtain

$$g(t)-\frac{t\mu g'(t)}{\nu}=\left(\frac{\alpha+\mu}{\alpha}\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu-1}+\frac{t\mu}{\alpha}\left(\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\right)\left(t\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t)\right)^{\nu}.$$

Theorem 2.6. If p is convex in $\mathcal{J}$ such that $p(0) = 1, \mathcal{G} \in \Sigma,\ \nu, \tau \in \mathbb{C}\backslash\{0\}$, suppose $\delta, \pi, \rho \in \mathbb{C},\ \pi + \rho \neq 0, \Re e\left(\frac{\delta}{\tau}\right) > 0$. Assume $\mathcal{G}$ satisfy the following conditions:

$$\left\{\frac{t\{\pi\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t) + \rho\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\}}{\rho - \pi}\right\} \neq 0,$$

and

$$\left\{\frac{t\{\pi\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t) + \rho\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\}}{\rho - \pi}\right\}^{\nu} \in G[p(0),1] \cap W.$$

If

$$\delta w(t) + \tau t w'(t) \prec \phi(t), \tag{19}$$

then

$$p(t) \prec \left\{\frac{t\{\pi\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t) + \rho\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\}}{\rho - \pi}\right\}^{\nu}.$$

Theorem 2.7. Assume p_1, p_2 be two convex in $\mathcal{J}$ with $p_1(0) = p_2(0) = 1, \delta, \pi, \rho \in \mathbb{C}, \nu, \tau \in \mathbb{C}\backslash\{0\}$and $\pi + \rho \neq 0$ with $\Re e\left(\frac{\delta}{\tau}\right) > 0$. Assume $\mathcal{G} \in \Sigma$ and $\mathcal{G}$ satisfy the following conditions:

$$\left\{\frac{t\{\pi\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t) + \rho\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\}}{\rho - \pi}\right\} \neq 0,$$

and

$$\left\{\frac{t\{\pi\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t) + \rho\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\}}{\rho - \pi}\right\}^{\nu} \in G[p(0),1] \cap W.$$

If

$$\delta p_1(t) + \tau t {p_1}'(t) \prec \phi(t) \prec \delta p_2(t) + \tau t {p_2}'(t), \tag{20}$$

then

$$p_1(t) \prec \left\{\frac{t\{\pi\mathcal{N}_{\alpha,\tau}^{m+1}(u,e;t)\mathcal{G}(t) + \rho\mathcal{N}_{\alpha,\tau}^{m}(u,e;t)\mathcal{G}(t)\}}{\rho - \pi}\right\}^{\nu} \prec p_2(z).$$

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